IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEVADA

NEVADA POWER COMPANY,	)	
	)	
Plaintiff,	)	
-vs-	)	
	)	# CV-S-89-555-LDG (LRI
	)	
MONSANTO COMPANY, et al.,	)	
	)	
Defendants.	)	

CONTINUATION OF THE DISCOVERY
DEPOSITION OF WILLIAM B. PAPAGEORGE

On the part of the Plaintiff

July 20, 1993

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General Court Reporters
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WATER_PCB-SD0000072751

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEVADA

NEVADA POWER COMPANY,)
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Plaintiff,)
-vs-) # CV-S-89-555-LDG (LRL)
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MONSANTO COMPANY, et al.,)
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Defendants.)

* * *

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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEVADA

NEVADA POWER COMPANY, Plaintiff,
-vs-
MONSANTO COMPANY, et al., Defendants.
CV-S-89-555-LDG (LRL)

CONTINUATION OF THE DISCOVERY DEPOSITION OF WITNESS, to be used in an action pending in the District Court of the United States, for the District of Nevada, wherein NEVADA POWER COMPANY is Plaintiff, and MONSANTO COMPANY, et al. are Defendants, pursuant to Notice, under the provisions of Rule 26 of the Rules of Civil Procedure, taken on July 20, 1993, at the law offices of Messrs. Husch, Eppenberger, Donohue, Cornfeld & Jenkins, 100 N. Broadway, Ste. 1300, St. Louis, Missouri 63102, before Mark D. Concannon, a Notary Public within and for the State of Missouri.

A P P E A R A N C E S

The Plaintiff was represented by Attorney Ralph A. Bradley of the law firm of Jones, Jones, Close & Brown, Chartered, 700 Bank of America Plaza, 300 South Fourth Street, Ste. 700, Las Vegas, Nevada 89101.

The Defendant, Monsanto, was represented by Attorney Scott R. Bauer of the law firm of Kirkland & Ellis, 1999 Broadway, Ste. 4000, Denver, Colorado 70202.

The Defendant, Westinghouse, was represented by Robert P. Morgan, In-House Counsel, Westinghouse Electric Corporation, Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 15222.

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WILLIAM B. PAPAGEORGE,

of lawful age, having been previously sworn to tell the truth, the whole truth, and nothing but the truth, deposes and says on behalf of the Plaintiff, as follows:

CONTINUATION OF DIRECT EXAMINATION

QUESTIONS BY MR. BRADLEY:

Q. Mr. Papageorge, today is Tuesday, the 20th of July. You are still under oath; do you understand that?

A. Yes.

Q. Yesterday we talked about a product brochure that you recalled being written, and I don't remember when -- the fifties, I think is when you thought it might have been written, that contained information indicating that PCB's might be absorbed through the skin and produce some kind of systemic liver problems. Do you recall discussing that topic yesterday?

A. I do recall it.

Q. Do you recall there being more than one product brochure put out by Monsanto that contained that information?

A. As best as my recollection will help me on that, yes.

Q. How many product brochures do you recall Monsanto publishing that contained that information?

A. At least a couple.

Q. And by "a couple," you mean two?

A. At least two; it was more than one. It could be three or four out of half a dozen or more.

Q. Okay. How frequently did Monsanto prepare product brochures on its Aroclor products, that you're aware of, based upon your personal knowledge, which would include review of documents while you were an employee of Monsanto?

MR. BAUER: Object to the form. Indefinite as to time. Lacks foundation.

A. There was no set schedule. It depended on the availability of new information, primarily, and it on depended on the supply of pamphlets on hand. It -- As best as I recall, it was about a cycle of maybe a half a dozen years between issues.

Q. (by Mr. Bradley) Was there a period in time when, either before 1950 or following the 1950's, when the product brochures did not contain that information?

MR. BAUER: Object to the form. Vague as to "that information."

Q. (by Mr. Bradley) When I refer to "that information," I'm referring to the information that PCB's can get absorbed through the skin and can cause systemic injury, including damage to the liver.

A. I understand.

Q. You indicated that a couple, up to three or four out of maybe half a dozen, of the product brochures that you're familiar with contained that information; is that correct?

MR. BAUER: Object to the form. He said he thinks that. He didn't say it was a fact.

A. That is my best recollection, yes.

Q. (by Mr. Bradley) Was there a time before the 1950's when the product brochures did not have that information in them?

MR. BAUER: Object to the form. Lacks foundation.

A. I don't recall the dates of these publications.

Q. (by Mr. Bradley) Was there a time after the 1950's when the product brochures did not contain that information?

MR. BAUER: Same objection.

MR. BRADLEY: The objection is what?

MR. BAUER: Objection to the form. Lacks foundation.

MR. BRADLEY: Okay.

A. There were pamphlets describing PCB products in the seventies that did not contain that specific information.

Q. (by Mr. Bradley) Were there any product brochures in the 1960's that did not contain that specific information, as we have defined it?

MR. BAUER: Same objection.

A. Again, my memory fails me. I don't remember.

Q. (by Mr. Bradley) In your work at Monsanto did you review the product brochures on the Aroclor products manufactured by Monsanto?

MR. BAUER: Objection What do you mean, "the product brochures"? Some, all, through all periods of time? Object to the form.

A. Depending on what period of time we're talking about, when I was involved with the use of PCB products in my assigned responsibilities, I would read the product bulletins that applied to the uses that I was involved with. When I was plant manager at Anniston, where we made PCB's, I was in a position where, and as best I could tell, I read all of the pamphlets that were current at that time.

Q. Okay. And when were you plant manager at Anniston?

A. 1965 to the end of 1969.

Q. And when did you have responsibilities relative to PCB's at Monsanto that would have caused you to review then-current product brochures?

A. Starting at about 1955 through about 1958,

'59, and again in 1963 to 1965.

Q. So, is it fair to say that between 1955 and 1958 or '59, and 1963 to 1965, and 1965 to '69, you reviewed then-current product brochures on Monsanto's Aroclor products?

A. Some of the product brochures on Monsanto's PCB products.

Q. All right. My question and your answer don't match exactly, so I am going to pursue that somewhat. Between '55 and '58, and between 1963 to 1965 and 1965 to '69, did Monsanto have product brochures regarding the Aroclor products or blends that it developed?

A. Yes.

Q. During those periods of time that I have identified did you review those product brochures?

MR. BAUER: Object to the form, again. He has said "some," and you're saying "those." It's vague as to what you mean --

MR. BRADLEY: I am interested in what he reviewed.

A. I reviewed those product bulletins of the Monsanto PCB product that I was involved with during those periods of time, and they varied.

Q. (by Mr. Bradley) But you didn't review product brochures necessarily before 1955; is that correct?

A. That is correct.

Q. And you wouldn't necessarily have reviewed product brochures between 1958 or '59 and 1963.

A. Correct.

Q. Do you recall, in your review of the product brochures between 1963 and '65 and 1965 and '69, whether any of the product brochures on Monsanto's Aroclor products contained that information as we have defined it for purposes of this morning's deposition?

A. Yes. During at least one of those periods I recall that information being in at least one of those bulletins.

Q. Is there a reason that that information as we have defined it here this morning was not present in all of Monsanto's Aroclor product brochures?

MR. BAUER: Object to the form. Lacks foundation.

A. You'd have to ask the medical department. They made that decision.

Q. (by Mr. Bradley) Was the medical department responsible for what medical information went into the product brochures during any period Monsanto manufactured Aroclors?

A. Yes.

Q. Did that information as we have defined it for

this morning's deposition also appear in any of the maintenance manuals that went out with the Aroclor products that Monsanto blended?

A. Since I can't recall in just which of those product-oriented booklets I read that information, I have a hard time associating it with a maintenance manual. That doesn't mean it didn't happen. I just don't remember.

Q. What manuals, information booklets, information packages, anything written, did Monsanto give to purchasers of its Aroclor blends?

MR. BAUER: Over any period of time?

Q. (by Mr. Bradley) That you're aware of, over any period of time, personally aware of.

A. There was literature that described the material containing the PCB's.

Q. Let me stop you for a moment. What I'm looking for are titles of different types of documents. A maintenance manual, for example, might be one.

A. I just don't remember titles. There was a, as I recall, a manual referring to maintenance of PCB-type materials, products, as used in transformers. I don't recall the title of that pamphlet, but the subject matter was the maintenance of that material. How to test for it, recycle it, how to clean it up, and on and on.

Q. Did Monsanto also provide to purchasers of its

Aroclor blends any manufacturing safety data sheets that Monsanto developed?

A. Manufacturing safety data sheets?

Q. MSDS sheets. Material Safety Data Sheets, I think it is. Excuse me.

A. Starting in 1971, Monsanto prepared Material Safety Data Sheets, using OSHA Form 20, as I remember the number.

Q. And those were supplied to all users of the PCB products?

A. Or all customers of the PCB products.

Q. And as I recall your testimony yesterday, you don't know to whom the product brochures were distributed, other than the prospective purchasers of Aroclor products; is that correct?

A. I don't know specific individuals or organizations. I do know that this reading material was available to anyone who showed any interest, whether it be a potential customer, or some researcher somewhere. I do not know the individuals by name.

Q. While at Monsanto, did you gain -- Excuse me. While at Monsanto, did Monsanto gain knowledge regarding the hazards, if any, to users of transformers or capacitors containing PCB fluids?

MR. BAUER: Would you read that back, please.

(Thereupon, the reporter read back the question.)

MR. BAUER: Object to the form to the extent it asks the witness to testify about what anybody at Monsanto, worldwide, knew, but you could certainly tell him what you knew about.

Q. (by Mr. Bradley) Before you answer the question, Mr. Papageorge, I have Monsanto Company's preliminary designation of possible trial witnesses pursuant to an order entered April 9th, 1993, and in it it has your name, and it has thirty areas of potential testimony that you might testify to in this lawsuit. Have you seen that document?

A. I have not seen it.

Q. For your benefit in answering my question, I am referring to item eleven on that list.

MR. BAUER: Well, first of all I don't know why in a deposition we're referring to a pleading. The fact that he's listed as a person who could testify about this doesn't mean that he is the only one that could testify about it. It doesn't means he's the only one that could testify about that topic or that he has all of the knowledge.

MR. BRADLEY: I am only interested in what he knows. That is why my questions are geared to areas indicated as the areas that he will testify if this case

comes to trial.

Now, if you would answer the question, please, sir.

A. I can share with you my understanding.

Q. (by Mr. Bradley) Fine.

A. The hazards that Monsanto, through its representatives, understood would exist with the use of PCB's in transformers were identical to those that Monsanto associated with the manufacture and the handling of PCB's in its own plants, and those hazards are, of course, related to mishandling of PCB-type materials. That is the information that Monsanto had.

Q. Did Monsanto have knowledge of whether a transformer -- Excuse me -- users of transformers or capacitors containing PCB's, if any of them got PCB fluid on their skin, that the PCB fluid would be absorbed through the skin into the body?

MR. BAUER: Object to the form. Lacks foundation that the witness would know what anyone at Monsanto knew; and it's indefinite as to time.

A. That was the information Monsanto shared regarding PCB products, so that is reflective of the understanding of what these materials can do.

Q. (by Mr. Bradley) Do you know when Monsanto had knowledge that, if PCB's are on human skin, that the

PCB's get absorbed through the skin into the body?

A. I understand this knowledge was available to Monsanto's medical department back in the 1930's.

Q. Did Monsanto know that, if PCB's entered the body through the skin, that it could cause a condition known as chloracne?

MR. BAUER: Object to the form. Indefinite as to time.

Go ahead.

A. Yes, that was information that we, Monsanto, had, yes.

Q. (by Mr. Bradley) And when did Monsanto obtain that information?

A. It dates back to the thirties, forties.

Q. Did Monsanto know that if someone developed chloracne from exposure to PCB's, that it could cause systemic poisoning?

MR. BAUER: Object to the form of the question, use of the word "could", and also lacks foundation.

A. Yes. They were aware of that, also, at about that time, the thirties and forties.

Q. (by Mr. Bradley) And did Monsanto learn that if someone suffered systemic poisoning as a result of PCB's being absorbed through the skin, that the systemic poisoning could include liver damage?

MR. BAUER: Same objection.

A. Keep in mind, I am not a medical person; I am relaying to you my understanding as given to me by medical personnel. Yes, that was the message that I was given, and that is the thought that I followed with my own employees.

Q. (by Mr. Bradley) And Monsanto knew that information also back in the thirties and forties; is that correct?

A. That is my understanding.

Q. Were there any hazards that Monsanto knew about regarding transformers or capacitors containing PCB fluids and those people using them that were not contained in Monsanto's material that accompanied the PCB fluid that Monsanto sold?

MR. BAUER: Object to the form. Lacks foundation. It's also vague.

Go ahead.

A. Monsanto's knowledge was limited to the fluids used in those transformers and the fact that they contained PCB's. Since Monsanto was not in the business of manufacturing, designing transformers and capacitors, it could not in any way be in a position to know all of the hazards associated with the use of PCB's in the electrical equipment. So it could not address explosions, arcs, and that kind of phenomena. All it could speak to with some

knowledge was the effect of the material in the liquid and how it might affect employees, or if people mishandled it.

Q. (by Mr. Bradley) When Monsanto sold PCB dielectric fluid that it blended, it knew that ultimately that PCB dielectric fluid would be used in electrical transformers or capacitors; is that correct?

A. That was the intent of the material.

Q. When Monsanto sold its PCB dielectric fluids, did it provide information to the purchasers regarding Monsanto's knowledge regarding the hazards of the PCB dielectric fluids?

A. Yes.

Q. Did the information that Monsanto provided to the purchasers of the PCB dielectric fluid contain all of the hazards that Monsanto knew were associated with that particular PCB dielectric fluid?

MR. BAUER: Object to the form. Lacks foundation. Vague.

You can answer.

A. When you use the words "information" and "all of the hazards," I don't know if that was relayed.

Q. (by Mr. Bradley) Well, do you know whether Monsanto withheld information about some of the hazards it was aware of regarding the PCB dielectric fluids it was blending and selling?

MR. BAUER: Object to the form of the question. Argumentative. "Avoid skin contact," if you don't include -- we're getting into an area of argument, the argument about whether things were disclosed or not disclosed. Object, argumentative.

Q. (by Mr. Bradley) Go ahead and answer the question.

A. I forgot the question.

Q. Do you know whether Monsanto withheld information regarding the PCB dielectric fluids that it sold to its customers?

MR. BAUER: Same objection.

A. Not to my knowledge.

Q. (by Mr. Bradley) All right. To your knowledge -- I'm not sure I got an answer to this question -- did Monsanto inform purchasers of its PCB dielectric fluids of all of the hazards that Monsanto knew where associated with the PCB dielectric fluids that it manufacture and blended?

A. To my knowledge, yes.

Q. Did it provide that -- How did it provide that information?

MR. BAUER: Object to the form of the question. Lacks foundation that he would know all of the ways. But you may answer.

A. Some of it went through the product literature that we have referred to.

Q. (by Mr. Bradley) Which product literature?

A. All of the literature that described the material: maintenance, product description, or potential uses to which the product may be applied, and so on. It was done through our field representatives when they made calls to the customers. It was done directly out of the medical department to their counterparts at the customer's office. It was done through, again, contact with technical people, from one laboratory to the other, or one technical center to the other. I'm sure I haven't covered all of the ways that it was done.

Q. Well, let's discuss the ways that you have described. Did the field reps have training in toxicology relating to PCB dielectric fluids during the period of time that you were an employee at Monsanto?

A. I don't know how to define "toxicology training." They had information provided by the medical department that they were encouraged to share with the customer.

Q. Was that written material from the medical department?

A. Some of it was; some of it was given to them on a one-to-one basis. Some of it was given to them at their sales meetings, conferences that they held; and it

varied through the years. When the question asked of this representative exceeded his area of knowledge, because it was limited, he would make a contact, either personally, with Monsanto's medical personnel, or he would provide the customer with a name and a telephone number or an address to pursue it further.

Q. Regarding the written material that went from the medical department to the field reps --

A. Uh-huh.

Q. -- did that written material get sent out systematically? Once a year, twice a year, whatever the schedule?

A. Well, there was no schedule. It depended on whether new information was available. And since, with this particular product line there was nothing new for decades, there was no scheduled distribution.

Q. Was there a name for the written material that was sent from Monsanto's medical department to its field representatives?

A. I don't know if there was a name for it. You could go under toxicity or safe handling, or all kinds of titles. It didn't have a unique name.

Q. Was it essentially a memorandum?

MR. BAUER: Object to the form.

Q. (by Mr. Bradley) Was it a memorandum?

A. It varied through the decades, depending on the author in the medical department.

Q. Some of the purchasers of PCB dielectric fluid from Monsanto did not have a medical department; is that correct?

MR. BAUER: Objection. Lacks foundation.

A. Are you talking about access to medical or their own medical departments?

Q. (by Mr. Bradley) You had indicated that information regarding hazards would go from Monsanto's medical department directly to their counterparts at customers offices.

A. Yes.

Q. Did all of the customers have counterparts to Monsanto's medical department?

A. They all had access to professional medical opinions and service. Dependent on their size, some of them had their own medical staffs, and some of them had access to medical help on a contractual basis.

Q. Some of them didn't have their own medical staff; is that correct?

A. They had access to them.

Q. But my answer is yes; is that correct?

MR. BAUER: Your answer doesn't matter.

Q. (by Mr. Bradley) I understand you are saying

they could hire a medical person to give them assistance.

A. To look after the health of their employees.

Q. Some of them didn't have medical people on their staff; is that correct?

A. That is immaterial, though, as long as they had the advice.

Q. In fact, Monsanto sold some PCB dielectric fluid to individual electric utilities; isn't that true?

MR. BAUER: Object. Lacks foundation.

A. Yes.

Q. (by Mr. Bradley) And those individual electric utilities did not have medical people on their staff; isn't that true?

MR. BAUER: Object. Lacks foundation. Which utilities?

MR. BRADLEY: The ones that Monsanto sold PCB dielectric fluids to.

MR. BAUER: If you can't identify who they are, how can he answer your question.

Q. (by Mr. Bradley) Do you know which individual electric utilities companies Monsanto sold PCB dielectric fluid to?

A. Detroit Edison, Commonwealth Edison.

Q. Did either of those two companies have medical people on staff?

A. I have no idea.

MR. BAUER: Objection. Lacks foundation.

Q. (by Mr. Bradley) Did Monsanto's customers of its PCB dielectric fluids have technical centers comparable to Monsanto's technical centers?

MR. BAUER: Objection. Lacks foundation.

A. I was not in a position to compare.

Q. (by Mr. Bradley) The reason I am -- If you have no reason to compare, then how are you able --

A. I didn't say "reason." I should have said "basis for comparison."

Q. If you have no basis for comparison, how is it, then, that you can say that Monsanto had transferred information regarding the hazards of its PCB dielectric fluids by contact with its technical people with the technical people or centers of its customers?

A. I can say that because it happened.

Q. Then how can you -- All right. Then tell me about the technical people or centers of Monsanto's customers of PCB dielectric fluids.

A. I don't propose to know all of these centers.

Q. Tell me what you do know.

MR. BAUER: What? The names of people, where they were, what kind of analytical capabilities they had, what kind of work they did?

MR. BRADLEY: Anything.

A. I can't be aware of all of that.

Q. (by Mr. Bradley) I am not asking if you were aware of it all. Just describe for me what you recall.

A. I know that for years Dr. Ralph Munch of Monsanto was in contact with representatives from Westinghouse, Pittsburgh Laboratories, their South Boston, transformer plant.

Q. Which is a Westinghouse plant?

A. South Boston, yes, sir. I am also aware that Dr. Munch -- and he wasn't the only one, but he is the key man -- was in contact with individuals like Mr. Ed Raab at General Electric, and he was in contact with individuals like Dr. Pozefsky at General Electric. I can't remember all of the individuals. There were representatives of a capacitor plant in the New England area. There was a plant outside of Chicago, La Salle, the technical person was a lady doctor; I can't recall her name. Those are just some examples that come to mind of a very intimate relationship. Everything that was known by Dr. Munch was shared, and he in turn picked up a lot of information from the customer's representatives.

Q. Now you're speculating, because you don't know what Dr. Munch told these people, do you?

A. I know that I was with him on some occasions

where that was discussed in my presence.

Q. Did Monsanto have any contact with customers of the transformer and capacitor manufacturers while you were a Monsanto employee?

A. The fact that Monsanto sold some of these fluids to owners, operators of the electrical equipment indicated contact.

Q. Did you personally have any contact with any customers of the transformer and capacitor manufacturers?

A. I had limited contact.

Q. Tell me what contact you had with customers of transformer and capacitor manufacturers. I am interested in knowing the date, who you spoke with, the subject matter, and your conversation.

A. In the early seventies I had -- I don't recall the exact date -- contact with Individuals within the TVA Authority. I had, I recall, a meeting with the Ontario Power Generating Commission -- I forget the exact title -- up in Canada. I had a meeting with a group of individuals and later had telephone conversations and met some of these individuals at meetings elsewhere.

I had some contact with some of the utilities. I mentioned Detroit Edison and Commonwealth Edison, and another one in Ohio. Again, the dates are not specific, but there was a period, '70. '71, and '72.

Q. Did Monsanto make any effort to determine who the customers were of the transformer and capacitor manufacturers who were purchasing PCB dielectric fluid from Monsanto?

MR. BAUER: Object to the form. Lacks foundation, indefinite as to time.

Q. (by Mr. Bradley) Any time that you are personally aware of.

(Thereupon, the reporter propounded the previous question.)

A. I am not aware of any such effort.

Q. (by Mr. Bradley) When individual electric utility companies purchased PCB dielectric fluids from Monsanto, do you know whether they were given any written literature regarding the hazards of the PCB dielectric fluids?

A. I personally don't.

Q. Who would know that?

A. Could be several individuals that could have been involved. It could be the Dr. Munches out of the laboratory, with a previous contact, or it could be the person that took the order over the telephone, whether it be in the field office or the general office. It could be the field salesman, who, when he hears the order is placed, puts it on his list of calls to make.

Q. Well, then let me ask this question: Do you have personal knowledge of whether Monsanto routinely sent information regarding the hazards of its PCB dielectric fluids to any electric utility that was making a purchase of PCB dielectric fluid from Monsanto during the period of time that you were a Monsanto employee?

A. Routinely, I don't know that. I can't speak to that.

Q. Okay. Is there anyone at Monsanto, that you're aware of, who would have more information than you regarding Monsanto's evolving knowledge of the actual or potential hazards of PCB's to the environment?

MR. BAUER: Object to the form. Are you talking about current employees? Are you talking about a specific time period in terms of the scope of the knowledge? Different people may have more information regarding Monsanto at different periods of time.

Q. (by Mr. Bradley) Starting from the period 1960 to 1970, then. To help you, let's start with that.

A. '60 to '70. Are you talking about Monsanto employees at that time who are still alive?

Q. Let me start the question all over again. I don't care if they're alive or not presently. I'm interested in knowing whether between 1960 and 1970 there is anyone who was then a Monsanto employee who would have

more information than you regarding Monsanto's knowledge of the hazards of PCB dielectric fluid to the environment.

A. Yes. That would be the director of Monsanto's medical department at the time, Dr. Emmett Kelly, and his assistant director at that time, Elmer Wheeler.

Q. I am going to give a brief statement so that I make certain that you understood my question. I have differentiated in my question between human health effects and the effects on the environment, and I am not certain that you understood that I did so. So, with that in mind, let me ask this question: Between 1960 and 1970, would Monsanto's medical department have, and its employees during that period of time, have more information regarding the hazards of PCB dielectric fluid manufactured by Monsanto regarding effects on the environment than you?

MR. BAUER: Object to the form of the question. Perhaps one of the difficulties is whether or not man is part of the environment or not. But you can answer if you are able, Mr. Papageorge.

A. My answer is yes. I didn't come aboard this environmental PCB situation until -- beginning in 1970.

Q. (by Mr. Bradley) Between 1970 and 1976, did the then-employees of Monsanto's medical department have the greatest information regarding the effects of PCB's on the environment?

MR. BAUER: Object to the form of the question. You're asking the witness to sort of compare what was in his head versus what was in other people's heads. Calls for speculation.

You can answer if you are able.

A. I need some help with understanding what is meant by the reference to "environment."

Q. (by Mr. Bradley) Are you familiar with the differentiation between the effects on human health versus effects on the environment?

A. I have a personal understanding of the effects on human beings, and I distinguish that from the environment in general.

Q. As you have your understanding relative to the environment in general versus the effects on human health, during the period of '70 to '76, was there anyone within Monsanto who was designated as the expert on the hazards of PCB dielectric fluid on the environment in general?

A. When you define the material as dielectric fluid, I don't know of anyone at Monsanto who had unique experience and expertise there, but if you limit that to the one component, in fire-resistant dielectric fluids, the PCB component, the expertise was not centered on any one person. It varied with what part of the environment was being considered.

Q. Which Monsanto employees between 1970 and 1976 had responsibility for determining the hazards to the environment in general from exposure to PCB's?

A. Will you help me with "hazards"? Are we talking about presence in the air, presence in the water, presence in the soil?

Q. Yes, presence.

A. Presence. The expertise predominantly relayed from the analytical chemistry group of the Monsanto research department.

Q. And who headed that group between 1970 and 1976?

A. Dr. Robert Keller.

Q. Now, let's define hazards as any potential adverse affect, for example, interfering with the ability of shrimp to exist. Who at Monsanto was responsible for knowing the hazards of PCB's in the environment in general?

A. Are you talking about living creatures in the environment?

Q. Yes.

A. That responsibility was with the Monsanto medical department.

Q. Help me for a moment. You were never a member of the medical department; is that correct?

A. That is correct.

Q. Okay. Was there a time during your employment at Monsanto when you believe you knew what information was publicly available regarding any real or alleged hazards of PCB's?

MR. BAUER: Object to the form.

MR. BRADLEY: What's wrong with the form?

MR. BAUER: Well, what "believe you knew" meant.

A. There was a period of time when I attempted to find out as much as was humanly possible. This does not mean that I succeeded in knowing everything.

Q. (by Mr. Bradley) What period of time was it that you made that effort?

A. Starting in 1970, up through the early part of '76.

Q. And what did you learn was publicly available information regarding the real or alleged hazards of PCB's during the 1970-to-1976 period?

MR. BAUER: Object to the form. Overbroad, asking the witnesses to recite dozens, if not hundreds, of papers and their contents.

MR. BRADLEY: If it helps, I am referring to item eighteen in the areas listed for your testimony.

MR. BAUER: We can show him the dozens or hundreds of papers instead.

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MR. BRADLEY: If you list him as a witness on a topic, I ought to be able to ask him about his knowledge on that topic. That's all I have done.

Go ahead.

MR. BAUER: Same objection.

A. I do not of course recall all of the studies that were reported. I do recall references to findings by some investigators that wild birds were being affected by the presence of PCB's in their diets.

Q. (by Mr. Bradley) Was that information transferred to customers of electrical transformer and capacitor manufacturers?

A. Yes.

Q. How?

A. One example was the statement on the product label that refers to the presence, or the findings of PCB's in the environment, and the possible harm -- these are not the exact words -- the possible harm to creatures, or animals in the environment.

Q. When was that information included in the label that Monsanto attached to its PCB dielectric fluids?

A. May of 1970.

Q. Do you know whether that information on those labels was transferred to the customers of the transformer and capacitor manufacturers?

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MR. BAUER: Objection. Vague as to what you mean by "transferred." But you can answer.

Q. (by Mr. Bradley) Well, let's explore that. When Monsanto sold its PCB dielectric fluids, it was not in a transformer and it was not in a capacitor; is that correct?

A. Yes.

Q. And you knew the PCB dielectric fluids would be taken by your customers and added to electrical transformers or electrical capacitors; is that correct?

A. Yes.

Q. Did Monsanto take any steps to determine whether the warnings on any of its labels were transferred or made known to the customers of the transformer or capacitor manufacturers?

MR. BAUER: Object on the basis that he would know of all of the steps that anyone at Monsanto took to make that information known.

A. The steps I am aware of is that we had a repeated contact with our customer's representatives with the re-emphasis to make certain that the information that they received from Monsanto was relayed to their customers and to their service agents, and so on, anyone that could have some involvement with the fluid.

Q. Now --

MR. BAUER: Were you finish with your answer?

THE WITNESS: Yes.

Q. (by Mr. Bradley) Now, Monsanto knew -- Strike that. Did you review documents at Monsanto while you were a Monsanto employee that referred to the reasons Monsanto manufactured or blended PCB's?

A. I don't know that any such document exists. I have never seen any.

Q. One of the benefits of PCB's is that they are stable; is that correct?

A. Yes.

Q. You have described them in the past as being like pebbles on a beach; is that correct?

A. I have used that expression, yes, sir.

Q. And you knew that those pebbles, meaning PCB's, would be found throughout the environment, did you not?

A. No. I would not say that I knew they would be found throughout the environment. I used that expression to describe those situations when, for some reason, the material would be spilled in the environment, and if so they would be perceived as not affecting the environment any more than a pebble on a beach.

Q. You knew that -- At some point in time you knew that PCB's were being used in plasticizers; is that

correct?

A. Yes.

Q. Including inks?

A. Yes.

Q. Including carbon paper?

A. Yes.

Q. Including solvents?

A. Yes.

Q. Including adhesives?

A. Yes.

Q. Including paints?

A. Yes.

Q. Including an extender of Lindane, as a pesticide?

A. Yes.

Q. And you knew that when PCB's were used in those plasticizers, that the PCB's would become part of the environment, just like there are pebbles on a beach; isn't that true?

MR. BAUER: Object to the form. No definite period of time when he knew this.

A. Yes. I was aware that there was the opportunity for the material to enter the environment.

Q. (by Mr. Bradley) And when did you become aware of the opportunity for the material to enter the

environment? Did you learn of that when you learned that the PCB's were being used in the plasticizers?

A. I have difficulty describing this. It wasn't so much an awareness as it was a situation that was given consideration once the reports were made known to Monsanto that the PCB's were found in the environment.

Q. I appreciate that. My question, though, is, did Monsanto know, when it used PCB's in plasticizers, that PCB's would escape to the environment?

MR. BAUER: Object to the form of the question. It's not the same question. You said, "I appreciate that. My question, though, is..," implying that you were restating your question. Lacks foundation, that this witness would know everything that Monsanto knew, going all of the way back to the thirties and forties when this witness was ten years old. But you can answer.

Q. (by Mr. Bradley) Well, let me rephrase the question. Did you ever become aware that, when PCB's were added to plasticizers, that the PCB's would escape to the environment?

A. Did I ever become aware of this?

Q. Yes.

A. I find that difficult to respond to, because that awareness is no different than all of the other ingredients that go into that plastic material.

Q. For example, you knew that when PCB's were added to Lindane as a plasticizer, that when Lindane with PCB's added to it was used, that PCB's then, along with all the other ingredients being used, would be added to the environment?

A. Yes.

Q. The same would be true for PCB's added to paint. You knew that when paint was used that contained PCB's, PCB's then would be part of the environment, along with the paint.

A. You can go on and on. Yes.

Q. I take it that you believed that information when you learned that PCB's were being added to the different plasticizers?

A. I hesitate, because I don't know that I personally gave it a thought, along the lines that you're describing, at that time.

Q. Is there a reason, that you're aware of, that Monsanto, knowing PCB's were stable in the environment, and knowing that they were escaping into the environment through use as plasticizers, that Monsanto did not conduct any studies to determine the presence of PCB's in the environment until the reports from Sweden came out?

MR. BAUER: Object to the form of question. Lacks foundation. Assumes facts not in evidence, and

argumentative.

Q. (by Mr. Bradley) Well, then, let me rephrase the question. Prior to the studies coming out of Sweden in '66 or '67, did Monsanto undertake any studies to determine the presence of PCB's in the environment?

MR. BAUER: Objection. Lacks foundation.

A. No studies were made because the technology was not available.

Q. (by Mr. Bradley) And the technology became available apparently when the Swedish researchers undertook their efforts?

MR. BAUER: Object to the form of the question. The use of the word "apparently."

Q. (by Mr. Bradley) Well, then, let me rephrase the question. The technology was certainly available by the time the Swedish researchers Jensen and Widmark reported the presence of PCB's in 1966 and 1967; is that correct?

A. Professors Widmark and Jensen developed the technology in conjunction of the development of the technology for the detection of DDT.

Q. Is there a reason, that you're personally aware of, why Monsanto did not develop technology before 1966 to determine the presence of PCB's in the environment?

A. I can think of several reasons, really, the

primary one being the lack of the sophisticated equipment that was being developed, which was not available to Monsanto until after '66 -- in 1966.

Q. Any other reasons?

A. I suppose another key reason is one of a perceived need to conduct such a study. What is the problem? What are we looking for? What solution are we seeking?

Q. Any other reasons?

A. That is all I can think of at the moment.

Q. Now, when Dr. Jensen and Dr. Widmark developed sophisticated equipment to determine the presence of PCB's in the environment, do you know what resources they had to develop that sophisticated equipment?

A. I didn't mean to imply that they developed the equipment. They were in a position where they could obtain the latest in equipment in Europe because of their deep involvement in DDT studies.

Q. Who within Europe developed the sophisticated equipment that was used by Jensen and Widmark to detect the presence of PCB's in the environment?

A. I don't remember.

Q. Is there a reason that Monsanto did not develop that sophisticated equipment?

A. That is not their business.

Q. Is there a reason that Monsanto did not

request the development of that sophisticated equipment?

MR. BAUER: Object. Assumes facts not in evidence?

A. I would be speculating.

Q. (by Mr. Bradley) Do you have any personal knowledge whether Monsanto ever requested the development of that type of sophisticated equipment? Do you have any personal knowledge of whether Monsanto requested development of that type of sophisticated equipment that Professors Jensen and Widmark or Jensen used to determine the presence of PCB's in the environment?

A. I have no knowledge of that.

Q. As a general statement, is it true that Monsanto has prided itself on the resources and expertise it has regarding the chemicals that it manufactures?

A. I have no reason to disagree with that.

Q. And is it fair to say, in 1957, that if Monsanto, with its sophistication regarding the chemicals that it manufactures, that if it had wanted to determine the presence of PCB's in the environment, it had the resources to request the development of whatever sophisticated equipment was ultimately developed that was used by Professors Jensen and Widmark to determine the presence PCB's in the environment?

MR. BAUER: Same objection.

A. I don't feel qualified to respond to that. I just don't know.

Can we take a break?

MR. BRADLEY: Yes.

(Thereupon, a short recess was taken.)

Q. (by Mr. Bradley) What did you think would happen to the PCB's used in plasticizers? Did you think they would enter the environment and remain there like pebbles on a beach?

MR. BAUER: Objection. At what point in time?

MR. BRADLEY: When he learned that PCB's were being used in plasticizers.

MR. BAUER: Objection. He already testified that he didn't recall giving it any particular thought at that point in time. Asked and answered.

A. It depended on the period of time that you had in mind.

Q. (by Mr. Bradley) The time that you learned that PCB's were used in plasticizers, what did you think was going to happen to the PCB's? Did you think it would enter the environment and be like a pebble on the beach?

A. Yes. And that is based on all of the information that we had, that PCB's were very, very stable, did not react, therefore, would do nothing in the environment.

Q. Are you aware of any information regarding the

hazards or presence of PCB's that was provided to customers of transformer and capacitor manufacturers from any public or private organization?

A. At what point in time?

Q. Any point in time.

A. Any point in time?

Q. Yes.

A. Eventually the governmental agencies and departments did get involved and did communicate.

Q. When was the first time that there was a governmental organization or agency that communicated information regarding the presence or hazards of PCB's to customers of capacitor and transformer manufacturers?

A. About 1971 is as close as I can recall.

Q. Which government agency was it in '71 that provided that type of information?

A. As best as I can recall, the Food and Drug Administration published in the Federal Register some guidelines regarding the presence of PCB's in certain foods.

Q. So subscribers to the Federal Register would have conceivably seen that?

MR. BAUER: Object to the form.

A. Certainly.

Q. (by Mr. Bradley) Did the FDA provide that

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information in any form other than through the Federal Register?

MR. BAUER: Objection. Lacks foundation.

A. I don't know.

Q. (by Mr. Bradley) When was the next governmental agency action that provided information on the presence or hazards of PCB's to customers of transformer and capacitor manufacturers using PCB dielectric fluid?

MR. BAUER: Objection. Lacks foundation.

MR. BRADLEY: Would you like to stipulate to the "Lacks foundation" and answer questions on that topic? If you do, then that will save us some time.

MR. BAUER: Being defined as what?

MR. BRADLEY: The nature and extent of the publicly-available information regarding PCB's from various public or private organizations.

MR. BAUER: No. You have to establish a foundation.

MR. BRADLEY: Then I am going to assume that at some point in time we'll have a foundation established for you. I apologize for going through that.

Would you read back the last question.

(Thereupon, the reporter read back the question.)

A. Will you help me with the definition of "government"? Are we talking about federal, state, or

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both?

Q. (by Mr. Bradley) Either, any government, including local, city, county.

MR. BAUER: Same objection.

Q. (by Mr. Bradley) Anything that you are personally aware of.

A. There were many meetings on the subject of PCB's in the environment, some of which I attended, and some of which I couldn't attend. I am having difficulty recalling the dates when these meetings occurred, but they were open to the public. I recall a large group gathering in the Chicago area that concerned itself with the Great Lakes.

Q. Was that before a national conference on PCB's in Chicago?

A. Oh, yes. This was in 1970 or so.

Q. How did you learn of the meeting in 1970 regarding the Great Lakes?

A. As I recall, the manager of the Chicago sales district called Monsanto, Mr. Bergen, and informed them of a meeting that he had heard about and suggested that we attend, and I was one of several that attended, along with medical department personnel and chemistry people.

Q. What other governmental action was taken that informed the customers of transformer and capacitor manu-

facturers who were using PCB dielectric fluids of the hazards of the presence of PCB's in the environment?

MR. BAUER: Objection. Compound. Lacks foundation that he would know about all of them. But go ahead.

A. The Federal Interagency PCB Task Force published in May of 1972 a very extensive report on PCB's and their affect on the environment or presence in the environment, and so on.

Q. (by Mr. Bradley) Did Monsanto make copies of the interagency report and send them to the customers of transformer and capacitor manufacturers who were using PCB dielectric fluid?

A. Yes. I did it personally.

Q. Let me ask -- You sent it --

Would you read my question back.

(Thereupon, the reporter read back the question.)

A. I misunderstood your question.

Q. (by Mr. Bradley) Would you now answer the question? As I understand it, you made copies and sent it to purchasers of Monsanto's PCB dielectric fluids.

A. Correct.

Q. And did Monsanto send it to the customers of the transformer and capacitor manufacturers?

A. Not to my knowledge.

Q. To your knowledge, did any of your customers send copies of that interagency report to the electric utility companies that were purchasing transformers or capacitors from you?

A. I was repeatedly informed that they did. I personally did not know.

Q. Who told you that they provided that information?

A. Many, if not all, of the representatives on the ANSI Committee indicated that their customers had received copies.

Q. So, Mr. Raab, for example, indicated that customers of GE had received copies of the interagency task force report?

A. Yes.

Q. And Mr. Sloat stated that customers of Westinghouse had received copies of the interagency task force report?

A. As best I recall, yes.

Q. Who prepared the interagency report?

A. I don't know.

Q. Did Monsanto have any role in the preparation of that report?

MR. BAUER: Objection. Vague as to what you mean. Drafting it, or providing information to the

government?

Q. (by Mr. Bradley) If you answer yes, then I'll ask you what type of involvement. Do you know whether they had any involvement whatsoever in the interagency report?

A. Yes.

Q. What involvement did they have?

A. Mr. Wheeler and I, and Dr. Robert Kelly, met with the interagency task force in the latter part of 1971 and reviewed with them our relevant information regarding PCB's, findings in the environment, the uses of PCB's, Monsanto's program for withdrawal, the analytical methodologies, the toxicity, animal studies, and so on.

And later, as I recall, still in late '71, Monsanto sent to the interagency task force representatives, at least some of them, the information regarding the production of PCB's through the years '58 through '71, as I recall, and also broke that -- those numbers down into the types of uses, how many PC pounds went into each of the uses. Those are the two, what I consider, key contributions to the task force.

Q. Did Monsanto provide any written information to the task force?

A. The numbers regarding the PCB production, yes.

Q. And any written information on PCB's, finding PCB's in the environment, uses, Monsanto's planned with-

drawal, toxicity or animal studies?

A. They provided copies of Monsanto's analytical methodology for detecting the presence of PCB's in water, air, or solid material. Mr. Wheeler provided them with some written documents summarizing the toxicity studies. I don't recall any other written material.

Q. Who were members of whatever group authored the interagency task force report?

A. You mean by individual names, or departments?

Q. Let me ask you this: Do you know who wrote the interagency task force report?

A. I do not.

Q. Do you know whether Monsanto employees helped write the interagency task force report?

A. Monsanto had no involvement in the writing of the report.

Q. Did you read the interagency task force report?

A. When I got a copy, yes.

Q. Do you know whether the report fairly represents the information that Monsanto provided to the interagency task force?

A. It does.

Q. Are you aware of any information Monsanto provided to the task force that was not included within the

report?

MR. BAUER: Object to the form of the question. Every single piece of information that was passed on was included in the report? Every topic that they discussed. Object to the form of the question. Calls for speculation. Compound.

A. There was some information we shared with the members of the interagency task force that did not appear in the report.

Q. (by Mr. Bradley) And what information was that?

A. There was information in detail regarding some biodegradation testing conducted by Monsanto. There was information put together by a Monsanto representative that attempted to understand why the higher chlorinated PCB's were found by the scientists of the day, when the lower chlorinated biphenyls were really the dominant type sold. And there was another report we made to that agency regarding the presence of PCB's in animal tissue before the study began, after the study was underway, and at the end of the study, that did not appear in that agency task force report.

Q. Did you have any written or oral contacts with any electrical trade association regarding PCB's?

A. Yes.

Q. Did those communications result in the publication of any documents by the trade association?

A. Yes.

Q. Which publications resulted that touched on or related to the contacts you had with those trade associations?

A. I need a little help with the word "publication." Are you talking about an information sheet of some sort, or correspondence?

Q. Let's define it as anything written.

A. An example of what I had in mind was my close contact with the NEMA organization, and the correspondence that resulted from the formation of the ANSI Committee, the group that ended up being the ANSI Committee. I was working with another group, EIA, Electronic Industries Association. As I recall, there was correspondence from that group, the group that I met with, to its members.

Q. Was the EIA an association of manufacturers?

A. Yes. Are you talking about manufacturers of electrical equipment?

Q. Yes. Manufacturers of electrical equipment.

A. As I understood it, the EIA included companies, memberships -- its members included companies that made capacitors, and companies that made TV sets in which capacitors are used.

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Q. Did its members include customers of manufacturers?

A. Well, the TV manufacturer who bought a capacitor from the capacitor manufacturer would represent that type of relationship.

Q. Do you know whether any EIA members included the electrical utility companies that were obtaining PCB dielectric fluid from Monsanto by purchasing from the companies that made transformers?

A. I don't know.

Q. What other contact with trade associations?

MR. BAUER: You mean direct contacts with the trade association, as such? He already testified some about the one representative from Union Electric who was on ANSI. Are you including that kind of contact where a representative of an association attended a different meeting, or are you talking about where Mr. Papageorge was going to communicate with an organization as an organization?

MR. BRADLEY: The latter.

A. I can't think of any organizations of the type we are discussing here.

Q. (by Mr. Bradley) Did you have any communications with any electric utility industry associations regarding the presence or hazards of PCB's?

A. No.

Q. Do you know whether anyone within Monsanto had communications with electric utility industry associations regarding the presence or hazards of PCB's?

A. I do not know.

Q. Do you know whether there are any electric utility trade associations or electric utility industry associations that informed its members that Monsanto knew in the 1930's that PCB's could be absorbed through the skin?

A. I do not know.

Q. And if I asked you other questions regarding the specific information Monsanto may have known in the 1930's, would you also not know whether that information was transferred from the electric utility trade or industry associations to its members?

A. I personally do not know, no.

Q. Monsanto hired Industrial Bio-Test Lab to conduct some tests of its PCB material, correct?

A. That is correct.

Q. And Dr. Paul Wright at IBT was responsible for conducting parts of those studies; is that correct?

MR. BAUER: Objection. Lacks foundation.

Q. (by Mr. Bradley) Well, do you know whether Dr. Paul Wright was responsible at IBT for participating in

any of the testing being done on Monsanto PCB products?

A. I know that Dr. Wright was an employee of IBT Laboratories. I also know that he was involved in some way with these studies. I do not know the extent of his involvement.

Q. And do you know that before Dr. Wright was an IBT employee, that he was a Monsanto employee?

A. I found that out later, yes.

Q. Do you know that Dr. Wright went directly from being a Monsanto employee to being an IBT employee?

A. I was told that.

Q. And did you learn that in September of '72, following his work at IBT, that he returned to Monsanto as an employee?

MR. BAUER: Objection. Vague on as to when Mr. Papageorge learned of this, whether he learned at the time or later.

A. I recall Dr. Wright rejoining Monsanto medical department in late '72. I didn't have any of his background.

Q. (by Mr. Bradley) When you learned that he rejoined Monday in late '72 did you learn that at or about the time that he became employed at Monsanto in September of '72?

A. Yes. About that time, yes.

Q. And when Dr. Wright again was working for Monsanto in September of '72, was he part of Monsanto's toxicology section in the medical department?

A. Yes.

Q. And after Dr. Wright left IBT and returned to Monsanto in September of '72, was Dr. Wright given any responsibilities regarding the testing that IBT was doing regarding PCB products manufactured or blended by Monsanto?

A. Yes.

Q. And what responsibilities did he have in that regard?

A. All I know is that Dr. Wright was involved, to a limited degree, really, from my perspective, with the studies.

Q. Did anyone at Monsanto ever write to IBT requesting that they change the conclusions regarding the carcinogenicity of PCB material that was blended by Monsanto that IBT was testing?

MR. BAUER: Object. Lacks foundation.

A. I was made aware years later that such correspondence had taken place.

Q. (by Mr. Bradley) When were you made aware of that correspondence?

MR. BAUER: Repeat the previous question, please.

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(Thereupon, the reporter propounded the previous question.)

A. As best I recall, it was early eighties.

Q. (by Mr. Bradley) How did you become aware of that correspondence?

A. I was involved with a legal matter, and the attorneys showed me some documents.

Q. What legal matter were you involved in?

A. This was a trial that I am going to refer to as the Scott case. I don't know if that is the official or legal or formal designation.

Q. Did you become aware that Dr. Wright was indicted for fraudulently reporting test results that he was involved with at IBT?

A. I read it in the local newspaper, yes.

Q. Did you ever become aware that part of the test results that Dr. Wright was alleged to have falsified involved Monsanto products?

A. That is what I read in the local newspaper.

Q. Roughly, when did you read that in the local newspaper?

A. Again, early eighties.

Q. What response, if any, are you aware of, that Monsanto took in response to the publications in local newspapers that Dr. Wright had been indicted for falsifying

data at IBT regarding Monsanto products?

A. I don't personally know the response.

Q. Do you know whether Monsanto, after it read about Dr. Wright's falsification of data at IBT regarding Monsanto products, undertook an investigation of the criminal proceedings to determine what evidence, if any, Dr. Wright may have falsified?

MR. BAUER: Object to the form of the question. He's also answered that he was not aware of the response.

A. I just do not know what anyone did regarding that case other than what appeared in the local newspaper.

Q. (by Mr. Bradley) Do you know whether any committee outside of Monsanto's legal staff, or any other assemblage of Monsanto employees, whether it's an ad hoc group or a group by any other name, was formed at Monsanto to investigate the allegations that Paul Wright had falsified data involving Monsanto products?

A. I am not aware of that.

Q. As far as you know, Monsanto did nothing, then, upon learning of that information through the local newspaper?

MR. BAUER: Object. Repetitive. Argumentative. He said he doesn't know what the response was, three times.

A. Something happened, but I don't know what regarding the response to this.

Q. (by Mr. Bradley) When you say "Something happened," what leads you to conclude that something happened?

A. Well, I don't know where I got that information.

MR. BAUER: If you're going to reveal contents of any communications with attorneys, we need to talk before you do.

A. I don't know how I got that impression. Maybe I just assumed that something was going to happen. I don't know.

Q. (by Mr. Bradley) Did Monsanto ever gain knowledge that furans or dioxins were present in PCB blends that it manufactured?

MR. BAUER: Object. Compound, and vague as to whether you are talking about as it went out the door, or after some other event.

Q. (by Mr. Bradley) Well, let me rephrase the question. Did Monsanto ever gain knowledge regarding the presence of furans in any of the PC blends it manufactured?

MR. BAUER: Did you say "PC"?

Q. (by Mr. Bradley) Did Monsanto gain knowledge regarding the presence of furans in PCB mixtures it

blended?

A. First, I believe you're referring to chlorinated dibenzofurans; it's two different chemicals. Secondly, when you say PCB mixtures that had been blended, I need some help understanding what you mean by that, because the PCB's that Monsanto manufactured are mixtures of the various kind of PCB's, but there is no blending that takes place. It's part of the process.

If, by blending, you're talking about making dielectric fluids that contain PCB's, plus chlorobenzenes, plus other ingredients, that is a different mixture altogether.

Q. Let me rephrase the question, then. Did Monsanto gain knowledge regarding the presence of either dibenzofurans or chlorinated dibenzofurans in PCB dielectric fluids that Monsanto blended and sold?

A. I am not aware of any study conducted by anyone that attempted to determine chlorinated dibenzofurans in dielectric fluids in which PCB's are a component, along with other materials.

Q. Did Monsanto gain knowledge regarding the presence or absence of furans in the PCB's it manufactured?

MR. BAUER: For the purposes of this deposition, now, we're going to use furans as a shorthand reference for chlorinated dibenzofurans?

Q. (by Mr. Bradley) No. Any type of furan, either chlorinated dibenzofurans or --

MR. BAUER: Okay. So furan is a shorthand reference for chlorinated dibenzofurans?

MR. BRADLEY: Or any other form of furan, if there is such a thing.

MR. BAUER: Okay.

A. Eventually.

Q. (by Mr. Bradley) When did Monsanto gain that knowledge?

A. As best I recall, it was in 1976.

Q. Did the knowledge that Monsanto gained in 1976 involve the presence of chlorinated dibenzofurans in its PCB's that Monsanto manufactured?

A. Some of them, yes.

Q. What is the difference between a chlorinated dibenzofuran and a dibenzofuran?

A. A chlorinated material has chlorine added to it.

Q. Is there any difference regarding the toxicity of the material?

MR. BAUER: Objection. Lacks foundation. Calls for expert --

Q. (by Mr. Bradley) Were you ever given any tutorial by Wheeler, Kelly, Roush, or anyone else within

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Monsanto, regarding the difference in toxicity between dibenzofurans and chlorinated dibenzofurans?

A. No.

Q. Did you ever undertake any study to determine the difference in toxicity, if any, between dibenzofurans and chlorinated dibenzofurans while you were at Monsanto as an employee?

A. No.

Q. Were you ever given any information by anyone who was an employee in the medical department at Monsanto regarding the toxicity effects of chlorinated dibenzofurans?

A. Yes. There was some discussion regarding the toxicity effects.

Q. What were you told were the toxicity -- What were you told regarding the toxicity of chlorinated dibenzofurans when you had the discussion with the employees at Monsanto's medical department?

A. I don't recall the specifics, other than there were some studies made. As I remember, they involved poultry, and there were some health effects noted. I don't know the levels of exposure, or the symptoms.

Q. Okay. Were you ever told that chlorinated dibenzofurans were more toxic than PCB's?

MR. BAUER: Objection. It's unclear whether

you have now gone outside of what Monsanto told him.

Q. (by Mr. Bradley) Were you ever told by any Monsanto employee that chlorinated dibenzofurans are more toxic than PCB's?

A. Yes, but it was based on limited information. But that was the impression that I was left with.

Q. Were you ever informed prior to 1976 that chlorinated dibenzofurans were present in Santowax R?

A. No.

Q. Were you ever told that dibenzofurans were present in Santowax R?

A. Yes.

Q. When were you told that?

A. In the seventies. I don't remember the exact year.

Q. Were you told whether or not the dibenzofurans that were present in the Santowax R were chlorinated?

A. No. Couldn't have been.

Q. Your answer is that the dibenzofurans in the Santowax R could not have been present?

A. There was no chlorine solution in the Santowax R.

Q. Were you ever told that if PCB's were incinerated at a low temperature, that they could produce vapors that contained chlorinated dibenzofurans?

MR. BAUER: Would you read that back, please.

(Thereupon, the reporter read back the question.)

A. I don't recall anyone ever telling me that. But with my chemistry background, I speculated that way, without any testing, that conditions could be such that the chlorinated dibenzofurans might be formed.

Q. (by Mr. Bradley) Did you also conclude that dioxins might be formed if PCB's were incinerated at low temperatures?

A. Well, there I was not as confident of my guesswork, to call it that, because the chemical configuration was different.

Q. Do you recall ever reporting to anyone that, if PCB's were incinerated at a low temperature, that dioxins could be formed?

A. I recall using those words of caution as a means of getting attention regarding the proper conditions for incineration, yes.

Q. And you issued that caution in 1970; is that correct?

A. Started in 1970, yes.

Q. And you knew at that time that, on occasion, because of arcing in electrical transformers, that PCB's in transformers could get to elevated temperatures; is that correct?

A. I was aware of the elevated temperature, yes, sir.

Q. Did you then require that Monsanto's labels for its PCB products indicate that, if temperatures reached a certain height, that furans could be produced? Excuse me, chlorinated dibenzofurans could be produced?

A. It's not only temperature; you have to have a source of oxygen. It's a sealed unit. Where would it get its oxygen?

Q. Did the units ever leak?

A. It's unlikely; and the arcing occurs down at the bottom. If there is any oxygen, it would be up at the little airspace up at the top. It's very remote.

Q. Despite whether its report -- Did Monsanto, as far as you know, ever include that information in its label, that if oxygen is added and the PCB gets elevated in temperature to a certain degree, that chlorinated dibenzofurans could be produced?

A. It did not.

Q. Did Monsanto ever include in its label the warning that, if PCB's are elevated to a particular temperature, and there is the presence of oxygen, and the PCB comes in contact with oxygen, that dioxin is going to be produced?

A. No. Because there is no scientific basis for

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such a statement.

Q. In fact, do you now know whether, if PCB's are heated to a certain temperature, and oxygen is added, whether chlorinated dibenzofurans are formed?

A. I understand that that is possible.

Q. And in fact, the guesswork you did in 1970 proved accurate, didn't it, in that what you were warning about regarding the formation of chlorinated dibenzofurans and dioxins if PCB's were not heated at a sufficiently high temperature, your guesswork came true?

A. Yes.

Q. You're presently retired from Monsanto, correct?

A. I am.

Q. As part of your retirement benefits with Monsanto, were you provided shares of any Monsanto stock?

A. No.

Q. Are you a shareholder of Monsanto stock?

A. I am.

Q. Do you know whether Paul Benignus is a shareholder of Monsanto stock?

A. I do not, no.

Q. Do you know whether any past or present employees other than yourself are shareholders of Monsanto stock?

A. I do not know.

Q. Do you know what the source of funds are, if there is a discreet source of funds that are used to pay retirement benefits to any former Monsanto employees?

A. I don't know anything about that program.

Q. Do you know whether you would still receive retirement benefits if for some reason Monsanto went out of business?

A. I --

MR. BAUER: Object to the form. Calls for speculation about all kind of things, including the financial capability of pension guaranteed trust funds.

A. I know nothing about it. All I can do is be hopeful that it stays as is.

Q. I am now showing you Plaintiff's Exhibit 2791, which is a letter from J.C. Calandra to O.J. Levinskas, dated July 1, 1975. Have you seen that document before?

A. I don't recall seeing it.

Q. I am going to show you Plaintiff's Exhibit 2796, which is a letter from Paul Wright, the section head of toxicology of Industrial Bio-Test Laboratories, dated September 30, 1970, to Dr. Levinskas and ask you if you have seen that document before.

MR. BAUER: That was 2796?

MR. BRADLEY: Yes.

MR. BAUER: Okay.

A. I have not seen this document before.

Q. (by Mr. Bradley) I am now going to show you Plaintiff's Exhibit 1577. Is that a document you have seen before?

A. Yes.

Q. What is that?

A. This is a multipage document containing questions and answers relating to the PCB environmental issue.

Q. When was it authored?

A. As best I recall, fairly early in 1970.

Q. Who authored it?

A. Mr. E.V. John.

Q. And what was his title when he authorized it?

A. He was in public relations, the manager.

Q. At Monsanto?

A. Yes.

Q. Is this a true and accurate copy of the document that he authored in the early seventies?

A. This appears to be, as best I recall.

Q. Did he prepare that as part of his regular business activities as a Monsanto employee?

A. Yes.

Q. Did Monsanto maintain a copy of that as part of its regularly-conducted business?

A. Yes.

Q. Does that exhibit contain information that became available to Mr. John at or about the time the document was prepared?

A. Yes, sir.

Q. I am going to show you Plaintiff's Exhibit 1337 and ask if you have seen that document before.

A. I have seen this before, yes.

Q. What is it?

A. It consists of a transmittal letter from the Department of Health, Education, and Welfare, authored by Mr. Mark Jones, addressed to Paul Heisler at Monsanto in Sauget, Illinois, S-a-u-g-e-t, and attached to it is a copy of a report covering an industrial hygiene survey of the PCB facilities at the W.G. Krummrich Plant of Monsanto.

Q. Is that letter dated May 10th, 1977.

A. Yes.

Q. Is this a true and accurate copy of the document that you saw previously that was authored by that gentleman on that date?

MR. BAUER: Speaking of the cover letter?

MR. BRADLEY: And the report.

MR. BAUER: Well, the report has a different date.

A. Well, there's some handwritten notes that I

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don't recognize here on page five of the report, otherwise it appears to be the document I saw back in '77.

Q. (by Mr. Bradley) When you saw the document in '77 did it have the report attached to the cover letter?

A. Yes.

Q. All right. And may I see it?

A. Yes.

Q. Was a final report of the industrial hygiene survey conducted at the W.G. Krummrich Plant issued on or about July 21, 1976?

A. Well, no. The survey was made in '76. The report is the one we're looking at now, which came out almost a year later.

Q. I see. And does this letter convey that the report is being transmitted to Monsanto and to NIOSH and other administrative agencies?

A. That is the purpose of it, yes.

Q. And did Monsanto maintain a copy of this in its files as part of its regularly-conducted business?

A. Yes.

Q. The report that is attached, is that a report that Monsanto prepared or somebody else prepared?

A. This report was prepared by the NIOSH people.

Q. And is that a true and accurate copy of the report that was prepared by Niosh?

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A. As I indicated earlier, except for some hand-written notes on page five, it appears to be so.

Q. Was the report prepared at or about the time that the survey was completed?

MR. BAUER: Objection. Asked and answered.

Q. (by Mr. Bradley) Excuse me. You said it was about a year later?

A. The report was issued about a year later. When they started preparing it and finished preparing it, I have no way of knowing.

Q. I am showing you Plaintiff's Exhibit 1119. Have you seen that before?

A. Yes.

Q. Is that a true and accurate copy of a document entitled "Aroclor Business to be Discontinued Immediately"?

MR. BAUER: Is this a complete document by itself or an accurate copy of a portion of the document?

Q. (by Mr. Bradley) Is it an accurate copy of whatever you reviewed before that had this document in it?

A. Yes.

Q. Is this a page out of what appears to be a larger volume?

A. Yes.

Q. Are you able to tell us what the larger volume was that this was a part of?

A. In was part of a presentation made to Monsanto's corporate management committee meeting.

Q. When?

A. As best I remember, it was May of 1970.

Q. Did -- Was that document prepared at all as part of the presentations and activities referred to in Plaintiff's Exhibit 1118?

A. No. This document is 1969, and this is 1970.

MR. BAUER: I think there may be some confusion about what you mean. If you mean this was part of the continuing following activity --

Q. (by Mr. Bradley) That is my question. Was document 1119 prepared as part of the follow-up activities that resulted from the activities that were described in Plaintiff's Exhibit 1118?

A. Oh, yes.

Q. Is that a true and accurate copy of the page that -- of the slide presentation that was presented to the corporate management committee in 1970?

A. It appears to be, yes.

Q. Does that exhibit contain information that is correct as of the day it was written?

A. Yes.

Q. And are you able to tell the day that exhibit was authorized?

A. Not the exact date. April, 1970 period.
Q. And was this exhibit prepared as part of the regular business activities of Monsanto?
A. Yes.
Q. Was a copy maintained within Monsanto's files as part of its regularly-conducted business?
A. Yes.
Q. Now, I am going to show you Plaintiff's Exhibit 1186 and ask if you have seen that document before?
A. I don't recall seeing this document.
Q. Now, I am going to show you Plaintiff's Exhibit 540. Have you seen that document before?
A. Yes, or I have seen the principle document. I don't recall specifically seeing the cover page.
Q. Okay. Other than the cover page, you have seen the document before?
A. Yes.
Q. And that is entitled "Askarel Inspection and Maintenance Guide"?
A. Yes.
Q. Are you able to tell the date that was authored?
A. 1967.
Q. Is that "Instruction" --
MR. BAUER: Inspection.

Q. (by Mr. Bradley) -- "Inspection and Maintenance Guide a document that was given to purchasers of PCB dielectric fluid from Monsanto on or about 1967?

A. Yes.

Q. Is that a true and accurate copy of the "Inspection and Maintenance Guide" that you had in 1967, or whenever it was that you reviewed it?

A. It appears to be, yes, sir.

Q. Does that guide contain information that was current as of 1967?

A. As best as I can determine, yes.

Q. Was that guide authored as part of the regular business activity of Monsanto?

A. Yes, sir.

Q. Was a copy maintained in Monsanto's files as part of its regularly-conducted business?

A. Yes.

Q. I am going to show you Plaintiff's Exhibit 1942 and ask if you have seen that document before?

A. I have not seen the document as I read it now, but I recognize its contents that I have seen at different times, but not as a package, so to speak.

Q. Do the contents of that exhibit reflect true and accurate copies of the contents that you reviewed prior to today?

A. Yes.
Q. Okay.
A. Except for the color scheme.
Q. All right. The originals have color on them?
A. Yes, they do.
Q. Okay. And do the pages within that exhibit contain information that was then current when those documents were prepared?
A. Yes.
Q. Were those, the pages within that exhibit, prepared as part of the regular business activity of Monsanto?
A. Yes.
Q. Were copies maintained within Monsanto's files as part of its regularly-conducted business?
A. Yes.
Q. I am now going to show you Plaintiff's Exhibit 1458, and ask if you have seen that document before?
A. I have seen the document as part of a manual describing the manufacturing process for Aroclors.
Q. May I see that? This exhibit contains the toxicity section of a "Standard Manufacturing Process, Aroclors (Take-Over Distilled), Department 246;" is that correct?
A. That is the title, yes.

Q. Are you able to tell what date that document was authored?

A. I have no way of determining that.

Q. Okay. Is that a document that was intended only for distribution to Monsanto employees?

A. Yes.

Q. Okay. Is that a true and accurate copy of the toxicity section of the standard manufacturing process that you reviewed before today?

A. It appears to be.

Q. Does that -- Were standard operating procedure, or -- excuse me -- standard manufacturing process documents on processing Aroclors prepared from information that was then current?

A. Yes.

Q. And did Monsanto create that document as part of the regular business activity of Monsanto?

A. Yes.

Q. Did Monsanto maintain a copy in its files as part of its regularly-conducted business?

A. Yes.

Q. I am now going to show you Plaintiff's Exhibit 1124, and ask you if you have seen that document before today.

A. As I glance through this, I don't recognize

this as a document that I have seen before.

Q. I am going to show you Exhibit 1757 and represent to you that it is a portion of a finality report that appears to have more than three hundred pages in the actual report, and the exhibit has roughly two hundred and twelve pages. If you would review that. First tell me whether you have seen that document before.

A. I don't recall seeing this document at all.

Q. Okay.

Q. I am now showings you Plaintiff's Exhibit 2798, and ask that you review it.

A. I have reviewed the document.

Q. Is this a document you have seen before today's date?

A. I don't recall seeing this.

Q. I am now going to show you Plaintiff's Exhibit 424 and ask you to review that document.

A. Yes, I have reviewed this document.

Q. First of all, there are some words missing on the right-hand side of different pages because of the copying; is that correct?

A. Yes.

Q. Other than that one deficiency, is this a true and accurate copy of a document you have seen before today's date?

A. Yes.
Q. What is that?
A. A Monsanto memorandum by Dr. Richard to Mr. E. Wheeler dated September 9th, 1969.
Q. Does the memorandum have attachments?
A. Well --
Q. I guess it doesn't, does it?
A. I don't recall seeing any.
Q. And does the information contained in that exhibit -- Is the information contained in that exhibit current as of the date that the exhibit was authored?
MR. BAUER: Objection. Lacks foundation. You can answer if you are able.
A. It appears to be so, yes.
Q. (by Mr. Bradley) And was that exhibit prepared as part of W.R. Richard's and Monsanto's regular business activities?
A. Yes.
Q. Did Monsanto maintain a copy in its files as part of its regularly-conducted business?
A. Yes.
Q. Now, I am going to show you Plaintiff's Exhibit 1452. Is that a document you have seen before?
A. Yes. I am the author.
Q. And what is the date of that?

A. May 20, 1971.

Q. Is that a true and accurate copy of a document you authored May 20th, 1971?

A. It appears to be, yes, sir.

Q. Is the information contained in the exhibit the same as was transmitted to you on or about the date of the exhibit?

A. Yes.

Q. Did you author that document as part of your regular business activity and Monsanto's regular business activity?

A. I did.

Q. Did Monsanto maintain a copy of the exhibit as part of its regularly-conducted business?

A. Yes.

Q. I am now going to show you Plaintiff's Exhibit 1552 and ask you to review that document.

A. I have reviewed the document.

Q. Have you seen the document before?

A. Yes.

Q. What is it?

A. It is a copy of the minutes of a meeting held at Monsanto Company in St. Louis on February 28th, 1974.

Q. is it a true and accurate copy of the minutes of that meeting?

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A. It appears to be.

Q. Is the information contained in the minutes roughly the same information that was presented at the meeting.

MR. BAUER: Object to the form.

Q. (by Mr. Bradley) All right. Does that exhibit contain the information that was presented at the meeting that is referenced in the exhibit?

MR. BAUER: Object to that form. It's a summary. What do you mean by "information"?

A. It's a summary prepared by the author as he understood the meeting.

Q. (by Mr. Bradley) Was it authored at or about the time of the meeting that it references?

A. Yes.

Q. Was this exhibit prepared as part of the regular business activities of Monsanto?

A. Yes.

Q. Was a copy maintained in Monsanto's files as part of its regularly-conducted business?

A. Yes.

Q. I am now going to show you Plaintiff's Exhibit 2799 and ask you to review that document.

A. I have reviewed the document.

Q. Is that a document that you have seen before

today?

A. I don't recall ever seeing this.

May we take a break now, or is it too close to lunch time?

MR. BRADLEY: Let's take an hour luncheon break now, and let's return this afternoon at one o'clock.

(Thereupon, a luncheon recess was taken.)

Q. (by Mr. Bradley) Mr. Papageorge, I am going to reshow you Plaintiff's Exhibit 1335, which I showed to you yesterday. It's a July 6th, 1970 letter from you to Mr. Garlington Wilburn. In your letter you indicate in the second full paragraph, "As we discussed previously total destruction of PCB's can only occur above 800 degrees C. Any temperature below this minimum will result in vaporization with release to the atmosphere or worse yet it is possible to partially oxidize PCB's into materials which can be highly toxic (e.g. dioxins or furans)."

As I understand your testimony from this morning, you indicated that it was your background in chemistry that led you to make your statement that it is possible to partially oxidize PCB's into materials which can be highly toxic, for example, dioxins and furans; is that correct?

A. That is correct.

Q. Can you tell me what information you have

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gained as part of your chemistry background that led you to conclude that a temperature below eight hundred degrees centigrade for destruction of PCB's could result in toxic materials such as dioxins or furans?

A. The temperature, eight hundred degrees, was obtained from some testing that was done for Monsanto at the, I believe it was the John Zinck Company that made incinerators in Tulsa, Oklahoma. These tests were conducted in March of 1970, and indicated that, above eight hundred degrees centigrade, that the gases given off by the incinerator were carbon dioxide and water and hydrogen chloride, which meant destruction of the original chemicals. That is where the temperature came from. There were no other impurities found in the gases.

Now, my scientific speculation at this point, that chlorinated dibenzofurans could be formed, was based on my understanding of the configuration of the chlorinated biphenyls and the fact that the chlorinated furans and chlorinated biphenyls are related in that they both have the double benzene ring with chlorines. The only thing missing from the chlorinated biphenyl is the presence of an oxygen atom. So I jumped into a conclusion that, if there is enough oxygen around and the temperature is not high enough to break up this molecule of PCB, you might get an oxygen attaching itself in such a way that it becomes a

furan, and I did that, recognizing that I had no scientific basis, but wanting to attract attention to the reader of my memorandum to make certain that he looked into all the conditions of incineration to make sure that he got complete incineration. I used those as an example to make my point. I hope I achieved it. I don't know.

Q. You indicate that you didn't have any scientific basis. In fact your opinion did have a scientific basis, did it not, because of the configuration of the chlorinated biphenyls, the fact that their configuration to chlorinated dibenzofurans are related, that they both have double benzene rings with chlorine, and that, apparently, one has an oxygen atom and one does not?

MR. BAUER: Object to the form of the question with reference to the word "opinion."

MR. BRADLEY: Would you read the question back, then, please.

MR. BAUER: I wasn't finished with the objection. The rest of my objection was going to be in light of the fact that the document talks about "could possibly," and I am not sure that that justifies the term, "opinion." But you can answer the question if you are able, or the question can be read back.

(Thereupon, the reporter propounded the previous question.)

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Q. (by Mr. Bradley) I'm going to rephrase the question. When you indicated there was no scientific basis for your statement, there was a scientific basis for that statement, was there not, considering that you have indicated the configuration of furans and benzene were similar, that the furans and biphenyls were related in configuration, that they both had double benzene rings with chlorine, and that one had an oxygen atom and one didn't. So my question is: Your statement actually had some scientific basis, did it not?

A. True. But I was using the word scientific to indicate that I had no laboratory-bench experiment to demonstrate what my chemistry training had taught me.

Q. Following July 6th, 1970, didn't you instruct anyone at Monsanto to undertake an investigation of whether your statement that it is possible to partially oxidize PCB's into materials which can be highly toxic, for example, dioxins or furans, was accurate?

A. No. I had no compelling reason to do that as long as the eight-hundred-degree-centigrade temperature was reached.

Q. All right. Looking back now at Plaintiff's Exhibit 419, and I'll show it to you before I ask you some questions about it, but, if you don't mind, I'd like it back when I ask the questions, unless you need it to refer

to.

In 1970 was it possible to identify dibenzofurans in Santowax R?

A. I am under the understanding, yes. What I don't recall was the level of detection.

Q. In 1970 would it -- was it possible to detect chlorinated dibenzofurans if they existed in Santowax R, or any other material?

A. There was methodology available at the time of that memorandum, October, '70, yes, for determining chlorinated dibenzofurans, if they were present, yes.

Q. And what was the level of detection for determining the presence or absence of chlorinated dibenzofurans in October of 1970?

A. Yes. I remember it was parts-per-billion range.

Q. And is there a reason that -- Or let me ask this: Did Monsanto test for the presence of chlorinated dibenzofurans in the parts-per-billion range for the Aroclor products it blended in 1970?

A. It was tested, yes. There was a program under way.

Q. And what were the results of that testing program?

A. Not detectable.

Q. Isn't it true that the levels of detection that were reported by Monsanto in 1970, '71 or '72, for its Aroclor products, showed a level of detection at two parts per million, or five parts per million?

A. Of what?

Q. Chlorinated dibenzofurans.

A. No, sir. It was zero detectable.

Q. Was there a point in time when Monsanto determined that chlorinated dibenzofurans were present in the Aroclors that they produced?

A. Eventually it was detected, yes, sir.

Q. And how do you explain that it was eventually detected and not detected in early tests?

A. My understanding from the chemists is that their methodology was being fine tuned to the point where the method became sensitive enough that it could be detected and they could quantify it.

Q. When you say the methodology could be sensitive enough, is that also another way of inferring levels of detection?

A. That's one way, but it also includes the full process of taking the sample and pretreating it in such a way that you extract the material that you're looking for efficiently and take it through the steps and through the instrumentation to the point where finally you see some-

thing that you can believe in and quantify.

Q. The methodology that was ultimately used that found the chlorinated dibenzofurans in Aroclors was not a methodology developed by Monsanto. That's true, isn't it?

MR. BAUER: Objection. Vague as to what you mean by "methodology." I mean, there are certain aspects of testing, gas chromatography, gas spectrometry, whatever; but I think what you're trying to get at is, there are particular nuances with respect to detecting a particular substance in another particular substance.

MR. BRADLEY: He had indicated that the methodology had been refined in his prior answer.

The question is: The refinement of the methodology that you referred to was not a refinement that was developed by Monsanto; is that correct?

A. I can give you my understanding. The initial procedure was obtained from some investigators in Holland. Dr. Keller got that information, came back to his laboratory and adapted it to his instruments, and I have an understanding that it was modified by Monsanto scientists through the years until, finally, in '76, they got results.

Q. (by Mr. Bradley) Have you reviewed any documents that state that Monsanto was attempting to refine methodology between 1970 and 1976 to determine the presence of chlorinated dibenzofuran in its Aroclor products?

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A. Documents referring to refining the process, no. Documents referring to the continued efforts to detect, there are some.

Q. What do those documents state?

A. They state in essence that we have tested again and do not see any.

Q. Did they indicate that the tests that they used to test generally used the same methodology as the prior tests?

A. No. These reports do not go into the details of the methods used.

Q. Chlorinated dibenzofurans were found in competitors' PCB products, competitors to Monsanto, in 1970; is that correct?

A. The European competitors, yes, sir.

Q. And following publication of the data that found polychlorinated dibenzofurans in Monsanto competitors' PCB's, did the board of directors of Monsanto or the medical department of Monsanto or any other department at Monsanto give money to anyone for the specific purpose of refining methodology to determine whether polychlorinated dibenzofurans were in Aroclor products manufactured by Monsanto?

MR. BAUER: Objection. Lacks foundation.

A. Certainly the activity within Monsanto was

financed by Monsanto, and that is where the emphasis was placed.

Q. (by Mr. Bradley) Okay. Did you view any documents indicating that Monsanto's board of directors or Monsanto's medical department or Monsanto's toxicology department, or any other department within Monsanto, instructed anyone, including its own employees, following publication of the finding of the polychlorinated dibenzofurans in European PCB products, to spend money or time or effort to refine the methodology to determine whether polychlorinated dibenzofurans were in Aroclor products manufacture by Monsanto?

MR. BAUER: Object. Lacks foundation.

A. I know I personally was very involved with Dr. Keller. I recall Dr. Keller issuing, in essence, progress reports. I do not recall any document, but it could well exist yet, in which this was outlined. There was, from my part, an awful lot of emphasis placed with Dr. Keller, "Let's keep looking."

Q. (by Mr. Bradley) Did Dr. Keller's progress reports -- First of all, did you read Dr. Keller's progress reports?

A. When he issued them, yes.

Q. And did his progress -- Were his progress reports called "progress reports"?

A. No. I don't think that word was used.

Q. Do you recall what his progress reports were referred to as by him when he issued them?

A. No, I don't. I'd have to see them again.

Q. Do you recall whether the progress reports related in any way to efforts by Monsanto to refine a methodology for determining the presence of polychlorinated dibenzofurans in Aroclor products manufactured by Monsanto?

A. That is not the way it's done, sir. The results are important, not the method.

Q. The progress reports simply reported the continued testing of Monsanto's Aroclor products for the presence of polychlorinated dibenzofurans; isn't that true?

A. That would be one way. Another way would be, "Here's our program. We'll test for chlorinated dibenzofurans. We'll test for the chlorine. Here's the program. Here's how many people were involved. Who's assigned the tasks." These kinds of reports did exist at one time.

Q. Exhibit 419 indicates that J.P. Mieure's work located the presence of naphthalene and biphenyl; is that correct?

A. Yes.

Q. J.P. Mieure is a Monsanto employee?

A. Yes.

Q. And the naphthalene that was found was

chlorinated naphthalene; isn't that true?

A. There is no mention of chlorine in that copy.

MR. BAUER: Object to the form of the question. You can ask him if Santowax contained chlorine.

THE WITNESS: There is no chlorine involved in Santowax.

Q. (by Mr. Bradley) Was there any testing done to determine the presence of chlorinated naphthalene in any Aroclor products manufactured by Monsanto?

A. Not that I recall, no.

Q. Do you know whether Monsanto tested any of its Aroclor products for the presence of chlorinated naphthalene?

MR. BAUER: Isn't that the same question?

THE WITNESS: It sounds like it, but I am trying to recall -- I don't recall vividly the product specifications. It seems to me that one of the specifications could have called for a limit on that impurity, but I am not certain at this point.

Q. (by Mr. Bradley) In the 1970's --

A. Yes.

Q. -- professionals working in the field of PCB's and related chemicals would refer to chlorinated dibenzofurans as simply furans; isn't that true?

MR. BAUER: Object to the form. Lacks founda-

tion and calls for speculation as to what unspecified people were thinking.

MR. BRADLEY: I wasn't asking that.

When they would write and refer to furans, you occasionally would know that by furans they meant chlorinated dibenzofurans?

A. Not always.

Q. Sometimes?

A. Sometimes. The careless chemist would use that word inappropriately.

Q. I am now going to show you Plaintiff's Exhibit 408 and ask you to review that document.

MR. BAUER: There is a 1973 document attached to a 1971 document. I take it you probably did not intend for that to be part of the same exhibit.

MR. BRADLEY: I did not. I am going to separate these and remove the last two pages of 408 and ask the court reporter to mark them as 408A.

(Thereupon, the reporter marked Plaintiff's Deposition Exhibit # 408A, for identification.)

A. I have reviewed the exhibit.

Q. (by Mr. Bradley) Is that a document that you have seen before today?

A. Yes, I have.

Q. What is it?

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A. A Monsanto memorandum authored by Dr. Keller, addressed to Dr. Richard, dated October 28, 1971.

Q. Is this what you called a progress report?

A. It falls in that category.

Q. Is this a true and accurate copy of the memo Dr. Keller wrote to -- is it Mr. Richard or Dr. Richard? --

A. Dr. Richard.

Q. -- Dr. Richard on October 28th, 1971?

A. As best as I can recall the first three pages appear to be the same as those I saw back in '71. I don't recognize this fourth page.

MR. BRADLEY: I'm going to remove the fourth page and ask the court reporter to mark that as Plaintiff's Exhibit as 408B.

(Thereupon, the reporter marked Plaintiff's Deposition Exhibit # 408B, for identification.)

Q. (by Mr. Bradley) Does Exhibit 408 contain information that was available to Dr. Keller at or about the time he authored this exhibit?

A. It appears to do so.

Q. And did Dr. Keller prepare this exhibit as part of his regular business activities as a Monsanto employee and as part of Monsanto's regular business activities?

A. Yes.

Q. Was a copy of this document maintained in Monsanto's files as a part of Monsanto's regularly-conducted business?

A. Yes.

Q. What is the title of the memorandum?

A. "Alleged Dioxins and Benzofurans in PCB's - Inputs for Reports."

Q. Would you read the second full paragraph?. Read it out loud, if you would, please.

A. "Overall, we should be able to meet predicted regulatory agency maximum permissible levels of chlorodibenzofurans in our PCB/PCT products. Data in hand show that Aroclor 1242, 1254, 1260 and MCS 1016 contain no detectable," parenthesis, less than two ppm, close parenthesis, "furans (or chlorodibenzo-p-dioxins). Aroclor 5442 contains no detectable," parenthesis, less than five parts per million, close parenthesis, "furans."

Q. When -- What does the word "furans" mean, at the end of that paragraph, to you, as you're reading this? Does it mean dibenzofuran, chlorinated dibenzofuran, or something else?

MR. BAUER: Objection to the form.

A. In this case I'm forced to read that it refers to the chlorinated furans.

Q. (by Mr. Bradley) And the subject matter

doesn't say alleged dioxin and chlorinated benzofurans; is that correct?

A. That is correct.

Q. So the reference in the second paragraph does not refer technically to the title of the memorandum; is that correct?

A. That is correct. Except that the first sentence in that paragraph does use the word "chlorodibenzofurans."

Q. And Dr. Keller is the one within Monsanto who was responsible for determining the presence of chlorinated dibenzofurans in Aroclor products; is that correct?

A. Yes.

Q. In this memorandum he's referred interchangeably to benzofurans, chlorinated dibenzofurans, and furans; is that correct?

A. Yes.

Q. And in this exhibit, as you understand it, each of those terms refers to the same thing, which is chlorinated dibenzofurans?

MR. BAUER: Objection to the form of the question?

A. That is the way I would read this report.

Q. (by Mr. Bradley) Okay. Does -- Now would you read the section one under the portion of the exhibit that

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says, "We Know"?

A. Would I read it?

Q. Please. Out loud.

A. "Monsanto Aroclor 1242, 1254, 1260 and MCS 1016 contain no detectable," parenthesis, less than two ppm, close parenthesis, "chlorodibenzofurans (I) or chlorodibenzo-p-dioxins (II) of the type below. Aroclor 5442 also contains no detectable," parenthesis, less than five parts per million, close parenthesis, "chlorodibenzofurans or chlorodibenzo-p-dioxins."

Q. Are you able to tell from reading that paragraph what the limits of detection were?

A. The limits of detection as of the date of this memorandum were two parts per million for the chlorodibenzofurans, and also for the chlorodibenzodioxins, and for the Aroclor 5442 material, it's five parts per million.

Q. Do you know why the five parts per million was used as a level of detection for the Aroclor 5442 as opposed to the two parts per million that was used for the other Aroclors that you have referred to?

MR. BAUER: Object to the form. It was the level of detection.

Q. (by Mr. Bradley) Why was there not a method used on 5442 that had a limit of detection down to two parts per million?

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A. You will have to ask the analytical chemist the difficulty he has in arriving at the same limit of detection.

Q. Do you know whether on or about October of 1971 it was known that Aroclor 5442 had any chlorodibenzofurans?

A. Well, this report says that they were not detectable. That is the only information that I have.

Q. All right.

MR. BAUER: Off the record.

(Thereupon, a short colloquy was had.)

Q. (by Mr. Bradley) I am now going to show you Plaintiff's Exhibit 2858 and ask that you review that document?

A. I have reviewed the exhibit.

Q. Is this a document you have seen before today?

MR. BAUER: Object to the form. It's not a document.

A. I only recognize one sheet of the many that are in this exhibit.

Q. (by Mr. Bradley) And which sheet is that?

A. This is the number NEV033428, which was attached to the previous exhibit.

Q. I am going to hand you Plaintiff's Exhibit 404 and ask you to review that document.

A. I have reviewed the exhibit.

Q. Is Plaintiff's Exhibit 404 a document you have seen before today?

A. I have seen the first two pages of the document. I do not recognize the last two pages, one of which appears to be a typewritten version of the other. Those two last pages appear to be dated 1975 - the handwritten pages.

MR. BRADLEY: I am separating the exhibit so that the last two pages are removed, and I ask the court reporter to staple and mark the last two pages as 404A.

(Thereupon, the reporter marked Plaintiff's Deposition Exhibit # 404A, for identification.)

Q. (by Mr. Bradley) Is this a --

MR. BAUER: By "this," you are talking about 404?

Q. (by Mr. Bradley) Is Plaintiff's Exhibit 404 a memorandum dated May 27th, 1975 from R.G. Kaley, II, to R.E. Keller?

A. Yes.

Q. And on that page, who was Mr. Kaley, II?

A. Dr. Kaley was one of the analytical chemists working in Dr. Keller's analytical chemistry group.

Q. Is the information contained in that exhibit information that came to Dr. Kaley, II, on or about the

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date of the exhibit?

A. Yes.

Q. Did Dr. Raley author this exhibit as part of the regular business activities of Monsanto?

A. Yes.

Q. And was a copy of this document maintained in Monsanto's files as part of its regularly-conducted business?

A. It was.

Q. I am now going to show you Plaintiff's Exhibit 3001 and ask you to review that document.

A. I have reviewed it.

Q. Is that a copy that you have seen before?

A. Yes.

Q. What is it?

A. A copy of a memorandum that I composed on December 6th, 1974, on the subject of PCB's, chlorinated dibenzofurans.

Q. Does that information in that memorandum reflect information that you became aware of on or about the date of that memo?

A. Yes.

Q. Was that exhibit maintained in the ordinary course of Monsanto's business activities?

A. Yes.

MR. BAUER: Are you talking about the text or the handwritten notes?

Q. (by Mr. Bradley) Okay. Let's go back. The document has handwritten notes on it, does it not?

A. Yes.

Q. And part of these handwritten notes you authored?

A. Yes.

Q. Who authored the other handwritten notes, at the bottom, say?

A. At the bottom, there is a handwritten note addressed to me by David Wood.

Q. And is there handwriting at the top of the exhibit?

A. There is additional handwriting at the top, both the left-hand corner and the right-hand corner.

Q. Whose handwriting is that?

A. The left-hand corner is David Wood. The right-hand corner is Howard Bergen.

Q. Did you maintain a copy of that document in your files at Monsanto that had all of the handwriting on it?

A. I didn't, no.

Q. Was a copy maintained at Monsanto that had all of the handwriting on it?

A. It must have been, otherwise we wouldn't have this.

Q. Did you review the document when it had all of the handwriting on it prior to today's date?

A. Yes. When I composed my paragraph, that completed all of the information we now see.

Q. And did Monsanto maintain -- Well, I already asked you these questions.

Would you go back now, about six questions. I was asking him a question about whether he authored this document as part of Monsanto's business activities, and I would like you to find that question and his answer.

(Thereupon, the reporter propounded the previous question.)

Q. (by Mr. Bradley) Did you author this document as part of the ordinary business activities at Monsanto?

A. The typewritten paragraph, yes.

Q. And how about the handwritten part?

A. And one of the paragraphs is also my work.

Q. Okay. And was the handwriting of David Wood also included as part of the regular business activities of Monsanto?

A. Yes.

Q. And any notes by any other authors -- I have forgotten who you said authored the top left-hand part.

A. Mr. Wood. The right-hand corner is Mr. Bergen.

Q. Are those handwritings put there as part of Monsanto's regular business activities?

A. Yes.

Q. I am going now going to show you Plaintiff's Exhibit 405 and ask you to review that.

Off the record.

(Thereupon, a short colloquy was had.)

MR. BRADLEY: Back on the record. By agreement of counsel, we have agreed to renumber Plaintiff's Exhibit 3000 so that it's Plaintiff's Exhibit 3000A and to renumber Plaintiff's Exhibit 3001 so that it reads 3001A, and I would ask the court reporter to make the appropriate changes.

MR. BAUER: I agree with that, but I'm not sure whether 3000 wasn't from yesterday. I think it was.

MR. BRADLEY: Yes, it was. And that is all right with Westinghouse?

MR. MORGAN: That's fine.

A. I have reviewed the exhibit.

Q. (by Mr. Bradley) Is that a document you have seen before today?

A. I have seen this document, but I note a missing attachment.

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Q. What is the document?

A. This is a memorandum addressed to me, authored by J.P. Mieure, dated December 3, 1974, entitled, "FDA Detection of Chlorinated Dibenzofurans in Aroclor."

Q. Do you recall what was attached to the document when you saw it the first time?

A. Yes, I believe I do. It was a copy of a procedure used by analytical chemists to determine chlorinated dibenzofurans in a Japanese PCB mixture.

Q. Other than the missing attachment, is this an accurate copy of the report that you have referred to?

A. As best as I can tell, yes.

Q. And did Mr. Mieure author this based on information that became available to him on or about the date of the exhibit?

A. Yes.

Q. Was this document authored by Mr. Mieure as part of Monsanto's regular business activities?

A. Yes.

Q. Did Monsanto maintain a copy of that as part of its regularly-conducted business?

A. They did.

Q. Now I am going to show you Plaintiff's Exhibit 1366 and ask you to review that.

A. I have reviewed the exhibit.

Q. What is the exhibit?

A. It appears to be a collection of Material Safety Data Sheets issued by General Electric Company on Aroclor 1254 and Pyranol.

Q. Have you seen those Materials Safety Data Sheets before today?

A. This is the first time I've ever seen these.

Q. I am now going to show you Plaintiff's Exhibit 1504 and ask you to review that document.

MR. BAUER: 1504?

MR. BRADLEY: Yes.

A. I have reviewed the exhibit.

Q. (by Mr. Bradley) Is that a document you have seen before today?

A. Yes, but, again, I note that there is an attachment missing.

Q. What attachment is missing?

A. As noted in the paragraph at the bottom of the first page, there is a reference to a prepublication copy of the paper to be published, "(Copy attached.)"

Q. Other than the missing attachment, is that a true and accurate copy of the document dated November 20th, 1973, to you from E.S. Tucker?

A. It appears to be, yes.

Q. Was that document authored by Mr. Tucker as

part of Monsanto's regular business activity?

A. Yes.

Q. Did Monsanto maintain a copy of that as part of its regular business activity?

A. It did.

Q. I am now going to show you Plaintiff's Exhibit 2701 and ask you to review that document.

A. I have glanced at the document.

Q. Have you seen that document before today?

A. I have not seen this before today.

Q. Are able to tell who the author of that document is by examining it?

A. No more than anybody else who reads handwritten notes.

Q. The handwriting doesn't appear familiar to you?

A. It does not.

Q. I'm going to show you Plaintiff's Exhibit 2941 and ask you to review that document.

A. I have reviewed the exhibit.

Q. Have you seen that exhibit before today?

A. I have not seen this.

Q. I am now going to show you Plaintiff's Exhibit 2942, and I'll ask you to review that document.

A. I have reviewed that document, yes.

Q. What is that document?
A. It's a memorandum, authored by R.E. Keller, addressed to me, dated June 30, 1970. The subject is "Chlorinated Dibenzofurans - PCB."
Q. Is that a true and accurate copy of the memo sent to you by Dr. Keller?
A. Yes, except for the addition of Dr. Tucker to the distribution list.
Q. Was that written on or about the time that Dr. Keller gained the information that is contained in the exhibit?
A. Yes.
Q. Did Dr. Keller author that exhibit at part of Monsanto's regular business activities?
A. Yes.
Q. Did Monsanto maintain a copy of that exhibit as part of Monsanto's regularly-conducted business?
A. Yes.
Q. I am now going to show you Plaintiff's Exhibit 2943 and ask you to review that document.
A. I have glanced at the document.
Q. Have you seen that document before?
A. I have not seen it before.
Q. All right. I am now going to show you Plaintiff's Exhibit 1342, which it appears we received from

General Electric. Have you seen that document before?

A. I have quickly reviewed the document.

Q. Is that a document that you have seen before?

A. I have seen this before, yes.

Q. Is that a document that Monsanto maintained in its files as part of its regularly-conducted business?

MR. BAUER: You are talking about the publication, now, and not the specific copy with the notes?

MR. BRADLEY: That's correct.

A. The publication, yes, sir.

Q. (by Mr. Bradley) May I see it please? Are you aware of a study in 1959 by T-o-m-i-t-a, and others, where they determined that chlorophenols, when heated to about two hundred degrees centigrade or more, under alkaline conditions, and pressure, will form chlorodibenzodioxins?

A. I have read that statement, yes.

Q. Do you recall whether you read that statement before 1970?

MR. BAUER: Well, I'll object to the form. The document is dated after 1970.

Q. (by Mr. Bradley) Well, let me ask you this: The statement in the document is referring to a study in 1959. Were you familiar with that 1959 study before 1970?

A. Not the study itself, no.

Q. Were you familiar with the results of the study before 1970?

A. Not of the study itself.

Q. Were you familiar before 1970 with the conclusion that chlorophenols, when heated to about two hundred degrees centigrade, or more, under alkaline conditions and pressure, will form chlorodibenzodioxins?

A. I was aware of that, yes.

Q. When did you become aware of that?

A. 1964 --

Q. Okay.

A. -- or thereabouts.

Q. Did you learn in 1964 or thereabouts that, under similar conditions, i.e., when chlorophenols are heated to about two hundred degrees centigrade, or more, under alkaline conditions and pressure, that a chlorodibenzofuran may also be formed?

A. That, I didn't know.

MR. BAUER: I don't have the document in front of me. Are you saying phenols, as in p-h-e-n-o-l-s?

MR. BRADLEY: Yes.

THE WITNESS: That's the way I understood it.

Q. (by Mr. Bradley) Does that information have any bearing on any of the testimony you have given in your deposition?

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MR. BAUER: Object to the form.

A. No. It's an entirely different product line.

Q. (by Mr. Bradley) Okay. The studies that found chlorinated dibenzofuran in two of the products of Monsanto's competitors also tested their Monsanto product -- is that correct? -- for the presence of chlorinated dibenzofurans?

A. Which study are you talking about?

Q. The first study -- Was there a study in the 1970's that determined polychlorinated dibenzofurans were present in the PCB products of Monsanto's competitors?

A. There were several studies, as I recall.

Q. And in any of those studies was an Aroclor product manufactured by Monsanto also tested for impurities, including polychlorinated dibenzofurans?

A. Yes.

Q. In any of those studies did they determined that chlorinated naphthalene was present in the Aroclor products manufactured by Monsanto?

A. I don't recall any reference to chlorinated naphthalene.

Q. I'm going to show you Plaintiff's Exhibit 1547, and, before you examine it, give me a minute.

(Thereupon, a short recess was taken.)

Q. (by Mr. Bradley) You have in front of you

Exhibit 1547?

A. Yes.

Q. Have you had a chance to review that document?

A. Not yet.

Q. Okay.

A. I have reviewed the exhibit.

Q. Have you seen that document before today?

A. Yes, I have. I am the author.

Q. What is it?

A. It's a Monsanto memorandum. It's from me, addressed to the dozen people here listed, and dated November 10, 1970, and the title is, "PCB Environmental Problem, October Status Report."

Q. Is that a true and accurate copy of the memorandum you prepared on November 10, 1970, sir?

A. As best I can tell, it is.

Q. Is that a document that you authored as part of Monsanto's regular business activities?

A. It is.

Q. Was a copy of that maintained in Monsanto's files as part of Monsanto's regularly-conducted business?

A. Yes.

Q. I am going to now show you Plaintiff's Exhibit 622 and ask you to review that.

A. I have reviewed the exhibit.

Q. Have you seen it before?
A. No, I have not.
Q. I am now going to show you Plaintiff's Exhibits 621 and 620 and 627 and 624 and 626. Let me ask you, to begin with, have you reviewed any documents that originated from Younger Laboratories?
A. I recall reviewing a few documents when I had my tutorial with Dr. Kelly and Mr. Wheeler.
Q. All right. Which exhibit are you looking at now?
A. 621.
Q. Is that a document you have seen before today?
A. I don't recall this document.
Q. Is 620 a document you have seen before today?
A. I believe I saw this one.
Q. And what is that document?
A. Exhibit 620 is a certificate of analysis issued by Younger Laboratories, dated March 4, 1963, and the subject is, "Toxicological Investigation of: Inerteen PPO."
Q. Is that a true and accurate copy of the document that you reviewed as part of a tutorial?
A. As best as I can remember, it appears to be so, yes.
Q. Is this a document that Monsanto maintains in

its files as part of its regularly-conducted business?

A. Yes.

Q. Does the document indicate it is the result of some studies performed for Monsanto?

A. Yes.

Q. And does the exhibit contain information that was generated on or about the date of the exhibit?

MR. BAUER: Object to the form. Lacks foundation.

MR. MORGAN: Join in that objection.

A. I have no way of knowing when the studies were conducted.

Q. (by Mr. Bradley) All right. Do you know whether Monsanto, on or about 1963, requested Younger Laboratories to do a toxicological investigation of Inerteen PPO?

A. On or about '63, yes.

Q. Do you see the Monsanto project number Y-63-12?

A. Yes.

Q. What does that mean? If anything.

A. I don't know.

Q. You don't know whether the "63" refers to the date the material was submitted to Younger Labs?

A. I'd be guessing.

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Q. We don't want you to guess.

Do you know whether Younger Laboratories generated this document as part of the request of Monsanto and as part of Monsanto's regular business activities?

MR. BAUER: Object to the form. Lacks foundation.

MR. BRADLEY: Would you read the question back, please.

(Thereupon, the reporter read back the question.)

A. Yes.

Q. (by Mr. Bradley) As part of Monsanto's regular business activities, it on occasion requested studies of the toxicity of the chemicals it manufactured; is that true?

A. That is true.

Q. I am now going to show you 626, 627, and 624 and ask you if you have seen any of those documents before today.

A. As best I can recall, I believe I was shown 624 back in January of 1970. I have not seen Exhibits 626 and 627 before.

Q. What is document 624?

A. It's a certificate of analysis from Younger Laboratories, dated June 25th, 1962, subject, "Toxicological Investigation Of: Aroclor 1260."

Q. Who showed you that document?
A. Mr. Elmer Wheeler.
Q. Is that a document that Monsanto maintained in its files as part of its regularly-conducted business?
A. Yes.
Q. Is that a true and accurate copy of the document that was shown to you by Mr. Wheeler?
A. As best as I can recall, this appears to be an accurate copy, yes.
Q. I can't recall whether I asked you this question about 620, but is that a true and accurate copy of a document that was shown to you during one of your tutorials?
A. It appears to be, as best as I can remember, yes.
Q. All right. I am now going to show you Plaintiff's Exhibit 628, and I'll ask you to tell me if you have seen that document before.
A. I don't recall ever having seen this document before.
Q. I am now showing you Plaintiff's Exhibit 623 and I would ask you to review it and let me know whether it's a document you have seen before.
A. As best as I can remember, I have seen a copy of this document.

Q. What is it?

A. It's a report from Industrial Bio-Test Laboratories, Incorporated, to Monsanto Company, on a two-year chronic oral toxicity study with Aroclor 1254 in albino rats. It's a histopathological evaluation of additional liver sections, dated March 24, 1975.

Q. Is this a true and accurate copy of the IBT report to Monsanto?

A. As best as I can recall.

Q. Does that exhibit relay information on the reanalysis of certain liver slides?

A. Yes.

Q. And it appears to be written at or about the time of the reanalysis?

A. Yes.

Q. Was it authored at the request of Monsanto as part of Monsanto's regular business activities?

MR. BAUER: Objection. Lacks foundation.

A. I don't know if Monsanto asked for the written report. I do know that Monsanto asked for further study.

Q. (by Mr. Bradley) Wasn't it routine for Monsanto to expect a report along with further studies on tests involving its Aroclor products?

A. You would expect a report for a regularly placed study, a routinely placed study for its products.

This study was conducted several years after the completion of the feeding program, and was a special effort to respond as questions had arisen; and I am in no position to know if Monsanto expected or requested a written report. They wanted an opinion from a laboratory.

Q. And as far as you know, Monsanto may have wanted an oral opinion?

A. I have no way of knowing what they wanted. All they wanted was the laboratory to review its total study and come up with their re-evaluation report.

Q. All right. And is this a true and accurate copy of the re-evaluation report that Monsanto requested from IBT?

MR. BAUER: Object to the form. Asked and answered. Lacks foundation.

A. If I understand this particular report, it addressed the additional samples looked at. The report Monsanto eventually got consisted of the previous samples, plus these samples, to come up with a composite picture, if you will, of what happened.

Q. (by Mr. Bradley) Whether or not Monsanto requested the report, it at least requested the reanalysis; is that correct?

A. Yes.

Q. And in response to its request, as part of its

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regular business activities, for the reanalysis, it received the reanalysis with the report; is that correct?

A. Yes.

Q. And did Monsanto maintain a copy of that report in its files as part of its regularly-conducted business?

A. It did.

Q. I am now going to show you Plaintiff's Exhibit 1194 and ask you to review that for me, please.

A. I have quickly reviewed the report.

Q. Is that a document you have seen before today?

A. I have.

Q. What is the document?

A. This is a copy of the text and slides used in a presentation to Monsanto's corporate development committee in November of 1969.

A. Is that a true and accurate copy of the text and slides regarding that presentation to Monsanto's corporate development committee in 1969?

A. As far as I can tell it appears to be so, yes.

Q. Does that exhibit contain information that was made known to the authors on or about the date of the exhibit?

MR. BAUER: Objection. Lacks foundation.

A. Yes.

Q. (by Mr. Bradley) How do you know that?
A. All of the information that was contained in there was the information that I was tutored on eventually by the individuals involved with this presentation and formed the basis for the whole Monsanto program.
Q. And who was the author of 1194?
A. As best as I can recall, it was the work of two individuals, Mr. Bergen and Mr. Springgate. Most of the text was prepared by Mr. Bergen.
Q. Was this exhibit prepared as part of Monsanto's regular business activities?
A. Yes.
Q. And was it maintained in Monsanto's files as part of Monsanto's regularly-conducted business?
A. It was.
Q. I am now going to show you Plaintiff's Exhibit 1185.
MR. BRADLEY: Bill, I want to talk to you a minute.
MR. BRADLEY: You want to go off the record so you can confer with your witness?
MR. BAUER: I am going to confer with him. I don't care if we go off the record or not. It will certainly be out of the hearing of the court reporter.
MR. BRADLEY: Well, that's fine with me.

MR. BAUER: Good.

(Thereupon, a short colloquy was had.)

Q. (by Mr. Bradley) Have you had a chance to confer with your attorney?

A. Yes.

Q. And have you had a chance to review Plaintiff's Exhibit 1185?

A. Not yet.

Q. All right.

MR. MORGAN: 1185?

MR. BRADLEY: Yes.

A. I have reviewed the exhibit.

Q. (by Mr. Bradley) Is that a document you have seen before today?

A. I have, yes.

Q. What is 1185?

A. It is a copy of a report describing the topics and discussions at a meeting held between General Electric representatives and Monsanto representatives in St. Louis on January 21st and 22nd, 1970 on the subject of the PCB pollution problem.

Q. Is that a true and accurate copy of the minutes of that meeting?

A. It is, as far as I can tell, yes.

Q. And were the minutes generated shortly after

the meeting occurred?

A. Yes.

Q. And was that exhibit prepared as part of Monsanto's regular business activities?

A. Yes.

Q. Was a copy maintained in Monsanto's files as part of Monsanto's regularly-conducted business?

A. It was.

Q. I am now going to show you Plaintiff's Exhibit 1582 and ask that you review that document.

A. I have reviewed the document.

Q. Is this a document you have seen before today?

A. Yes.

Q. And what is it?

A. It's a memorandum authored by me, dated February 8, 1971, addressed to about a dozen people that are listed, the top sheet. The subject is "PCB Environmental Problem, January Status Report."

Q. And absent any highlighting, is that a true and accurate copy of the memo that you wrote on or about February 8th, 1971?

A. It appears to be, yes, sir. There are also some marginal notes here added by others.

Q. All right. So those were not on any copy that you authorized?

A. That is correct.

Q. Were those handwritten notes on any copy that you viewed prior to today's date?

A. I don't recall any.

Q. So absent the highlighting and the handwritten notes, it's a true and accurate copy of the document you authored February 8th, 1971?

A. As far as I can tell, yes, sir.

Q. Was there a meeting in January of 1971 to which that memo was addressed? Let me ask it this way: Do the contents of that exhibit reflect information that was made available to you on or about the date of the exhibit?

A. Yes.

Q. Did you author that exhibit as part of Monsanto's regular business activities?

A. I did.

Q. Was it Monsanto's regular practice to generate documents such as that one?

A. Yes.

Q. Did Monsanto maintain a copy of that in its files as part of its regularly-conducted business?

A. Yes.

Q. I am now going to show you Plaintiff's Exhibit 425 and ask you to review that document.

Have you reviewed it?

A. Yes.
Q. Is that a document you have seen before today's date?
A. I don't recall that at all.
Q. I am now going to show you Plaintiff's Exhibit 1455 and ask that you review that.
MR. BAUER: I will note for the record that one of the documents that we talked about earlier and Mr. Papageorge testified that it was part of a larger document. a shingle sheet, that page is contained in this document, and Mr. Papageorge pointed it out to me as we have gone through it.
A. I have quickly reviewed this document.
Q. (by Mr. Bradley) Is that a document that you have seen before today?
A. Yes.
Q. What is the document?
A. This is a copy of the text and slides used in a presentation I made to Monsanto's corporate management committee on April 20th, 1970.
Q. Is that a true and accurate copy of the text and slides used in that presentation?
A. It appears to be, yes, sir.
Q. Does the information contained in the exhibit reflect what was currently known to you on or about the

date of the exhibit?

A. Yes.

Q. Did you author that document as part of Monsanto's regular business activity?

A. I did.

Q. Was it the practice of Monsanto to generate documents of that sort?

A. Yes.

Q. Did Monsanto maintain a copy of that in its files as part of its regularly-conducted business?

A. It did.

Q. I am now going go show you Plaintiff's Exhibit 1590 and as you to review that document.

A. I have reviewed it.

Q. Is that a document you have seen before today?

A. Yes, I have.

Q. What is it?

A. It's a memorandum authored by me, dated August 18, 1970, addressed to about a dozen individuals listed on the first page. The subject is "PCB Environmental Problem, July Status Report."

Q. Does that exhibit contain information that you became aware of on or about the date of the exhibit?

A. It does.

Q. Did you author that document as part of

Monsanto's regular business activity?

A. Yes.

Q. Was it -- Were documents of that sort regularly generated by Monsanto as part of its regular business activity?

A. Yes.

Q. Was a copy of that exhibit maintained in Monsanto's files as part of Monsanto's regularly-conducted business?

A. Yes.

Q. I am now going to show you Plaintiff's Exhibit 414 and ask you to review that document.

A. I have reviewed the exhibit.

Q. Is that a document you have seen before today?

A. Yes, I have.

Q. What is it?

A. It's a memorandum authored by me, dated October 6th, 1970, subject, "PCB Environmental Problem, September Status Report," addressed to about a dozen individuals listed on the first page.

Q. Does that document contain information that was made available to you on or about the date of the exhibit?

A. Yes.

Q. Did you author that document as part of

Monsanto's regular business activities?

A. Yes.

Q. Was it the regular practice of Monsanto to generate documents of this sort?

A. Yes.

Q. And did Monsanto maintain a copy of that exhibit as part of its regularly-conducted business?

A. It did.

Q. I am now going to show you Plaintiff's Exhibit 417 and ask you to review that exhibit.

A. I have reviewed the exhibit.

Q. Is that an exhibit that you have seen before today?

A. Yes, I've seem it.

Q. What is it?

A. It's a memorandum authored by John Mason, dated May 11th, 1970. It's a Monsanto addressed to H.S. Bergen and J.E. Springgate, and attached to that memorandum are copies of slides used in a presentation made before the corporate management committee on May 11th, 1970.

MR. BRADLEY: Would you read that back, please.

(Thereupon, the reporter read back the answer.)

Q. (by Mr. Bradley) Is that a true and accurate

copy of the memorandum, with attachments, that was authored by John Mason on May 11th, 1970?

A. It appears to be, yes.

Q. Is the information contained in that exhibit information that was made available to Mr. Mason on or about the date of the exhibit?

A. Yes.

Q. Is that a document that was authored by Mr. Mason as part of Monsanto's regular business activities?

A. Yes.

Q. Was it Monsanto's regular practice to generate documents of that sort?

A. Yes.

Q. Was a copy of that document maintained in Monsanto's files as part it's regularly-conducted business?

A. It was.

Q. I am now going to show you Plaintiff's Exhibit 3054.

A. I have reviewed the exhibit.

Q. May I see it for a moment?

A. Sure.

MR. BRADLEY: I am going to provide this to Westinghouse's counsel because it's not a document we previously supplied to Westinghouse as an exhibit.

Is this a document you have seen before today?

A. I don't remember seeing this document.

Q. (by Mr. Bradley) In September of 1969, did Monsanto have an employee named P.B. Hodges?

A. Yes.

Q. Who was P.B. Hodges in September of 1969?

A. He was a member of Monsanto's manufacturing group that was assigned the environmental monitoring task. I don't recall his formal title.

Q. Do you recall what department or division P.B. Hodges worked in at Monsanto in September of 1969?

A. He was in the manufacturing division -- I'm sorry -- the manufacturing department of the organic chemicals division of Monsanto Chemical Company.

Q. I am now going to show you Plaintiff's Exhibit 1526 and ask you to review that document.

A. I have reviewed the document.

Q. Is that a document you have seen before today?

A. I have.

Q. What is it?

A. It's a summary of toxicological studies on commercial PCB's, authored by J.C. Calandra, dated October 10th, 1975.

Q. Is that a document that Monsanto maintained in its files as part of its regularly-conducted business?

A. Yes.

Q. Did Monsanto request that J.C. Calandra author that particular summary?

A. Yes.

Q. Was that summary prepared as part of Monsanto's regular business activity?

MR. BAUER: Object to the form. It wasn't prepared by Monsanto.

MR. BRADLEY: But he said that Monsanto requested its preparation.

THE WITNESS: And your question, sir?

Q. (by Mr. Bradley) is that a document that was prepared as part of Monsanto's regular business activity?

A. Yes.

Q. Did Monsanto request, as part of its regular business activity, that Dr. Calandra prepare that summary?

A. Yes.

Q. I don't know if I've already asked you this: Did Monsanto maintain a copy of this data as part of its regularly-conducted business?

A. Yes.

Q. Was Dr. Calandra requested by Monsanto on or about November 10th, 1975 to develop a summary of the then-existing, including any new studies, and by that I mean studies generated in 1975 regarding the toxicological characteristics of PCB's? Do you want that question read

back?

A. I think I understand it, except that your wording indicated that this summary would include all studies conducted by any known laboratories in 1975. Dr. Calandra was not speaking for all studies. He was only speaking for those conducted by his laboratory.

Q. I am now going to show you Plaintiff's Exhibit 1527 and ask you to tell me what that document is. Will you first review it and tell me if you have ever seen it before?

A. Okay. I have reviewed the document; and I have seen it before, yes.

Q. What is the document?

A. It's a document authored by J.D. Calandra, dated November 19th, 1975, entitled, "Summary of Toxicological Studies Conducted on Commercial PCB's."

Q. Is this a document that Monsanto requested Dr. Calandra to prepare as part of Monsanto's regular business activities?

MR. BAUER: Objection. Lacks foundation.

A. This document was prepared by Dr. Calandra for presentation at a PCB symposium at Chicago in November of 1975, and it relates to the work performed in his laboratory for Monsanto.

Q. (by Mr. Bradley) Was Dr. Calandra requested

by Monsanto to prepare that exhibit?

MR. BAUER: Objection. Lacks foundation.

A. I am not aware of such a request.

Q. (by Mr. Bradley) Did Monsanto maintain a copy of that exhibit as part of its regularly-conducted business?

A. It did, yes.

Q. All right. I am now going to show you Plaintiff's Exhibit 375 and ask you to review that document.

A. I very quickly glanced through the document.

Q. Have you ever seen that document before today?

A. I have never seen it before.

MR. BRADLEY: It is now a few minutes to 4:00. Let's take a break now because counsel are expecting a conference call at 4:00

THE WITNESS: Okay.

(Thereupon, a short recess was taken.)

Q. (by Mr. Bradley) I am going to show you what's been mark for identification as Plaintiff's Exhibit 422 and ask you to tell me what that document is.

MR. BAUER: Are we on the personal deposition at this point, Mr. Bradley?

MR. BRADLEY: Yes.

MR. BAUER: Okay.

MR. BRADLEY: Okay. Off the record for a

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moment.

(Thereupon, a short colloquy was had.)

MR. BRADLEY: Back on the record. Off the record again.

(Thereupon, a short colloquy was had.)

MR. BRADLEY: On the record.

The attorneys present, which include the attorney for Nevada Power and the attorney for Monsanto and the attorney for Westinghouse, have agreed that when we take the 30(b)(6) deposition of Mr. Papageorge regarding Exhibits 422 and 1118, that, in order to avoid asking the same questions in a 30(b)(6) deposition and in a personal deposition, that we will determine during the 30(b)(6) deposition on Exhibits 1118 and 422 which portion of Mr. Papageorge's testimony is based on personal knowledge and which portion is not.

Off the record.

(Thereupon, a short colloquy was had.)

MR. BRADLEY: And we have agreed that the testimony relative to those two exhibits, which is based upon personal knowledge, will be considered both as a part of his personal deposition and as a part of his 30(B)(6) deposition. Except for including in Mr. Papageorge's personal deposition the testimony regarding Exhibits 1118 and 422 which he will give and identify as based on his person-

al knowledge, of which will be included in his personal deposition, Nevada Power has no further questions of Mr. Papageorge in his personal capacity.

Any questions from any defendant?

QUESTIONS BY MR. MORGAN:

Q. Mr. Papageorge, we have been introduced before. I'm Bob Morgan and I represent Westinghouse in this case. I would like to ask you a couple of questions about Plaintiff's Exhibit 1335, which you talked about earlier with Mr. Bradley, and that was your July 6th, 1970 letter to Mr. Garlington Wilburn at Westinghouse Electric, South Boston. Do you recall that?

A. Yes, I do.

Q. Okay. I'll hand you this in a second.

The question I wanted to ask you is centered on your testimony regarding a portion of your letter where you talked about incineration of PCB's, and specifically where you've noticed that any temperature below eight hundred degrees centigrade will result in vaporization with release to the atmosphere, or worse yet, it's possible to partially oxidize PCB's into materials which can be highly toxic, for instance, dioxin or furans. Do you see that line in your letter?

A. I do.

Q. Was it your testimony in response to a

question by Mr. Bradley that that particular sentence that I just read was your own conclusion, based on your scientific training or background?

A. Yes.

Q. Okay. And would it be fair to say, then, that that was a theory you had, or a hypothesis that you formed?

MR. BRADLEY: Object to the form of the question. It's compound.

A. I think it would fall more into the hypothesis category. My preliminary did not quite reach the theory level.

Q. (by Mr. Morgan) Do you still hold that theory today, or hypothesis today?

A. Since then, I have been informed of the presence of some studies that indicate in a more concrete way that the chlorinated dibenzofurans, at temperatures below this total destruction temperature, and oxygen, and some other favorable conditions, that the chlorinated dibenzofurans are formed. I have seen or heard no information that relates to PCB's under incineration under any conditions that led to chlorinated dibenzodioxins. That hypothesis I had appears to have been wrong.

Q. When was that study done?

A. I believe in the late seventies, early eighties - in that time frame.

Q. By whom were they conducted?
A. Oh, gosh. The best I remember, the government agencies were involved somehow.
Q. In any event, it was not studies conducted by Monsanto?
A. That is true.
Q. At or about the time that you wrote this letter to Mr. Wilburn, did you have any other contact with him, either discussion or letters?
A. Yes. With Mr. Wilburn I had more than just this one contact. Personal contact? I don't remember all of the situations.
Q. Well, my question was going to be, did you tell Mr. Wilburn that the information in your letter there regarding the possibility of production of dioxins and furans was your hypothesis?
MR. BRADLEY: Objection to the form of the question. It doesn't identify a time period.
Q. (by Mr. Morgan) Or words to that affect, if you didn't use the word "hypothesis."
A. I had so many discussions with so many individuals on this subject that I just cannot pinpoint the time, place, and date with Mr. Wilburn on exactly that subject. It could have happened and I just don't recall.
Q. Do you recall -- I believe it was your testi-

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mony in response to a question by Mr. Bradley that at the time you wrote this letter you had no scientific basis for the statement regarding the production of the furans and dioxins; is that correct?

MR. BAUER: Object to the form of the question. I don't think that that accurately represents his prior testimony.

A. I did use the expression that I had no scientific basis to indicate, I had no results of formal scientific tests to demonstrate my hypothesis.

Q. Did you ever indicate that to Mr. Wilburn?

A. I may have, but --

MR. BAUER: Objection to the form of the question, as to what is meant by "that."

Go ahead.

A. I may have, but I just cannot recall the circumstances under which I spoke specifically with Mr. Wilburn.

Q. (by Mr. Morgan) Okay. I believe, in response to a question put to you by Mr. Bradley, you indicated that you came aboard with respect to the environmental situation and PCB's in 1970; is that correct?

A. Yes.

Q. When you said you came aboard, what did you mean by that?

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A. I was assigned a newly created position, manager of environmental control, to address the evolving PCB environmental situation.

Q. Before you took that position, did you have any responsibility with respect to informing Monsanto customers about the environmental effects of PCB?

A. I did not.

Q. Did you have any knowledge of any information that was provided to Monsanto customers about the environmental effects of PCB's prior to 1970?

A. No.

MR. MORGAN: That's all of the question I have. Thank you.

MR. BAUER: I have a few, Mr. Papageorge.

CROSS EXAMINATION

QUESTIONS BY MR. BAUER:

Q. You testified this morning in response to questions by Mr. Bradley on the topic of wording changes in IBT studies. Do you recall that topic of your testimony?

A. Yes.

Q. And you referenced some correspondence that you saw on that topic at some point in time. I'd like to show you Plaintiff's Exhibit 352 and ask you if that's the correspondence to which you were referring in your answer.

MR. BRADLEY: Object to the form of the

question since it's not clear what answer he's referring to. So it's vague and ambiguous.

A. Yes. This is the document that I eventually saw.

Q. (by Mr. Bauer) When did you first see that document?

A. As best as I recall, it was in early 1980's. It was brought to my attention by attorneys, involving a lawsuit.

Q. Okay. Do you currently recall any other correspondence -- again, this morning your answer referenced seeing correspondence discussing changes in wording involving IBT studies. My question is, do you recall any other correspondence other than what you referred to in that answer?

MR. BRADLEY: Objection to the form of the question. Vague and ambiguous, and relies on attorney testimony.

A. This is the only document I recall having seen that addressed that subject.

Q. (by Mr. Bauer) Plaintiff's Exhibit 352 references a change in language from "Slightly," to "Does not appear to be carcinogenic." Is that the wording changes that you were referring to in your earlier testimony?

MR. BRADLEY: Objection to the form of the question. He didn't talking about wording changes; he talked about changes in conclusions. Go ahead.

A. Yes.

Q. (by Mr. Bauer) To the best of your recollection, did you have any knowledge of a wording change in this letter during 1975?

MR. BRADLEY: Object to the form of the question. The document talks about changes of conclusions, not changes in wording. So I object to the mischaracterization. Go ahead.

A. I did not know it at the time.

MR. BAUER: That is all I have.

REDIRECT EXAMINATION

QUESTIONS BY MR. BRADLEY:

Q. The only exhibit that Mr. Bauer showed you during his examination of you was Plaintiff's Exhibit 352; is that correct?

A. Yes.

Q. Looking now at Plaintiff's Exhibit 1335, when you used the terms here, "dioxins and furans," did you mean chlorodibenzodioxins and chlorodibenzofurans?

A. I did.

MR. BRADLEY: That is all I have.

MR. MORGAN: No questions.

MR. BAUER: Nothing further.

WILLIAM B. PAPAGEORGE

Subscribed and sworn to before me this _____ day of _____, A. D., 1993.

MY COMMISSION EXPIRES:

Notary Public, within and for the State of Missouri

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STATE OF MISSOURI)
) SS
COUNTY OF ST. LOUIS)

I, Mark D. Concannon, a Notary Public within and for the State of Missouri, duly commissioned, qualified and authorized to administer oaths and to take and certify to depositions, do hereby certify that pursuant to Notice in the civil cause now pending and undetermined in the District Court of the United States, within and for the District of Nevada, entitled NEVADA POWER COMPANY, Plaintiff, -vs- MONSANTO COMPANY, et al., Defendants, to be used in the trial of said cause in said Court, I was attended at the law offices of Messrs. Husch, Eppenberger, Donohue, Cornfeld & Jenkins, 100 N. Broadway, Ste. 1300, in the City of St. Louis, State of Missouri, by Ralph A. Bradley, attorney for the Plaintiff; by Scott R. Bauer, attorney for the Defendant Monsanto; by Robert P. Morgan, In-House Counsel for the Defendant Westinghouse; and by WILLIAM B. PAPAGEORGE, the witness, in said office on July 20, 1993.

The said witness, WILLIAM B. PAPAGEORGE, being of sound mind and being by me first carefully examined and duly cautioned and sworn to testify the truth, the whole truth and nothing but the truth in the case aforesaid, thereupon testified as is shown in the foregoing transcript, said testimony being by me reported in shorthand

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and caused to be transcribed into typewriting, and that the foregoing pages correctly set out the testimony of the aforementioned witness, WILLIAM B. PAPAGEORGE, together with the questions propounded by counsel and the remarks and objections of counsel thereto, and is in all respects a full, true and complete transcript of the questions propounded to and the answers given by said witness; and that said testimony, so transcribed, was subscribed to by the witness on the _____ day of _____, A.D., 1993.

I FURTHER CERTIFY that I am not of counsel nor attorney for any of the parties to said suit, nor related, nor interested in any of the parties or their attorneys.

I FURTHER CERTIFY that Plaintiff's Deposition Exhibits were marked for identification and attached to and made a part of this deposition and are the identical exhibits referred to and identified by the witness in the foregoing deposition.

WITNESS MY HAND and Notarial Seal, given this _____ day of _____, A. D., 1993, at St. Louis, Missouri.

MY COMMISSION EXPIRES MARCH 21, 1994.

_____
MARK D. CONCANNON,
Notary Public, within and
for the State of Missouri

Concannon and Jaeger
General Court Reporters
705 Olive Street, Ste. 604
St. Louis, Missouri 63101

August 10, 1993

Mr. Scott R. Bauer
Kirkland & Ellis
1999 Broadway
Denver, Colorado 80202

Re: Nevada Power Vs. Monsanto

Dear Mr. Bauer:

This letter, incorporated as the last page of Mr. Papageorge's deposition, taken on July 20, 1993, will serve as notice to you that Mr. Papageorge's testimony is now ready for his reading and signing of same.

Enclosed, please find your copy of the deposition, along with the original signature page, (pg. 269), and errata sheets. Please have Mr. Papageorge read his deposition at his earliest possible convenience, making whatever changes he feels necessary on the errata sheets, along with his reason for making same. Have him sign the original signature page and eratta sheets before any notary, and return the original signature page and eratta sheets to me at the above address so that I may file the original transcript in Court and notify opposing counsel of the changes.

Thank you for your cooperation in this regard.

Sincerely,

MARK D. CONCANNON

MDC:mk
encls.

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WILLIAM B. PAPAGEORGE

- DEPOSITION CORRECTION SHEET -

In Re: NEVADA POWER Vs. MONSANTO

Upon reading his deposition transcript and before subscribing thereto, the deponent indicated the following:

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WILLIAM B. PAPAGEORGE

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Concannon and Jaeger
General Court Reporters
705 Olive Street, Ste. 604
St. Louis, Missouri 63101

August 10, 1993

Mr. Scott R. Bauer
Kirkland & Ellis
1999 Broadway
Denver, Colorado 80202

Re: Nevada Power Vs. Monsanto

Dear Mr. Bauer:

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Enclosed, please find your copy of the deposition, along with the original signature page, (pg. 269), and errata sheets. Please have Mr. Papageorge read his deposition at his earliest possible convenience, making whatever changes he feels necessary on the errata sheets, along with his reason for making same. Have him sign the original signature page and eratta sheets before any notary, and return the original signature page and eratta sheets to me at the above address so that I may file the original transcript in Court and notify opposing counsel of the changes.

Thank you for your cooperation in this regard.

Sincerely,

MARK D. CONCANNON

MDC:mk
encls.

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MR. BAUER: Nothing further.

_____
WILLIAM B. PAPAGEORGE

Subscribed and sworn to before me this _____ day of _____, A. D., 1993.

MY COMMISSION EXPIRES:

_____
Notary Public, within and for the State of Missouri

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WILLIAM B. PAPAGEORGE

- DEPOSITION CORRECTION SHEET -

In Re: NEVADA POWER Vs. MONSANTO

Upon reading his deposition transcript and before subscribing thereto, the deponent indicated the following:

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WILLIAM B. PAPAGEORGE

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Monsanto

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166
Phone: (314) 694-1000

July 18, 1975

Dr. J.C. Calandra
Industrial BIO-TEST Laboratories
1810 Frontage Rd.
Northbrook, Ill. 60062

re: AROCLOR 2-year Rat Feeding Studies

Dear Joe:

The attached table summarizes a comparison of the 3 revised AROCLOR reports (1242, 1254, 1260).

In 2 instances, the previous conclusion of "slightly tumorigenic" was changed to "does not appear to be carcinogenic". The latter phrase is preferable. May we request that the AROCLOR 1254 report be amended to say "does not appear to be carcinogenic".

The number of hepatomas reported for AROCLORS 1260 and 1242 have been interchanged. This appears to have arisen from confusion regarding the numbering of the animals. The original reports show tumors in animals with numbers in the 100-300 range for AROCLOR 1260 and in the 500 to 800 range for AROCLOR 1242. This leads me to conclude that the numbering scheme shown in the second set of reports is correct. With AROCLOR 1254 confusion is compounded. The original report showed tumors in animals with numbers in the units to teens, but the revised report shows animal numbers ranging from 40 to 1000. Can this be straightened out?

I was unable to reconcile the differences in the animal numbers between the first supplemental report and the original reports, I had inquired as to the changes in the numbers. As I recall, I was told that the sections had been renumbered when the new slides were made and that a key relating to the sets of numbers

cc MLK DEG JBP

PLAINTIFF'S EXHIBIT 352

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would be supplied. This has not been done. It may not be necessary for AROCLORS 1260 and 1242, but AROCLOR 1254 remains unresolved.

Insofar as I can see, the remainder of the reports appear acceptable.

Kindest personal regards,

Sincerely,

George J. Levinskas, PhD
Mgr., Environmental Assessment
and Toxicology

/bkp

att.

cc: Dr. George Roush, Jr., M.D.

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Product	Supplemental Report #1 (mailed)	Supplemental Report #2 (JCC delivered)
AROCLOR 1260		
conclusion	slightly tumorigenic	does not appear carcinogenic
hepatomas	3	7
range of test animal nos:		
p. 9	600 to 800	100 to 300
p. 10	1000 series	800 to 900
p. 11	70 to 100	10 to 40
p. 12	500 to 600	80 to 200
p. 13	600 to 700	200 to 300
p. 14	700 series	200 to 300
AROCLOR 1254		
conclusion	slightly tumorigenic	slightly tumorigenic
hepatomas	6	6
AROCLOR 1242		
conclusion	slightly tumorigenic	does not appear carcinogenic
hepatomas	7	3
range of test animal nos.	as in report #2 for AROCLOR 1260	as in report #1 AROCLOR 1260

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18 USC 1001

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

UNITED STATES OF AMERICA	)	
	)	
vs.	)	No. 81 CR 335
	)	Violation: Title 18, United State
JOSEPH C. CALANDRA,	)	Code, Sections 1001, 1341 and 1343
MORENO L. KEPLINGER,	)	
PAUL L. WRIGHT, and	)	
JAMES B. PLANK,	)	

The SPECIAL OCTOBER 1980 GRAND JURY charges:

1. At all times material herein, Industrial Bio-Test Laboratories, Inc. (hereinafter referred to as IBT) did business in Northbrook, Illinois in the Northern District of Illinois and was a contract research laboratory which conducted animal studies on various drugs, pesticides, chemicals, and other substances, for the sponsors of said substances, in order to determine the safety and effectiveness of the substances.

2. At all times material herein, JOSEPH C. CALANDRA was President of IBT.

3. At all times material herein, MORENO L. KEPLINGER was Manager of Toxicology at IBT.

4. PAUL L. WRIGHT was Section Head for Rat Toxicology at IBT from approximately March, 1971 until September, 1972, at which time he became Manager of Toxicology for the Department of Medicine and Environmental Health at Monsanto Corporation in St. Louis, Missouri, from approximately October, 1972 until the present.

5. JAMES B. PLANK was the Senior Group Leader for Rat Toxicology at IBT until October of 1972, at which time he became the Assistant to the

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PLAINTIFF'S EXHIBIT 375

APP. 4 83642

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Manager of Toxicology at IBT from approximately October, 1972 until April, 1977.

6. IBT conducted a two-year chronic oral toxicity study on Trichlorocarbanilide (TCC) in albino rats, IBT Study Number B9575, for Monsanto Company (Monsanto). TCC is an antibacterial agent used in soaps. On or about May 10, 1976, IBT mailed its final version of the report of the study to Monsanto who submitted the IBT study report to the United States Food and Drug Administration (FDA) with a cover letter dated May 11, 1976, for that agency's use in its evaluation of the safety of TCC.

7. IBT conducted a 22 month chronic oral toxicity study on Naprosyn in albino rats, IBT Study Number B7922, for Syntex Corporation (Syntex). Naprosyn (also known as naproxen) is a drug used in the treatment of arthritis. On or about March 3, 1972, IBT mailed its report of the study to Syntex who submitted the IBT study report to FDA, with a cover letter dated March 22, 1972, as part of its application for approval to test Naprosyn on humans and ultimately market the product.

8. IBT conducted two carcinogenic studies on mice (tests to determine whether a compound causes cancer) for Chemagro Corporation (Chemagro). One study was on Sencor, a herbicide, IBT Study Number 9069, and one on Nemacur, a pesticide, IBT Study Number 9068. IBT submitted the reports of the studies with a cover letter dated August 15, 1972 to Chemagro, who submitted the IBT study reports to the United States Environmental Protection Agency (EPA), the Sencor study report by mail on March 8, 1973 and the Nemacur study report by mail on October 15, 1975. Both study reports were submitted as part of Chemagro's application for approval to market these products for use on food crops.

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9. Beginning in or about 1970 and continuing until about July, 1977, in Northbrook, in the Northern District of Illinois, Eastern Division, and elsewhere,

JOSEPH C. CALANDRA,
MORENO K. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, together with co-schemers both known and unknown to the grand jury, devised and intended to devise a scheme to defraud clients and government agencies by writing and distributing false and fraudulent study reports and false and fraudulent explanations of studies and study reports, and by concealing the fraudulent nature of the study reports and explanations of studies and study reports, all by means of false and fraudulent representations and concealments, knowing and intending that the representations and concealments were false when made.

10. It was a part of the scheme to defraud that the defendants wrote and distributed false and fraudulent animal study reports to clients who commissioned the studies, which study reports were submitted by the clients to government agencies that evaluate such reports as part of their determination of the safety of those test materials.

11. It was further a part of the scheme to defraud that the defendants provided FDA with false and fraudulent written submissions which reaffirmed and made new false and fraudulent statements as to material facts, and concealments and omissions of material facts in, or pertaining to, the studies and study reports.

12. It was further a part of the scheme to defraud that the

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original version of the TCC study report was written and distributed by IBT to Monsanto on or about March 21, 1974. IBT submitted this version of the TCC report to FDA on December 12, 1976, which study report the defendants knew to be false and fraudulent in that the study report:

a. stated that the data reported were from animals that had been on the study for 24 months, when defendants then knew that the report included data from a substantial number of animals that had been on the study for significantly lesser periods of time;

b. stated that 480 animals were in the study when defendants then knew that a substantially greater number of animals were also part of the study; and

c. contained an Animal Mortality Table (Table IV) which defendants then knew to be false in that it substantially under-reported the number of animals that were in the study and the number of animals that died during the study.

13. It was further a part of the scheme to defraud that the final version of the TCC study report was written in April and May, 1976, was dated March 21, 1974, and was mailed to Monsanto by IBT on or about May 10, 1976, was submitted to FDA by Monsanto under a cover letter dated May 11, 1976, and was known by defendants to be false and fraudulent in that the study report:

a. stated that the data reported were from animals that had been on the study for 24 months, when defendants then knew that the report included data from a substantial number of animals that had been on the study for significantly lesser periods of time;

b. stated that 480 animals were in the study when defendants

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then knew that a substantially greater number of animals were also part of the study;

c. contained an Animal Mortality Table (Table IV) which defendants then knew to be false in that it substantially under-reported the number of animals that were part of the study and the number of animals that died during the study;

d. stated that 250 extra animals were on the study for 24 months and were an independent IBT "research" group, separate from the animals reported in the TCC study, when defendants then knew (1) that the so-called "research" group animals were not an independent "research" group, but were used as a source of extra animals and animal tissues for the TCC study; (2) that the so-called "research" animals had been on study for significantly lesser periods of time than 24 months; and (3) that a substantial number of the extra animals were commingled into, and reported as part of, the TCC study group;

e. stated that no histopathological examination (study of tissue characteristic of animal disease) was performed on the so-called "research" group animals, when defendants then knew that tissues from many of the so-called "research" group animals had been so examined;

f. omitted and concealed the findings listed in a table of "Histopathological Changes in Testes — Postmortem Animals", when defendants then knew that the table existed;

g. stated that postmortem autolysis (chemical deterioration of tissue after animal death) of testicular tissue precluded meaningful histopathologic evaluation of the testicular tissues of the postmortem animals, when defendants then knew that many of those tissues had been so

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examined and graded;

h. stated that the IBT pathologist, Dr. Donovan Gordon, examined the tissues of the study animals and concluded that the findings in the testes of the lowest dose level (T_1) animals were indistinguishable from the findings of the testes of the control group animals, when defendants then knew that Dr. Gordon's conclusion was that there were TCC related toxic effects in the testes of the animals in the lowest dose level; and

i. omitted and concealed, as defendants then knew, that Dr. William Ribelin, a pathologist hired by Monsanto, had examined some of the testicular tissues of the TCC study animals and had concluded that the lowest dose level showed TCC treatment-related toxic effects.

14. It was further a part of the scheme to defraud that in response to FDA questions concerning the TCC study, a written explanation of the TCC study and report, dated December 12, 1976 was prepared and submitted to FDA by IBT on December 14, 1976, which explanation defendants then knew to be false and fraudulent in that the submission:

a. stated that the data reported in the May, 1976 report (dated March 21, 1974) were from animals that had been on the study for 24 months, when defendants then knew that the report included data from a substantial number of animals that had been on the study for significantly lesser periods of time;

b. concealed, as defendants then knew, that the animal mortality in the TCC study was substantially greater than reported in any version of the study report;

c. stated that 250 extra animals were on the study for 24 months and were an independent IBT "research" group, separate from the

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animals reported in the TOC study, when defendants then knew (1) that the so-called "research" group animals were not an independent "research" group, but were used as a source of extra animals and animal tissues for the TOC study; (2) that the so-called "research" animals had been on study for significantly lesser periods of time than 24 months; and (3) that a substantial number of the extra animals were commingled into, and reported as part of, the TOC study group;

d. concealed that histopathologic examinations were performed on a substantial number of the so-called "research" animals, when defendants then knew that such examinations had been performed; and

e. omitted and concealed, as defendants then knew, that Dr. William Ribelin, a pathologist hired by Monsanto, had examined some of the testicular tissues of the TOC study animals and had concluded in a written report that the lowest dose level showed TOC treatment-related toxic effects.

15. It was further a part of the scheme to defraud that the final study report on Naprosyn, dated January 4, 1972, was written by IBT and was received through the mail by Syntex from IBT on or about March 3, 1972, and submitted to the FDA by Syntex under cover letter dated March 22, 1972, which report defendants then knew to be false and fraudulent in that the report:

a. contained individual animal and summary animal data allegedly based on blood and urine tests performed on or about the time of final sacrifice of the study, when defendants then knew that no such tests had been conducted and that the data was fabricated and false; and

b. was supplemented by an Appendix II which was submitted to FDA by Syntex on April 9, 1974 which purported to represent, among other things, all the findings from gross examination of the study animals, when

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defendants then knew that for a substantial portion of the gross findings for postmortem animals, no such examinations were performed and the findings were fabricated and false.

16. It was further a part of the scheme to defraud that in response to FDA questions raised in September, 1976 concerning the Naprosyn study, a letter signed by Joseph C. Calandra and an explanation of the Naprosyn study dated November 11, 1976 was written and submitted to FDA, and a copy was mailed to Syntex under cover letter dated November 17, 1976. Defendants then knew that the November 11, 1976 submission to the FDA was false and fraudulent in that the submission:

a. stated that the data reported for individual animal and summary animal blood and urine values allegedly collected on or about the time of final sacrifice of the study were accurate, when defendants then knew that the data were fabricated and false; and

b. stated that gross examinations were performed on the postmortem animals and that the data from those examinations reported in Appendix II were obtained from animal cage cards and animal disposition sheets, when defendants then knew that for a substantial number of the reported postmortem animal findings no gross examinations were performed and the data were fabricated and false.

17. It was further a part of the scheme to defraud that IBT prepared and mailed to Chemagro final reports for the Sencor and Nemacur studies under cover letter dated August 15, 1972 to Chemagro. Chemagro submitted the IBT Sencor study report to EPA by mail on or about March 8, 1973, and submitted the IBT Nemacur study report to EPA by mail on or about October 15, 1975, which reports defendants then knew to be false and

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fraudulent in that each report:

a. stated that all the mice on the study were fed the test material for 18 months, when defendants knew that (1) the study only ran for 14 months; and (2) the mice sacrificed and examined at the end of the study included a substantial number of mice which had been fed the test material 14 months or less;

b. contained a Mortality Table which defendants then knew substantially under-reported the number of animals that were on the study and the number of animals that died during the study;

c. concealed that a larger number of extra mice were added to and were a part of the study; and

d. stated that there was a third positive control group fed benzedine, when the defendants then knew that no such control group had been conducted with these studies.

18. It was further a part of the scheme to defraud that IBT wrote an "Addendum Report to Chemagro" regarding the Sencor study report and mailed it to Chemagro on or about December 21, 1973, which addendum Chemagro mailed to EPA on or about October 8, 1974, and which defendants knew to be false and fraudulent in that the addendum:

1. listed the number of days that each mouse was on the study as if the study had run for 18 months, when defendants then knew that the mice had been on the study for significantly lesser periods of time;

2. omitted and concealed that a substantially greater number of mice were on the study than reported; and

3. listed for the individual animals designated as PCIII, their alleged number of days on the study and gross pathological findings which

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information defendants knew was false because no such positive control group had been conducted with this study.

19. It was further a part of the scheme to defraud that an IBT audit was conducted on the Chemagro studies in April, 1976 which documented that the studies were false, as specified above in Paragraph 17a, and that the defendants concealed the results of this audit from Chemagro until July, 1977.

20. It was further a part of the scheme to defraud that the United States mails and interstate wire communications were used in furtherance of the scheme.

21. On or about May 10, 1976, in the Northern District of Illinois, Eastern Division,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, for the purposes of executing the aforesaid scheme to defraud, and attempting to do so, knowingly did cause to be placed in the United States mails the final version of the TOC study report, addressed to:

Daniel Roman
Monsanto Company
800 Lindbergh Blvd.
St. Louis, Missouri

to be sent and delivered by the United States Postal Service according to the directions thereon.

In violation of Title 18, United States Code, Section 1341.

EXHIBIT
APP. 13 100337

WATER_PCB-SD0000072907

COUNT TWO

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1.- Paragraphs One through Twenty of Count One of the indictment are realleged herein.

2. On or about August 11, 1976, in the Northern District of Illinois, Eastern Division,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, for the purposes of executing the aforesaid scheme to defraud, and attempting to do so, knowingly did cause to be placed in the United States mails a letter from Joseph C. Calandra dated August 11, 1976, addressed to:

Dr. Carl M. Leventhal
Deputy Director, Bureau of Drugs
Department of Health, Education and Welfare
Public Health Service
Food and Drug Administration
Rockville, Maryland 20852

to be sent and delivered by the United States Postal Service according to the directions thereon.

In violation of Title 18, United States Code, Section 1341.

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APP.14 100335

WATER_PCB-SD0000072908

COUNT THREE

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Twenty of Count One of this indictment are realleged herein.

2. On or about November 17, 1976, in the Northern District of Illinois, Eastern Division,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. FLANK,

defendants herein, for the purposes of executing the aforesaid scheme to defraud, and attempting to do so, knowingly did cause to be placed in the United States mails a copy of the written submission by IBT to the FDA regarding Naprosyn dated November 11, 1976, addressed to:

Mr. Virgil Thompson
Syntex Corporation
3401 Hillview Avenue
Palo Alto, California 94304

to be sent and delivered by the United States Postal Service according to the directions thereon.

In violation of Title 18, United States Code, Section 1341.

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WATER_PCB-SD0000072909

COUNT FOUR

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Twenty of Count One of this indictment are realleged herein.

2. In or about October, 1976, in the Northern District of Illinois, Eastern Division,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. FLANK,

defendants herein, for the purposes of executing the aforesaid scheme to defraud, and attempting to do so, knowingly did transmit and cause to be transmitted in interstate commerce, by means of wire communication, certain signs, signals and sounds, to wit: a long distance telephone call between IBT and Dr. D.W. Lamb at Chemagro in Kansas City, Missouri.

In violation of Title 18, United States Code, Section 1343.

FOOTAGE

APP. 14 10083?

WATER_PCB-SD0000072910

COUNT FIVE

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Six of Count One of this indictment are realleged herein.

2. At all times material herein, the Food and Drug Administration (FDA) was an agency of the United States Government.

3. On or about May 10, 1976, in Northbrook, in the Northern District of Illinois, Eastern Division, and elsewhere,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, wilfully and knowingly did make, and cause to be made, false, fictitious and fraudulent statements and representations as to material facts and concealed and covered up material facts, in a matter within the jurisdiction of FDA, to wit: "Report to Monsanto Company, Two-Year Chronic Oral Toxicity Study with TCC in Albino Rats, BTL 71-8, March 21, 1974, IBT No. 9575," which study report was submitted to FDA by Monsanto under cover letter dated May 11, 1976. The aforesaid false, fictitious and fraudulent statements and representations and omissions as to material facts are listed in Paragraph Thirteen of Count One of this indictment and are realleged herein.

In violation of Title 18, United States Code, Section 1001.

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APP. 17 100336

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COUNT SIX

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Six of Count One and Paragraph Two of Count Five of this indictment are realleged herein.

2. On or about December 12, 1976, in Northbrook, in the Northern District of Illinois, Eastern Division, and elsewhere,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. FLANK,

defendants herein, wilfully and knowingly did make, and cause to be made, false, fictitious and fraudulent statements and representations as to material facts and concealed and covered up material facts, in a matter within the jurisdiction of the FDA, to wit: a written explanation to the FDA by IBT regarding IBT's "Report to Monsanto Company, Two-Year Chronic Oral Toxicity Study with TOC in Albino Rats, BTL 71-8, March 21, 1974, IBT No. 9575." The aforesaid false, fictitious and fraudulent statements and representations and omissions as to material facts are listed in Paragraph Fourteen of Count One of this indictment and are realleged herein.

In violation of Title 18, United States Code, Section 1001.

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APP. 18

WATER_PCB-SD0000072912

COUNT SEVEN

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Six of Count One and Paragraph Two of Count Five of this indictment are realleged herein.

2. On or about December 12, 1976, in Northbrook, in the Northern District of Illinois, Eastern Division, and elsewhere,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, wilfully and knowingly did make, and cause to be made, false, fictitious and fraudulent statements and representations as to material facts and concealed and covered up material facts, in a matter within the jurisdiction of the FDA, to wit: the original version of the study report called "Report to Monsanto Company, Two-Year Chronic Oral Toxicity Study with TOC in Albino Rats, BIL 71-8, March 21, 1974, IBT No. 9575", which was submitted along with the written explanation of the TOC study to the FDA under cover letter dated December 12, 1976 by IBT. The aforesaid false, fictitious and fraudulent statements and representations and omissions as to material facts are listed in Paragraph Twelve of Count One of this indictment and are realleged herein.

In violation of Title 18, United States Code, Section 1001.

EXHIBIT

WATER_PCB-SD0000072913

COUNT EIGHT

The SPECIAL OCTOBER 1980 GRAND JURY further charges:

1. Paragraphs One through Five and Paragraph Seven of Count One and Paragraph Two of Count Five of this indictment are realleged herein.

2. On or about November 11, 1976, in Northbrook, in the Northern District of Illinois, Eastern Division, and elsewhere,

JOSEPH C. CALANDRA,
MORENO L. KEPLINGER,
PAUL L. WRIGHT, and
JAMES B. PLANK,

defendants herein, wilfully and knowingly did make, and cause to be made, false, fictitious and fraudulent statements and representations as to material facts and concealed and covered up material facts, in a matter within the jurisdiction of the FDA, to wit: a letter and written explanation to the FDA prepared and submitted by IBT dated November 11, 1976 regarding the IBT study report on Naprosyn called: "Report to Syntex Research, Division of Syntex Corporation, 22-Month Chronic Oral Toxicity Study with RS 3540 Albino Rats, January 4, 1972, IBT No. B7922". The aforesaid false, fictitious and fraudulent statements and representations and omissions as to material facts are listed in Paragraph Sixteen of Count One of this indictment and are realleged herein.

In violation of Title 18, United States Code, Section 1001.

A TRUE BILL:

FOREPERSON

F0011410

UNITED STATES ATTORNEY

APP. 20

WATER_PCB-SD0000072914

Monsanto INDUSTRIAL CHEMICALS CO. JUN 2 1975

FROM (NAME & LOCATION): R. G. Kaley, II - T2F

DATE: May 27, 1975

cc: J. P. Mieure - T2F

SUBJECT: 5TH ANNUAL SYMPOSIUM ON RECENT ADVANCES IN THE ANALYTICAL CHEMISTRY OF POLLUTANTS

REFERENCE:

TO: R. E. Keller
T1B

TRIP REPORT

The 5th Annual Symposium on Recent Advances in the Analytical Chemistry of Pollutants was held from May 19 through May 21 at Jekyll Island, Georgia. Twenty-one technical papers and three plenary lectures were presented.

Most of the technical papers were survey papers of various spectroscopic techniques of limited interest to Applied Sciences. The techniques included neutron activation, X-ray and UV photoelectron spectroscopy, ESCA, spark source MS, and GC-IR using Fourier transform.

The paper of most interest to Applied Sciences was that presented by I. H. Pomerantz of FDA on Analytical Studies of Chlorinated Dibenzofurans. After a brief history of the occurrence of DBF in various products, he showed data of the DBF homologs found in Aroclors.

Aroclor	DBF by Cl #
1221	0
1016	2
1242	2,3,4
1254	4,5

He stated that the DBFs occur at one to several ppm, but showed no numerical data. Further, he indicated preliminary toxicity data for DBFs are like those for CDDs, but again showed no data. Lastly he showed no actual chromatograms of Aroclor solutions containing DBFs although the thrust of his paper was the analytical detection and measurement of the DBFs in Aroclor fluid. His conclusion that DBFs are best separated on polar columns has been known to us for some time.

Several papers of potential interest to Applied Sciences were disappointing. L. B. Rogers' paper on improvements in LC was primarily a review of not so recent developments. His one notable point was that one should remember that one can increase S/N by decreasing noise. Improved temperature control of LC instruments, including control of column, detector and solvent temperatures would, for instance, give much better retention time reproducibility.

It appears that Monsanto and Applied Sciences are certainly current with regard to environmental compatability technology, based on the level of the papers presented and personal conversations.

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PLAINTIFF'S EXHIBIT 404

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Overall, I was disappointed in that I expected more technical and less survey-type papers. However, I feel that this conference is important enough that it should remain as a "must-coverage" meeting every other year. (It is held in a foreign country every second year.) The participants were a nearly equal mix of industrial, governmental, and academic scientists, so that inter-area contacts are readily established.

Robert G. Kaley, II

R. G. Kaley, II

db.

STR CC6715

WATER_PCB-SD0000072916

Monsanto INDUSTRIAL CHEMICALS CO.

FROM (NAME & LOCATION): J. P. Mieure - T2F

DATE : December 3, 1974

SUBJECT : FDA DETECTION OF CHLORINATED DIBENZOFURANS IN AROCLOR

REFERENCE :

cc: R. E. Keller - T1B
R.H. Munch - T1B
W. R. Richard - T3A

TO : W. B. Papageorge
B2SK

Per your recent request, I have talked by telephone with John Roach of FDA regarding his paper at the national meeting of the Association of Official Analytical Chemists reporting detection of chlorinated dibenzofurans (CDF) in Aroclors. This memo documents our conversation.

According to Mr. Roach, he and his co-workers have isolated and identified CDF in Aroclors 1016, 1242 and 1254 but not in Aroclor 1221. These reference Aroclors were provided by Monsanto. The concentrations were in the low (probably 1-10) ppm range. Dichlorodibenzofurans were found in Aroclor 1016, di-tetra homologs in Aroclor 1242 and tetra and penta homologs in Aroclor 1254. He estimates their lower limit of detection. at less than 0.1 ppm.

The analytical method was similar, but not identical, to that used to determine CDF in Kanechlor 400 (see attached reference). Isolation of the CDF was accomplished by column chromatography followed by identification by GC/MS. I raised the question whether other potential impurities such as chlorinated methyl biphenyls (which have similar mass spectra) could have been mistakenly identified as CDF. Roach's response was negative, followed by a sophisticated and technically correct explanation that they have obtained and characterized several chlorinated methyl biphenyls as reference materials to eliminate this possibility. They are currently attempting to identify some of the individual isomers which have been isolated.

Roach agreed to send me a copy of the paper he presented at the AOAC meeting as well as a preprint of their entire study when completed in about two months. They plan to publish their findings.

Their methodology is similar to that first reported by Vos and duplicated in our laboratories during a 1971 survey of our Aroclor products for CDF. This survey did not detect any CDF with a lower detection limit of 0.5 ppm for each isomer. (Several isomers at lower concentrations totaling >1 ppm could have been present). Roach indicated their current technique gives better (but not complete) recoveries than the method of Vos. FDA also has a more sensitive MS than our current model, although we will have a superior instrument in a few weeks.

J. P. Mieure

db

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PLAINTIFF'S EXHIBIT 405

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EX. 757

WATER_PCB-SD0000072917

Monsanto INDUSTRIAL CHEMICALS COMPANY

R. E. Keller - South Second Street - St. Louis

DATE: October 28, 1971

SUBJECT: ALLEGED DIOXINS AND BENZOFURANS IN PCB'S - INPUTS FOR REPORT

REFERENCE: HSB 10-22-71 Memo to REK/WRR

TO: W. R. Richard
General Offices

cc: C. W. Roos - Res. 1
T. M. Patrick - Res. 1
M. W. Dietrich - Res. 2
J. P. Mieure - Res. 2
E. S. Tucker - Res. 2

The attached reports and summary data table for furans cover information in hand on the above subject.

Overall, we should be able to meet predicted regulatory agency maximum permissible levels of chlorodibenzofurans in our PCB/PCT products. Data in hand show that Aroclor 1242, 1254, 1260 and MCS 1016 contain no detectable (<2 ppm)* furans (or chlorodibenzo-p-dioxins). Aroclor 5442 contains no detectable (<5 ppm) furans.

The above position is based on the belief that higher levels would be permitted for furans because of lower toxicity compared to dioxins. The data shown on the confidential attachment from a European manufacturer shows that tetrachlorodibenzo-p-dioxin has an acute toxicity to rabbits at least 30X that for tetrachlorodibenzofuran. Regulatory agencies, including the EPA, are currently imposing 0.1 ppm max. for tetrachlorodibenzo-p-dioxin in 2,4,5-T and hexachlorophene. On this basis, a 2 ppm max. level should be acceptable for furans.

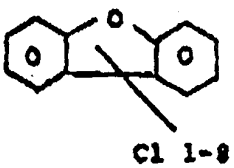
If we are required to push the detection to 0.1 ppm, we will need to synthesize furans and develop more sensitive methods. This will be costly, and difficult technically, especially for PCT products.

Based on experimental work in our own laboratories and in part at the University of Utrecht -

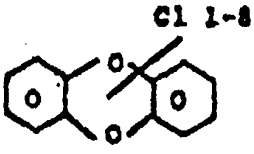
We Know

1. Monsanto Aroclor 1242, 1254, 1260 and MCS 1016 contain no detectable (<2 ppm) chlorodibenzofurans (I) or chlorodibenzo-p-dioxins (II) of the type below. Aroclor 5442 also contains no detectable (<5 ppm) chlorodibenzofurans or chlorodibenzo-p-dioxins.

(I)



(II)



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*On a per component and not total furan basis.

PLAINTIFF'S EXHIBIT 408

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2. Competitive products - Prodelec and Bayer chlorinated biphenyls similar in composition to Aroclor 1260 contain detectable furans (up to 30 ppm) and no dioxins (<2 ppm). Japanese product from Shizuki similar to Aroclor 1242 contains no detectable (<2 ppm) furans or dioxins.

3. All the above PCB products contain chlorinated naphthalenes at ppm levels. Aroclor 5442 contains either chlorinated anthracene or phenanthrene.

Don't Know or Limited Information Only

1. Biodegradability of furans -

   Toxicity to bacteria may be a problem for biodegradation studies.

2. Photodegradation of furans -

   Work by the USDA indicates that photodegradation of dioxins under conditions in which water is the solvent is probably extremely slow in the natural environment.

3. Existence of furans (or dioxins) in the environment or as biological residues -

   Methodology normally applied to analysis of environmental materials will not make this detection.

Questions for Medical

1. Toxicity of other impurities -

   Chlorinated naphthalenes, anthracene and/or phenanthrene found in above commercial products?

2. Acute toxicity or teratogenic effects of chlorodibenzofurans relative to dioxins? Availability of published data in the public domain for reference purposes?

3. Based on the above - the odds that 2 ppm max. for chlorodibenzofurans will be put on our products?

I suggest that the only immediate analytical work would be to firm up furan data for remaining PCB/PCT products with existing methodology. Out of this, we should decide what minimum monitoring is needed to insure that our manufacturing process produces no furans in our final products. Additional analytical method development work should be done only if lower detections are needed, based on inputs such as adverse toxicity findings from others.

R. E. Keller

db

STR 030682

WATER_PCB-SD0000072919

GC/MS ANALYSIS DATA FOR TOXIC COMPONENTS IN PCB/PCT PRODUCTS

LABORATORY/PRODUCTS	CHLORODIBENZOFURANS FOUND		
	<4 Cl/mol	4 Cl/mol	5 Cl/mol
Vos, et al			
University of Utrecht			
Prodelec Phenoclor DP6 (Composition similar to Aroclor 1260)	ND (<1 ppm)	Detected (1-20 ppm)	Detected (1-20 ppm)
Bayer Clophen A60, Lot 912434 (Composition similar to Aroclor 1260)	ND (<1 ppm)	Detected (1-20 ppm)	Detected (1-5 ppm)
Monsanto Aroclor 1260, Lot AK-3	ND (<1 ppm)	ND (<1 ppm)	ND (<1 ppm)
Applied Sciences			
Monsanto Industrial Chemicals			
Prodelec Phenoclor DP6	ND (<2 ppm)	Detected	Detected (15-30 ppm)
Prodelec Phenoclor DP6	ND (<2 ppm)	Detected	Detected (15-30 ppm)
Bayer Clophen A60, Lot 931134	ND (<2 ppm)	Detected	Detected
Kaneclor KC-300 Shizuki, July 1970 (Composition similar to Aroclor 1242)	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto Aroclor 1242, Lot AK-255	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto Aroclor 1254, Lot AK-38	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto Aroclor 1260, Lot AK-3	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto MCS 1016, Drum B	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto MCS 1016, KA-708	ND (<2 ppm)	ND (<2 ppm)	ND (<2 ppm)
Monsanto Aroclor 5442, Lot AI-9	ND (<5 ppm)	ND (<5 ppm)	ND (<5 ppm)

SIR 030653

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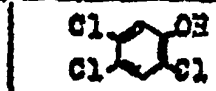
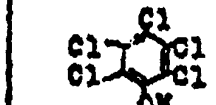
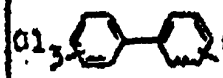
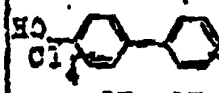
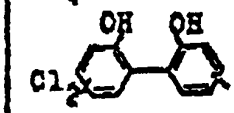
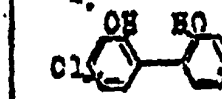
2,4,5-Trichlorphenol		1,0	0/8
1,2,4,5-Tetrachlorbenzol		1,0	0/5
Pentachlorphenol		0,5 0,2	0/2 0/2
Hexachlornaphthalin		0,1 0,05 0,01 0,003	+ 2/2 + 2/4 + 1/4 0/2
Pentachlordiphenyl		0,05 0,005	0/1 0/2
Heptachlor-4,4'-dioxy-diphenyl		0,05	0/2
Tetrachlor-2,2'-dioxy-diphenyl		0,05	0/2
Tetrachlor-4,4'-dioxy-diphenyl		0,05	0/2
Trichlor-2,2'-dioxy-diphenyl		0,05	0/4
Hexachlordiphenylenoxyd		0,005 0,001 0,0003 0,0001	+ 2/2 + 3/4 + 1/7 0/2
Pentachlordiphenylen-oxyd		0,001 0,0003 0,0001	+ 5/6 + 1/2 + 1/11
Tetrachlordiphenylen-oxyd		0,001 0,0003 0,0001	+ 2/2 + 1/2 0/2
Trichlordiphenylenoxyd		0,005 0,001 0,0003 0,0001	+ 2/2 + 6/20 + 4/9 0/2
Tetrachlordiphenylen-dioxyd		0,0003 0,0001	+ 4/4 0/5

030654 STR

WATER_PCB-SD0000072921

Monsanto

W. B. PAPAGEORGE - ST. LOUIS

OCTOBER 6, 1970

cc H. S. Bergen
J. Mason
J. E. Springgate

PCB ENVIRONMENTAL PROBLEM
MEMBER STATUS REPORT

P.J.A. Marsh - BRUSSELS
W. S. Clark
J. R. Durland - TOKYO
M. W. Farrar - 2nd Street
E. V. John
R. E. Keller - 2nd Street
R. M. Kountz
T. L. Gossage
P. S. Park
W. R. Richard
J. R. Savage
E. P. Wheeler

GENERAL:

Performance against the PCB plan was reviewed with the CMC on September 14. Overall the committee was satisfied with the progress which has been made and complimented the various departments in the Division who have been involved in the action. However, it was emphasized that we must continue to emphasize to all remaining users of PCB's the importance of preventing escape to the environment and we must ensure that these warnings are fully documented so that they will support the action we have taken in this area should we become involved in legal actions.

Two variances from the original plan were requested and approved:

1. NCR - As the customer has proved unwilling to commit himself to a take or pay contract, it was agreed that we can go ahead on the basis of producing MIPB in existing equipment or using toll manufacturing facilities ensuring that a satisfactory level of profitability is maintained. The emphasis here was to phase 1242 out of NCR formulations as soon as possible.

2. It was recognized that good progress is being made in reformulating industrial/hydraulic fluids and that it was not easy to completely replace PCB's with alternate material. In view of the progress made, an extension of a further three months (i.e. end first quarter 1971) was granted to enable

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us to reformulate those products still containing Aroclor 1242. It was emphasized, however, that this would be the last extension granted and if we are not successful in reformulating, it will be necessary to discontinue the business in spite of the significant gross profit involved.

Preparations are underway to test the disposal of solid waste contaminated with Aroclors in Enviro-Chem Systems pilot unit in St. Charles, Mo. Solid wastes from transformer and capacitor manufactures will be introduced into the unit during the week of October 12.

Negotiations are continuing with Rollins-Purle, Inc. to establish their capabilities and cost of incineration of liquid Aroclor waste.

MARKETING:

The withdrawal of Aroclor plasticizers from the market appears to have been completed with very few loose ends. Only a couple of companies have called claiming that they had not heard of our withdrawal, and to date these inquiries have not caused any significant problems. Our distributors are well on their way to zero inventories of the Aroclors, having pretty well matched their purchases from Monsanto with firm orders from their customers. It does not appear that there will be any extensive returning of unsold materials.

Orders for the products which will replace the withdrawn Aroclors in the market are starting to come in. It will be several months before substantial volumes are being sold, however, as most companies have some inventory of the old products in stock. Two major items of information indicate that the replacement program is progressing well. The first is that 3M has replaced Aroclors 1254 and 4465 with Aroclor 5442 in five product lines in the Industrial Tape and Electro Products Division. The second is that Thiokol states that Santicizer 261 now has the inside track ahead of all other products including chlorinated paraffins as a replacement for Aroclors 1254 and 1260.

ENGINEERING:

Waste Incineration - CEA 2415

Design is in progress both internally and at John Zinck's. Approval drawings for the incinerator are expected the week of October 7.

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Aroclor Distillation - CEA 2417

Definitive design is in progress. Because of recent decisions by Corporate and Division Management, marketing forecasts for MCS 1016 have been reduced. Accordingly, elements of the project are being reviewed with the idea of reducing the scope of work.

Tributyl Phosphate - CEA 2371

The project scope report is being reviewed by the plant. The II building explosion and subsequent related work has delayed this plant review. A preliminary estimate has been developed. Timing of the project has become critical so pre-approval funds will be requested for engineering and commitment of long-delivery equipment.

N-C Phosphate

Although Research has had success in bench scale operation, it has been decided to prove out the process in the E-E building at JFQ. Thus, the latest schedule for having process assurance is March 1971. Project development will not be resumed until after the process is proven.

EUROPE:

An informal meeting was held with the Directors of some of the voluntary societies, e.g. British Trust, for Ornothology, and they expressed considerable satisfaction at the responsible attitude adopted by Monsanto in Northern America and the U.K.

The N.E.R.C. REPORT on the Irish Sea incident is now expected to be published November/December.

We have been promised a copy of the latest draft.

Further contact with the other European manufacturers has not yet yielded agreement on when or how to act and it has not yet been possible to arrange a decision-making meeting with them.

LEGAL:

WATER_PCB-SD0000072924

MEDICAL:

The latest status reports on the dog and
feeding studies, rat reproduction studies
toxicity, reproduction and residue studie
viewed with representatives of the Nation
of Environmental Health Sciences, Bureau
Fisheries Laboratory, Food and Drug Admin
U.S. Department of Agriculture and the Pa
Research Center.

PUBLIC RELATIONS

The July news release, stating our positi
from certain PCB markets, was used in who
by 13 more major newspapers. Total to da
the month closed, plant management at Pen
ulated Monsanto may be sued by the Southe
Association, Inc. for polluting Escambia
At this writing, the suit has not been fi
paredness statement was drafted for use b
Manager, should a suit develop.

RESEARCH:

Carbonless Carbon Paper Solvents

NCR now seems more committed to MIPB-2 as
Aroclor 1242. It appears that an additio
will be required for full scale trial wit
answer expected late 1970 or early 1971.

Assistance has been provided the plant in
the upcoming run of MIPB. An amendment w
allow the manufacture of a MIPB containin
0.6) ratios of propylene to biphenyl. Th
information indicates that this higher ra
will not be needed by NCR.

Manufacturing is searching for a location
quantities of MIPB.

Nashua likes a blend of Aroclor 5442/HB-4
solvent even though its viscosity is abov
limit". Three more blends are being sent
zero in on the proper ratio.

WATER_PCB-SD0000072925

Print fade on Nashua Clay coated paper is caused by light (as with NCR paper) but not by excess solvent. Use of a resin or rubber to extract excess solvent (beneficial in NCR paper) is harmful in the Nashua system.

Hydrogenation of the aliphatic double bond in AMS Dimer (liquid) eliminates most of the odor and reduced print fade, making this a very good hydrocarbon solvent.

Acute toxicity tests show the mono and dichlorinated AMS Dimer to be comparable to Aroclors of corresponding viscosities. The solid and liquid AMS Dimers and isopropyl biphenyl like HB-40 are "practically non-toxic" (or safe) but are noticeably more irritating to rabbit skin. Twenty four hour patch tests on one person showed no irritation from any of these materials.

Industrial Hydraulics

The removal of Aroclor 1242 from all Pydrauls will require reformulation of A-200, 281, 540, 312, 230, 135, 150, MCS 153 and MCS 974. The Pydraul 312 reformulation is farthest along. Fire resistance of the new formulation is greater than the fire resistance of Pydraul 312. Performance in the V-105C was excellent. Samples were sent to Ford for evaluation.

It will be desirable to make the hydraulic fluid application into a closed loop system. We cannot expect to stop leaks but we can expect to minimize contamination of water by (1) minimizing run-off to sewers; (2) treating contaminated water by adsorption (Anniston had no detectable PCB after passing through a limestone bed); (3) recycling adsorbents to remove Aroclor by squeezing, by extraction or by devolatilization-destruction.

Aroclor Pollution Study - Anniston

In the 13 day pilot run, initial concentrations of 1000-8000 ppb Aroclor in waste water were reduced to a range of 0-15 ppb upon passing through a series of packed carbon beds at an average flow rate of 25 cc/min. Over 99% of Aroclor removal occurred in the prefilter. This unusual reduction is believed to be due to the filtration of solid on which Aroclor was adsorbed. In tests run at higher flow rates (0.5 gpm/ft.^{2}) through the prefilter, these plugged the prefilter. The study is presently being divided into two phases: 1) feasibility studies for continuous solids (with Aroclor) removal from limestone pit effluent and 2) carbon adsorption from the clear stream at the Aroclor sump.

STA CC17

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There was a temporary delay in the shipment of the pilot adsorption unit.[2] Start-up is now targeted for 9/23.

[1] The adsorber consisted of a prefilter (3.5 inch diameter tube packed to 5.5 inch bed depth) and a series of one (1) inch diameter columns packed to a total bed depth of 13.5.

[2] Pittsburgh Carbon (Calgon Division) rental unit containing pumps, 5 inch diameter columns, etc.

Determination of Polychlorinated Biphenyl Residues in Rats from 30 day Aroclor feeding Studies

One of the more significant objectives of the Aroclor-Environment program has been to develop a more complete picture of what occurs to Aroclor products once they are released to the ecosystem. The importance of this information is two fold, first it can be used to guide the development of a more "degradable" Aroclor product and secondly, the general methods developed to study the current Aroclor products can be used to determine the degree of control that must be exercised over the replacement products to avoid similar problems with these materials in the future.

As a part of achieving this overall objective, Industrial Bio-Test Laboratories was requested to carry out a 30 day tissue collection study in albino rats with Aroclor 1242, Aroclor 1254 and Aroclor 1260. This report deals with the subsequent analysis of these tissues for residual PCB's.

Summary: The results of this study demonstrate that the residual PCB levels in all tissues decreased significantly as the degree of chlorination and the dietary exposure level of the material fed decreased. Additionally, it was observed that the amount of isomeric alteration increased as the degree of chlorination decreased resulting in the fact that the major PCB isomers retained by the rats fed Aroclor 1242 were those predominantly present in Aroclor 1254 and Aroclor 1260. There were no significant differences in the type of isomeric alteration from tissue to tissue or between sexes.

Aroclor - Environmental Program - St. Louis

Preliminary testing by the National Water Quality Laboratory at Duluth, Minnesota of the tolerance of fish and fish food organisms (survival and reproduction) to our Aroclor products has indicated that Aroclor 5442 is much more toxic to Daphnia than any of the PCB's. Eleven reserve samples of production Aroclor 5442, one of which was used in test, have been received from Anniston to determine if

WATER_PCB-SD0000072927

any water soluble tramp component(s) could be responsible for the alleged increased toxicity. Initial results indicate that the pH of the water used to extract and/or solubilize the Aroclor 5442 is not changed; however, a number of EC active components can be isolated from the water extracts via a hexane extraction. An attempt will be made to identify these components.

A meeting was held to review the status of the residue analysis of the Bio-Test Laboratories tissues. It was agreed that the work should proceed and that in terms of current priorities the tissues from the chronic rat study should be done first, followed by the fish toxicity study, and then by the chronic chicken study. Provisions have been made for shipment of the rat tissues and fish samples to Monsanto.

Arrangements have also been made to have samples of fish from the semi-annual Anniston area survey and samples of shrimp from three locations around our Pensacola collected, quick frozen and shipped to St. Louis for confirmatory residue analysis.

Environmental Studies - Ruabon

The paper entitled 'Askarels - Environmental Pollution' was presented at the CIGRE conference in Paris. This was welcomed by the delegates as a useful guide to good practice and suggestions were made for wider publication. A modified version of this paper is being made available for the PCB conference organized by the Swedish National Environment Protection Board at Stockholm on Sept. 29.

The draft of the report on the deaths of sea-birds on the Irish Sea is now being made available to Monsanto, but we have not yet received a copy.

Biodegration Testing - St. Louis

Functional Fluids

Testing of Aroclor 1242, Aroclor 1254, MCS 1016 and fractionated Aroclor 1130 in our semi-continuous activated sludge units is continuing. Calculation of ED/GC analyses for the first five weeks of operation have been completed. Due to the high degree of scatter in the data, no conclusions can be made at this stage concerning differences in biodegradation rates. The source of the scatter is currently being investigated. One of the units has been equipped with a stirrer to determine if agitation is a significant factor.

Five additional units are now being added to our setup to permit simultaneous testing of a greater number of products. Testing of trichlorobenzene, Arobromchlor 1232, and Gulf 200

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Bright Stock will be started shortly. Testing of the chlorinated terphenyls, e.g., Aroclor 5432, is awaiting the development of the necessary analytical methodology.

Several enrichment tests involving biphenyl-acclimated sludge and nutrient feed withdrawal are also planned.

Plasticizers

A three-day sampling of the HB-40 and mono-isopropyl biphenyl (MIPD) semi-continuous activated sludge units nine weeks after the previous sampling period has shown significant changes in the biodegradation rates. For MIPB, disappearance rates for the three days by UV analyses were 75, 70 and 77 per cent compared with the mean of 67 per cent in the previous sampling period. GC analyses indicate that the predominant mono-isopropyl biphenyl components are almost completely degraded during the cycle, leaving as the undegraded portion the dialkylated components. For HB-40, the previous sampling period had shown essentially a zero disappearance rate with a high degree of scatter. During the three-day period, disappearance rates of 54, 52 and 58 per cent were found. From GC analyses, it appears that the one-ring hydrogenated components are more readily degradable than the two-ring hydrogenated components.

Feeding of the MIPB and HB-40 is continuing. An additional sampling period is planned to determine if any further significant changes will occur.

Five additional units are now being added to our setup to permit simultaneous testing of a greater number of products. Testing of Aroclor 1221 will be started in one of the new units.

Biodegradation Testing - Ruabon

In the presence of lower chlorine isomers and biphenyl we appear to have succeeded in degrading the key hexa-chlorinated isomer with the biphenyl-active soil culture C_2, but the penta-chlorinated isomer has not degraded under these conditions. Work is being initiated to check whether any of the "non-degradable" isomers (e.g. 4-4'dichlor-biphenyl) can be degraded under these more severe conditions.

The sensitivity of the analytical technique used was not high enough to show conclusively whether HB-40 was degraded by C_2. This is being repeated using a higher concentration.

Progress continues in the development of GLC-Mass Spectrometry techniques to allow identification and quantification of residues remaining after prolonged biodegradation tests on various products.

SIA CC173c

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MANUFACTURING

Anniston Plant

PCB Levels In Snow Creek

Average PCB loss for the month was high at 2600 ppb or 32 lbs/day, largely as a result of one very bad day (400 lbs). Contributing causes were:

1. The old limestone pit was overloaded and solid sludges were carried through,
2. Detergent cleaning of the department,
3. Sewering of excessive amounts of muriatic acid.

Since the new limestone bed was placed in service on September 23, pit effluent has been at 0-3 ppb PCB's. However, leaching of PCB's from the creek bed results in a plant effluent level of 90 - 240ppb or 1.1 - 2.8 lbs/day, gradually declining. The plant believes that the new pit can handle ordinary upsets and peak loads.

Regulatory Action

Telephone contact continued with the Alabama Water Improvement Commission. However, a planned meeting did not take place due to illness of AWIC members. Pressure for routine submission of analytical data is not intense at this time.

Department Suspended Aroclor Control

An experimental skimmer operated very well removing the PCB laden scum which accumulates in the new sump.

Solid Wastes

Solid waste data for evaluation of disposal methods has been accumulated. A report will be issued in October.

STR CC1735

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W. G. Krummrich Plant

PCB Levels In Sewer

Current losses to the river from the treatment plant range from 12 to 742 ppb with an average loss of 311 ppb for 11 samples. This is an equivalent average loss of 71.5 lbs/day.

Projects To Reduce Sewered PCB's From Aroclor Department.

Slow Tank Demister (Estimate 2031) project construction is underway with completion scheduled for October. A Process Amendment was approved.

Project for about $30,000 to provide paving, curbs, trenches and catch basin in tank car and tank truck loading areas will be added to the incineration project to speed approval.

Program To Eliminate Sewered PCB's From Using Departments

Departments 243 and 244

Plans are to replace the Therminol FR-1 with Therminol 55. Lab work has been conducted to verify that there is no reaction between Therminol 55 and any process materials. Engineering is underway on system modifications required for use of Therminol 55. Target date for changeover is 12/1/70.

Department 245

The major problem here is air pollution from the supply tank vent. Our target is to scope a solution and prepare an estimate by 11/1. Changeover to a different fluid is undesirable in this department due to the high fire potential.

Department 251

No work has yet been done on the lubrication and hydraulic type systems in this department.

Department 239

Work is in progress to develop project premise. We expect to eliminate two pumps and a cooler in the Therminol lines. (Pending results of thermal stability of Santophen 1 residue). The project will include a new expansion tank with submerged

WATER_PCB-SD0000072931

W. G. Krummrich Plant

Department 239 (Cont'd)

pump. We also plan to upgrade controls and make furnace operation more reliable. How to sump the area around potential spills is still unresolved. To go to a flammable heat transfer fluid is considered too great a process safety hazard in this area.

Department 255

Plans are to replace FR-2 with Therminol 66 by 11/15/70.

Department 248

No progress has been made to date. A definite plan will be developed by 11/1/70 with the objective of solving any problems by 1/1/71.

Department 258 (DDS)

The unit is still down and most likely will not be started up again. The material on the pad has been removed.

Department 270

A 55-gallon drum has been placed under the vent. Chat soaked with Aroclor around the furnace must still be replaced.

Department 275

A 55-gallon drum must still be placed under the vent line (the vent will have to be shortened to do this). Chat around the furnace still needs to be replaced.

Department 273

Work completed. Drum placed under surge tank vent. Buckets placed to collect material from drip pans under Therminol circulating pumps.

Department 222

Unit in start-up. No visible source of loss observed.

Estimate 2292 will be revised. This is the project to provide 150,000 gallons of storage for scrap Aroclor. A plant level earnings expense estimate will be prepared

WATER_PCB-SD0000072932

W. G. Krummrich Plant

Department 222 (Cont'd)

to cover the cost of altering the storage tanks. The 4,000 gallon trailer originally used to haul Aroclors to Queeny Plant will be used for scrap Aroclor hauling in the plant.

PCB Levels In Atmosphere

Vapor losses from the Aroclor Department are estimated at 2.3 #/day now and 1.6#/day after the installation of the blow tank demister.

1. Scrubber Stack (from blow tank drowning jet) 0.90#/day

   This is a measured quantity. With installation of the demister and closing the batch blow tanks, air flow should be decreased to about 20% of present flow. Assuming the concentration to be the same, loss would be reduced to ~0.2#/day.

2. Fume Removal Stack (from drowning area and sampling stations) 0.05#/day

   This is an estimated quantity based on most vapors coming from the drumming station and assuming 10,000,000 #/year drummed, and 1242 vapor pressure at 80°C. Samples are being taken to verify.

3. Aroclor Transfers Within Department 1.34#/day

   This is an estimated quantity assuming 70M #/year production and 2.5 transfers/pound at 100°C. Samples will be taken at storage vents to verify.

4. Steam Jets - unknown

   Will be measured.

STR CC174.

WATER_PCB-SD0000072933

W. G. Krummrich Plant

PCB-Rework Project (Estimate 2095)

Phase II — Construction sufficiently complete to allow unloading tank cars to the rework still.

Phase III — Design package will be completed by mid-October.

This project will be added to the incineration project for approval. Phase III will be held up until approval is received. This will mean that material will be reworked direct from tank cars until the Phase III storage facilities are installed.

W. B. Papageorge

W. B. PAPAGEORGE

ms

STK CC1743

WATER_PCB-SD0000072934

Monsanto

St. Louis - General Offices

May 11, 1970 W. B. Papageorge

TO : H. S. BERGEN
J. E. SPRINGGATE

Attached hereto are copies of charts I used in the presentation with the CMC this morning.

The CMC gave its approval for us to implement the plan as outlined on the two sheets marked "PRESENT PLAN".

We are required to report to the CMC should we make any major deviation from these plans and we are also required to make a progress report probably around the 1st of August. Would you please go ahead and take the necessary action within your individual business groups and keep me advised of progress.

JOHN MASON

Att.

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STR 001479

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WATER_PCB-SD0000072935

COST OF RAPID PHASE-OUT - ALL CHLORINATED BIPHENYLS EXCEPT DIELECTRICS

1970

LOSS IN SALES - $ 5.4 M

LOSS IN GROSS PROFIT - $ 2.6 M

IN ADDITION COGS WOULD INCREASE GIVING TOTAL LOSS IN GROSS PROFIT OF - $ 2.75 M.

1971

LOSS IN SALES - $ 12 M

TOTAL LOSS IN GROSS PROFIT - $ 6.1 M

PLUS POSSIBLE WRITE-OFF OF SOME $ 2.6 M KRUMMRICH AROCLOR FACILITIES.

STR C0148C

WATER_PCB-SD0000072936

OBJECTIVE

TO MAINTAIN A PROFITABLE BUSINESS SERVING THE NEEDS OF FUNCTIONAL FLUIDS USERS AND THE CARBONLESS DUPLICATING PAPER INDUSTRY WHILST MINIMIZING THE ESCAPE OF NON-BIODEGRADABLE BIPHENYLS INTO THE ENVIRONMENT.

STR 00156

WATER_PCB-SD0000072937

ACTION TO ACHIEVE OBJECTIVES

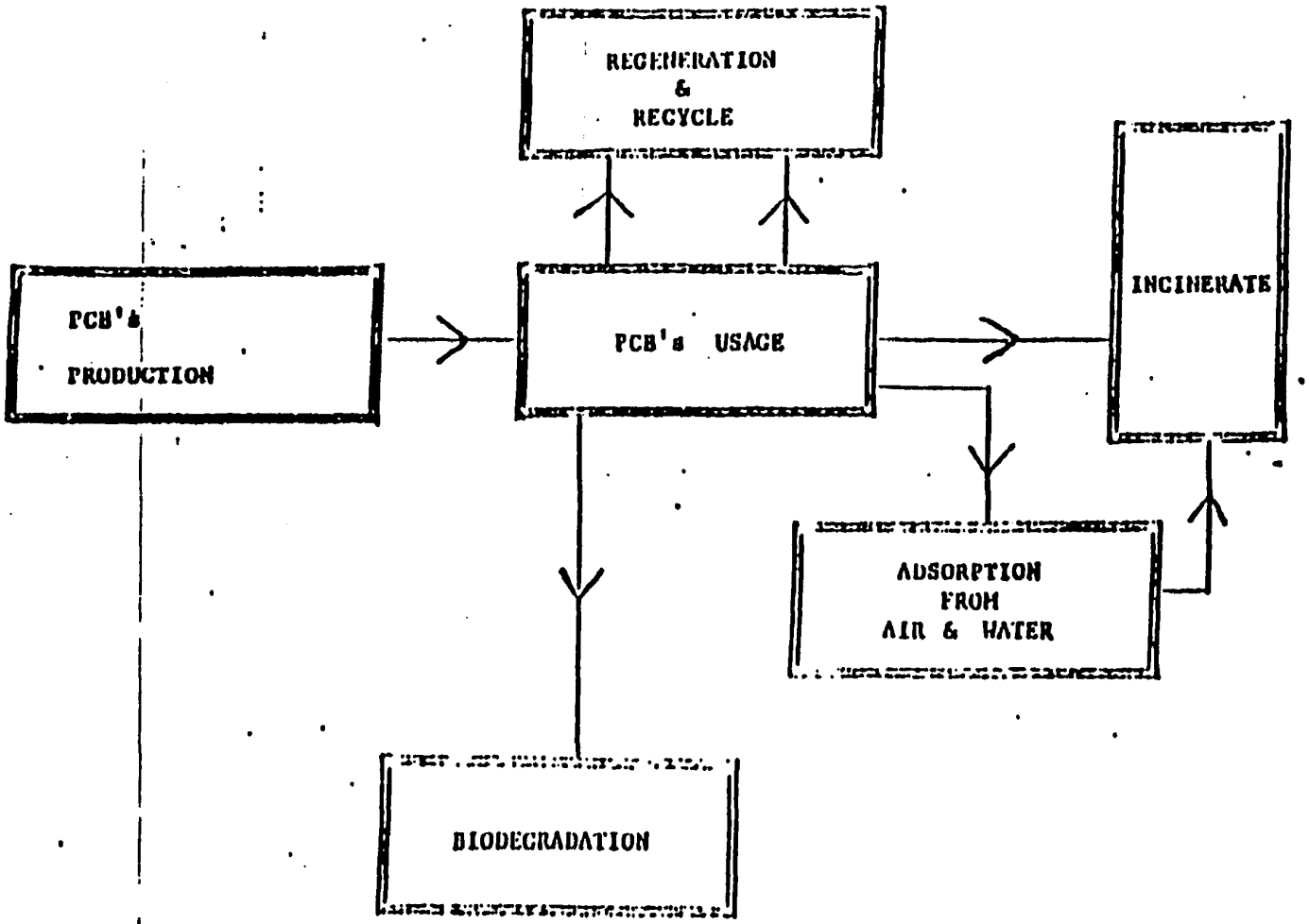
1) MARKET NON-BIODEGRADABLE CHLORINATED BIPHENYLS ONLY FOR CLOSED SYSTEM APPLICATIONS WHERE CONTROL IS POSSIBLE.

2) PHASE OUT OF ALL NON-CONTROLLABLE APPLICATIONS REPLACING WITH BIODEGRADABLE CHLORINATED BIPHENYLS OR OTHER SATISFACTORY PRODUCTS.

STR C01482

WATER_PCB-SD0000072938

THE CLOSED LOOP



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DO WE HAVE THE CAPABILITY TO CLOSE

THE LOOP ?

STR CC1484

WATER_PCB-SD0000072940

BIODEGRADATION

1) GOOD PROGRESS AT BOTH RICHMOND AND ST. LOUIS.

2) LOWER CHLORINATED ISOMERS RESPONDING WELL, BUT 5 & 6 CHLORINE ISOMERS EITHER NOT RESPONDING OR VERY SLOW.

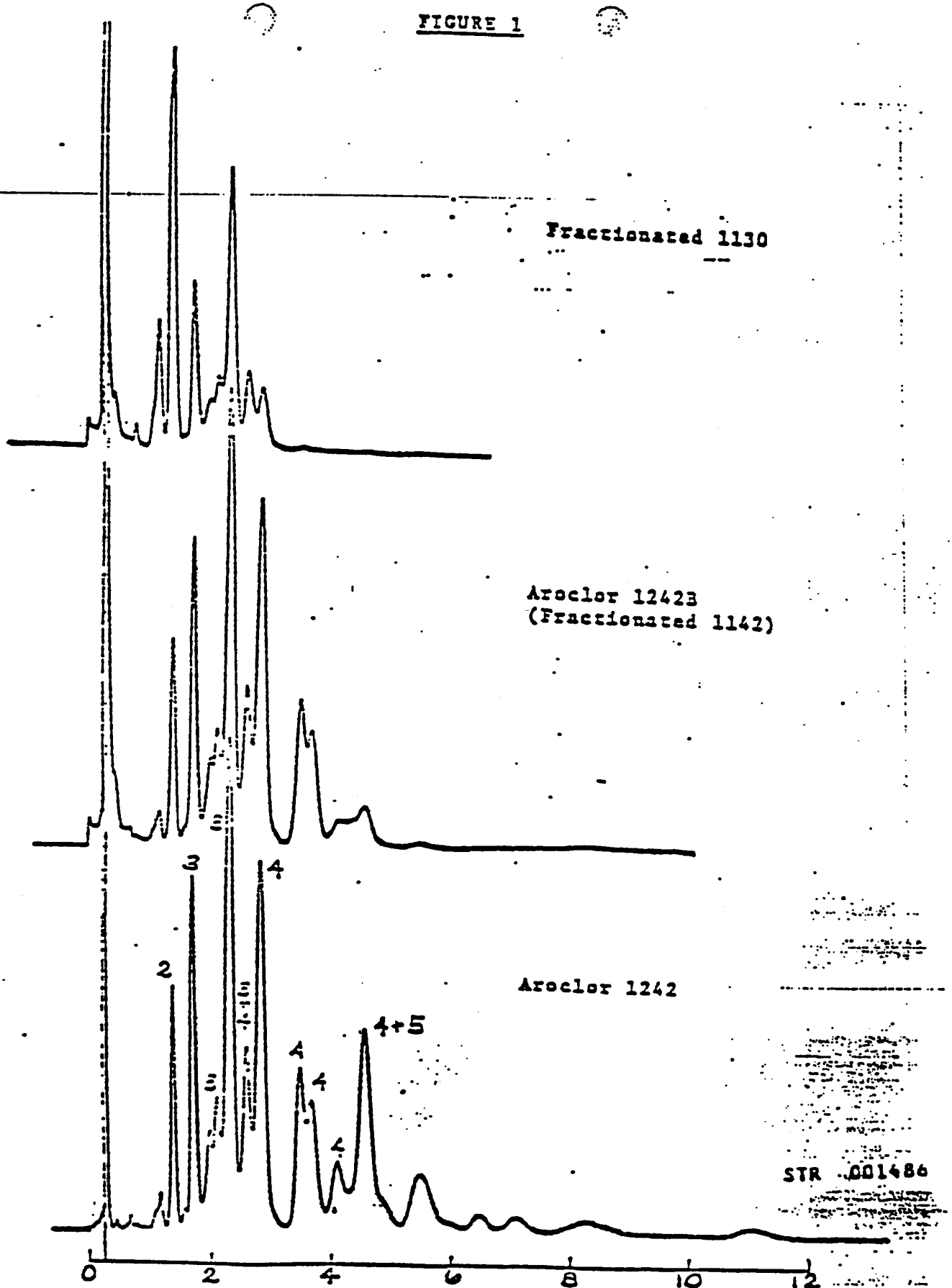
3) CRITICAL PRODUCT IS 1242, CONTAINS SOME 50 ISOMERS — GOOD RESPONSE ON 2, 3, & SOME 4 CHLORINE ISOMERS.

4) WORK IN HAND ON FRACTIONATED 1242 GOOD PROGRESS TO DATE.

STR 001485

WATER_PCB-SD0000072941

FIGURE 1



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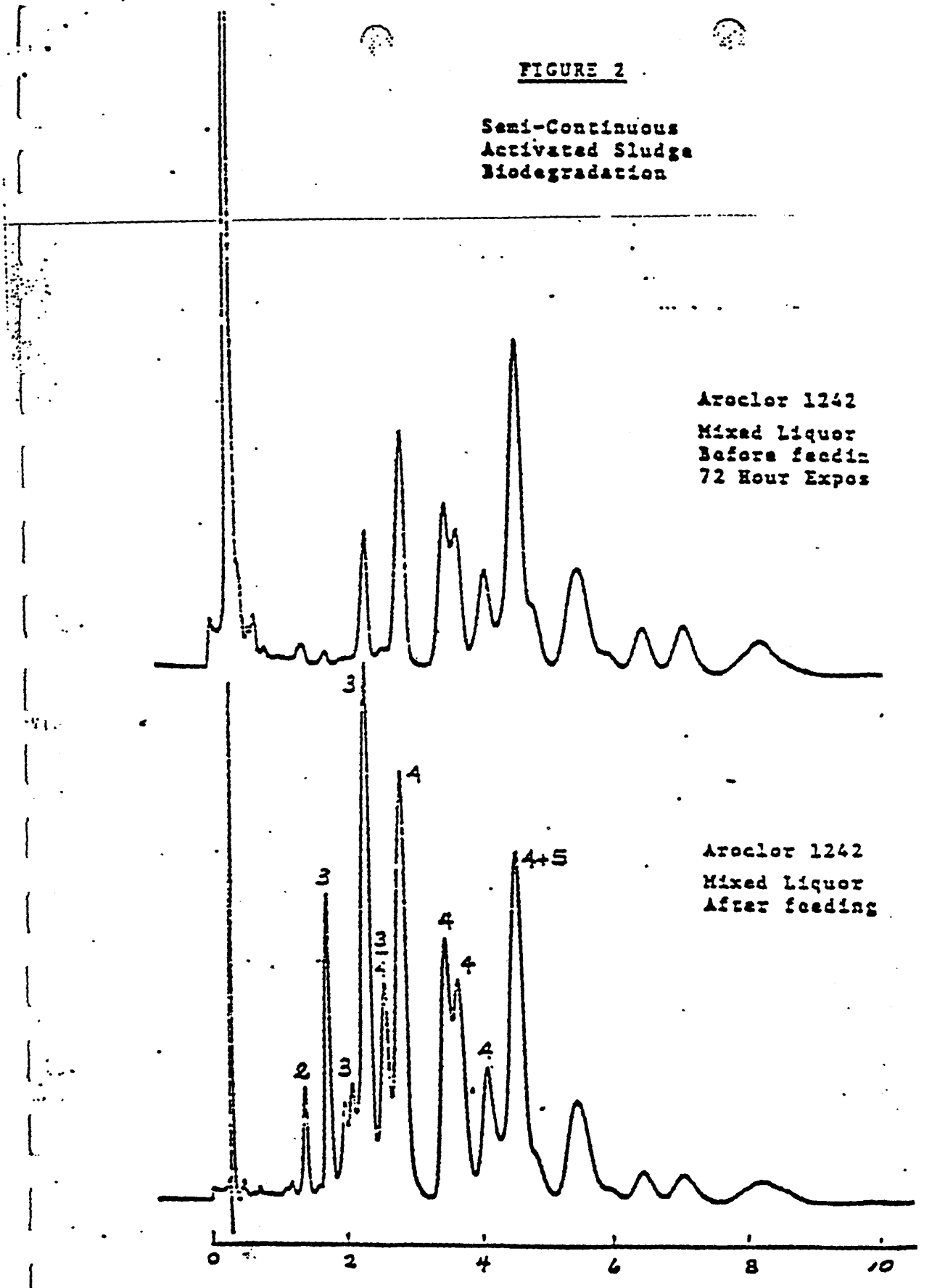
WATER_PCB-SD0000072942

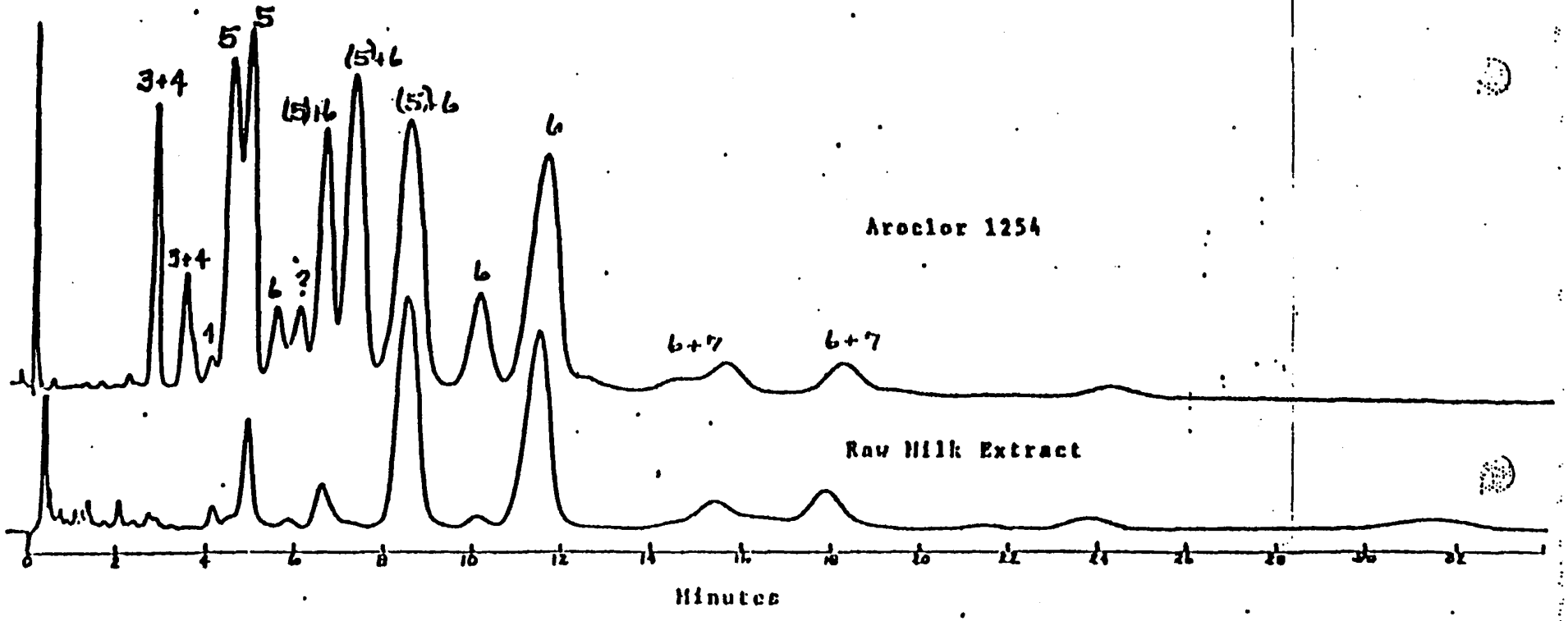
FIGURE 2

Semi-Continuous
Activated Sludge
Biodegradation



WATER_PCB-SD0000072943

FIGURE 3



WATER_PCB-SD0000072944

REPLACEMENT PRODUCTS

1) 1242B SHOWS GOOD PROPERTIES AS CAPACITOR DIELECTRIC - NOW MAKING 500 GALS. AT DAYTON FOR CUSTOMER TRIALS. - ALSO WORKING ON 1230B.

2) GOOD PROGRESS ON PHOSPHATE ESTER REPLACEMENTS FOR HYDRAULIC FLUID APPLICATIONS. — TCP — CDP — T2P — NONYL PHENYL/CONYL PHENYL DIPHENYL PHOSPHATE.

3) HEAT TRANSFER FLUIDS — USING MAINLY ESTABLISHED PRODUCTS, E.G. HB-40 — EXAMINING POSSIBLE ENTRY INTO DIPHENYL OXIDE PRODUCTION EITHER OWN PROCESS OR LICENSING.

STR 0014

WATER_PCB-SD0000072945

TOXICITY

1) NO CHANGE SINCE LAST REPORT - HAVE DISCUSSED RESULTS WITH DR. BURGER, EXECUTIVE OFFICE OF THE PRESIDENT.

2) WE HAVE ANALYZED AROCLORS 1248 AND 1254 FOR OCTOCHLORO DIBENZO p-DIOXIN -- NONE FOUND.

3) CENTRAL INSTITUTE FOR NUTRITION AND FOOD RESEARCH, ZEIST, HOLLAND -- EXAMINED BAYER, PRODELAC AND MONSANTO CHLORINATED BIPHENYLS FOR DIBENZO FURANS -- NONE FOUND IN MONSANTO MATERIAL.

STR 001490

WATER_PCB-SD0000072946

INCINERATION

1) SUCCESSFUL TRIAL AT JOHN ZINC CO., TULSA. 1242, 1260, 1254 DESTROYED AT 2000° F. -- OFF GAS HCl. ENGINEERING WORK NOW IN HAND TO BUILD SUITABLE INCINERATOR. ESTIMATED COST $250,000 M.

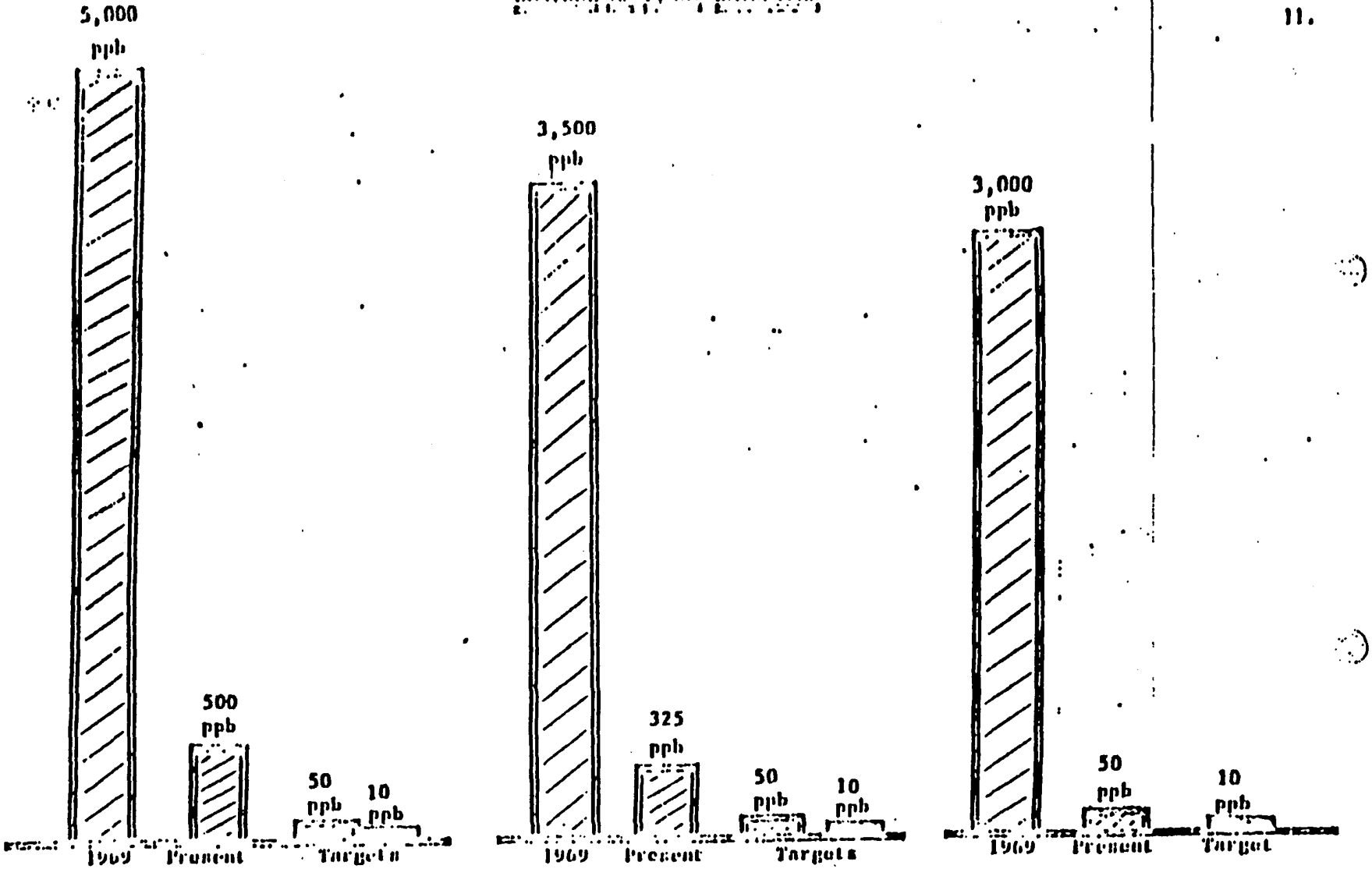
2) INTEND TO CARRY OUT FURTHER TRIALS ON STILL BOTTOMS.

3) INCINERATOR PROBABLY LOCATED AT KRUMRICH.

STR 001491

WATER_PCB-SD0000072947

CONTROL OF PLANT EMISSIONS



STR CO1492

WATER_PCB-SD0000072948

CLOSING THE LOOP FOR INDIVIDUAL BUSINESSES.

STR 0014

WATER_PCB-SD0000072949

TRANSFORMER & CAPACITOR DIELECTRICS

1) RESPONSIBLE INDUSTRIES USING 1254 AND 1242.

2) FIRE RESISTANCE EXTREMELY IMPORTANT.

3) COLLECTION AND RETURN OF SPENT AND ARCED FLUID.

4) REGENERATION AND RECYCLE.

5) TRIALS PLANNED FOR 1242B AND 1230B IF SATISFACTORY.

6) LABELLING OF ASKAREL TRANSFORMERS.

STR 0014

WATER_PCB-SD0000072950

HEAT TRANSFER FLUIDS

1) EDUCATION OF USERS WHERE FIRE RESISTANCE IS OBLIGATORY -- MAJOR INDUSTRIAL CORPORATIONS -- E.G. GOODYEAR AND CHEMICAL COMPANIES.

2) PHASE OUT OF ALL FOOD APPLICATIONS -- LETTERS WILL BE SENT OUT MAY 15th -- NO SALES AFTER AUGUST 15th -- WILL COLLECT AND DESTROY OLD FLUID.

3) INSTITUTION OF REGULAR COLLECTION REGENERATION OR INCINERATION SERVICE.

4) PHASING IN NEW PRODUCTS WHERE CONTROL NOT POSSIBLE.

STR OC14

WATER_PCB-SD0000072951

HYDRAULIC FLUIDS

1) RECOGNIZE THAT CONTROL OF SPILLAGE AND PUMP LEAKAGE MAKES THE USE OF NON-BIODEGRADABLE CHLORINATED BIPHENYLS UNDESIRABLE.

2) ALREADY REFORMULATED PYDRAUL 625, ACWG, 280 and F9 — REPLACEMENT COMPLETE BY AUGUST 1

3) OTHER PRODUCTS IN INTERIM STAGES (E.G. PYDRAUL AC FORMULATION ON COMPRESSOR TEST AT JFQ).

4) AIM TO COMPLETE 90% PHASE-OUT BY DECEMBER, 1970.

STR 001496

WATER_PCB-SD0000072952

N. C. R.

1) U.K. HAS APPROVED HB-40, NOW PLACED REGULAR ORDERS — EXPECT COMPLETE PHASE-OUT BY 1st JULY.

2) U.S. RUNNING TRIALS ON M.I.B.P., EXPECT DECISION 22nd MAY — PRELIMINARY INTERIUM PRODUCTION OF 40 M POUNDS PER MONTH TARGETED FOR 30th AUGUST — PLANNING FULL SCALE PLANT 10 M LBS. PER ANNUM ON STREAM END JANUARY 1971 — ESTIMATED NFC $1 - 1.2 M.

WATER_PCB-SD0000072953

PLASTICIZER & MISCELLANEOUS APPLICATIONS

1) DISTRIBUTORS ALREADY ADVISED NO MORE SALES AFTER 30th AUGUST. (200 CUSTOMERS)

2) LETTERS TO 661 CUSTOMERS WILL BE SENT OUT 27th MAY ADVISING NO MORE SALES AFTER 30th AUGUST — DISPOSAL INSTRUCTIONS WILL BE GIVEN.

3) IN CONTACT WITH U.S.D.A. THROUGH AG DIVISION ON SILO PAINT PROBLEM.

4) BY 30th AUGUST ALL BUSINESS IN THIS AREA WILL BE PHASED OUT.

STR 001498

WATER_PCB-SD0000072954

PRESENT PLAN

1) TERMINATE SALES OF ALL NON-BIODEGRADABLE CHLORINATED BIPHENYLS TO NON-CONTROLLABLE END USES.

COMPLETE - AUGUST 30th, 1970.

2) DISCONTINUE SALE OF AROCLOR 1242 TO NCR AND REPLACE WITH EB-40 IN U.K., AND NCB2 IN U.S.A.

COMPLETE - U.K. -- JULY 1st, 1970

COMPLETE - U.S. -- JANUARY 30th, 1971

3) CLOSE THE LOOP ON EDAC TRANSFER APPLICATIONS WHERE T/R IS VITAL AND REPLACE WITH ALTERNATES IN OTHER CASES.

COMPLETE - DECEMBER 30th, 1970.

STR 00149

WATER_PCB-SD0000072955

4) REPLACE ALL NON-BIODEGRADABLE CHLORINATED SOLVENTS IN HYDRAULIC APPLICATIONS.

COMPLETE 20% - AUGUST 1st, 1970

" 40% - NOVEMBER 1st, 1970

" 100% - DECEMBER 30th, 1970

5) CLOSE THE LOOP ON ALL NON-BIODEGRADABLE CHLORINATED SOLVENTS IN TRANSFORMER APPLICATIONS.

COMPLETE - AUGUST 1st, 1970

6) CLOSE THE LOOP ON CAPACITORS AS FAR AS POSSIBLE AND REPLACE 1242 WITH 1242S.

COMPLETE - DECEMBER 31st, 1970

STR G015CC

WATER_PCB-SD0000072956

(18

[redacted]

[redacted]	- $ 275,000
[redacted]	- $ 250,000
[redacted]	- $ 1,000,000
[redacted]	- $ 1,200,000
[redacted]	- $ 575,000
[redacted]	- $ 235,000
[redacted]	= $ 3,535,000

STR 001501

WATER_PCB-SD0000072957

[redacted]

[redacted]

[redacted]

	[redacted]	[redacted]
[redacted]	$ 22.0 M	$ 20.8 M
[redacted]	$ 3.5 M	$ 3.0 M
[redacted]	$ 2.9 M	$ 2.7 M
[redacted]	$ 25.4 M	$ 23.8 M
[redacted]	11.5%	9.5%

STR 001502

WATER_PCB-SD0000072958

W. B. PAPAGEORGE

October 26, 1970

H. S. Bergen
W. R. Richard
R. E. Keller
E. P. Wheeler

J. R. Savage

Recent data from Dr. J. P. Mieure's work indicates the presence of naphthalene in biphenyl and anthracene or phenanthrene and dibenzofuran in Santowax R used in the manufacture of Aroclors.

The naphthalene, anthracene or phenanthrene could be present in the benzene used in the diphenyl unit or could be co-produced with the biphenyl, terphenyl and quaterphenyl.

The dibenzofuran could result from oxygen containing contaminants in the benzene or, more likely, be formed because of the presence of the promoter, acetone.

The Anniston Plant should design and execute a program for determining the source or sources of these contaminants.

W. B. PAPAGEORGE

WB

84136

PLAINTIFF'S EXHIBIT 419

SIM 1Ce713

EX 707

WATER_PCB-SD0000072959

ROUGH DRAFT - 11/10/69

OUTLINE

PCB ENVIRONMENTAL POLLUTION ABATEMENT PLAN

I. Introduction

II. Problem

III. Extensiveness

IV. Nature of the Problem

~~Research and medical input~~

V. Effect on Monsanto

VI. Effect on Customer

VII. Involvement with other producers

VIII. Sources of Contamination

~~A. Indirect Pollution~~

IX. Recent technical changes which have bearing on the contamination

X. Courses of Action

XI. Recommended Course of Action

XII. Implementation of the Recommended Course of Action

A. Immediate Action (12-1-69)

B. Interim 1-3 months

C. Short term - 3-6 months

D. Long term (1-3 years)

1. Research medical
2. Manufacturing
3. Engineering
4. Market
5. Patent
6. Environmental Control
7. Legal
8. Public Relations
9. Others

PLAINTIFF'S EXHIBIT 422

STR 021938

WATER_PCB-SD0000072960

XIII. Probability of Success

XIV. Cost of Program

$220,000 and bio with max at $20-25M

XV. Future

STR 021939

WATER_PCB-SD0000072961

PCB ENVIRONMENTAL POLLUTION ABATEMENT PLAN

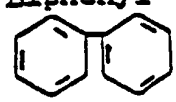
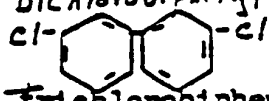
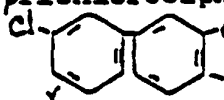
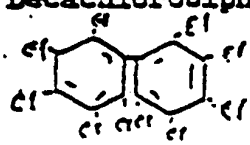
Introduction

On 15 October the "AD HOC" Committee consisting of Messrs. M. Farrar, P. Hodges, E. John, W. Richard, and E. Wheeler issued a report summarizing the polychlorinated biphenyl (PCB) pollution problems from the known available information to date. Out of this report came considerable information, conclusions, and recommendations which we have attempted to tie together into a plan of action in this document. Our objective has been to take a reasonable and responsible approach to the entire problem. Before we get into the problem, we should clarify the meaning of PCB, the nature of the entire line, and how these tie into our product line of Aroclors.

STR 021940

WATER_PCB-SD0000072962

Monsanto entered the Aroclor market in 1930 by acquiring Swain Electrical Company or known today as our Anniston, Alabama plant. The first load of Aroclor which incidentally was Aroclor 1254 -- went out of Anniston, Alabama to GE in 1931. Since that time the market has grown to 170 to 200M worldwide.

Chemical	Monsanto Product Line	Nature of Material at Ambient
Biphenyl  Solid at ~~Sublimes at~~		Solid
Monochlorobiphenyl 	Aroclor 1221	thin liquid (oil)
Dichlorobiphenyl 	Aroclor 1232	thin flush water
Trichlorobiphenyl 	Aroclor 1242	oily type fluid material
Quaterchlorobiphenyl 	Aroclor 1248	Thicker - transmission oil
Pentachlorobiphenyl 	Aroclor 1254	Heavy-Molasses
Hexachlorobiphenyl 	Aroclor 1260	Thick - tar
Heptachlorobiphenyl 	Aroclor 1262	Very thick - liquid
Octchlorobiphenyl 	Aroclor 1268	Solid
Decachlorobiphenyl 	Aroclor 12715	Solid

STR 021941

WATER_PCB-SD0000072963

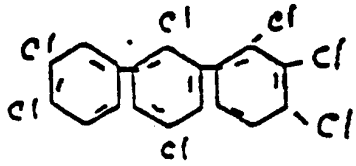
Total possibility are 210 theoretically possible chlorinated biphenyls

~~terphenyls~~ Terphenyls



Santowax or terphenyl

Solid



Aroclor 5460

Solid

II. Problem

Damage to the ecological system by contamination from polychlorinated biphenyl (PCB).

III. Extensiveness

The problem involves the entire United States, Canada, and sections of Europe especially the United Kingdom and Sweden. As the investigation broadens other areas of Europe, Asia and Latin America will surely become involved. Evidence of contamination have been shown in some of the very remote parts of the world. The involvement could and most likely will follow the DDT investigations.

IV. Nature of the Problem

Professors Widmark and Jensen of the Institute of Analytical Chemistry at Stockholm, Sweden, in November 1966, announced and confirmed finding PCB in fish, birds, and eggs. Subsequent findings were made in 1967 in Great Britain. In February 1969, Professor Risebrough of the Universit of California published an article in the San Francisco Chronicle relaying his findings of PCB in the environment of the United States. Monsanto confirmed the presence of PCB's in mid-1969 and confirmed the adequacy of work by Widmark and Jensen and others; truly, the PCB's are a worldwide ecological problem.

STR 021942

WATER_PCB-SD0000072964

Analysis indicates the environmental presence of the 5 and higher chlorinated biphenyls which take the appearance of Aroclor 1254 and Aroclor 1260. We have strong indications that Aroclor 1242 or at least part of it degrades biologically. Since the Aroclor 1242 contains arou 7 percent of the 5 chlorine biphenyl or higher we cannot rule out the possibility that the observations may be a concentration affect of the higher chlorinated biphenyls of Aroclor 1242.

To date there have been no reports of finding Aroclor 1242 present in the environment (except outside the effluent of our plants where we kno Aroclor 1242 is present).

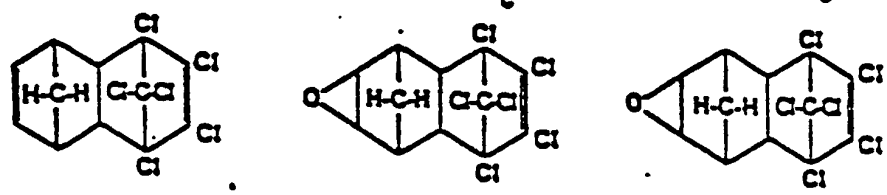
The seriousness of the problem can best be spelled out as follows:

1. Fish - Marine or aquatic species concentrate PCB in the fatty tissue. Toxic is small quantities (down to 5 ppb) to sensitive mar life such as shrimp.
2. Birds - Predatory species feeding on the marine or aquatic life can further concentrate PCB to possible harmful effects. Specifically in birds PCB can affect the calcium metabolism leading to egg shell imperfections which prevents proper hatch of the young. In fact, Monsanto has confirmed the eggshell by feeding chickens, a high order of the species, PCB's in controlled tests.
3. Man - There is no harmful effect known to man or other mammals aft 40 years of production. Investigations are underway by various sources.

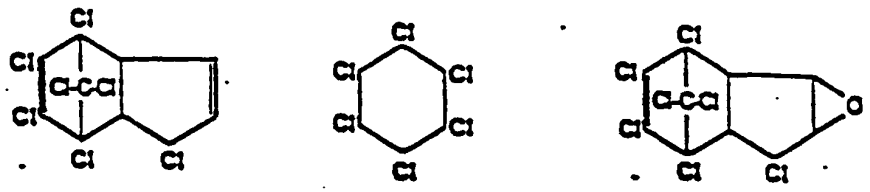
STR 021943

4. Political and Public Emotion - PCB's are falsely linked with DDT because PCB's show up in the analysis for DDT. PCB's are linked w other permanent type chlorinated hydrocarbon pesticides. This becomes particularly serious since about every article of food in country is being examined for a trace of these materials.

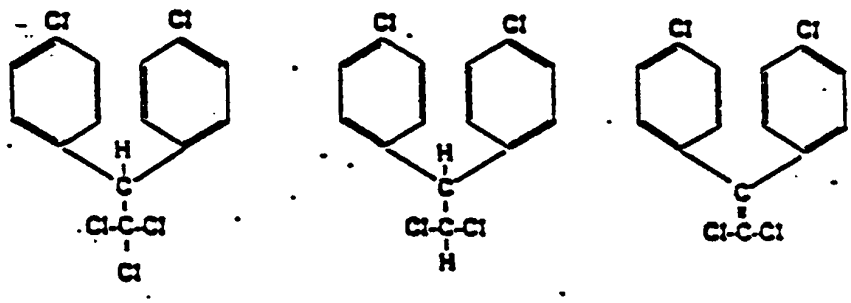
WATER_PCB-SD0000072965



ALDRIN DIELDRIN ENDRIN



HEPTACHLOR LINDANE HEPTACHLOR EPOXIDE

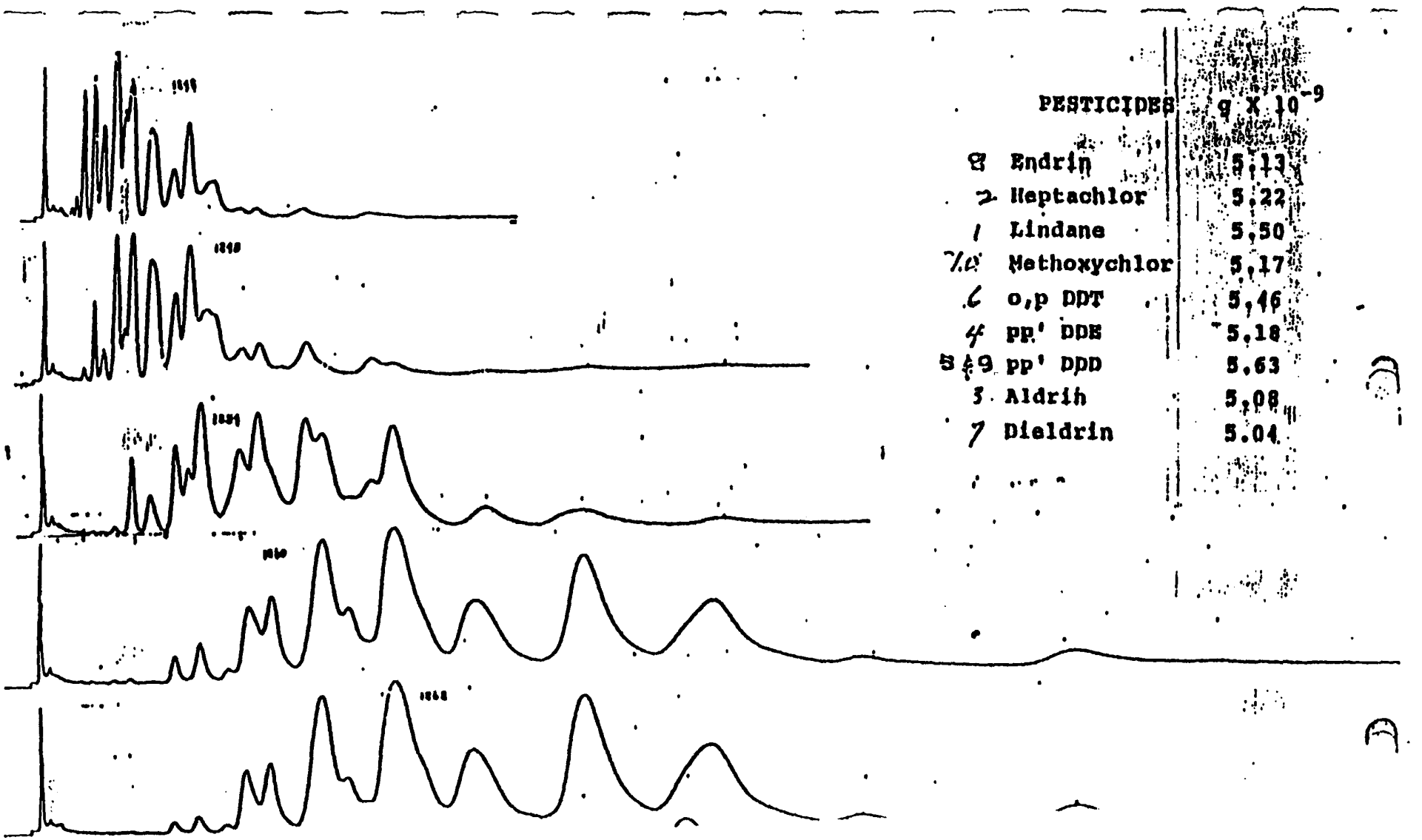


DDT DDD

Fig 1 Structural Formulae of Nine Chlorinated Hydrocarbon P

STR 021944

WATER_PCB-SD0000072966



PESTICIDES	q X 10^{-9}
8 Endrin	5,13
2 Heptachlor	5,22
1 Lindane	5,50
10 Methoxychlor	5,17
6 o,p DDT	5,46
4 pp' DDE	5,18
5 & 9 pp' DDD	5,63
3 Aldrin	5,08
7 Dieldrin	5.04

WATER_PCB-SD0000072967

V. Effect on Monsanto

Business potential at stake on a worldwide basis:

Fluids	Plasticizers	Total/Year
70M lbs.	34M lbs.	104M lbs.
$16M	$6M	$22M
$6-8M G.P.	$2-3M G.P.	$8-11M G.P.

Already competition is using certain data against us in competitive situations.

A. Legal Liability

Direct lawsuits are possible. The materials are already present in nature having done their "alleged damage". All customers using thes products have not been officially notified about known effects nor d our labels carry this information. These are only a few of the possible legal implications which would best be covered by the legal department.

B. Public Image

The corporate image of Monsanto as a responsible member of the business world genuinely concerned with the welfare of our environment will be adversely affected with increased publicity.

The evidence proving the persistence of these compounds and their universal presence as residues in the environment is beyond questioning. This combined with certain scare publications is certa to give an adverse image. Guilty by association (with DDT) will prevail as the background while actual facts may be sparse.

C. Customer Relations

STR 021946

Some customers who presently use these materials will be "scared of to other competitive products. Products associated with the same name or "trademark" will be adversely affected ie., Therminol, Pydraul and Aroclor. Competitors will use the information for an

WATER_PCB-SD0000072968

X. Courses of Action

A. Do Nothing

We cannot deny the findings and the acquisitions by the various agencies. If we took no action we would likely face numerous suits. We would let government tolerances be based on public and political pressure along with any experimental or developed data which they may generate. We would most likely be forced out of this business. Other product areas would be adversely affected. We would project an image as an irresponsible member of the business world. Project poor customer relations. The only advantage to this technique offers is it reduces the cost but this too must be weighed against potential loss of business.

B. Discontinue Manufacture of All Polychlorinated Biphenyls (PCB)

Although we all realize this could be an eventually unfortunately the solution is not this simple. Assuming we did stop manufacture immediately, the pollutants are present in the environment, the liability is present and possibly by the shifting to the lower chlorinated materials and the recovery techniques the contamination may already be reduced to an acceptable level. Obviously the entire business would be lost without any or very few substitutes to be offered. Other product areas would be affected. Financial loss could be considered due to raw material contracts, customer contracts and royalty -- secrecy contracts. Competition would take advantage on all fronts. We would be admitting guilt by our actions. Loss of capitol investment in the plant, associated utilities, and associated processes. We would possibly gain a little public image on this action.

STR 021951

C. Respond responsibly, admitting that there is growing evidence of environmental contamination by the higher chlorinated biphenyls and take action as new data is generated to correct the problem.

WATER_PCB-SD0000072969

This approach would enable us to phase out the higher chlorinated materials in many applications where they are no longer necessary or really desired. Wecould maximize the corporate image by publicizing this act. We would reduce a known pollutant. Additionally we could gain precious time needed to develop new products and investigate further the lower chlorinated materials. As new research data is generated our course may be altered considerably. Certain limited actions may reduce or limit the problem.

STR 021952

WATER_PCB-SD0000072970

XI. Recommended Course of Action

Based on the information available today the only recommendation we can honestly make is respond responsibly admitting that there is growing evidence of environmental contamination by the higher chlorinated biphenyls and take action as new data is generated to correct the problem.

XII. Implementation of the Recommended Course of Action

A. Immediate (By 12-1-69)

1. Set up a task force under a project manager or the equivalent responsible for initiating, directing and implementing all action that Monsanto decides to take. This includes sufficient budget necessary to cope with the immediate problems. This task force should include representatives from Medical, Legal, Research and the two involved Marketing Groups and Public Relations and must conduct liaison with MCL and other locations involved in the problem.

2. Decide on timing and content of any public and/or customer notification of PCB problem.

B. Interim (Within 3 months)

Fluids	Plasticizers
1. Confirm Aroclor 1254/Aroclor 1260 are found in the environment.	1. Announce differential between fluids/plasticizer uses.
2. Publicize the difficult anal. tasks.	2. Announce safety of other PCB's chlorinated terphenyl.
3. Protect other PCB/chl. terph.	3. Educate customers on control c effluent for all products.
4. Announce plans to reformulate certain Therminols and Pydraul where control of the product is difficult.	4. Initiate program to develop A/ 1254 & 1260 substitutes

STR 021953

WATER_PCB-SD0000072971

influence on Monsanto products.

Customers will seek other "outs" rather than become involved.

VI. Effect on Customers and Ultimate Consumers

One of the unique features of PCB's is their fire resistance. Here the basic decision whether to risk lives due to fire or risk extinction of, some species of birds. In this case the PCB would probably be accepted as a necessary pollutant and tolerated under controlled conditions.

A. Electrical Industry - Capacitors and Transformers use Aroclor because it is the best inexpensive dielectric fluid available.

B. Food Processing - Bulk "deep frying" units for potato chips, fish, and doughnuts use the fire resistance fluid as an indirect heating medium.

C. Die Caster -- and other hot metal working industries fire resistance fluids to protect the workers.

Affects a wide range of plastics and adhesives because the PCB serves as the plasticizer.

A wide range of paints and coatings are affected. The "Carbonless" carbon paper used so widely would disappear.

VII. Involvement With Other Producers

Although Monsanto is most probably responsible for the U.S. contamination and jointly responsible with MCL for the United Kingdom problem, we cannot accept responsibility for the world. There are five known producers in the free world, several possible producers behind the iron curtain and couple of additional companies making overtures about entering the business. Monsanto representatives have on one occasion discussed this problem with a couple of these producers but they expressed no great concern. In fact, it is highly possible that one of

WATER_PCB-SD0000072972

these manufacturers is dumping his waste into the Rhine River. Certainl any action taken by one producer will most assuredly affect the other. It is entirely possible that a joint plan of action could be developed but will most probably have to be spearheaded by Monsanto. It is also likely that producers of other chlorinated products used with PCB's will be dragged into the investigation.

VIII. Sources of Contamination

Although there may be some soil and air contamination involved, by far the most critical problem at present is water contamination. To our knowledge to date the contamination can be broken down into two general categories, open and indirect pollution.

A. Open Pollution - Our manufacturing facilities sewered a sizeable quantity of PCB's in a years time.

1. Fluids

Fluids are probably the most open source of pollution because of their mobility. They also may be the least serious because they are generally the lower chlorinated materials.

2. Electrical

Electrical customers have in the past sewered their wastes.

3. Heat Transfer

Heat transfer customers have sewered their objectionable and their spilled material.

4. Industrial

These fluids have generally been sprayed into drains, washed down sewers and generally regarded as very harmless.

All of the fluids have had the "[illegible]" constituent dumped on dirt roads a "dedusting agent" which inadvertently found its way back to the stream.

WATER_PCB-SD0000072973

5. Plastics

The plastics are not as mobile as the fluids so therefore they have not found and cannot find their way back to streams in ope pollution.

B. Indirect

Shipping containers and the cleaning thereof for subsequent use a source of contamination.

1. Fluids

a. Electrical - Disposal of "burned out" transformer and capacitors may find its way back to streams. Scrap units (new) are generally disposed of in land fills but could possibly get back to the stream.

b. Heat Transfer - Leaks could contaminate.

c. Industrial - Cross product contamination carried out of an air compressor. Residual material carried on parts.

2. Plasticizers

a. Process Contamination from Washing

(1.) Environment Contamination

Swimming pool paints

Incineration of wax coatings

Traffic paints

(2.) Product Contamination STR 021949

Coating for tank lining

Painting inks and paper coatings

Certain adhesives

IX. Recent Technical Changes Which Have Bearing on the Contamination

A. Fluids

The sources of pollution were pointed out as they have been in the past because we are dealing with that quantity of material in the

WATER_PCB-SD0000072974

environment today which was deposited over the past forty years. We must state that responsible people throughout the industry have taken corrective action to reduce contamination in the last two years. There have also been technical advances which have brought about the use of lower chlorinated biphenyls which may be an advantage because to date th low chlorinated ones have not been identified present in nature.

1. Electrical - The large customers have established collect systems ar the waste is recovered. Incinerators are being investigated and built for the disposal of the materials. There has been a shift away from the higher chlorinated types products and could probably shift almost entirely away from those products.
2. Heat Transfer - System have been tightened up and redesigned to confine the contents Here, too, the trend has been to shift away from the higher chlorinated materials.
3. Industrial - Selling ponds have been built by the large manufacture to catch the material and decant off the PCB for reprocessing. The trend here as the other fluid areas has been towards the lower chlorinated materials.
4. Plants - The plants effluent has been passed through limestone whi provides surface to catch some of the material. But high concentrations can be found in our effluent (that is relative to those findings in nature causing the problem).

B. Plasticizer

Quite opposite to fluids the trend in plasticizer Aroclor has been to higher chlorinated biphenyls. In plasticizers the lower chlorinated biphenyl will not be an acceptable solution however, the lower chlorin terphenyl could offer a possible solution.

STR 021950

WATER_PCB-SD0000072975

5. Emphasize better control over other Aroclor 1254 & 1260 uses.

5. Investigate with manufacturers the feasibility of alternate products.

6. Initiate customer education on need for effluent control of all products.

~~6. Analyze 1242~~

7. Determine composition of all PCB's.

Develop a comprehensive Program

C. Short Term (within the next 12 months)

1. Research - Expand program for more meaningful biodegradation studies and confirming analytical results. Expand toxicity studies. Follow developments concerning publicity and those developments covering political implications of PCB contamination.

Medical

2. Marketing - Discontinue or substitute replacement products for those applications of Aroclors 1254 and 1260 where the Aroclor remains mobile.

Work with customers to clean up plants on other Aroclors. Report the habitual violators or "do nothings" to the product group.

Reclaim or safely dispose of fluids. STR 021954

Consider renaming products that do not contain PCB. Follow and report market developments such as customer disposal systems. Follow and report any political or public feedback which may affect the contamination problems and must be coordinated with Medical, Research and Legal.

3. Production - Clean up plants and stop gross contamination.

4. Legal - Define our present position, recommend reasonable action that will not unduely alarm the market but reduce the exposure in terms of liability. Coordinate recommendations with Marketi

WATER_PCB-SD0000072976

5. Public Relations - Publicize actions where believed advantageous Certainly discussions should be held with other producers within same period to determine their planned course of action, if any.

D. Long Range Tentative Outline (From 1 year to 3 years)

Realizing that the comprehensive program must be outlined the "Long Range Tentative Outline" is meant to serve as a guide: All aspects of this program should review quarterly by Organic Management.

1. Research-Medical

Continue biodegradation studies and analytical support

Isomer distribution

Toxicity and metabolism studies

Water soluble removal

Incineration analytical support

Confirmation analytical

Contract academic research for reference

Develop new and improved formulations

2. Manufacturing

a. Process Research and Development

(1.) Identification of typical Aroclor isomers

(2.) Develop control for effluent composition

(3.) Test substitute formulations, etc.

(4.) Develop new processes

b. Clean Up Plants

c. Modify processes to meet market needs

3. Engineering

a. Develop and set up on plant locations incineration systems

b. Design new processing equipment as necessary

4. Marketing

a. Specify alternates or changes

b. Customer-liaison

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c. Set reclaim or disposal of fluids

d. Work on name association problems

5. Patent

Investigate trademarks registered

Cover with patents any work felt patentable

6. Environmental Control

Develop cheap disposal systems for customers

a. Incineration or pyrolysis

b. Biodegradation unit etc.

c. Consultants in pollution control

7. Legal

Investigate and define our position on Royalty secrecy agreements.

Contracts - Raw Material and Customer

8. Public Relations

Portray to public positive actions at correcting the contamination problem. Release periodical statements covering our position.

XIII. Probability of Success

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XIV. Cost of Program

Neither the program nor the costs have been clearly defined at this tim However, a cost estimate of $220,000 for toxicological work alone has been presented. Tentative figures indicated under the worst conditions the entire program could run as high as $2.0-2.5M. At this stage it is very difficult if not impossible to develop a reasonable cost figure bu one point is clear it will be larger than the normal research budget ca handle. For this reason, assuming the approach is acceptable, we shall be forced to ask for additional appropriations to fund the program.

XV. Future

Follow developments on the problem as they unfold.

Develop an aggressive research program to confirm or deny findings and better understand the problem.

Develop costs for the duplementation of the Recommended course of action.

Develop specific actions with each department involved

Submit the actions with costs for approval

Develop a timetable to solve the overall problem.

Prepare for "precipitious pullout" or drastic legislative action althc we do not feel this is a likely possibility.

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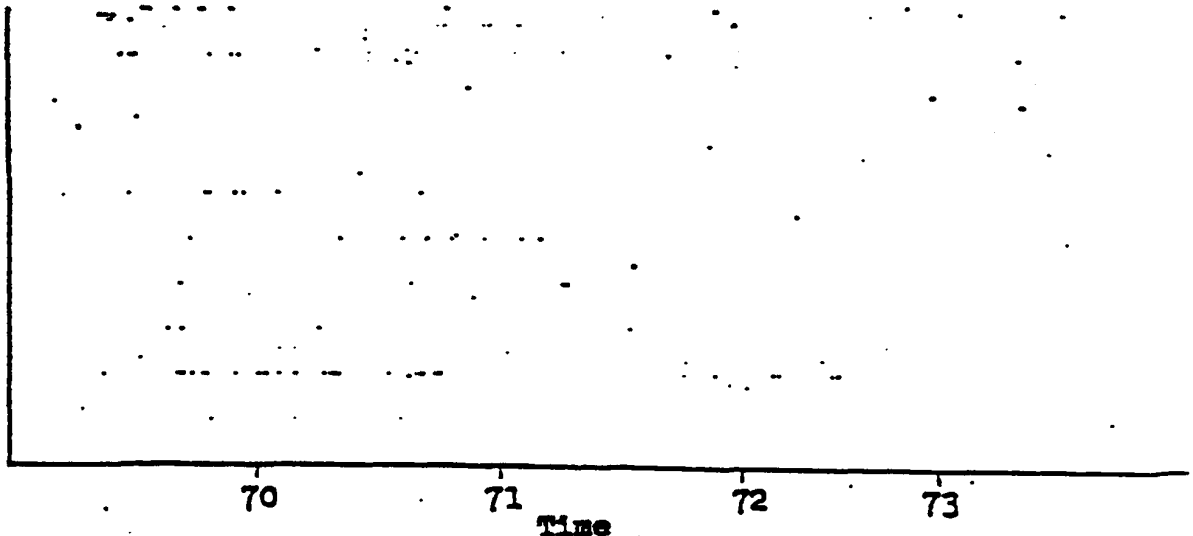
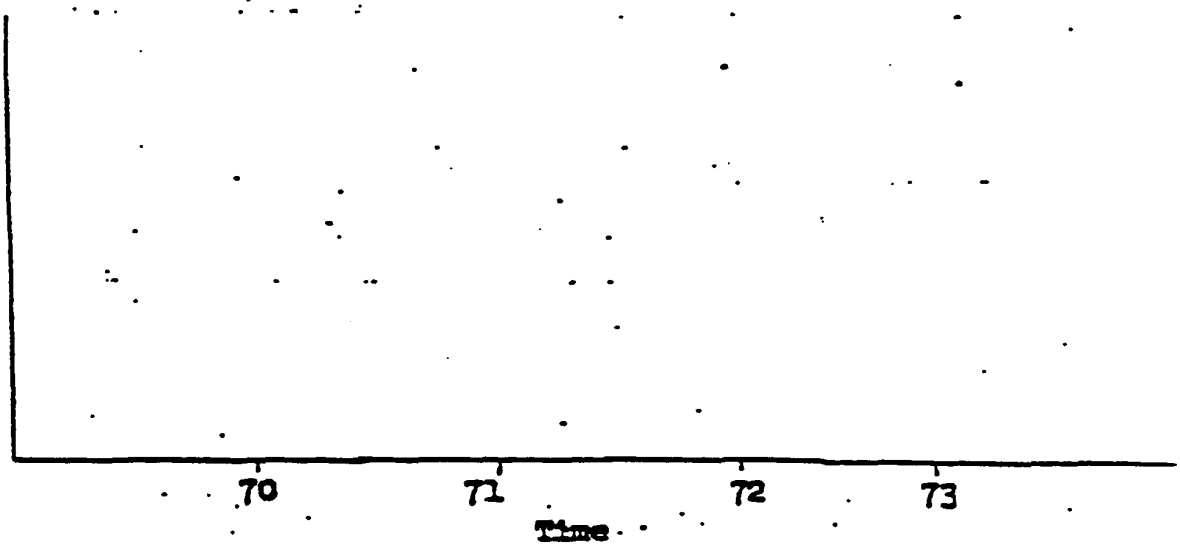
PROFIT AND LIABILITY VS. TIME

ACTION

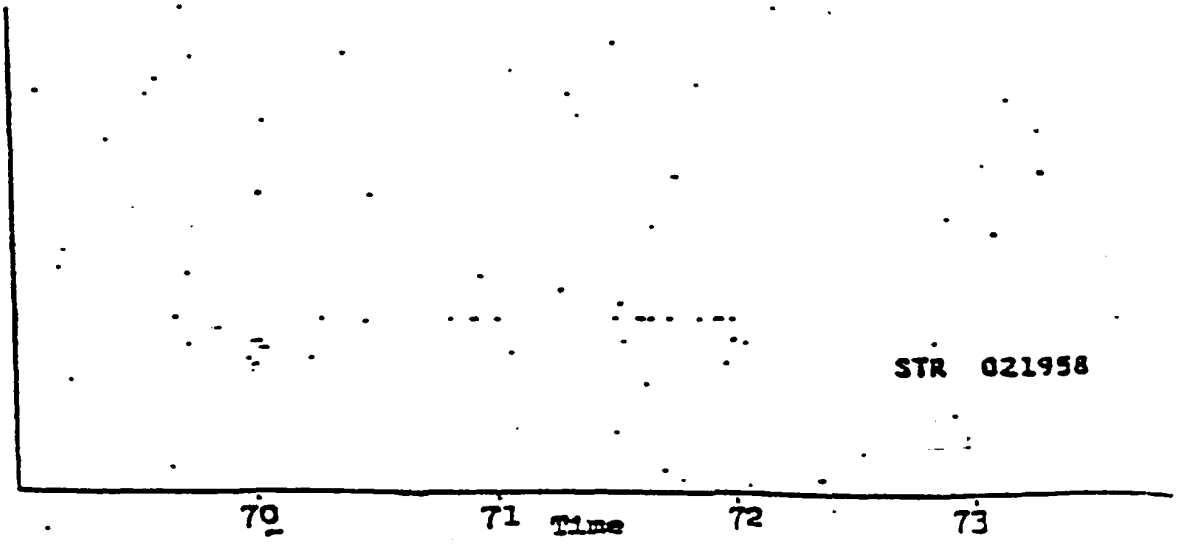
DO NOTHING



DISCONTINUE MANUFACTURE OF PCB



RESPONSIBLE APPROACH



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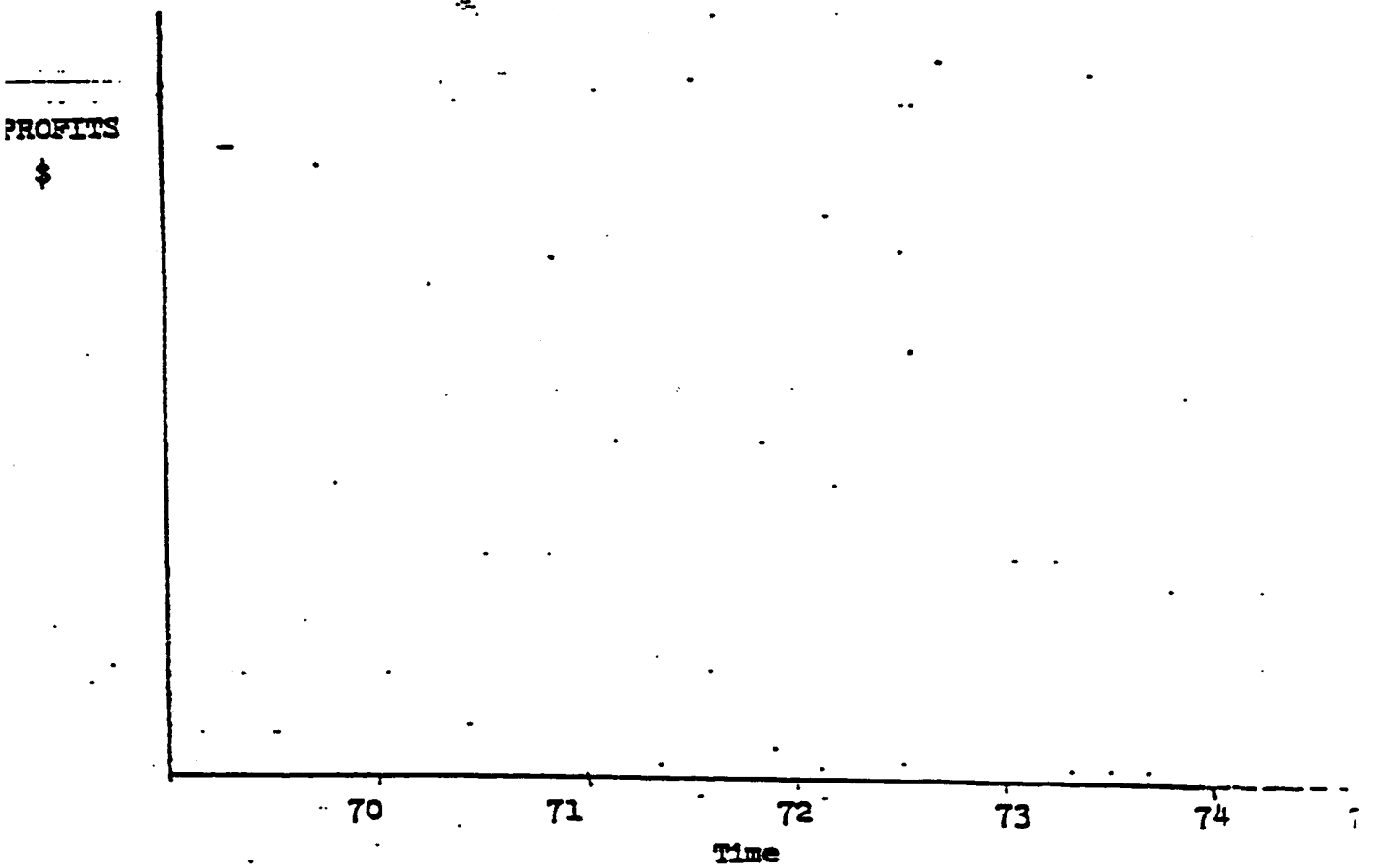
PROBABILITY OF SUCCESS



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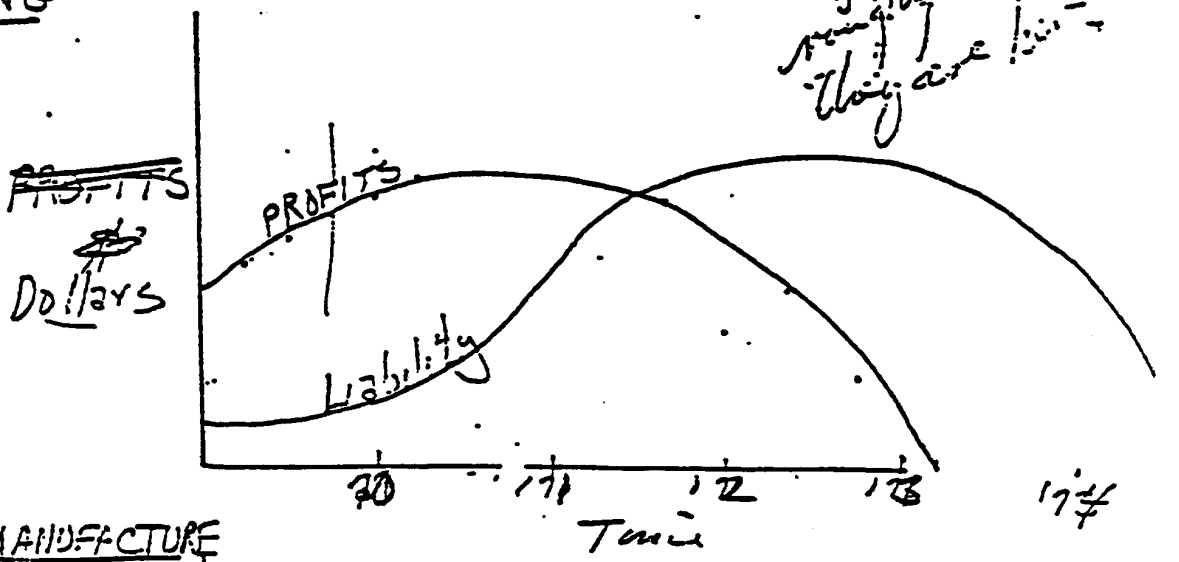
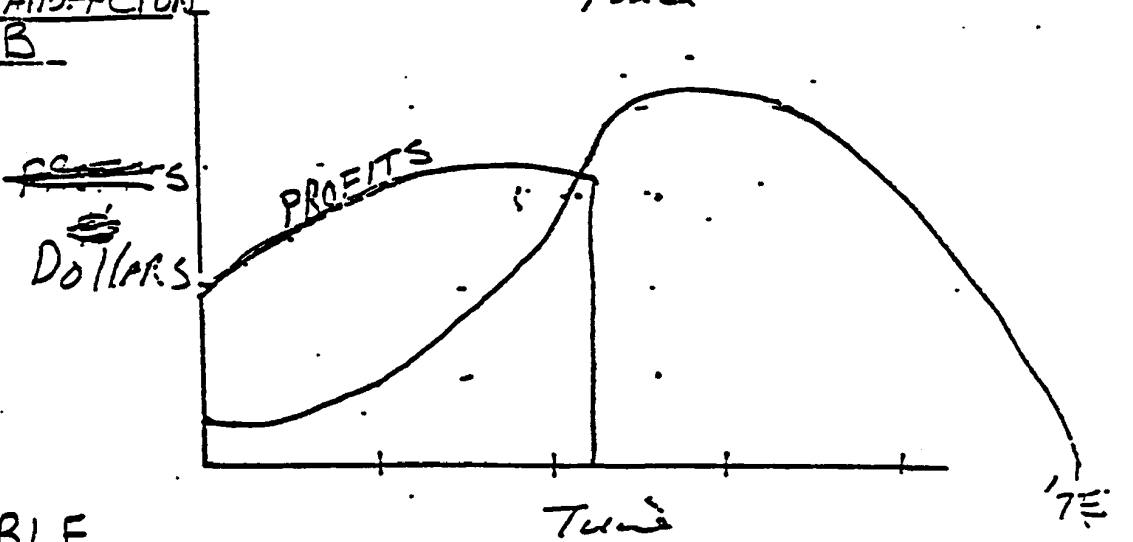
PROFIT AND LIABILITY VS TIME

ACTION

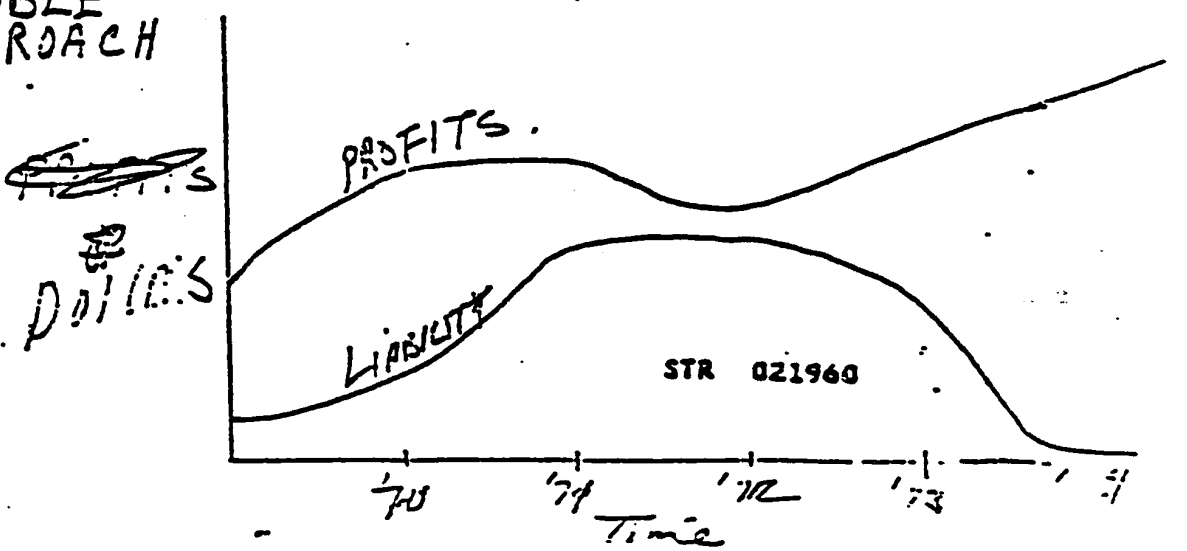
DO NOTHING



DISCONTINUE MANUFACTURE of PCB



RESPONSIBLE APPROACH



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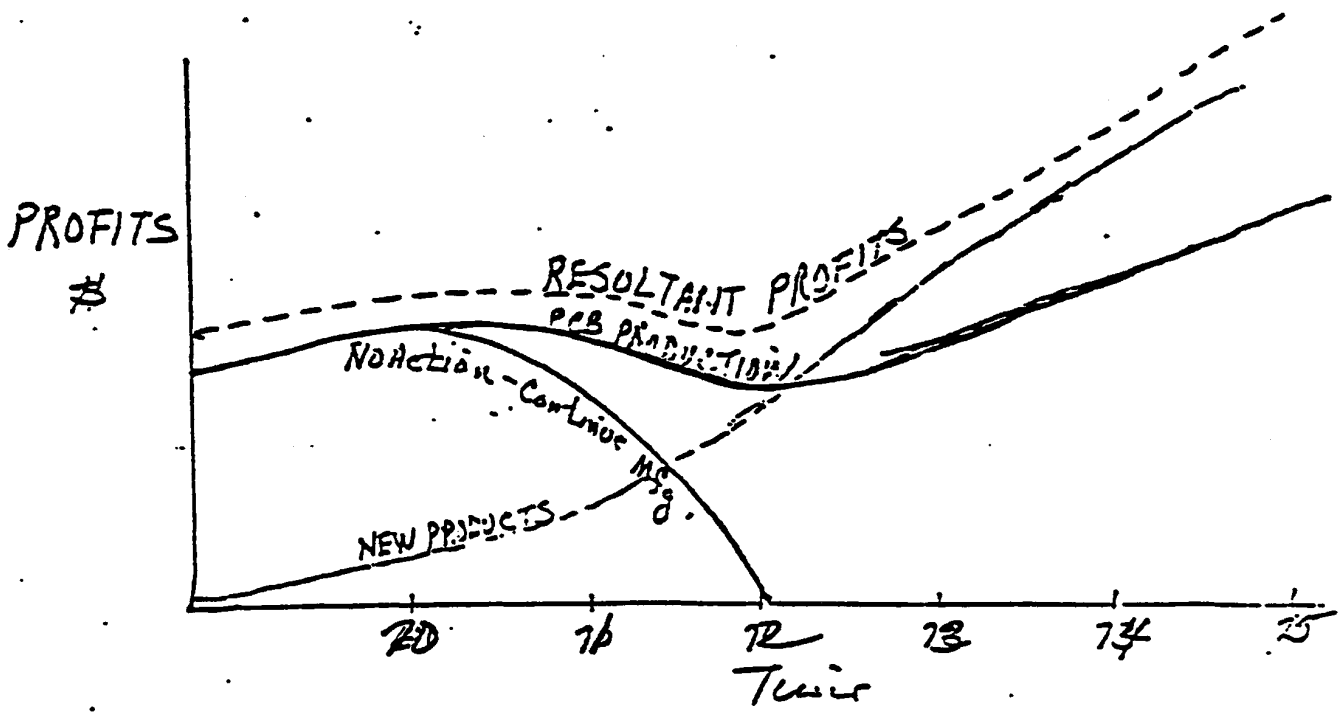
PROBABILITY OF SUCCESS



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Monsanto

FROM (NAME & LOCATION): W. R. Richard - Research Center

DATE: September 9, 1969

SUBJECT: DEFENSE OF AROCLOR - F. FLUIDS

REFERENCE:

TO: E. Wheeler - EWHEE

cc: P. Hodges PHODG
M. Farrar Res. 1
H. Bergen HBERG

General Policy

Make the Govt., States and Universities prove their case, but avoid as much confrontation as possible. Comply and work with public officials to meet or exceed requirements ahead of time. Adverse publicity and competition are the real weapons.

Analytical for Aroclor { In Air - Which Aroclors are present? Where? / In Water - Which compounds / In Animals - interfere? } G Ag

Keep track of how much contamination - which sources.

Prove Bioharmful - Let Govt. prove its case, on case by case l

Monsanto Visit-Govt. Biolabs - in search of toxicologi experiments and evidenc vs. Aroclors to keep up progress.

Monsanto Prove Bioharmless - Limited work at Ind. Bio-test -

"Safe" toxic level for { man / mammals via Rats / Chickens / fish Fish

Seek evidence of Bio da
Question evidence ag us
Question shrimp toxic especially other to chemicals.
If Aroclor bad, oth must be worse.

Probable Outcome

We can prove some things are OK at low concentration. Give Monsanto some defense.

We can't defend vs. everything. Some animals or fish or insects will be harmed.

Aroclor degradation rate will be slow. Tough to defend against. Higher chlorination compounds will be worse ... lower chlorine compounds.

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Therefore we will have to restrict uses and clean-up as much as we can, starting immediately. A

↑ for what sense?

Which one?

PLAINTIFF'S EXHIBIT 424

PLAINTIFF'S EXHIBIT 4575A

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Therefore we will have to work for alternate products in end use applications; for Aroclor production facilities.

Clean Up Aroclors and substitute products where necessary and when required, before threats of publicity and competitive activity overwhelm us.

Water Pollution seems to be first issue

Aroclor product is refractive, will settle out on solids - sewerage sludge - river bottoms, and apparently has a long life.

Florida or Gulf Coast - Aroclor 1254 - Aroclor 1260 pres issue.

40-200 ppb - causing problem at Pensacola (Monsanto) in plant effluent-causing " with shrimp.
- can't risk shut-down of plant.

Federal and State can extrapolate to other plants in Gulf area.

San Francisco - Aroclor 1254 and 1260

Reported Aroclor to be present in San Francisco Bay.

Reported to be thin egg shells in birds -

Lot of screaming -

Great Lakes Warf studies on DDT

Aroclor 1254 will be found!

Aroclor 1242 will be found?

Air Pollution - Possible spread - but less of an issue right now.
Analytical work more difficult.

Direct Contact with Product

Doesn't seem to be an issue - except for food heat transfer

We don't believe Aroclor is being used as carrier for insecticide - sprayed around -

We are not positive but most uses are "closed" systems or products used in solid plastics, or adhesives, or sealants.

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F. Fluids	Possible Pollution by Customers Plant Operation	Possible P by Custome
Product		
Hydraulic Fluids	Yes, leakage external	Possible - Johnson Mot Castings.
Air Compressor Fluids	Yes, leakage external	Leakage int
Heat Transfer	Yes, leakage external	Leakage int
Capacitor Fluids	Yes, leakage from plant - Scrap materials.	In product closed for
Transformer Fluids	No, Should be clean. Yes, Reworked transformers	In product closed for

* Capacitors can go to land fill dumps. Probably not burned, in Al containers.

** Need to take care of Aroclor in discarded transformers. Product could be drained and reworked.

Probable Conclusions

Hydraulic Leakage - Product could be caught at machines but will take a lot of clean-up work with customers. - Will have to have replacement product - with less-sensitive components. Work from this base on clean-up to prevent more pollution problems.

Air Compressor Fluids -

Hydraulic Fluids - Must expect "shrimp" experiments, West Florida State, to be "aired" sometime soon; next few months.

This will lead to bad publicity and competitive action vs. all Pydrauls.

We will have to try to confine to Aroclor 1254 and Aroclor 1260.

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We will have to take action before that time.

Gulf Coast -

Action W. Richard	Be able to replace Aroclor 1254 and Aroclor 1260 in Pydraul AC and 625 in 2 month's time before Nov. 15, 1969.
Fallon/ Richard	Have trial product in hands of Gulf Coast accounts and distributor before Dec. 15.
Fallon	Suggest possible buy of "all phosphate" ester from Food Machinery. Use this as one trial fluid MCS___ for insurance.
Richard/	Suggest possible substitution of Aroclor 5442 for Aroclor 1254 in hydraulic and compressor blends. E. Wheeler judges lower order of toxicity and solubility for 5442 series. Have to test product in pump test for deposits.
Fallon/ Richard	Suggest field trials of our own all-phosphate ester.
Fallon/ Kuhn/ Kountz	Work with large customers to clean-up streams. Bring in Findett as mfg. partner in the recycle business. Get money out of recycle operations.

Inland-Waterways-

Wheeler/ Richard	Be close enough to Great Lakes studies to judge situation. Are there animals which are being affected by the concentrations found?
Richard	Be prepared to replace Aroclor 1254 and Aroclor 1260 in 4 months in hydraulic fluids and in air compressor fluids.
Richard	Be prepared to replace all Aroclor 1242 or 1248 in 6 months in hydraulic fluids. This means replacement of Pydraul 312 series, and control of sale of Aroclor 1248 to other hydraulic accounts such as Cities Service and Mobil.

Heat Transfer

4 0081

Fallon/ Roush/ Kountz	Systems will have some leakage depending strongly on engineering and maintenance. Need to work with customers on clean-up.
Fallon/ Roush	Need to replace FR especially in food or sensitive product areas where the product is getting into water. See dish washer compounds. See letter E. Wheeler to J. Fallon.

We have possible replacement products in Thermin[illegible] 55.

MDN 0212 Thermin[illegible] 65.

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Action

Kuhn

Try to assure adequate production of Therminol 66 in face of decreased Aroclor production. H_2 and terphenyl supply may become short.

Switch customers to Therminol 55 or Therminol 66 ahead of pollution problems in customers plant.

Work with customers on plant and dumping practices.

Kuhn/ Fallon

Findett already set up to rework. Need to make them a manufacturing arm. We get sale of recycle-rework fluid.

Capacitor Fluids

Capacitor plants have re-purification and recycle systems but up to 5% of product can be lost by poor plant producers and off-quality material.

Mkt. Benignus/ Bryant

Eng.-Kountz/ Mfg-Hodges

5% of production could be 1M lbs/year. This is a big loss for the type of pollution we are trying now to guard against.

Capacitor products

Enclosed in Al or stainless steel for 5 to 25 year period.

Will ultimately have to dispose of capacitor products.

Recommend we try to save this product for a time.

Action

Eng.,TSD-Plant Pollution Control

Hodges/ Kountz

Monsanto must start to work with capacitor people to clean up plant practices. We have set-up to accept material for rework into hydraulic fluid but this relocation is not a satisfactory solution. Material must be reworked to electrical grade or destroyed, whichever is more economical. Must start now to get control of off-grade material.

Recommend replacement future Aroclor busine with other products. Have 2 years.

Action

Monsanto must help plant clean-up of customer plants decantation, coalescing, adsorption, disposal of adsorbent or recycle of adsorbents.
Monsanto badly needs "know-how" for clean-up.

Monsanto should seek Govt. contract money for clean-up research, (See MRC R. Binning, D. Nelson)

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Transformers	Transformer Plant can operate in a clean, efficient manner with recycle of off-grade Aroclor.	Product transform can remain closed no exposure for 2
Action Benignus/ Bryant	Should advise disposal of filter element materials so as to minimize chance of water pollution. Incinerate or dispose.	
	Reworked transformers pose a threat if the Aroclor is dumped into a water stream.	Should try to ret business by clean by education of c tomers.
Action Benignus/ Bryant	Should try to minimize chance of dumping "old" fluid by re-working and by educating co. shops and collecting product for rework or disposal.	
	Dalton is set up in England to rework electrical grade fluid.	
Kuhn/Kountz Findett?	Need rework facility here + disposal scheme.	

Monsanto Plants

The Dept. of Interior and/or State authorities could monitor plant outfall and find ppm of chlorinated biphenyls at Krummrich or Anniston anytime they choose to do so. This would shut us down depending on what plants or animals they choose to find harmed.

Action - Take steps to see that every precaution is taken to prevent Aroclor entering water streams. Try to reduce to ppb level.

P.Hodges-TSD Engrg.- Seek a Govt. contract on adsorption and incineration cycles - MRC.

Kountz Take samples of streams and river water and mud evidence for before and after clean-up. Samples can be stored for further analysis if we can't keep up current with analytical determinations.

Apply Monsanto clean-up methods to customer plant clean up equipment and procedures.

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Action -

Engrg. & Mfg.

Kountz and Kuhn

Evaluate liquid incinerators vs. solids handling incinerators for disposing of Aroclor and pentachlorophenol wastes. I estimate Aroclor disposal at 1-4M lbs/year, exclusive of cleaning up river bottoms or outfall bottoms.

Hydraulics	20% of 4M lbs	800,000 lbs
Heat Transfer	10% of 2M lbs	200,000 lbs
Capacitors	5% of 20M	1,000,000 lbs
Transformers	5% of 15M	750,000 lbs
		2,750,000 lbs

Central Eng. & Mfg TSD

Kountz & Kuhn

Set up an incinerator to handle Aroclor disposal - preferably one which will handle solids such as muds - slurries as well as liquids. Have in operation within 12 months. Ideally have incinerators available different sections for disposal.

Possible help from MRC

Chronic Toxicity Studies - Ind. Bio-Test

Wheeler
Keller
Ind.Bio-Test

Continue studies to establish FDA type limits of toxicity on Aroclor 1242, Aroclor 1254 and Aroclor 1260.

Rework with R. Keller-S. Tucker the number of samples which are to be analyzed for Aroclor in tissue. Try to see if Aroclors are changed metabolically. Does concentration level off, decline if feeding is stopped?

Institute studies against the most limiting biological parameters. If shrimp are the most limiting species for Aroclor levels of toxicity, then we will have to have biological studies on these species to confirm or deny adverse findings.

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Biodegradation Studies

Set up rate of biodegradation studies with Inorganic Div. on Aroclor 1242 vs. Aroclor 1254
Aroclor 5442 vs. Aroclor 5460

Swisher
Chlorinated diphenyl ether
Chlorinated paraffin vs. chlorinated naphthalene
Chlorobromo Aroclors 1242 and 1248

Baxter
Lidgett
MCL
Contact Baxter and Lidgett at MCL regularly for results on Aroclor degradation. They are reported to be moving on laboratory experiments.

Establish contact with chlorophenol degradation studies of Cellu-Chem Group.

WRR

W. R. Richard

WRR:ms

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CONFIDENTIAL

Elmer P. Wheeler, St. Louis

M. W. Farrar
~~J. W. Lobe~~
W. R. Richard

P. B. Hodges

In your absence I took the liberty of having your hand-written notes typed for distribution as attached.

Elmer P. Wheeler

EPW:ju

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PLAINTIFF'S EXHIBIT 431

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EX 14 MON 0178

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CONFIDENTIAL

MINUTES OF AROCLOR "AD HOC" COMMITTEE

First Meeting

Date: September 5, 1969

Present: M. W. Farrar
P. B. Hodges, Secretary
E. V. John
W. R. Richard
E. P. Wheeler, Chairman

Objectives: (Agreed to by the Committee)

Submit recommendations for action which will:

1. Permit continued sales and profits of Aroclors and Terphenyls.
2. Permit continued development of uses and sales.
3. Protect image of Organic Division and of the Corporation.

Background Discussion of Problem:

1. Agreed that we should concentrate on Aroclor 1254 and 1260. Aroclor 1242 has not yet been incriminated for these possible reasons:
   a. Nature of uses of 1242 minimizes environmental contamination.
   b. It may degrade biologically.
   c. Unless analytical techniques are performed carefully, 1242 can be destroyed by oxidation during the analyses.
2. PCB has been found in:
   a. Fish, oysters, shrimp, birds.
   b. Along coastlines of industrialized areas such as Great Britain, Sweden, Rhine River, low countries, Lake Michigan, Pensacola Bay, in Western wild life (eagles). It may be a global contaminant.
3. PCB has been tied to DDT in effects on disappearance of wild birds which have fish diets. Ratio of PCB to DDT has been about 40-50:1 generally. Dr. Reisboro reported almost 1:1 ratio. PCB may be contributing to or exaggerating the effects of other chlorinated aromatics.

MON 0178

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4. Sample acceptance from the numerous researchers was discussed. This has been done on a limited basis. Our corroboration of testing of their samples adds to our knowledge and demonstrates a willingness by Monsanto to help define the problem, but it is expensive and also tightens any possible legal cases against us--it rules out possibilities that Aroclors are not involved.

5. Toxicity levels:

Aroclors have been shown to be safe for man in reasonable exposure concentrations. We are testing 100 ppm in diet of rats and dogs on a rule-of-thumb basis that 1/100 of toxicity level is safe and 1 ppm is probably the upper limit in total diet.

"Allowable levels" are probably lower than DDT. The worst example to date is the test at Pensacola where 5 ppb was found to be toxic to shrimp in 18 days exposure.

One problem we are facing is to keep the "safe level" (?) for shrimp from being applied to e.g. Lake Michigan where more tolerant fish species probably exist. We need to show the safe level in shrimp, clams, oysters and several species of fish.

Many toxicity studies on PCB are underway and it was agreed to be desirable to keep contact with all laboratories which have requested Aroclor samples. One-half to two-thirds of the sample requests have come from state labs (who would let us know what they are doing) and about 1/3 have come from universities (who may give us the "brush-off"). Question of who should call on the laboratories was not resolved.

6. Escambia River Problem:

For a clearer understanding of the general problem, the situation at Pensacola was reviewed. From a relatively negligible discharge of 1-3 gal/day into a large river, 1/4 mile downstream levels of 42 ppb in water and 476 ppm in mud were found. Although use of Aroclor was halted immediately, we can expect the water contamination to continue for a lengthy period by leaching from the contaminated mud. No downstream samples have yet been taken to measure the decrease in contamination (as of 9/5/69).

MON 0180

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7. Problem in Producing Plants:

P. Hodges reviewed what was being done to stop gross losses at Anniston and at WGK. Basically, the work to date consists of stopping or trapping any sewering of free Aroclor with return to process or land fill disposal of the trapped Aroclor. This will reduce levels in plant effluents to below solubility ranges, particularly as we move to install traps (or sumps) back into the waste source points where flows are small and as yet undiluted by Aroclor-free waste streams. The question of exactly how far to reduce (how much money to spend) is not yet clear and expenditures to date have been comparatively small. It was agreed that, until the problems of gross environmental contamination by our customers have been alleviated, there is little object in going to expensive extremes in limiting discharges from the plants.

One problem that has been interfering with logical development of our plant Aroclor waste reduction programs has been delays in obtaining analytical results from in-plant and ex-plant sampling. It was agreed that additional help was necessary in Dr. Tucker's lab but no specific actions were proposed. In addition to in-plant work, the plants are sampling the receiving streams.

Air pollution reduction has not been considered by the plants to date except as incidental prevention of product contamination during tank car and drum loading operations. Long range (1-2 year) improvements at Anniston are planned to reduce product contamination (and air emissions) in car loading operations. It was agreed that a comprehensive air sampling and testing program would be very expensive and is probably not justified at this stage of the problem.

8. Environmental Contamination by Customers:

Our in-plant problems are very small vs. problems of dealing with environmental contamination by customers. In one application alone (highway paints), one million lbs/year are used. Through abrasion and leaching we can assume that nearly all of this Aroclor winds up in the environment.

Because the rate of natural (bio-degradation) is very low, other degradation must destroy PCB equal to the rate of environmental exposure in order to avoid build-up of contamination.

A general discussion was held on philosophy of controlling sales or working with customers to prevent pollution by PC

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Action Planned:

Each member of the group will submit to the other members for consideration possible ideas and programs to help accomplish the overall objectives set by the Committee. Following review of the suggestions, the Committee will meet again at an early date to be arranged by the Chairman.

P. B. Hodges
Secretary

:ju

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Monsanto ASKAREL

Inspection and Maintenance Guide

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PLAINTIFF'S EXHIBIT
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WATER_PCB-SD0000072997



ASKAREL

Inspection and Maintenance Guide

ADM 001465

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SECTION A
TRANSFORMER ASKAREL

I. INTRODUCTION:

This manual describes the operating characteristics of transformer *askarel liquid* insulation and how it differs from mineral oil.

The information given is based on facts gathered by Monsanto over 30 years as producer of askarel, plus knowledge gained from the experience of transformer manufacturers and users. This guide is provided to outline the very simple maintenance required for askarel fluid in "modern" transformers and to offer suggestions for the sealing and maintaining of askarel in old units. By following this guide, users will obtain maximum service from askarel insulation with a reasonable minimum of maintenance. If questions arise relating to the designing and building of transformers — these should be referred to regular transformer suppliers.

Monsanto gratefully acknowledges the assistance, guidance, and the contributions of certain data by the following:

Frank M. Clark.....General Electric
Edward L. Raab.....General Electric
James G. Ford.....Westinghouse Electric
George Shombert, Jr.....Allis Chalmers

II. HISTORY OF TRADE NAME TYPES

"Askarel" is the generic name for non-combustible (fire-resistant) liquid insulation. In this respect, the insulation is completely different from ordinary transformer mineral oils. Transformer askarel is marketed by Monsanto. Whatever the trade-marked brand, the askarel contains Monsanto's Aroclor (chlorobiphenyl) . . . one of the best liquid insulations developed by science. This inert compound is chemically stable, fire-resistant, heat stable, non-corrosive, and has high dielectric strength under the operating conditions encountered in transformers.

ADM C01468

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Askarel liquid insulation is made by thinning Aroclor 1260 with trichlorobenzene or tri-, tetrachlorobenzene mix. The first transformer askarel was made in 1932, in accordance with General Electric Company's patents, and was trademarked Pyranol 1488. Westinghouse, too, offered this askarel insulation in 1936 under their trademark Inerteen.

In the mid-1940's, as shown in the following table, tin tetraphenyl was added to General Electric's Pyranol to scavenge hydrogen chloride. Shortly thereafter, Westinghouse added phenoxy propene oxide to Inerteen for the same purpose. In 1963, General Electric replaced tin tetraphenyl with a diepoxide scavenger. This new formula, which replaces previous Pyranols, is called Transformer Pyranol A13B3B. *Thus, today the two commercial types of formulations are General Electric's Transformer Pyranol A13B3B type and Westinghouse Inerteen PPO (7336-9) type.*

The composition changes made in transformer askarel formulations are shown in Table I.

Table I

THE COMPOSITION OF TRANSFORMER ASKARELS

	Pyranol					Inerteen PPO
	1488	1467	1470	A13B3B	Inerteen	(7336-9)
Year Introduced.....	1932	1944	1952	1963	1936	1945
Ingredients:						
Aroclor 1260.....	60	60	45	45	60	60
Trichlorobenzene.....	40	40	40	40	40	40
Tetrachlorobenzene.....			15	15		
Tin tetraphenyl.....		0.125	0.125			
Phenoxy propene oxide.....						0.20
Diepoxide.....				0.125		

OTHER BRAND NAMES

Various electrical equipment manufacturers use other trade-marked names for askarel liquid insulation, such as Chlorextol (Allis-Chalmers); Noflamol (Wagner Electric); Saf-T-Kuhl (Kuhlman Electric). These askarel insulating liquids are one or the other of the two standard formulations. Still other manufacturers, who designate their insulation only by its generic name, askarel, assign it a number or code. By this number, Monsanto knows whether to furnish Pyranol A13B3B or Inerteen PPO (7336-9) type formulation to the user.

III. OFFICIAL TRANSFORMER ASKAREL SHIPPING SPECIFICATIONS

The official shipping specifications for the two modern transformer askarel formulations are shown in Table II.

ADM 001469

WATER_PCB-SD0000073002

Table II

OFFICIAL TRANSFORMER askarel SHIPPING SPECIFICATIONS

Typical Properties	General Electric Co. Transformer Pyranol A13B3B	Westinghouse Transformer Inerteen PPO (7336-9)
Color, APHA	150 max.	150 max.
Condition	Clear	Clear
Water content, ppm (ASTM D1533-60)	30 max.	30 max.
Acidity, mg. KOH/g. (ASTM D974-55)	0.014 max.	0.014 max.
Dielectric Strength, 25°C., 0.1 inch gap (ASTM D877-49)	35 KV, min.	35 KV, min.
Dielectric Constant, 100°C., 1 KC (ASTM D924-49)	3.8 to 4.3	3.7 to 4.0
Volume Resistivity, 100°C., 500 volts DC 0.1 inch gap, 10^9 ohm-cm.	100	100
Inorganic chlorides, ppm. (ASTM D1821 and G.E. Method E4C41B)	0.10 max.	0.10 max.
Refractive index, 25°C. (ASTM D901-56)	1.6075 to 1.6085	1.6137 to 1.6147
Viscosity at 37.8°C. (ASTM D88-56) Saybolt Universal Seconds	41 to 45	54 ± 2
Pour point °C. (ASTM D-97-57)	—44 or lower	—32 or lower
Specific gravity 15.5/15.5°C. (ASTM D287)	1.560 to 1.571	1.560 to 1.568
Burn point (ASTM D92)	None to boiling	None to boiling
Distillation range (ASTM D20-56) corrected for stem and barometric pressure	1st drop 210°C. min. 35% 240 to 256 55% 290 to 330 65% 385 to 400 95% 395 to 415	1st drop 200°C. min. 40% below 270°C. 90% 395 to 415°C.
Fixed chlorine	60.5 ± 5%	59.1% min.
Corrosion test	After heating with aluminum for 6 hrs. at 200 to 220°C., the aluminum must not be corroded on either visual or weight inspection and the askarel should meet the following specifications:	
Color, APHA	200 max.	200 max.
Acidity, mg. KOH/g.	0.014 max.	0.014 max.
Inorganic chlorides ppm.	2.0 (tent.)	2.0 max.
Condition	Clear	Clear
Scavenger content	0.115 to 0.135% Diepoxide	0.18 to 0.22% phenoxy propene oxide
Arc formed gases	Less than 1.0% of total combustible gases including carbon monoxide, hydrogen and volatile hydrocarbons.	
Coefficient of Thermal Expansion (ASTM D1903), CC./CC./°C.	0.0007	0.0007

The above two formulas are used in modern transformers. There are a number of units in service dating back to 1933 with askarels of somewhat different compositions. These will be compatible with the above modern formulations.

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IV. INTERCHANGEABILITY AND STABILITY

A. Interchangeability:

The two general types of askarel insulation shown in Table II can be either mixed or interchanged and there will be no difference in the operation of the transformer. However, askarel insulation *must never be mixed* with mineral oil.

Over 2% mineral oil in askarel begins to lower its fire resistance. Further, materials of construction in the transformer that are compatible with askarel may not be compatible with oil and vice-versa. For example: a significant amount of askarel in a transformer built for mineral oil will attack gaskets, adhesives, core bindings, impregnating varnishes, etc.

B. Stability:

Askarel liquid insulation is highly pure, fire-proof liquid made under close chemical control. It does not vary in composition like the commercial range of mineral oils.

Askarel does not deteriorate when exposed to air, heat, hot metal; it does not break down over long use to form conducting or corrosive chemicals; it does not oxidize or sludge. Askarel will remain perfectly stable year after year unless broken down by exposure to severe arcing.

The only real "enemy" of askarel is *contamination by water*. Keeping askarel water-free will insure long-time service.

Askarel is heavier than water. If water gets into askarel insulation, only a tiny amount (125 ppm) dissolves — the rest floats on top.

V. DIRECTIONS FOR HANDLING

A. Keep Dry:

In handling, storing, sampling, inspecting askarel — and in operating askarel transformers — take every precaution to guard the askarel insulation from exposure to high humidity and moisture contamination. Keep 5, 30, or 55 gallon drums of askarel dry; lay stored drums on their sides with the bung at the highest point from floor to keep water off the drum head (which can be sucked into the askarel by the drum "breathing"). This precaution is not necessary when drums are stored indoors, which is the preferred way of storing.

B. Use Ordinary Personal Precautions:

Transformer askarel has been made, handled, and used for over 30 years without causing toxic or other ill effects. It can be handled with only minor precautions. If accidentally spilled on hands, no serious skin irritation will occur. However, liquid askarel has a solvent action (similar to paint thinner) on the fats and oils of the skin and prolonged contact may lead to drying and chapping of the skin.

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In case of contact, wash off the skin with soap and water; remove and dry clean saturated clothing. Clean up spills with rags, sawdust or absorbent clay. Eye contact may result in painful irritation but no permanent damage to tissues. If askarel gets in the eyes, flush with large amounts of water. As with all eye first-aid, refer to a physician. To relieve irritation, physicians have used a 1% Pontocaine as well as opthalmic cortisone acetate solution, or castor oil.

Infrequent exposure to askarel vapors will not cause ill effects. However, prolonged exposure to high vapor concentrations should be avoided. If hot askarel must be handled in a closed or confined area, provide the area with ordinary exhaust ventilation — or — wear an organic cartridge respirator approved by the U. S. Bureau of Mines.

VI. EXPECTED SERVICE LIFE

Properly designed and installed askarel transformers will give trouble-free service for a minimum of 30 years. Since their introduction in 1932, the manufacturers report finding the over-all failure rate to be less than 0.5% for all units under test and service conditions. The Edison Electric Institute's report (1956-1958) on their member utilities publishes the failure rate for askarel transformers as 0.13 per hundred banks per year. Even the rare reports of failure are invariably found to be due to improper sealing that allows moisture to enter.

VII. DIELECTRIC STRENGTH — MOISTURE RELATIONSHIP

The dielectric strength of askarel is highly sensitive to excess moisture; not sensitive to ordinary dissolved contaminants. While the dielectric strength can also be lowered by severe arcing, askarel turns noticeably black or has particles of sooty carbon floating in it if arcing has occurred. Then the transformer should be repaired and the askarel replaced.

New askarel has a minimum dielectric strength of 35 KV at 25°; a maximum moisture content of 30 ppm. If the dielectric strength is checked periodically and decreases significantly — this indicates moisture pick-up, arcing, or both. When the dielectric strength has dropped to 26 KV or less, an analysis for water is necessary. If water is found in excess of 100 ppm at 25° C., its source should be located and corrections made.

When the moisture content approaches 125 ppm (saturation level), the dielectric strength of askarel drops below the value required for efficient insulating. The moisture content should not be allowed to rise over 70 ppm; it should be held as near as possible to 30 ppm. Maintaining a low moisture level will assure high dielectric strength and top operating efficiency.

Table III shows the relationship of dielectric strength vs. moisture and Table IV indicates the approximate water solubility limits in askarel and mineral oil.

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Table III

RELATION OF "BREAKDOWN STRENGTH" TO AMOUNT OF DISSOLVED WATER IN ASKAREL AND MINERAL OIL

Water Content (PPM)	Breakdown Voltage (ASTM)	
	Askarel	Mineral Oil
0	70 KV	50 KV
20	55	39
40	47	30
60	40	26
80	38	22
110	10	5

Table IV

APPROXIMATE SOLUBILITY OF WATER IN TRANSFORMER ASKAREL AND MINERAL OIL

Temperature		Amount of Water (PPM) Dissolved	
°C.	°F.	Askarel	Mineral Oil
—30	—22	8	8
—20	— 4	16	10
—10	14	28	13
0	32	41	20
10	50	65	33
20	68	94	58
30	86	128	85
40	104	170	130

TURBIDITY

. . . may be the visual sign of undissolved water, or may indicate contamination from core materials, dirt, or deteriorating construction materials. Cloudiness may also result from cold precipitation of tin tetraphenyl "scavenger" that was used in the earlier Pyranols. This scavenger begins to come out of solution around 15°F. above zero. To redissolve it requires heating to 150 - 200°F. and agitation.

High dielectric strength will quickly indicate that any turbidity present is not moisture; that the insulating efficiency of the askarel is still excellent. However, if the dielectric strength is below 26 KV, moisture should be determined, using the Karl Fischer method (ASTM D1533-60).

The dielectric strength test for askarel serves primarily as an indicator for moisture. It is by far the most important maintenance test for transformer askarel.

VIII. TYPICAL VALUES FOUND IN ASKAREL FLUID UNDER VARIOUS USE CONDITIONS

Table V gives the entire spectrum of properties that are typical for freshly-made transformer askarel as it goes through the various normal and abnormal conditions of use.

The data in Table V are in terms of *only* the askarel *fluid* and do not refer to insulation resistance or power factor measurements on the over-all transformer insulation.

Several utilities studying the power factor values of the over-all transformer insulation system indicate that the unit power factor of a new askarel transformer should range from 1% *to not over* 5%. This would generally correspond with the askarel *fluid* properties as given under heading "B".

ADM 001473

WATER_PCB-SD0000073006

Table V

TYPICAL VALUES FOUND IN ASKAREL FLUID UNDER VARIOUS CONDITIONS OF USE

	A	B	C	D	E	F
	New askarel	Askarel in properly* built new or rebuilt units prior to use.	After normal operation; a survey of 50 units, most 2-5 yrs. old; some 10.	Non-arced but slightly contaminated askarel in improperly* built units, new or slightly used.	Same askarel as in Column D -- after relining.	Heavily arced askarel due to neglect and internal electrical malfunction.
Inspection Check Points						
Color	Light straw	Light straw	Light straw	Can have foreign shades, blue, green, red cast.	Foreign shades remain showing extraction of oil soluble color.	Black
Clarity	Clear, free from particles	Clear, practically free from particles	Clear, trace of particles	Clear, slight amount of particles	Clear, free from particles	Contains carbon particles
Moisture 25°C.	30 ppm	30 ppm	10-70 ppm all dissolved water	20-100 ppm all dissolved water	30 ppm	Near 125ppm saturation level — plus possible undissolved water
Dielectric Strength 25°C., 0.1" gap	35 KV minimum	35-48 KV	35-45 KV	30-42 KV	40-45 KV	5-15 KV
Volume Resistivity 100°C., 500 Volts, DC., 0.1" gap	100 x 10^9 ohm-cm. minimum usually 500-1,500	40 x 10^9 ohm-cm. minimum usually at least 100 x 10^9	15-400 x 10^9 ohm-cm.	about 5 x 10^9 ohm-cm.	at least 1,500 x 10^9 ohm-cm.	about 3 x 10^9 ohm-cm.
Power Factor:						
100°C. 60 cycles	2-5%	10-25%	10 to near 80%	30 to 100%	2-5%	100%
25°C. 60 cycles	0.05-0.1%	0.5-2%	0.5 to near 10%	about 7 to over 15%	0.1-0.2%	at least 25%

**A properly built transformer is defined as one in which the materials of construction are chemically and electrically compatible with askarel.*

ACM 001474

WATER_PCB-SD0000073007

Starting ideally with situation "*B*", *it is normal to expect the power factor of the fluid in a satisfactorily operating askarel transformer to increase as shown under heading* "*C*". The "over-all" power factor of the *transformer* in normal service is expected to rise, but preferably not much beyond 5% $\sim_C$. In this normal situation, the moisture level of the askarel fluid and its dielectric strength will be satisfactory, as shown in *heading* "*C*".

Occasionally the power factor of a non-arced, satisfactorily-operating askarel transformer is found to be relatively high, i.e., 15% $\sim_C$. *In this case, the power factor of the askarel fluid will also be high*, perhaps as high as 50% $\sim_C$ at 20°C. and 60 cycles.

It is not good practice merely to note that high power factor of the askarel fluid is to be expected. The important step is to check dielectric strength and note whether there has been a downward trend. A downward trend in dielectric strength very likely indicates moisture entrance and should be confirmed by a Karl Fischer test for water.

The importance of any abnormalities in dielectric strength and moisture content of the askarel fluid cannot be overemphasized! Where abnormal values for the dielectric strength or moisture content occur, the power factor of the transformer can be expected to be abnormally high; the expected high power factor of the askarel fluid will induce this.

The indication that a high power factor on the transformer and on the fluid is due to contamination can be verified by earth refining the askarel fluid and noting whether after refining the test results correspond with heading "*E*".

Assuming no mechanical defect or arcing, if the power factor of a *new askarel transformer* is relatively high, the power factor of the *fluid* will also be high, giving the situation under heading "*D*". This reflects contamination that should have been removed by the manufacturer of the transformer.

In absence of mechanical defect, where there are no abnormal losses in dielectric strength, and no moisture pick-up in non-arced askarel — the use history shows that a relatively high power factor for the askarel fluid (as compared with mineral oil) is to be expected. Normally, high power factor is due to contamination and not deterioration of the askarel operation.

As shown by F. M. Clark in his book, "*Insulating Materials For Design and Engineering Practice*," John Wiley & Sons, N. Y., 1962 — activated alumina can be used in the circulating system to bring the power factor down and keep it as low as possible.

ADM 001475

WATER_PCB-SD0000073008

IX. CHECK POINTS FOR MAINTAINING ASKAREL INSULATION

A. General Considerations:

Modern askarel transformers with welded construction or silicone gaskets for hand hole-cover, switch and terminal compartment covers, with properly constructed bushings require little or no maintenance. With properly constructed transformers, annual or semi-annual visual inspection and dielectric strength test of the askarel fluid should suffice for routine maintenance checking over many years of service.

However, many askarel units were installed in the early 1930's — before the development of some of the better modern gasketing materials and before improved designs were developed for sealing out moisture. Such early units should be, and can be, modernized. Leaky or deteriorated gaskets should be replaced. If the askarel has become contaminated, it should be reconditioned. At the same time, a general clean-up of the unit and possible refinishing may be desirable.

If it is not convenient to take an old transformer out of service for general repairs, leaky gaskets can be sealed temporarily by painting over the leaky area with epoxy cement.

A survey of users indicates a good number of early-built askarel transformers (over 20 years old) are kept in continuous service in critical installations by the following steps (instead of modernization).

The operating units are equipped with compound pressure gauges for reading pressure above and below atmospheric. Positive pressure is maintained on the shell by introducing nitrogen at 2 to 3 pounds above atomspheric. Regular workmen in the area daily record the temperature and pressure. If a sudend pressure drop is noted more nitrogen is introduced and the gaskets are checked for leaks with soap solution. Leaks are sealed by applying epoxy cement.

B. Modern Sealing Procedures:

Transformer purchasers should specify the following modern techniques for sealing:

1. **Welding Construction:** Covers, radiator connections, switch and terminal housings, instrument connections, etc. should be welded.
2. **Bushing Connections:** The most satisfactory bushings are the type with rolled-on flanges and two ring seals rolled into a depression in the porcelain — sealed with silicone rubber rings held under compression. Metal-to-glass or metal-to-porcelain sealed bushings are also satisfactory.

   If for any reason the above type bushings cannot be used then use a porcelain or glass bushing with a silicone or Viton gasket retained in a groove. The gasket can be either rectangular or circular cross section, usually ¼ inch thick.
3. **Small Size Connections:** When not possible to weld, small size connection seals should be made with Flexitallic stainless steel rings. The surfaces must be machined and parallel. The filler between the steel laminations of the Flexitallic ring should be either silicone or Viton.

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WATER_PCB-SD0000073009

4. **Gaskets For Hand-Hole Covers:** Modern design specifies silicone gaskets. Such gaskets must be retained in a groove. The groove preferably is machined into the flange or cover. However, it can also be formed by welding concentric steel strips to the flange or the cover.

   Generally the gaskets should be 5/16 to 1/2 inch thick for covers, depending on the depth of the groove. A rectangular section is usually used.

   The silicone material should be Dow-Corning No. 50 Silastic or equivalent. This is a low compression set material. For best sealing 20 to 25% compression is recommended, with ample clearance in the groove to allow for this compression.

   No cement is required. With reasonable care the gasket is removable without damage and is reusable.

   Silastic 50 is slightly swelled by askarel which contributes to the tightness of the seal. It is not deteriorated by askarel fluid or vapors. It resists weathering and it is thermally stable and flexible at all operating temperatures. It is an excellent moisture barrier.

Notes: a. Dow-Corning, Midland, Michigan will supply a list of Silastic 50 gasket fabricators to all transformer manufacturers or users. They will also furnish technical data.

b. Any user of Pyranol transformers, made by General Electric Company at Rome, Ga., will receive prompt and generous help for converting to the modern silicone or Viton gaskets by contacting the General Electric Company's Service Engineering Department at Rome, Ga.

See Appendix K: Seals, Properties and Procurements.

C. The Older Sealing Arrangements:

The older type gaskets consist of either cork or cork-nitrile rubber combinations or straight nitrile rubber.

1. **Cork-Nitrile Combinations:** Covers for the main tank, hand-holes, switch and terminal chambers, relief diaphrams etc. are held in place by studs welded to the flange or by bolts. The gaskets are cut with openings and placed over the bolts. Often Shellac (Westinghouse Style No. 1150419, or General Electric Company's Glyptal 1276) is used to cement the cork to the flanges.

   The following is recommended for sealing with the cork — nitrile rubber combination:

   Use Armstrong NC-757 cork-nitrile material or equivalent. The gasket can be cut from a single sheet or by scarfing strips of the material. A convenient method for joining strips is to make a Keystone Type joint. For this, Westinghouse, Sharon, Pa., offers their gasket cutter Style No. 328 B614 G01, (about $15).

   The joints should be cemented and the gasket also cemented to the flange, using one of the above cements. Excess cement should not be allowed to reach the interior of the transformer.

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WATER_PCB-SD0000073010

After installation and bolting, the outside edge of the gasket should be coated thoroughly with epoxy cement to increase weather resistance.

This epoxy cement is a paste to which a curing catalyst is added immediately before use. Typical are:

a. Epoxy Patch Kit #1-C
Hysol Corporation, Olean, N. Y.

b. Scotchcast Resin #4
Minnesota Mining and Manufacturing Co.
St. Paul, Minnesota

c. Adhesive A-1 and Activator Type B
Armstrong Products Company
Argonne Rd., Warsaw, Ind.

d. Adhesive 9860-1, Synthetics Organic Company, Cleveland, Ohio, used with activator diethylene triamine (Carbide and Carbon Chem. Co.)

2. **Straight Nitrile Rubber:** When straight nitrile rubber was originally used, invariably the gasket was recessed in a groove. This was to prevent gasket flow and to protect the material against excessive compression. Although this type seal was not cemented, the nitrile rubber gasket is not reuseable.

Since grooves or stops have already been provided for the nitrile rubber seal, Silastic 50 can be easily substituted and is recommended. This conforms with modern practice.

X. PERIODIC FLUID INSPECTION AND WHAT CHECKPOINTS MEAN

On a regular schedule — at six, nine, or twelve month intervals — make a simple visual inspection of your askarel insulation and run a dielectric strength check.

A. Visual Inspection:

Askarel is a clear, faint-yellow liquid. After long-term use this color may gradually intensify to light brown. The fluid should remain clear and free from turbidity or cloudiness.

Any color change — such as to a green, red or blue cast — indicates extraction of impurities from the solid insulation. If a distinct foreign color pick-up is noted, check the complete range of electrical characteristics and notify the transformer maker. The electrical characteristics may be found to be unimpaired. Color change alone (except for black) is not a danger signal since the contamination is not likely to impair the dielectric strength.

B. Dielectric Strength:

If the dielectric strength has decreased significantly from the last inspection, or if it has gradually decreased below 26 KV range (at 25°C.) — RUN A CHECK FOR MOISTURE. Use ASTM D901, D877 (Karl Fischer Method).

The dielectric strength of askarel is the major indicator to the operating efficiency of your liquid insulation and of the askarel transformer itself. Besides the "visual" inspection tests, dielectric strength is the only test necessary to run on a routine basis. Well-sealed askarel transformers have service records of 25 to 30 years on the original askarel. New askarel has a minimum dielectric strength of 35 KV at 35°C., a maximum moisture content of 30 ppm.

ADM 001478

WATER_PCB-SD0000073011

XI. INSPECTION CHECK LIST

1. If askarel is clear, even though darkened to light brown; has no sediment or turbidity; has dielectric strength over 26 KV . . . give it the inspection "OK".
2. If askarel is clear; has foreign color of blue, green, red . . . it is "extracting color" from internal materials. This is not, of itself, an operating hazard when the dielectric strength stays over 26 KV and moisture remains low. However, this rare occurrence calls for checking into condition of the interior construction and consulting the transformer maker.
3. If askarel is clear; but dielectric strength drops to 22 or lower KV, and moisture rises over 80 ppm . . . the askarel is ready for simple "refining". If the moisture is near the saturation level (about 125 ppm), a thorough inspection should be made for water droplets in the transformer tank, and even for "globules" or water floating on the askarel surface. If found, the transformer manufacturer should be consulted for reconditioning both the transformer and the fluid.
4. If askarel is dark brown to black; if black particles of carbon are seen; and dielectric strength is low . . . the askarel has been broken down by arcing. It cannot be refined and should be discarded.

If any of these four simple inspection tests appear out of the ordinary, or the relationship between appearance and test values is abnormal — contact your transformer supplier for a complete analysis.

Whenever a sample is to be shipped to Monsanto, please follow the directions shown under: "SAMPLING ASKAREL".

XII. CONTAMINATION IN TRANSFORMERS

Unlike mineral oil which can oxidize, sludge and deteriorate — askarel breaks down in transformer use *only when strongly arced.*

Thus, while askarel does not decompose in normal use — it can be contaminated more readily than the relatively non-polar mineral oil.

For example the following Table VI shows how a small amount of synthetic rubber or a bit of varnished cloth markedly increases the power factor of the askarel. Please note, however, that *such minor contamination has no adverse effect on the dielectric strength.* As explained, moisture entrance through faulty seals seems the only contaminant in normal use that lowers the dielectric strength of transformer askarel.

ADM 001479

WATER_PCB-SD0000073012

Table VI

EFFECT OF COMMON INSULATION MATERIALS ON POWER FACTOR AND DIELECTRIC STRENGTH (HEAT AGED 96 HOURS IN ASKAREL AT 100°C.)

Material Immersed	Askarel After Exposure: Power Factor, Percent at 60 cyc., 100°C.	Askarel After Exposure: Dielectric Strength 25°C.
None (control)	1.0	35 KV
Black varnished cloth	85.0	42
Copper	1.5	40
Pressboard	2.0	37
Manila paper	1.5	39
Phenol formaldehyde resins	1.6	41
Shellac	6.0	36
Iron	5.0	39
Synthetic rubber	70.0	39

Similarly, trace contaminants from commonly used construction materials can lower the volume - resistivity of askarel, without affecting its dielectric strength. Table VII shows this.

Table VII

EFFECT OF COMMON INSULATION MATERIALS ON VOLUME RESISTIVITY OF ASKAREL

Sample	Volume Resistivity x 10^9 ohm-cm (at 100°C., 500 Volts DC., 0.1" gap)
1. New askarel before heat aging	2,000
2. New askarel after heat aging 96 hours at 100°C.	1,900
3. After heat aging with 1 sq. inch specimens of:	
a. Phenolic resin tap changer material	1,200
b. Paper	750
c. Grade A press board (tan)	500
d. Grade A press board (gray)	500
e. Grade A press board, laminated strip	400
f. Cotton wrapping	300
g. Glyptal 1276 cement, cured 48 hrs. at 110°C.	100

While trace contamination easily lowers volume resistivity from high levels, it is important as previously noted in Table V Case F, that heavy contamination (as when arced) does not lower the resistivity below the order of 10^8 ohm-cm. at 100°C.

The different behavior of askarel vs. mineral oil in these respects can be summarized as follows:

High power factor and low volume resistivity in transformer mineral oils are commonly regarded as "danger signals" that the oil has deteriorated and broken down chemically.

This is NOT TRUE of askarel liquid insulation, unless the dielectric strength is low.

ADM C01480

WATER_PCB-SD0000073013

XIII. REFINING ASKAREL FOR RE-USE

A. Filtering Through Dry Blotter Paper to Remove Moisture and Extraneous Partciles:

Most operators prefer portable refining apparatus, such as a plate press fitted with a dolly, (available from Sparkler, Mundelein, Ill., Westinghouse Maintenance and Repair Dept., Chicago, or General Electric Co., Pittsfield, Mass.); or the earthen cartridge filter type, (available from Industrial Filter Corp., Lebanon, Ind.). Filter paper liners for the plate press are available from Carl Schleicher and Schuell Company, Keane, New Hampshire and manufacturers of filter presses listed above.

The filter paper must be dried immediately before use. For best results, spread the paper for maximum surface exposure in a hot air circulating oven and heat it for 4 to 6 hours at 110°C.

If possible do not take the transformer out of service until ready to filter the fluid. This will keep the transformer coils relatively hot and dry. Processing the fluid should start immediately after de-energizing the unit.

Circulate the askarel hot (but not over 55-60°C.) through the filter fitted with the dry paper liners.

After filtration the dielectric strength of the askarel should be 35 KV minimum.

1. **Precautions:** Filtering should not be done when the relative humidity exceeds 75%.
2. Any flexible hoses and gaskets on the refining equipment should be lined with or made of materials that will not be softened by contact with askarel fluid. (Silicone or Teflon-lined, or flexible metal materials are suitable.)

Table VIII

GUIDE TO RATE OF DISSOLVED WATER REMOVAL BY FILTERING ASKAREL THROUGH A PAPER PRESS

Passes Through Paper Press	Water in Askarel PPM
0	115
1	35
2	22
3	18
4	12
5	10
6	10

ADM 001481

WATER_PCB-SD0000073014

B. Earth Treatment for Maximum Improvement of Power Factor and Volume-Resistivity:

1. Procedure:

(The askarel liquid should be relatively dry prior to the following earth filtration.)

Use finely divided Attapulgus clay or Fuller's earth (dried and activated by heating for 12 hours at 300-350°F. immediately prior to use) as a coating on the filter paper surface. The amount of earth used should be 0.1 to 0.2 per cent by weight on the weight of the askarel to be treated. (Askarel weighs about 13 pounds per gallon).

To deposit the earth evenly, stir one-third of the earth with a small portion of askarel in a clean container. Pump the mixture through the filter and follow with two more one-third portions. Then circulate askarel taken from near the top of the transformer, pass it hot (not over 55-60°C.) through the earth coated filter and feed back through the bottom transformer outlet. Continue circulation until the fluid is clear and test shows that the electrical properties are fully restored.

2. Effect of Earth on Removal of Scavengers:

Only slight and insignificant loss (by selective absorption) of tintetraphenyl and epoxides occurs when askarel is refined by treatment with 0.1 to 0.2 per cent by weight of earth. To remove significant amounts of the scavengers requires repetitious treatment with much larger amounts of earth.

3. Table IX — Approximate Relationship Between Power Factor, Volume-Resistivity and Dielectric Strength of Transformer Askarel:

Power Factor (60 cyc.)		Volume Resistivity x 10^9 ohm-cm. (at 100°C., 500 Volts DC., 0.1" gap)	Dielectric Strength 25°C., 0.1" gap
100°C.	25°C.		
2%	0.05%	1500	35 KV
5%	0.1%	500	35
15%	0.7%	100	35
20-25%	2.0%	60-70	35
40-50%	—	25	35

If it is desired (although these factors are not generally considered important for askarel transformers), to keep the power factor as low as possible and the resistivity as high as possible, hang a container of anhydrous alumina or activated clay in the circulating system of the transformer.

XIV. CLEANING ARCED TRANSFORMERS

If a unit has arced so that the askarel is no longer fit for use, a thorough cleaning of the unit is necessary before refilling with new askarel insulation and returning it to service*. Follow this procedure:

ADM 001482

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A. Drain out all dark, carbon-contaminated askarel. (Discard by dumping or burying where it will not contaminate a water supply.)

B. Carefully brush carbon deposits from internal parts and insulation, using a soft bristle brush making sure that insulation is not damaged.

C. Flush thoroughly using new askarel (*not* an oil, *not* a cleaning solvent).

D. Flush a second time with fresh askarel; drain; then fill to the proper level with new askarel.

E. Energize transformer to warm the fluid for 24 to 48 hours; then circulate the askarel through a filter, returning it to the unit filtered and ready for use.

* This assumes that the cause of arcing has been established and corrections made. When severe arcing occurs, major repairs are usually necessary and the unit rebuilt. This procedure can be applied for flushing out repaired units.

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XV. SAMPLING ASKAREL

Take a sample as close to the top of the liquid surface as possible. (Many large askarel transformers have a built-in sampling tube near the surface for convenient sampling). Then, to make sure that your SAMPLE truly represents your askarel insulation, take another sample from the bottom. If additional sampling tube connections are contrived on the valves for easier sampling, make the tubes of clean glass, stainless steel, aluminum or tin for rigid types; and silicone or Teflon tubing for flexible types.

Use NEW containers for the askarel sample. A new and thoroughly pre-dried small-mouth quart glass bottle fitted with a Bakelite screw cap fitted with an aluminum or tin bottle cap liner is recommended for "quick on-the-site testing." (If complete analysis is to be made, a 5-pint size sample is required).

Be sure that the new bottle does not stand open to collect dust or moisture. Rinse the sample bottle and cap lining two or three times with askarel from the transformer: then fill it. If the sample will be tested promptly, a clear glass bottle can be used. If sample is to be stored indefinitely, use an amber glass bottle or wrap clear glass with aluminum foil.

A. Select a dry day. Do not sample insulation on a warm, moist day when humidity exceeds 75%, and . . .

B. Make sure that the askarel is at least as warm as the surrounding air. (Cold liquids can condense moisture from humid air.)

C. When sampling askarel from transformers, it is best to take the sample when the unit is warm and operating at average or maximum load. Especially as a check on moisture (as reflected by a dielectric strength test), sampling the warm askarel more truly represents its condition during operation.

Experience shows that water will migrate from a transformer's solid insulation to the askarel liquid and vice versa, depending on temperature. Therefore, when the transformer is hot, the moisture is most likely to be found in the liquid. This accounts largely for periodic variations in dielectric strength. For example: a relatively high dielectric strength may be found during winter months and a relatively low dielectric strength during the summer months on samples taken from the same unit.

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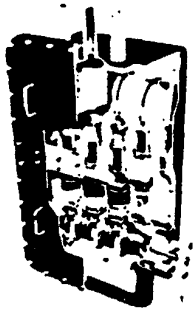
SECTION B

ASKAREL FILLED SWITCHES AND TERMINAL CHAMBERS

I. INTRODUCTION:

High voltage leads are usually connected to askarel or mineral oil-filled network transformers and power centers through terminal chambers and switches. In some cases terminal chambers are not used, and the high voltage leads are connected directly to the switch terminals. They may be filled with either askarel or mineral oil. Switches are usually rotary or drum type fitted with a revolving block and porcelain unit as the principal element arranged for three-phase service. (A cutaway view of a typical terminal chamber-switch combination is shown for reference.)



Askarel transformers with attached switches have been in use for about 30 years. When they were first introduced, the availability of insulating and gasketing materials was rather limited and even the best materials at the time had no service history. As a result, inadequate gasketing materials such as cork, nitrile rubber, and nitrile rubber-and-cork particles were used. While satisfactory for a limited period of time, these materials cannot be depended on for the expected long life of the equipment.

The terminal chamber is usually above or below the switch compartment and separated by a steel wall through which the bushings are inserted. When bushings are properly selected and correctly installed, there is no leakage from one compartment to the other. With poor bushing seals, and the terminal chamber above the switch, potting compounds or cable oil can seep into the askarel. When the terminal chamber is below the switch, askarel can drain into the terminal chamber.

II. SOURCES OF CONTAMINATION

There are three possible sources of contamination for askarel in switches and terminal chambers; they rank in this order of frequency: (1) water entering through poor gaskets; (2) decomposition products from arcing when switch is used to break magnetizing current; (3) entrance of pothead or cable compounds through leaky bushing seals.

Unlike an askarel transformer where the amount of contaminant is likely to be very small (probably only trace amounts) in relation to the volume of askarel fluid — in switches or terminal chambers with faulty seals, the amount of contamination can be relatively large.

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Experience has shown that, based on the number of installed askarel-switch units, the percentage of failures is extremely small. When investigated, it has been found that most failures originate in the switch chamber. Water is the chief source of contamination. However, heavy contamination of askarel with petrolatum and asphalt material, due to leakage, have caused a few failures.

Petrolatum is used frequently for filling terminal chambers. When either cable oil or petrolatum seeps into askarel, no great harm results. The fire resistance will be somewhat decreased and power factor of the askarel will increase with an accompanying drop in resistivity. While highly undesirable, it is doubtful that failure of the unit results. Where asphaltic compounds are used in place of petrolatum, the danger is increased somewhat because asphaltic contamination may cause excessively high dielectric losses in the askarel.

When the terminal chamber is below the switch chamber, the potting compound can be contaminated by askarel if the bushing seals are leaky. This is undesirable because the askarel will increase the power factor and conductivity of the potting compound or cable oil and develop heat from dielectric loss. If this mixture is drawn into the cable insulation, a cable failure is likely. This again emphasizes the importance of tight bushing assemblies.

III. SEALING SWITCHES AND TERMINAL CHAMBERS

Proper bushing construction, use of Silastic seals and welding wherever possible is highly desirable (as covered in Section A). Where an elastomeric seal is to be used in contact with both askarel and petroleum oil, DuPont's Viton is suggested.

For new equipment the user should specify these modern sealing arrangements to keep out contaminants and minimize maintenance.

IV. MAINTENANCE FOR ASKAREL FILLED SWITCHES

A. Switches used for grounding after power source has been de-energized will not undergo arcing.

B. Switches interrupting magnetizing current will be subject to arcing; the amount of decomposition will depend on power interrupted, time and frequency of operation. As a general rule, the liquid should be checked after 5 to 10 operations.

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1. On newly installed switches, check the askarel at 3, 6 and 12 month intervals; if found satisfactory, check once annually thereafter. With proper attention to the gasketing of covers and bushings, experience will probably indicate that less frequent inspection is warranted.

2. Check askarel for:

   a. Dielectric strength (ASTM D877): It should be 26 KV minimum. If dielectric strength is low, confirm presence of water by Karl Fischer method ASTM D-1533. Filter to remove moisture. Dielectric strength should then be 30 KV minimum.

   b. Presence of carbon from arcing: Fluid should be relatively free of carbon. If badly arced and very black, replace fluid. If only minute amounts of carbon are present, filtration is recommended. Check power factor of liquid (should not be over 5% at 25°C. and 60 cycles). Flush out switch chamber with several gallons of fresh askarel before refilling.

3. If there is discoloration, high power factor, detectable change in specific gravity or refractive index, or if fluid flashes below 250°F., there is a possibility of seepage of potting compound into the switch compartment. In this case, correct any leaky bushing seals with proper replacements and fill with new askarel.

4. If terminal chamber is below switch, check potting compound for presence of askarel (can usually be detected by odor or by an increase in specific gravity). If askarel is present, correct any leaky bushing seals with proper replacements, and renew compounds.

5. Examine cover gaskets visually. Deterioration can be detected by swelling and cracking of the exposed edge. In cases of severe deterioration, liquid seepage is usually present.

6. Check for leakage at packing gland of switching shaft. If leaking, repack with a Silastic ring type gasket.

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SECTION C

ANALYTICAL SERVICES ON TRANSFORMER ASKAREL AVAILABLE FROM MONSANTO

Transformer users not wishing to make their own fluid analyses can obtain the service from Monsanto. Simply contact Monsanto and specify what analyses are wanted. You will be sent the proper-sized sample container filled with fresh askarel. When you receive this, empty it and carefully take your sample (following the procedure for sampling in this guide). Send the container to Monsanto's laboratory. Charges listed include sample container, shipping, handling and laboratory costs.

Types of Analyses Available

Analysis 1)

ROUTINE MAINTENANCE CHECK

Total Charge: $20.00

To determine the general condition of the fluid and find whether further analysis is necessary. (one-quart sample required)

Properties Tested
Color and Condition
Dielectric Strength
Moisture

You will be notified of the results of this test. If further testing is indicated, and you want a complete analysis, you will be sent a five-pint sample container. This sample will be used for the following series of tests:

Analysis 2)

COMPLETE ANALYSIS

Total Charge: $50.00

(a) To determine the extent of fluid contamination, (b) earth refinement to determine what degree of restoration of electrical and insulating properties is possible, (c) check test to see how the fluid responded to earth treatment.

a) Complete Analysis: to determine the extent of contamination

Properties Tested
Color and Condition
Specific Gravity
Refractive Index
Water
Free Chlorides
Acidity
Dielectric Strength
Power Factor, Dielectric Constant, and Resistivity

ADM 001488

WATER_PCB-SD0000073021

b) Earth Refinement Response:

Consists of treatment for 2.5 hours at 50-60°C. with 0.1 to 0.2 percent by weight of properly conditioned Attapulgus clay and then filtration through dry filter paper.

c) Analysis After Laboratory Earth Refinement:

Properties Tested
Refractive Index
Water
Free Chlorides
Acidity
Dielectric Strength
Power Factor, Dielectric Constant, and Resistivity

You will be notified of the results of this test series on your sample. Then after refining your entire transformer fluid fill you can check on the results by requesting the following analysis:

Analysis 3)

ANALYSIS AFTER EARTH REFINEMENT

Total Charge: $30.00 (This charge will not apply when analyses 1 and 2 have already been made.)

To determine whether the entire lot of the askarel fill responded to the same extent as the laboratory sample. (five-pint sample required)

Properties Tested
Color and Condition
Refractive Index
Water
Free Chlorides
Acidity
Dielectric Strength
Power Factor, Dielectric Constant, and Resistivity

To arrange for the tests described above write to the following address:

Paul G. Benignus
Monsanto Chemical Company
800 North Lindbergh Blvd.
St. Louis 66, Missouri

Samples to be tested should be clearly marked for identification and sent directly to:

Monsanto Chemical Company
W. G. Krummrich Laboratory
Monsanto, Illinois
Attention: R. Kuster

ADM 001489

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APPENDIX A — Askarel Stability and Composition of Arc Formed Gas:

Askarel insulation is one of the most inert, chemically-stable heat resistant, non-corrosive liquids known. It will not break down, oxidize or sludge when exposed to air and high temperatures, 150°C. or even somewhat higher. Arcing, however, will break down the compound to liberate some hydrogen chloride and small amounts of carbon.

APPROXIMATE COMPOSITION
ARC FORMED GAS FROM TRANSFORMER ASKAREL

Gas	Amount
carbon monoxide	0.3 per cent
carbon dioxide	0.3
oxygen	0.6
inert gases	1.5
hydrogen chloride	97.3

(note the absence of phosgene)

This arc-formed gas is non-flammable and non-combustible. These requirements must be met in accordance with the Underwriters' Laboratory for permission to use the term askarel.

Mineral oil evolves combustible hydrogen and hydrocarbon gases.

For all practical purposes, the amount of gas liberated from mineral oil or askarel under a given set of conditions is about 100 cubic centimeters per kilowatt-second.

APPENDIX B

SOLUBILITY OF GAS IN
TRANSFORMER ASKAREL

	Percent of Gas By Volume Corrected to:			
	25°C. 760 mm		0°C. 760 mm	
	25°C.	100°C.	25°C.	100°C.
Carbon dioxide	71%	47%	—	—
Air	5.7	4.9	5.8	5.0
Nitrogen	6.0	4.8	5.5	4.4
Hydrogen chloride[1]	37.8	50.9	—	—

1) In absence of scavenger

ADM 001490

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APPENDIX C

APPROXIMATE VAPOR PRESSURE vs. TEMPERATURE FOR TRANSFORMER ASKAREL

Temperature °C	Inerteen PPO. 7336-9	Transformer Pyranol A13B3B
40	1 mm Hg.	0.9 mm Hg.
60	5	3.5
80	9	8.3
100	30	18
120	60	32
140	90	53

APPENDIX D

EFFECT OF TEMPERATURE ON DIELECTRIC STRENGTH OF ASKAREL

Temperature °C.	Dielectric Strength
—60	67 KV
—40	63
—20	57
0	55
20	50
40	50
60	48
80	45

APPENDIX E

COMPARISON QF THE APPROXIMATE VISCOSITY IN SAYBOLT UNIVERSAL SECONDS OF TRANSFORMER ASKARELS AND MINERAL OIL

Temp. °C.	Transformer Pyranol A13B3B	10-C Mineral Oil	Inerteen PPO. 7336-9
—20	1,000	1,000	2,800
0	100	150	195
20	70	85	85
40	45	49	50
60	39	40	40
80	34	34	36
100	30	30	33

ADM 001491

WATER_PCB-SD0000073024

APPENDIX F

THE DENSITY OF INERTEEN PPO 7336-9 AND TRANSFORMER PYRANOL A13B3B

Approx. Density gm/cc.

Temperature °C.	Inerteen PPO, 7336-9	Transformer Pyranol A13B3B
0	1.574	1.577
20	1.552	1.555
40	1.529	1.532
60	1.507	1.510
80	1.485	1.488

APPENDIX G

The thermal conductivity values of transformer Pyranol A13B3B at 27°C. and 58°C. are 26.2 and 25.8 x 10^{-5} calories centimeters^{-1}, degrees centrigrade^{-1}, second^{-1}, respectively. Or, approximately 0.06 BTU per (hr.) (sq. ft.) (°F.) per foot. This same approximation applies to Inerteen PPO (7336-9).

APPENDIX H

Heat Capacity

Over the temperature range of 25° to 125°C. the specific heat of transformer askarel is close to 0.30 calories per gram per degree.

APPENDIX I

Coefficient of Expansion

The average coefficient of expansion of transformer askarel over the temperature range 20 to 100°C. is 0.0007 cc/cc/°C. One gallon would increase to 1.056 gallons on heating from 20 to 100°C.

APPENDIX J

Fire-Resistance

To use the generic name "askarel," the fluids must be approved by the Underwriters' Laboratories as possessing adequate fire-resistance and freedom from forming explosive gases when arced. These liquids do not have a burn point (ASTM D92-33) (Cleveland open cup method) up to about 205°C., at which temperatures they begin to boil. The significance of this is that they do not burn or support combustion under conditions encountered in transformer operation. Thus the danger of secondary explosion (or fire) is eliminated.

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WATER_PCB-SD0000073025

APPENDIX K

Seals, Properties and Procurement

Dow Corning Corporation, Midland, Michigan with District's at Atlanta, Boston, Chicago, Cleveland, Dallas, Los Angeles, New York City, Washington, D. C. and Toronto has available Bulletin 09-019, August 1962 entitled "**Silastic Design Data**". This lists the gasket fabricators throughout the country from whom the "Silastic 50" gasketing can be purchased in sheet, extrusions or molded shapes.

Generally Silastic 50 sheet goods are stocked by local die cutters, hence, could be generally purchased locally. Usually, small quantities of gaskets are die cut. If larger quantities are needed, tools are made of the same type used to cut other elastomers.

Where the gasket is extruded for fitting into a machined groove or between gasket stops, Dow-Corning advises use of a scarved joint. This joint is then cemented using Dow Corning's Silastic 140 (clear) or their RTV 731 (white) materials, which air cure.

Dow Corning points out that the local "rubber" fabricators purchase the Silastic 50 in billet form. This is worked on a roll mill in preparation for sheeting or extrusion. Then to obtain the desired physical properties the fabricator must oven cure the Silastic 50 for 24 hours at 480°F.

SPECIFICATIONS*

	Color.....White
	Specific Gravity at 77°F. .....1.20 ± 0.02
ASTM D676 —	Hardness, Shore A. Scale.....45 to 60
ASTM D412 —	Tensile Strength, psi. min.....300
ASTM D412 —	Elongation, percent, min.....250
ASTM D395 —	Compression Set after 22 hours at 300°F., percent, max..... 30

* All physical properties measured on 0.075 inch thick samples molded 5 minutes at 240°F., and oven cured 24 hours at 480°F.

General Electric Company, Redmond Circle, Rome, Ga., uses silicone or DuPont's Viton wherever it is not possible or desirable to weld. For some small seals, where good matching surfaces are provided, Flexitallic stainless steel rings are used.

By contacting the Engineering Services Department of General Electric Company, Redmond Circle, Rome, Ga., users of Pyranol transformers made prior to development of these modern seals will obtain prompt assistance for conversion.

Users of askarel transformers made by other manufacturers should contact the original transformer manufacturer, or Monsanto for assistance in converting to these modern seals.

ADM 001493

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NOTES

WATER_PCB-SD0000073027



MONSANTO
FUNCTIONAL FLUIDS DEPT.

800 N. LINDBERGH BLVD.
ST. LOUIS, MISSOURI 63166

The information herein regarding obtaining optimum results from askarel fluids in your transformer has been accumulated by Monsanto for over 30 years from the experience of makers and users of askarel transformers and it is believed will be helpful.

Nothing herein shall be construed as applying to other than askarel insulation. Data and maintenance suggestions herein do not apply to the other components of the transformer. All operating and maintenance suggestions recommended by the manufacturer of the transformer should also be carefully followed.

Because these maintenance directions apply only to the askarel insulation, Monsanto disclaims any liability for damage to property or injury to persons arising from transformer operation.

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Litho in U.S.A.

WATER_PCB-SD0000073028

PROJECT NO. Y-63-12
REPORT FILE

YOUNGER LABORATORIES

Biochemists . . . Pharmacologists . . . Analysts

123 CLIFF CAVE ROAD
ST. LOUIS 29, MISSOURI

PHONE: TILDEN 6-2540

Certificate of Analysis

March 4th, 1963

SUBJECT - AROCLOR

Toxicological Investigation Of: Inerteen PPO

Monsanto Sample Number 22

Monsanto Project Number Y-63-12

STUDY CONDUCTED FOR -

Monsanto Chemical Company, St. Louis, Missouri

EXPERIMENTAL PROCEDURE -

A) Oral LD_{50} (Rats)

The undiluted compound was fed by stomach tube to Sprague-Dawley strain albino rats.

After the approximate Minimum Lethal Dose was determined, groups of male and female rats were fed in increasing doses at increments of 0.1 fractional log intervals at four levels designed to blanket the toxicity range thereby supplying data for calculation of the LD_{50} which was done according to a modification of the method of E. J. de Beer.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data are shown in Table I.

B) Skin Absorption MLD (Rabbits)

The undiluted compound was applied in increasing doses at increments of 0.2 fractional log intervals to the closely clipped, intact skin of New Zealand white female rabbits.

The treated areas were covered with plastic strips and the animals placed in wooden stocks for periods up to twenty-four hours, after which time they were assigned to individual cages.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data are shown in Table II.

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EXPERIMENTAL PROCEDURE - (Continued)

C) Skin Irritation (Rabbits)

The undiluted compound was applied to the clipped, intact skin of albino rabbits and removed after twenty-four hours. The application was covered with plastic strips to retard evaporation.

Observations were made over a period of several days for irritation.

The data, scored according to the method of Draize, Woodard and Calvery (Journal of Pharm. and Exp. Therapeutics, Volume 82, December, 1944) are shown in Table III.

D) Eye Irritation (Rabbits)

0.1 Milliliter of undiluted sample was placed in the conjunctival sac of the right eye of each of three albino rabbits and observations made over a period of several days for inflammation.

The eyes were rinsed with warm isotonic saline solution after twenty-four hours.

The data, scored according to the method of Draize, et al, are shown in Table IV.

E) Vapor Inhalation (Rats)

Four 150-gram male rats were placed in a glass desiccator, 250 mm in diameter, and exposed for six hours to a concentrated atmosphere of vapors produced by passing a stream of air through 100 milliliters of the compound contained in a 250-milliliter tall form gas washing bottle with fritted disc. Vapors from the bottle passed into a one liter bottle to remove droplets and then into the chamber. Air flow through the sample was 6 liters per minute as measured by a calibrated rotameter. This was sufficient to violently agitate the liquid. No supplementary air was introduced inasmuch as the above supply was ample for the animals oxygen requirements.

The animals were observed for behavior and, since there were no deaths, all were held for ten days observation.

The data are shown in Table V.

SUMMARY -

Inerteen PPO

A) Oral LD_{50} (Rats)

The Oral LD_{50} for male and female rats was placed at 2370 milligrams per kilogram with lower and upper limits of 2095 to 2690 milligrams per kilogram.

The compound was classed as slightly toxic by oral ingestion in male and female rats.

B) Skin Absorption MLD (Rabbits)

The Minimum Lethal Dose by Skin Absorption in female rabbits was found to be greater than 3160 milligrams per kilogram and less than 5010 milligrams per kilogram.

The compound was classed as slightly toxic by skin absorption in female rabbits.

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SUMMARY - (Continued)

C) Skin Irritation (Rabbits)

The compound was classed as a moderate skin irritant.

The average maximum score was 4.6 out of a possible 8 in twenty-four hours.

D) Eye Irritation (Rabbits)

The compound was classed as a moderate eye irritant.

The average maximum score was 35.6 out of a possible 110 in one hour.

E) Vapor Inhalation (Rats)

All animals survived the six hour exposure as well as the following ten day observation period.

It was concluded that the vapors were slightly toxic under conditions of the test.

YOUNGER LABORATORIES

Fred M. Younger

BY: FRED M. YOUNGER

The material in this report is to be used in development of the product and may be given to responsible sales contacts, but it is not to be used by them in advertising copy. The source of this material is not to be divulged until it appears in formal publications. No exceptions to the established rule may be made without the approval of the Medical Department in St. Louis. Customers' inquiries regarding matters of toxicity are to be referred as before to the Medical Department in St. Louis for reply.

— Monsanto Chemical Company

WATER_PCB-SD0000073031

TABLE I

THE ORAL LD_{50} OF 'Interteen PPO' FOR RATS

Sample Fed Undiluted

Animal No. - Sex	Weight Gm.	Dose Mg./Kg.	Fate
1- Female	220	1580	Survived
2- Female	210	1580	Survived
3- Male	235	1580	Survived
4- Male	240	1580	Survived
5- Female	215	1580	Survived
6- Female	225	2000	Survived
7- Male	245	2000	Survived
8- Male	240	2000	Died
9- Female	210	2000	Died
10- Female	220	2000	Survived
11- Male	235	2510	Died
12- Male	245	2510	Survived
13- Female	205	2510	Died
14- Female	215	2510	Died
15- Male	250	2510	Survived
16- Male	235	3160	Died
17- Female	210	3160	Died
18- Female	220	3160	Died
19- Male	235	3160	Survived
20- Male	245	3160	Died

DISCUSSION -

The Oral LD_{50} for male and female rats was placed at 2370 milligrams per kilogram with lower and upper limits of 2095 to 2690 milligrams per kilogram.

The compound was classed as slightly toxic by oral ingestion in male and female rats.

Survival time was approximately twenty-four hours to six days with most deaths occurring in three to five days.

Toxic symptoms included severe diarrhea, loss of appetite, increasing weakness, and collapse.

At autopsy there was marked liver and renal hyperemia as well as pulmonary congestion.

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TABLE II

THE MINIMUM LETHAL DOSE OF 'Inerteen PPO' BY SKIN ABSORPTION IN RABBITS

Sample Applied Undiluted

Animal No. - Sex	Weight Kg.	Dose Mg./Kg.	Weight Change 5 Days Later Kg.	Fate
1 - Female	2.3	794	+ 0.2	Survived
2 - Female	2.1	1260	0.0	Survived
3 - Female	2.4	2000	0.0	Survived
4 - Female	2.3	3160	- 0.1	Survived
5 - Female	2.5	5010	- 0.4	Died -- 5 Days
6 - Female	2.7	7940	- 0.6	Died -- 6 Days

DISCUSSION -

The Minimum Lethal Dose by Skin Absorption in female rabbits was found to be greater than 3160 milligrams per kilogram and less than 5010 milligrams per kilogram.

The compound was classed as slightly toxic by skin absorption in female rabbits.

Survival time was five to six days.

The animals that succumbed lost appetite and wasted away. Movement reduced as the animals weakened but no definite paralytic symptoms were observed.

At autopsy the liver had a jaundiced-like appearance and there was pulmonary hyperemia macroscopically.

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TABLE III

SKIN IRRITATION IN RABBITS AFTER APPLICATION OF 'Inerteen PPO'

Sample Applied Undiluted

Animal Number	Numerical Evaluation At The End Of 1 Hour	24 Hours	48 Hours	72 Hours	120 Hours	168 Hours
1	2	4	4	3	2	1
2	3	5	4	2	2	1
3	3	5	5	4	2	1
Average	2.6	4.6	4.3	3.0	2.0	1.0

DISCUSSION -

The compound was classed as a moderate skin irritant.

The average maximum score was 4.6 out of a possible 8 in twenty-four hours.

After one hour there was well-defined erythema with barely perceptible swelling for an average score of 2.6 out of a possible 8. Inflammation increased overnight at which time the average score was 4.6 based upon moderate redness and slight edema. Daily improvement was noted after the application was removed. Irritation reduced to barely perceptible erythema on all animals within seven days.

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T A B L E IV

EYE IRRITATION IN RABBITS AFTER APPLICATION OF 'Inerteen PPO'

Sample (0.1 Milliliter) Applied Undiluted

Animal Number	Numerical Evaluation At The End Of 1 Hour	24 Hours	48 Hours	72 Hours	120 Hours	168 Hours
1	37	30	21	15	8	4
2	29	21	15	9	4	0
3	41	30	19	12	6	0
Average	35.6	27.0	18.3	12.0	6.0	1.3

DISCUSSION -

The compound was classed as a moderate eye irritant.

The average maximum score was 35.6 out of a possible 110 in one hour.

Moderate discomfort was shown following application.

Within one hour there was mild edema, copious discharge, mild to moderate redness of the conjunctivae, and slight iris congestion and corneal dullness for an average score of 35.6 out of a possible 110. Discharge and cloudiness decreased overnight. Iris clarity was normal within five days and within seven days two of three animals were free of inflammation.

WATER_PCB-SD0000073035

TABLE V

INHALATION OF 'Inerteen PPO' VAPORS BY RATS

Average Temperature Inside Chamber ..... 76° F.
Average Relative Humidity Inside Chamber ..... 47 %

Animal No. - Sex	Fate	Observations During Exposure
1 - Male	Survived	Mild eye and nasal irritation after twenty to thirty minutes ...
2 - Male	Survived	Moderate discomfort ...
3 - Male	Survived	Lethargy ...
4 - Male	Survived	Occasional moderate dyspnea ...
		No serious weakness ...
		Slight nasal discharge.

DISCUSSION -

All animals survived the six hour exposure as well as the following ten day observation period.

It was concluded that the vapors were slightly toxic under conditions of the test.

Mild inflammation of the nasal mucosa was evident when the animals were removed from the chamber. Breathing was slightly irregular but no rasping sound was detected and the animals were only mildly weakened. Animal behavior was practically normal, in forty-eight hours. No respiratory complications developed during the ten day observation period.

WATER_PCB-SD0000073036

REPORT FILE

YOUNGER LABORATORIES
INCORPORATED

Consulting and Analytical Services

CHEMICAL ... MICROBIOLOGICAL ... BIOLOGICAL

123 CLIFF CAVE ROAD
SAINT LOUIS, MO., 63129
PHONE: (314) 487-6661

June 8th, 1974

Monsanto Company
800 North Lindbergh Boulevard
St. Louis, Missouri 63166

SUBJECT: ANIMAL FEEDING STUDIES FOR TISSUE RESIDUE ANALYSES
In Accordance With Modified Protocols Per G. Levinskas, Ph.D., December 7, 1973, and E. S. Tucker, February 19, 1974

MONSANTO PROJECT NUMBERS: Y-74-46 - Y-74-55

Monsanto Project Number	Test Material	Exposure Level (PPM) Low	High	Number Of Days On Test	Date Sacrificed
PILOT STUDY --					
Test Started: January 30, 1974 (0 Day)					
Animals sacrificed in groups of five; each level and control					
Y-74-52	MCS 1043	1	10	2	2/ 1/74
Y-74-55	AROCLOR 1242	1	10	5	2/ 4/74
				10	2/ 9/74
D.F. TISSUE RESIDUE STUDY --					
Test Started: February 23, 1974 (0 Day)					
Animals sacrificed in groups of five; each level and control					
Y-74-46	MCS 1633	25	100	2	2/25/74
Y-74-47	MCS 1623	25	100	5	2/28/74
Y-74-48	MCS 1238	25	100	10	3/ 5/74
Y-74-49	MCS 1475	25	100	20	3/15/74
Y-74-50	MCS 1302	5	25	30	3/25/74
Y-74-51	MCBP	25	100	32	3/27/74
Y-74-52	MCS 1043	25	100	35	3/30/74
Y-74-53	MCS 1489	5	25	45	4/ 9/74
Y-74-54	AROCLOR 1016	5	25	75	5/ 9/74
Y-74-55	AROCLOR 1242	5	25	105	6/ 8/74 *

* Y-74-53, Y-74-54, Y-74-55, and Control only

YOUNGER LABORATORIES, INC.

BY: MELVIN D. BIRCH

ADM 003144

PLAINTIFF'S EXHIBIT 621

90607

WATER_PCB-SD0000073037

PROJECT NO. Y-75-252
REPORT FILE

YOUNGER LABORATORIES
INCORPORATED
123 CLIFF CAVE ROAD SAINT LOUIS, MO., 63129

Toxicologic Investigation of: AROCLOR 1016 To: MONSANTO COMPANY

Lot Number KE 01-701 St. Louis, Missouri

Project No. Y-75-252 Date: October 22nd, 1975

ACUTE ORAL TOXICITY

Species Sprague-Dawley Albino Rats

LD_{50} 2,350 Mg/Kg 95% Confidence Limits 2,120 - 2,500 Mg/Kg
CONDITIONS Single Oral Dose - Undiluted

	Dosage Mg/Kg	Avg. Initial Weight Male	Avg. Initial Weight Female	Mortalities/Dosed Male	Mortalities/Dosed Female	Mortalities/Dosed Combined	Time of Mortality
1	1,580	230	235	1/3	0/2	1/5	
2	2,000	230	235	1/2	0/3	1/5	
3	2,510	235	240	2/3	1/2	3/5	One to four days, most within two days
4	3,160	230	220	2/2	2/3	4/5	
5	3,980	225	220	3/3	2/2	5/5	
6							

Signs of Intoxication: Reduced appetite and activity (one to three days in survivors), increasing weakness, collapse, and death.

Gross Autopsy Decedents: Hemorrhagic lungs and liver, and gastrointestinal inflammation.

Survivors (14 Days): Viscera appeared normal.

ACUTE DERMAL TOXICITY

Species New Zealand Albino Rabbits

LD_{50} > 1,580 Mg/Kg 95% Confidence Limits ---- Mg/Kg Exposure 24 Hours
CONDITIONS Applied Undiluted

	Dosage Mg/Kg	Initial Weight Male	Initial Weight Female	Mortalities/Dosed Male	Mortalities/Dosed Female	Mortalities/Dosed Combined	Time of Mortality
1	631	2.1	---	0/1	---	0/1	
2	1,000	---	2.2	---	0/1	0/1	
3	1,580	2.1	---	0/1	---	0/1	
4	2,000	---	2.1	---	1/1	1/1	Seven days
5	5,010	1.9	---	1/1	---	1/1	Six days
6							

Signs of Intoxication: Reduced appetite and activity (two to four days in survivors), increasing weakness, collapse, and death.

Gross Autopsy Decedents: Lung hyperemia, liver discoloration, enlarged gall bladder, darkened kidney and spleen, and gastrointestinal inflammation.

Survivors (14 Days): Viscera appeared normal.

ADM 003145

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90609

PLAINTIFF EXHIBIT 622

WATER_PCB-SD0000073038

ACUTE EYE IRRITATION

Species New Zealand Albino Rabbits
Irritation Score (24, 48, 72 Hour Avg.) 5.1 Classification Slight * Exposure 24 Hours
Dose and Conditions 0.1 Ml. Applied Undiluted / F.H.S.A.
* F.H.S.A.: NOT CLASSED as an Eye Irritant

Hours	1			24			48			72			120			168		
STRUCTURE / Animal Number	CORNEA	IRIS	CONJUNCTIVAE	CORNEA	IRIS	CONJUNCTIVAE	CORNEA	IRIS	CONJUNCTIVAE	CORNEA	IRIS	CONJUNCTIVAE	CORNEA	IRIS	CONJUNCTIVAE	CORNEA	IRIS	CONJUNCTIVAE
1	0	0	8	0	0	12	0	0	4	0	0	0	0	0	0	0	0	0
2	0	0	8	0	0	10	0	0	4	0	0	2	0	0	0	0	0	0
3	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	8	0	0	12	0	0	2	0	0	0	0	0	0	0	0	0
5	0	0	10	0	0	12	0	0	2	0	0	0	0	0	0	0	0	0
6	0	0	8	0	0	12	0	0	6	0	0	4	0	0	0	0	0	0
Mean Score (X/110.0)		8.6			11.3			3.0			1.0			0.0			0.0	

Comments
Immediate: Discomfort was slight
10 Minutes: Slight erythema, moderate to copious discharge
1 Hour: Slight erythema, very slight edema in two instances, copious discharge
24 Hours: Slight to moderate erythema, very slight edema, copious discharge containing whitish exudate
48 - 72 Hours: Gradual improvement
120 Hours: All scored zero

PRIMARY SKIN IRRITATION

Species New Zealand Albino Rabbits
Irritation Score (24, 72 Hour Avg.) 5.3 Classification Severe * Exposure: 24 Hours
Dose and Conditions 0.5 Ml. Applied Undiluted / F.H.S.A.
* F.H.S.A.: CLASSED as a Primary Skin Irritant

Animal Number	HOUR / SKIN	ERYTHEMA 4 I	4 A	24 I	24 A	48 I	48 A	72 I	72 A	168 I	168 A	EDEMA 4 I	4 A	24 I	24 A	48 I	48 A	72 I	72 A	168 I	168 A
1		2	2	2	2	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0
2		2	2	2	2	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0
3		2	2	3	3	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0
4		2	2	3	3	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0
5		2	2	3	3	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0
6		2	2	3	3	3	3	3	3	0	0	2	2	3	3	2	2	2	2	0	0

Comments Moderate defatting effect - skin sloughed off in ten to fourteen days. There was no injury in depth.

INHALATION TOXICITY

Species

Mortality		Initial sample	g	Chamber temperature ...	°C
Concentration	Mg/L	Recovered sample....	g	Chamber humidity.....	%
Exposure	Hrs	Condensed sample ...	g	Chamber volume.....	L
Sample temperature...	°C	Vaporized sample....	g	Air flow rate.....	L/Min

Signs of Intoxication

Gross Autopsy

Decedents

Survivors (Days)

ADM 003146

Test Method Reference A.T.S. 8/73

Submitted by: MELVIN D. BIRCH
YOUNGER LABORATORIES, INC.

WATER_PCB-SD0000073039

REPORT TO

MONSANTO COMPANY

TWO - YEAR CHRONIC ORAL TOXICITY STUDY WITH ARCCLOR 1254 IN ALBINO RATS

HISTOPATHOLOGICAL EVALUATION OF ADDITIONAL LIVER SECTIONS

MARCH 24, 1975

IBT NO. 641 - 06672

I. Introduction

At the request of Dr. Levinskas of the Monsanto Company, additional sections of liver from a two - year chronic oral toxicity study of Aroclor 1254 in rats (IBT No. 622-07298) were processed into H & E stained sections and evaluated by light microscopy. The following report presents the results of this study.

ADM 003147

PLAINTIFF'S EXHIBIT 623

90612

WATER_PCB-SD0000073040

II. Summary

In most instances, the spectrum of treatment-related histopathological findings in the liver from this re-evaluation did not differ significantly from that previously reported in our original report dated November 12, 1971. There were six hepatomas detected among six of the animals at the highest treatment level (100 ppm) of the 24-Month Sacrifice. No hepatocellular carcinomas were observed. One liver tumor (a hepatoma) previously reported in a T-II animal (No. 445) was re-classified as nodular hyperplasia. The other treatment-related lesions reported are regarded as degenerative or hyperplastic in nature and they are morphologic manifestations of an adaptive response of the liver ascribed to biotransformation of the test material. The latter lesions were confined primarily to test animals of the 12 and 24 month sacrifices and they were dose-related in incidence and severity.

In conclusion, Aroclor 1254 does not appear to be carcinogenic in rats fed for two years at levels up to and including 100 ppm.

Respectfully submitted,

INDUSTRIAL BIO-TEST LABORATORIES, INC.

Report Prepared and Reviewed by:

D. E. Gordon, D. V. M., Ph. D.
Section Head, Pathology

Report Approved by:

M. L. Keplinger, Ph. D.
Manager, Toxicology

aew

WATER_PCB-SD0000073041

IBT No. 622-07298
Monsanto

I have examined additional sections of liver from rats of IBT No. 622-07298 and have re-evaluated them for evidence of carcinogenesis. I have tabulated my findings for Aroclor 1254 on the following pages:

There is evidence of a chemical effect on the liver which is most pronounced at time of the 12-Month and 24-Month sacrifice. This consists of a hepatocellular alteration beginning as focal hypertrophy which progresses to nodular hyperplasia, and in a few animals to hepatoma or cholangiohepatoma. The hypertrophic cells contain large amounts of light staining cytoplasm which is probably rich in glycogen and endoplasmic reticulum. In some cases ring shaped structures, probably representing whorls of proliferative endoplasmic reticulum, were seen in the cytoplasm of these cells.

The hyperplastic nodules occupied larger areas and often compressed surrounding cells of the normal liver parenchyma. They also contained the same hypertrophic cells.

Those lesions classified as hepatomas or cholangiohepatomas were larger nodules which showed evidence of confluence or some variation in cell size, shape, staining or a ductular or adenomatous pattern of growth. In the absence of metastasis, invasiveness, severe basophilia, mitoses, or other evidence of anaplasia; these are benign tumors rather than malignant carcinomas. There was no evidence of metastasis or invasiveness of these tumors in this study.

WATER_PCB-SD0000073042

With exception of the vacuolar changes in the cytoplasm of hepatocytes, the more severe hepatocellular alterations were confined to animals of the 24-Month Sacrifice.

Ward R. Richter

Ward R. Richter, D.V.M., M.S.
Dipl., Am. College Vet. Path.

WATER_PCB-SD0000073043

Primary Liver Lesions - Aroclor 1254

3 Month Sacrifice - Rats

Lesion	Group			
	TI	TII	TIII	Control
Vacuolar Change	3/10	3/10	1/10	2/10
Focal Hypertrophy	0/10	0/10	1/10	0/10
Nodular Hyperplasia	0/10	0/10	0/10	0/10
Hepatoma	0/10	0/10	0/10	0/10
Ductular Hyperplasia	0/10	0/10	0/10	0/10
Cholangio-Hepatoma	0/10	0/10	0/10	0/10
Hepatocellular Necrosis	1/10	1/10	0/10	0/10

WATER_PCB-SD0000073044

Primary Liver Lesions - Aroclor 1254

6 Month Sacrifice - Rats

Lesion	Group			
	TI	TII	TIII	Control
Vacuolar Change	0/10	0/10	1/10	1/10
Focal Hypertrophy	0/10	0/10	4/10	0/10
Nodular Hyperplasia	0/10	0/10	0/10	0/10
Hepatoma	0/10	0/10	0/10	0/10
Ductular Hyperplasia	0/10	0/10	0/10	0/10
Cholangio-Hepatoma	0/10	0/10	0/10	0/10
Hepatocellular Necrosis	2/10	0/10	1/10	1/10

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Primary Liver Lesions - Aroclor 1254

12 Month Sacrifice - Rats

Lesion	Group			
	II	III	IIII	Control
Vacuolar Change	1/10	4/10	1/10	1/10
Focal Hypertrophy	0/10	4/10	2/10	0/10
Nodular Hyperplasia	0/10	0/10	0/10	0/10
Hepatoma	0/10	0/10	0/10	0/10
Ductular Hyperplasia	1/10	1/10	0/10	1/10
Cholangio-Hepatoma	0/10	0/10	0/10	0/10
Hepatocellular Necrosis	0/10	0/10	1/10	0/10

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WATER_PCB-SD0000073046

Primary Liver Lesions - Aroclor 1254

Terminal Sacrifice - Rats

Lesion	Group			
	TI	TII	TIII	Control
Vacuolar Change	8/31	10/26	13/27	1/23
Focal Hypertrophy	3/31	5/26	13/27	0/23
Nodular Hyperplasia	0/31	3/26	13/27	1/23
Hepatoma	0/31	0/26	4/27	0/23
Ductular Hyperplasia	6/31	3/26	4/27	5/23
Cholangio-Hepatoma	0/31	0/26	2/27	0/23
Hepatocellular Necrosis	3/31	1/26	2/27	1/23

WATER_PCB-SD0000073047

Tabulation of Individual Liver Lesions in Rats

Sacrifice Interval	Dose Level	Animal No. and Sex	Liver Lesions									
			Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
Month	B-I	356M	++									
	1ppm	357"	+									
		358"										
		359"		+								
		360"	+									
		396F										
		397"										
		398"										
		399"										
		400"										
	B-II	436M	+									
	10ppm	437"										
		438"	+									
		439"										
		440"	+									
		476F		+								
		477"										
		478"										
		479"										
		480"										
	B-III	516M										
	100ppm	517"										
		518"	+	+	+							
		519"										
		520"										
		555F										
		557"										
		558"										
		559"										
		560"										

ADM 003155

WATER_PCB-SD0000073048

Tabulation of Individual Liver Lesions in Rats

ifica rval	Dose Level	Animal No. and Sex	Liver Lesions									
			Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
lonth	B-I	921M		+								
	1ppm	922"										
		923"		+								
		924"										
		925"										
		936F										
		937"										
		938"										
		939"										
		940"										
	B-II	950M										
	10ppm	951"										
		952"										
		953"										
		954"										
		966F										
		967"										
		968"										
		969"										
		970"										
	B-III	981M		+	+							
	100ppm	982"			+							
		983"										
		984"										
		985"										
		996F				+						
		997"				+						
		998"										
		999"		+		+						
		1000"				+						

ADM C03156

WATER_PCB-SD0000073049

AROCLOR - 1254

Tabulation of Individual Liver Lesions in Rats

Sacrifice Interval	Dose Level	Animal No. and Sex	Liver Lesions									
			Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
2 Month	B-I 1ppm	41M	+									
		42"										
		43"										
		44"										
		45"										
		46F										
		47"										
		48"						+				
		49"										
		50"										
	B-II 10ppm	51M										
		52"	++									
		53"	++									
		54"			+							
		55"	+									
		56F			+							
		57"	+			+						
		58"				+						
		59"				+						
		60"				+		+				
	B-III 100ppm	61M				+						
		62"										
		63"										
		64"										
		65"	++			+						
		66F										
		67"			+							
		68"										
		69"										
		70"		+								

ADM 003157

WATER_PCB-SD0000073050

Tabulation of Individual Liver Lesions in Rats

ifice rval	Dose Level	Animal No. and Sex	Liver Lesions: Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
Month	B-I	326M										
	1ppm	330"										
		335"										
		338"										
		351"	++	+								
		323"		+								
		325"										
		343"	+									
		346"			+	+						
		342F										
		362"										
		368"						+				
		374"										
		375"						+				
		376"				+						
		475"	+++									
		366"						+				
		367"										
		372"						+				
		377"	++	++		+		+				
		378"	+									
		379"	+									
		380"										
		381"										
		384"										
		387"										
		388"										
		389"										
		391"	+					+				
		394"	+++									
		Ext"			++							

ADM 003158

WATER_PCB-SD0000073051

rifice erval	Dose Level	Anima No. and Sex	Liver Lesions									
			Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
Month	B-II	415M										
	10ppm	417"				++		+				
		418"										
		419"										
		423"										
		426"	++									
		427"	+									
		491"									P	
		402"	+									
		403"	+									
		405"										
		410"										
		434"	+									
		450F										
		451"	+				P					
		452"	+	+			P					
		456"				+						
		459"				++		++				
		463"	++									
		469"				+						
		470"										
		471"										
		478"						+				
		443"										
		445"					P					
		448"										

ADM 003159

WATER_PCB-SD0000073052

Tabulation of Individual Liver Lesions in Rats

ifice rval	Dose Level	Animal No. and Sex	Liver Lesions										
			Cytoplasmic vacuolation of hepatocytes	Focal necrosis of hepatocytes	Focal lymphoid infiltrations	Focal hypertrophy of hepatocytes	Nodular hyperplasia of hepatocytes	Focal bile duct hyperplasia	Hepatoma	Cholangio-hepatoma	Squamous Cell Carcinoma, metastatic	Mammary tumor, metastatic
Month	B-III	484M	++									
	100ppm	491"				+	P		P			
		497"				++	P					
		499"				+	P					
		507"					P					
		509"										
		510"	+									
		512"										
		483"	++					+				
		489"	+			+						
		522F	++			++						
		524"	++			+	P					
		527"	+++			+	P					P
		541"				+			P			
		547"	++				P					
		Ext1"	++			++++	P					
		Ext2"					P	+		P		
		Ext3"	++			+++						
		Ext4"					P		P			
		Ext5"		+			P					
		536"	++			+++	P					
		537"										
		539"	++			++		+				
		441"										
		Ex1"							P			
		Ex2"	++							P		
		Ex3"				+	P	+				

Grading System

\+ = minimal in severity
++ = mild in severity
+++ = moderate in severity
++++ = marked in severity
P = Present, no grade
\- = Absent

ADM 003160

WATER_PCB-SD0000073053

YOUNGER LABORATORIES
Biochemists . . . Pharmacologists . . . Analysts

5620 TELEGRAPH ROAD
ST. LOUIS 29, MISSOURI
PHONE: TILDEN 6-2540

Certificate of Analysis

June 25th, 1962

C+25AA

SUBJECT -

Toxicological Investigation Of: Aroclor 1260

Monsanto Sample Number 39
Monsanto Project Number Y-62-37

STUDY CONDUCTED FOR -

Monsanto Chemical Company, St. Louis, Missouri

COPY

EXPERIMENTAL PROCEDURE -

A) Oral LD_{50} (Rats)

The diluted compound was fed by stomach tube to Sprague-Dawley strain albino rats.

After the approximate Minimum Lethal Dose was determined, groups of male and female rats were fed in increasing doses at increments of 0.1 fractional log intervals at four levels designed to blanket the toxicity range thereby supplying data for calculation of the LD_{50} which was done according to a modification of the method of E. J. de Beer.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data, together with the dilution at which the compound was fed, are shown in Table I.

B) Skin Absorption MLD (Rabbits)

The diluted compound was applied in increasing doses at increments of 0.2 fractional log intervals to the closely clipped, intact skin of New Zealand white female rabbits.

The treated areas were covered with plastic strips and the animals placed in wooden stocks for periods up to twenty-four hours, after which time they were assigned to individual cages.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data, together with the dilution at which the compound was applied, are shown in Table II.

ADM 003161

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PLAINTIFF'S EXHIBIT 624

90627

WATER_PCB-SD0000073054

SUMMARY -

Aroclor 1260

A) Oral LD_{50} (Rats)

The Oral LD_{50} for male and female rats was placed at 10,000 milligrams per kilogram with lower and upper limits of 8,600 to 11,600 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

B) Skin Absorption MLD (Rabbits)

The Minimum Lethal Dose by Skin Absorption in female rabbits was found to be greater than 1260 milligrams per kilogram and less than 2000 milligrams per kilogram.

The compound was classed as mildly toxic by skin absorption in female rabbits.

YOUNGER LABORATORIES

BY: FRED M. YOUNGER

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— Monsanto Chemical Company

WATER_PCB-SD0000073055

TABLE I

THE ORAL LD_{50} OF 'Aroclor 1260' FOR RATS

Sample Fed As A 50.0% Solution In Corn Oil

Animal No. - Sex	Weight Gm.	Dose Mg./Kg.	Fate
1- Female	215	6,310	Survived
2- Female	230	6,310	Survived
3- Female	220	6,310	Survived
4- Male	245	6,310	Survived
5- Male	235	6,310	Survived
6- Male	250	7,940	Survived
7- Female	220	7,940	Survived
8- Female	210	7,940	Survived
9- Female	215	7,940	Died
10- Male	240	7,940	Survived
11- Male	225	10,000	Died
12- Male	235	10,000	Survived
13- Female	210	10,000	Survived
14- Female	225	10,000	Died
15- Female	210	10,000	Died
16- Male	230	10,000	Survived
17- Male	235	12,600	Died
18- Male	220	12,600	Died
19- Female	210	12,600	Survived
20- Female	215	12,600	Died
21- Male	240	12,600	Died

DISCUSSION -

The Oral LD_{50} for male and female rats was placed at 10,000 milligrams per kilogram with lower and upper limits of 8,600 to 11,600 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

Survival time was two to five days with most deaths occurring in three days.

Toxic symptoms included severe diarrhea, loss of appetite, and increasing lethargy and weakness.

At autopsy there was inflammation of the gastric mucosa and liver hyperemia macroscopically.

WATER_PCB-SD0000073056

T A B L E II

THE MINIMUM LETHAL DOSE OF 'Aroclor 1260' BY SKIN ABSORPTION IN RABBITS

Sample Applied As A 50.0% Solution In Corn Oil

Animal No. - Sex	Weight Kg.	Dose Mg./Kg.	Weight Change 5 Days Later Kg.	Fate
1 - Female	1.9	501	+ 0.1	Survived
2 - Female	2.2	794	0.0	Survived
3 - Female	2.4	1260	0.0	Survived
4 - Female	2.6	2000	- 0.4	Died — 8 Days
5 - Female	2.4	2000	- 0.4	Died — 7 Days
6 - Female	2.4	3160	- 0.5	Died — 7 Days

DISCUSSION -

The Minimum Lethal Dose by Skin Absorption in female rabbits was found to be greater than 1260 milligrams per kilogram and less than 2000 milligrams per kilogram.

The compound was classed as mildly toxic by skin absorption in female rabbits.

Survival time was seven to eight days.

Toxic symptoms included weight loss after two to three days with increasing weakness followed by collapse in six to seven days.

At autopsy there was evidence of liver dysfunction and renal hyperemia macroscopically

WATER_PCB-SD0000073057

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PHONE: TILDEN 6-2340

Certificate of Analysis

C-4-3-AM

June 25th, 1962

SUBJECT -

Toxicological Investigation Of: Aroclor 1262

Monsanto Sample Number 40
Monsanto Project Number Y-62-38

STUDY CONDUCTED FOR -

Monsanto Chemical Company, St. Louis, Missouri

COPY

EXPERIMENTAL PROCEDURE -

A) Oral LD_{50} (Rats)

The diluted compound was fed by stomach tube to Sprague-Dawley strain albino rats.

After the approximate Minimum Lethal Dose was determined, groups of male and female rats were fed in increasing doses at increments of 0.1 fractional log intervals at four levels designed to blanket the toxicity range thereby supplying data for calculation of the LD_{50} which was done according to a modification of the method of E. J. de Beer.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data, together with the dilution at which the compound was fed, are shown in Table I.

B) Skin Absorption MLD (Rabbits)

The diluted compound was applied in increasing doses at increments of 0.2 fractional log intervals to the closely clipped, intact skin of New Zealand white female rabbits.

The treated areas were covered with plastic strips and the animals placed in wooden stocks for periods up to twenty-four hours, after which time they were assigned to individual cages.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data, together with the dilution at which the compound was applied, are shown in Table II.

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PLAINTIFF'S EXHIBIT 626

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WATER_PCB-SD0000073058

SUMMARY -

Aroclor 1262

A) Oral LD_{50} (Rats)

The Oral LD_{50} for male and female rats was placed at 11,300 milligrams per kilogram with lower and upper limits of 9940 to 12,880 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

B) Skin Absorption MLD (Rabbits)

The Minimum Lethal Dose by skin absorption in female rabbits was found to be greater than 1260 milligrams per kilogram and less than 3160 milligrams per kilogram.

There was one death and one survival at 2000 milligrams per kilogram.

The compound was classed as mildly toxic by skin absorption in female rabbits.

YOUNGER LABORATORIES

Fred M. Younger

BY: FRED M. YOUNGER

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WATER_PCB-SD0000073059

TABLE I

THE ORAL LD_{50} OF 'Aroclor 1262' FOR RATS

Sample Fed As A 50.0% Solution In Corn Oil

Animal No. - Sex	Weight Gm.	Dose Mg./Kg.	Fate
1- Female	230	7,940	Survived
2- Female	215	7,940	Survived
3- Female	220	7,940	Survived
4- Male	235	7,940	Survived
5- Male	250	7,940	Survived
6- Male	230	10,000	Died
7- Female	215	10,000	Survived
8- Female	225	10,000	Died
9- Female	220	10,000	Survived
10- Male	230	10,000	Survived
11- Male	245	12,600	Died
12- Male	225	12,600	Died
13- Female	210	12,600	Survived
14- Female	220	12,600	Died
15- Female	225	12,600	Survived
16- Male	235	15,800	Died
17- Male	245	15,800	Died
18- Male	240	15,800	Died
19- Female	215	15,800	Died
20- Male	230	15,800	Died

DISCUSSION -

The Oral LD_{50} for male and female rats was placed at 11,300 milligrams per kilogram with lower and upper limits of 9940 to 12,880 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

Survival time was one to six days with most deaths occurring in three days.

Toxic symptoms included severe diarrhea, loss of appetite, lethargy, and increasing weakness.

At autopsy there was inflammation of the gastric mucosa, tissue edema, and liver congestion macroscopically.

WATER_PCB-SD0000073060

TABLE II

THE MINIMUM LETHAL DOSE OF 'Aroclor 1262'

BY SKIN ABSORPTION IN RABBITS

Sample Applied As A 50.0% Solution In Corn Oil

Animal No. - Sex	Weight Kg.	Dose Mg./Kg.	Weight Change 5 Days Later Kg.	Fate
1 - Female	2.2	794	- 0.1	Survived
2 - Female	2.7	1260	- 0.2	Survived
3 - Female	2.5	2000	- 0.3	Died — 7 Days
4 - Female	2.6	2000	- 0.2	Survived
5 - Female	2.4	3160	- 0.5	Died — 8 Days
6 - Female	2.7	5010	- 0.3	Died — 5 Days

DISCUSSION -

The Minimum Lethal Dose by Skin Absorption in female rabbits was found to be greater than 1260 milligrams per kilogram and less than 3160 milligrams per kilogram. There was one death and one survival at 2000 milligrams per kilogram.

The compound was classed as mildly toxic by skin absorption in female rabbits.

Survival time was five to eight days.

Toxic symptoms included poor appetite with resultant loss of weight, nervousness, increasing weakness, and sudden collapse.

At autopsy there was pulmonary hyperemia, liver discoloration, and renal congestion.

WATER_PCB-SD0000073061

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ST. LOUIS 29, MISSOURI

PHONE: TILDEN 6-2540

Certificate of Analysis

July 9th, 1962

SUBJECT -

Toxicological Investigation Of: Aroclor 1268

C+25AM

Monsanto Sample Number 44
Monsanto Project Number Y-62-42

STUDY CONDUCTED FOR -

Monsanto Chemical Company, St. Louis, Missouri

COPY

EXPERIMENTAL PROCEDURE -

A) Oral LD_{50} (Rats)

The diluted compound was fed by stomach tube to Sprague-Dawley strain albino rats.

After the approximate Minimum Lethal Dose was determined, groups of male and female rats were fed in increasing doses at increments of 0.1 fractional log intervals at four levels designed to blanket the toxicity range thereby supplying data for calculation of the LD_{50} which was done according to a modification of the method of D. J. de Beer.

Observations were made for toxic symptoms and the viscera of the animals that succumbed were examined macroscopically.

The data, together with the dilution at which the compound was fed, are shown in Table I.

B) Skin Absorption MLD (Rabbits)

The diluted compound was applied in increasing doses at increments of 0.1 fractional log intervals to the closely clipped, intact skin of New Zealand white female rabbits.

The treated areas were covered with plastic strips and the animals placed in wooden stocks for periods up to twentyfour hours, after which time they were assigned to individual cages.

Observations were made for toxic symptoms and since there were no deaths, no autopsies were performed.

The data, together with the dilution at which the compound was applied, are shown in Table II.

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PLAINTIFF'S EXHIBIT 627

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WATER_PCB-SD0000073062

SUMMARY -

Aroclor 1268

A) Oral LD_{50} (Rats)

The Oral LD_{50} for male and female rats was placed at 10,900 milligrams per kilogram with lower and upper limits of 9,590 to 12,320 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

B) Skin Absorption MLD (Rabbits)

The highest application of 2510 milligrams per kilogram was found to be non-lethal by skin absorption in female rabbits.

No higher dose was applied due to poor solubility of the compound in corn oil.

The compound was classed as not more than slightly toxic by skin absorption in female rabbits.

YOUNGER LABORATORIES

BY: FRED M. YOUNGER

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WATER_PCB-SD0000073063

TABLE I

THE ORAL LD_{50} OF 'Aroclor 1268' FOR RATS

Sample Fed As A 50.0% Solution-Suspension In Corn Oil

Animal No. - Sex	Weight Gm.	Dose Mg./Kg.	Fate
1- Female	195	7,940	Survived
2- Female	205	7,940	Survived
3- Female	215	7,940	Died
4- Male	230	7,940	Survived
5- Male	220	7,940	Survived
6- Male	245	10,000	Died
7- Female	200	10,000	Survived
8- Female	210	10,000	Survived
9- Female	210	10,000	Died
10- Male	235	10,000	Survived
11- Male	255	12,600	Died
12- Male	220	12,600	Survived
13- Female	210	12,600	Died
14- Female	215	12,600	Died
15- Female	195	12,600	Died
16- Male	240	15,800	Died
17- Male	235	15,800	Died
18- Male	220	15,800	Died
19- Female	210	15,800	Died
20- Male	230	15,800	Died

DISCUSSION -

The Oral LD_{50} for male and female rats was placed at 10,900 milligrams per kilogram with lower and upper limits of 9,590 to 12,320 milligrams per kilogram.

The compound was classed as practically non-toxic by oral ingestion in male and female rats.

Survival time was two to five days with most deaths occurring in two days.

Toxic symptoms included severe diarrhea, increasing weakness, lethargy, and loss of appetite.

At autopsy there was inflammation of the gastric mucosa, liver discoloration, and pulmonary hyperemia macroscopically.

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T A B L E II

THE MINIMUM LETHAL DOSE OF 'Aroclor 1268' BY SKIN ABSORPTION IN RABBITS

Sample Applied as a 10.0% Solution-Suspension In Corn Oil

Animal No. - Sex	Weight Kg.	Dose Mg./Kg.	Weight Change 4 Days Later Kg.	Fate
1 - Female	2.5	794	0.0	Survived
2 - Female	2.3	1000	+ 0.1	Survived
3 - Female	2.6	1260	0.0	Survived
4 - Female	2.4	1580	- 0.1	Survived
5 - Female	2.5	2000	- 0.2	Survived
6 - Female	2.4	2510	- 0.2	Survived

Note: The compound was applied to animals #4, #5, and #6 over a period of three days to avoid run-off.

DISCUSSION -

The highest application of 2510 milligrams per kilogram was found to be non-lethal by skin absorption in female rabbits.

The compound was classed as not more than slightly toxic by skin absorption in female rabbits.

No higher dose was applied due to poor solubility of the compound in corn oil.

There was lethargy and reduced appetite for several days at the higher dosage levels but no real symptoms of systemic toxicity were observed.

WATER_PCB-SD0000073065

Industrial **BIO-TEST** *Laboratories, Inc.*
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C425AM

REPORT TO

MONSANTO CHEMICAL COMPANY

SUBACUTE DERMAL TOXICITY OF

AROCLOR 4465

PLAINTIFF'S EXHIBIT 628

WATER_PCB-SD0000073066

REPORT TO

MONSANTO CHEMICAL COMPANY

SUBACUTE DERMAL TOXICITY OF

AROCLOR 4465

I. Introduction and Outline of Procedure

A sample identified as Aroclor 4465 was received from Monsanto Chemical Company for evaluation of 20-day subacute dermal toxicity in albino rabbits.

Skin applications of the test material, in the form of a corn oil solution, were made daily to three test groups consisting of two rabbits each (one male and one female) for a period of 20 days. These test groups corresponded to daily dermal doses of 75, 150, and 300 mg/kg/day respectively.

In addition to the three test groups, a treated control group of two rabbits was also employed. The animals in this group received daily dermal applications of corn oil comparable to the volume administered to the highest test dose group.

The rabbits in all groups were housed individually over the period of investigation and observations were made with respect to body weight effects, incidence of mortality, reactions displayed and status of the

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hematopoietic and urinary systems. Special emphasis was placed on observations for skin irritation produced by the test material.

Following the 20-day application period, the rabbits were kept under observation until an additional 14 days had elapsed. At the end of this period, final mortality tabulations were made and all surviving rabbits from each test and control group were sacrificed for pathologic studies. Gross autopsies were performed and a complete set of representative tissues and organs was taken from each rabbit and preserved in formalin. Microscopic examinations of selected tissues and organs were made to ascertain the presence or absence of histopathologic change as a result of dermal applications of the test material at the dose levels employed.

The dosage schedule and other pertinent data are presented in Table I.

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TABLE I

20-Day Subacute Dermal Toxicity - Albino Rabbits

Dosage Schedule

Group	Number of Animals	Dose * (mg/kg/day)	Number of Scheduled Consecutive Applications
T-C	2	**	20
T-I	2	75	20
T-II	2	150	20
T-III	2	300	20

* Administered as a 4.0 per cent solution (w/v) in corn oil.

** The treated control rabbits received doses of corn oil comparable in volume to that applied to the rabbits of the high dose group.

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II. Investigational Procedure

A. Experimental Animals

The animals employed in the 20-day subacute dermal toxicity study were adult, New Zealand strain albino rabbits. The body weights of the test animals were in the two-to-three kilogram range. A total of 8 adult rabbits were selected from a larger population after examination of each animal for general physical well-being. Each animal selected for the experiment was housed individually in a wire-bottomed stainless steel rabbit cage for the duration of the test. All rabbits were fed a standard laboratory rabbit ration* plus water ad libitum.

B. Method of Application

In preparation for the test, the back of each rabbit was shaved using electric clippers. The exposure site thus prepared on each animal constituted approximately ten per cent of the total body surface area. The animals were then returned to their stock cages, and 24 hours were allowed to elapse before the first percutaneous applications were made. This period permitted the skin to recover from the slight disturbance of the stratum corneum caused by the clipping procedure and also permitted the healing of any microscopic abrasions possibly produced during the shaving procedure.

At the end of the 24-hour recovery period, the calculated doses of the test material in the form of a 4.0 per cent (w/v) corn oil

* Rockland Rabbit Ration, Rockland Farms, New City, New York.

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solution were gently distributed (without rubbing) over the entire application sites on the test rabbits.

The animals in the treated control group were treated in the same manner as those in the test group with the exception that corn oil alone was applied to the skin.

Following the dermal applications, the animals were returned to their individual cages to await testing on the following day.

The above schedule was followed every day, including weekends, for a total of 20 consecutive days.

C. Body Weight Effects

On the morning of the first test day, the body weight of each rabbit in every group was determined and recorded. Thereafter, individual weighings were made weekly and the data recorded as an index to body weight effects. Dose calculations were made weekly to adjust for changes in body weight.

D. Mortality and Reactions

Checks for mortality and abnormal behavioral reactions were made daily during the 20-day test period as well as during the 14-day observation period. Special emphasis was placed on observations for local skin reactions in order to determine the degree of skin irritation produced by the test material.

E. Hematologic Studies and Urine Analyses

Blood studies including determinations of hemoglobin concentration, erythrocyte count, and both total and differential leukocyte

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counts, were made at the beginning of the study and at the end of the 20-day test period. Urine analyses for reducing substances and microscopic elements were also done at these time intervals. The blood studies and urine analyses were done on the individual rabbits in each group.

F. Gross and Microscopic Pathologic Studies

Arrangements were made to subject any animal which might die during the test to a gross autopsy. Also, in those instances where post-mortem changes were not advanced, sections of representative tissues and organs were scheduled to be taken for histopathologic study.

At the conclusion of the investigational period, all surviving rabbits in each group were sacrificed and gross and microscopic studies were performed. The following tissues and organs were included in the microscopic studies: heart, aorta, lung, trachea, liver, gall bladder, pancreas, esophagus, stomach, small intestine, caecum, colon, spleen, cervical and mesenteric lymph nodes, kidney, urinary bladder, testis, ovary, prostate, uterus, pituitary, adrenal gland, submaxillary salivary gland, thyroid, parathyroid, skeletal muscle, bone marrow, peripheral nerve, spinal cord, brain, and skin.

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III. Results

A. Body Weight Data

Weekly individual body weights for each test group and the control group are assembled in Table II.

TABLE II

Body Weight Data

Group	Animal Number and Sex	Individual Body Weights (Kilograms) Test Day Number: 0	7	14	20	Observation Day Number 14
T-C	1-M	2.31	2.35	2.49	2.57	2.74
	2-F	2.50	2.63	2.68	2.80	2.96
T-I	1-M	2.13	2.13	2.30	2.40	2.51
	2-F	2.52	2.55	2.58	2.73	2.91
T-II	1-M	2.04	1.97	1.98	1.98	1.87
	2-F	2.72	2.55	2.55	2.10	(2.04)
T-III	1-M	2.38	2.10	(1.87)	-	-
	2-F	2.78	2.55	1.96	(1.87)	-

Note: Figures in parentheses represent autopsy weights.

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B. Mortality

The mortality data are summarized in Table III. The data indicate the number dead and the total number of doses received prior to death. The female of Group II died on the third day of the 14-day observation period.

The mortality data were statistically analyzed employing the technique of Litchfield and Wilcoxon*, and the mean subacute percutaneous lethal dose (LD_{50}) was calculated together with the $LD_{0.01}$ and the $LD_{99.99}$. For the purpose of these calculations the test period was assumed to be 34 days, i.e. a 20-day application period plus a two-week observation period. All animals that died during the interval, at each dose level, were used in establishing the per cent mortality for the dose level. The data are presented in Table IV and are graphically illustrated in Figure 1.

* J. T. Litchfield, Jr. and F. Wilcoxon, "A Simplified Method of Evaluating Dose-Effect Experiments", J. Pharm. & Exp. Ther., Vol. 96, No. 2; pp. 99-113 (1949).

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TABLE III

Summary of Mortality Data

Group	Number Tested	Number Dead	Sex	Number of Consecutive Doses Received Prior to Death
T-C	2	0	-	-
T-I	2	0	-	-
T-II	2	1	F	20
T-III	2	1	M	11
		1	F	19

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TABLE IV

Statistical Analysis of Mortality Data

Dose mg/kg/day	Number Dead	Number Tested	Observed Per Cent Dead	Expected Per Cent Dead
75	0	2	0	0
150	1	2	50	50
300	2	2	100	100

Mean Subacute Dermal Lethal Dose (LD_{50}) = 150 mg/kg/day*
95 Per Cent Confidence Limits of LD_{50} = 105 to 214 mg/kg/day
Subacute Dermal $LD_{0.01}$ = 76 mg/kg/day
Subacute Dermal $LD_{99.99}$ = 300 mg/kg/day

* The LD_{50} specifically refers to the dose which, administered each day over a 20-day period, would be expected to kill 50 per cent of the animals so dosed within the 20-day dosing period plus an additional 14 days during which the test material is not applied.

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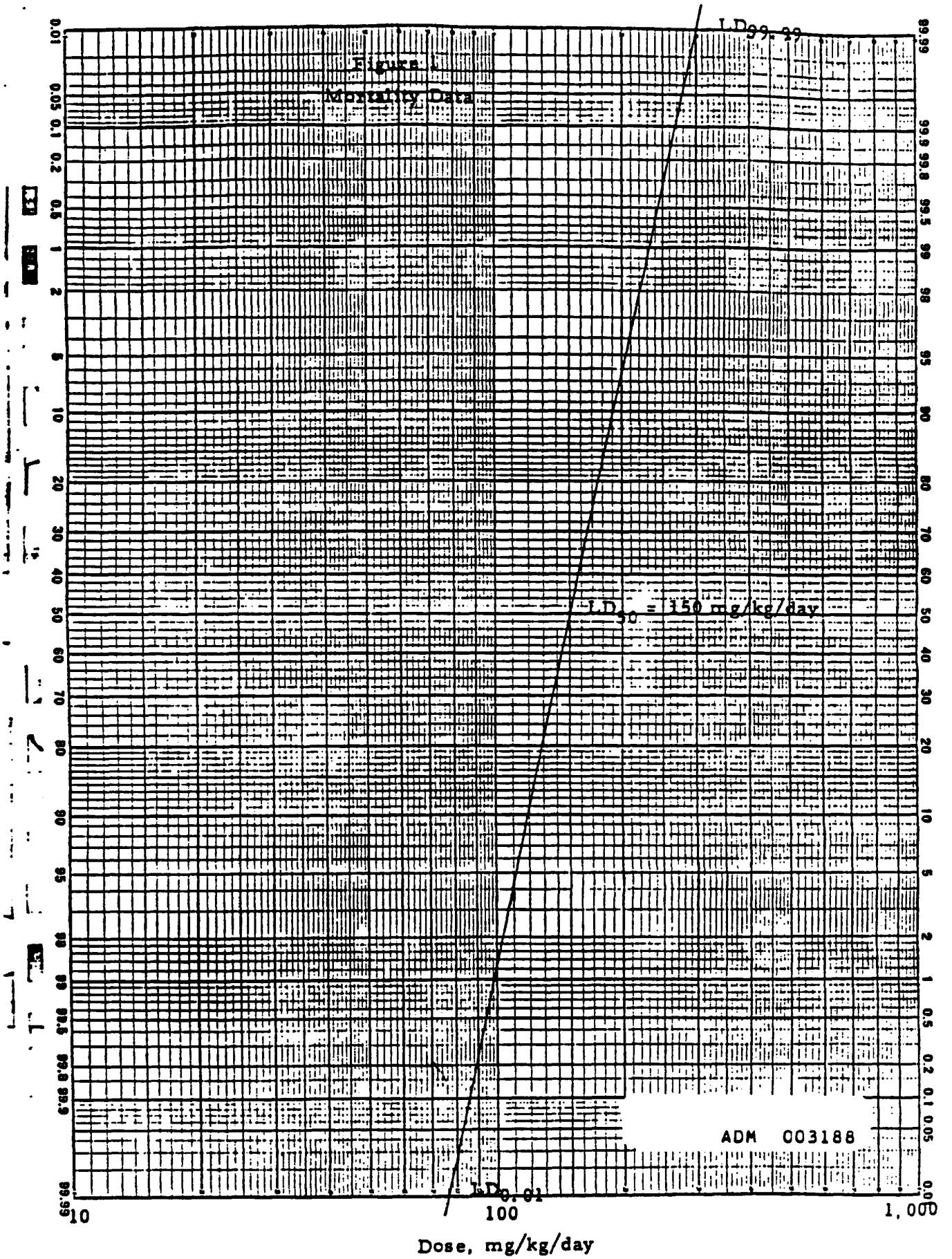

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C. Reactions

1. Behavioral Reactions

No untoward behavioral reactions were noted among the animals receiving doses of 75 mg/kg/day.

Generalized inactivity, weakness, lassitude, and loss of appetite were exhibited by rabbits receiving doses of 150 and 300 mg/kg/day respectively. These symptoms progressed in intensity and eventually ended in profound prostration and death in all but one rabbit in these dose groups. The surviving male in the 150 mg/kg/day dose group continued to show the above reactions during the 14-day observation period, but to a lesser degree than during the dosing period.

2. Local Skin Reactions

The skin at the application site of animals in all test groups became dry after the tenth application of the test material and remained in this condition throughout the test period. During the 14-day observation period, desquamation occurred and by the end of this period the skin of surviving animals appeared normal.

D. Hematologic Studies and Urine Analyses

Values for hematologic data and the results of urine analyses obtained on surviving test animals at the completion of the dosing period did not differ significantly either from those recorded initially or from the corresponding data secured from the treated control animals.

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E. Pathology

1. Gross Pathologic Findings

Complete necropsies were performed upon all animals that died during the test and upon all animals sacrificed at the end of the observation period. No gross pathologic findings were noted among rabbits receiving doses of 75 and 150 mg/kg/day respectively. Rabbits in the 300 mg/kg/day dose group showed liver discoloration (lighter in color) but otherwise no hepatic alterations were seen upon gross examination. All other tissues and organs examined from these animals were comparable to those of treated control animals.

2. Microscopic Pathologic Findings

Microscopic examinations were conducted upon the tissues and organs taken from all sacrificed animals. Animals that died during the test were examined grossly before advanced post-mortem changes had taken place and, consequently, tissue and organ specimens could be and were examined microscopically from these rabbits as well.

No significant histopathologic alterations were noted in any of the tissues and organs of rabbits receiving doses of 75 mg/kg/day.

Animals in the 150 mg/kg/day dose group exhibited mild to moderate hepatic necrosis characterized by multiple areas of individual or groups of hepatic cell degeneration with associated mononuclear infiltration. Vacuolization of liver cells, indicative of incipient liver

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necrosis, was noted among rabbits receiving doses of 300 mg/kg/day. These findings were considered to be directly related to the percutaneous absorption of the test material. All other tissues and organs examined from these animals were comparable to those of treated control animals.

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IV. Summary

A. Body Weight Data

Examination of the body weight data revealed a moderate to severe adverse effect among animals receiving doses of 150 and 300 mg/kg /day respectively. The body weight data of animals in the 75 mg/kg/day dose group compared well with those of the treated control group.

B. Mortality and Reactions

The 20-day subacute dermal mean lethal dose (LD_{50}) of Aroclor 4465 for the albino rabbit was found to be 150 mg/kg/day.

Generalized inactivity, weakness, lassitude, and loss of appetite were exhibited by rabbits receiving doses of 150 and 300 mg/kg/day respectively. No untoward reactions were noted among animals in the 75 mg /kg/day dose group.

The skin at the application site of animals in all test groups became dry during the application period. Desquamation occurred during the 14-day observation period and by the end of this period the skin of surviving animals appeared normal.

C. Hematologic Studies and Urine Analyses

Hematologic data and results of the urine analyses for surviving test group animals compared well with those of the treated control group animals.

D. Pathology

1. Gross Pathologic Findings

No significant gross pathologic findings were noted among

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animals in the 75 and 150 mg/kg/day dose groups. Rabbits receiving doses of 300 mg/kg/day revealed liver and discoloration (lighter in color). All other tissues and organs examined from these animals were comparable to those of treated control animals.

2. Microscopic Pathologic Findings

No significant histopathologic tissue alterations were noted among animals receiving doses of 75 mg/kg/day.

Mild to moderate hepatic necrosis, characterized by multiple areas of individual or groups of hepatic cell degeneration with associated mononuclear infiltration, was noted among rabbits in the 150 mg/kg /day dose group. Animals in the 300 mg/kg/day dose group exhibited vacuolization of liver cells indicative of incipient liver necrosis. These findings were considered to be directly related to the percutaneous absorption of the test material. All other tissues and organs examined from these animals were comparable to those seen in the treated control animals.

Respectfully submitted,

INDUSTRIAL BIO-TEST LABORATORIES, INC.

Report prepared by: Richard J. Palazzolo, B.S.
Departmental Director
Acute Toxicity Department

Report approved by: John H. Kay, Ph. D.
Associate Director

May 17, 1963

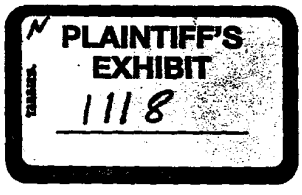
ADM 003193

WATER_PCB-SD0000073082

PCB ENVIRONMENTAL POLLUTION ABATEMENT PLAN

Introduction

On 15 October the "AD HOC" Committee consisting of Messrs. M. Farrar, P. Hodges, E. John, W. Richard, and E. Wheeler issued a report summarizing the polychlorinated biphenyl (PCB) pollution problems from the known available information to date. Out of this report came considerable information, conclusions, and recommendations which we have attempted to tie together into a plan of action in this document. Our objective has been to take a reasonable and responsible approach to the entire problem. Before we get into the problem, we should clarify the meaning of PCB, the nature of the entire line, and how these tie into our product line of Aroclors.



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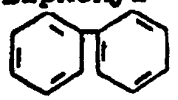
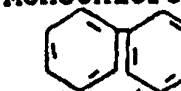
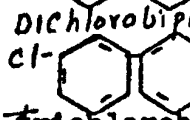
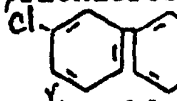
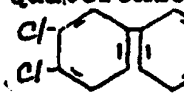
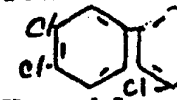
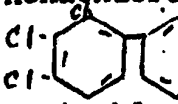
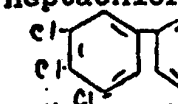
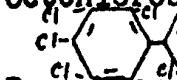
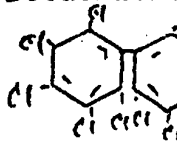
Monsanto entered the Aroclor market in 1930 by acquiring Swann Chemical ~~Electrical~~ Company or known today as our Anniston, Alabama plant. The first load of Aroclor which incidentally was Aroclor 1254 -- went out of Anniston, Alabama to GE in 1931: Since that time the market has grown to 170 to 200M lbs worldwide.

Chemical	Monsanto Product Line	Nature of Material at Ambient
Biphenyl  ~~Solid at~~ ~~Sublimes at~~		Solid
Monochlorobiphenyl 	Aroclor 1221	thin liquid (oil)
Dichlorobiphenyl 	Aroclor 1232	thin flush water
Trichlorobiphenyl 	Aroclor 1242	oily type fluid material
Quaterchlorobiphenyl 	Aroclor 1248	Thicker - transmission oil
Pentachlorobiphenyl 	Aroclor 1254	Heavy-Molasses
Hexachlorobiphenyl 	Aroclor 1260	Thick - tar
Heptachlorobiphenyl 	Aroclor 1262	Very thick - liquid
Octochlorobiphenyl 	Aroclor 1268	Solid
Decachlorobiphenyl 	Aroclor 12715	Solid

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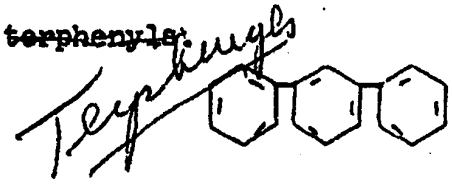
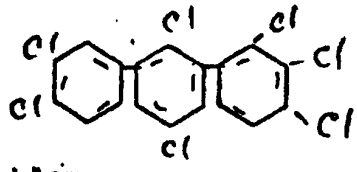
Total possibility are 210 theoretically possible chlorinated biphenyls ~~terphenyls~~.



Santowax or terphenyl

Solid



Aroclor 5460

Solid

II. Problem

Damage to the ecological system by contamination from polychlorinated biphenyl (PCB).

III. Extensiveness

The problem involves the entire United States, Canada, and sections of Europe especially the United Kingdom and Sweden. As the investigation broadens other areas of Europe, Asia and Latin America will surely become involved. Evidence of contamination have been shown in some of the very remote parts of the world. The involvement could and most likely will follow the DDT investigations.

IV. Nature of the Problem

Professors Widmark and Jensen of the Institute of Analytical Chemistry at Stockholm, Sweden, in November 1966, announced and confirmed findings PCB in fish, birds, and eggs. Subsequent findings were made in 1967 in Great Britain. In February 1969, Professor Risebrough of the University of California published an article in the San Francisco Chronicle relaying his findings of PCB in the environment of the United States. Monsanto confirmed the presence of PCB's in mid-1969 and confirmed the adequacy of work by Widmark and Jensen and others; truly, the PCB's are a worldwide ecological problem.

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Analysis indicates the environmental presence of the 5 and higher chlorinated biphenyls which take the appearance of Aroclor 1254 and Aroclor 1260. We have strong indications that Aroclor 1242 or at least part of it degrades biologically. Since the Aroclor 1242 contains aroun 7 percent of the 5 chlorine biphenyl or higher we cannot rule out the possibility that the observations may be a concentration affect of the higher chlorinated biphenyls of Aroclor 1242.

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To date ~~there~~ we have ~~been~~ no confirmed reports of finding Aroclor 1242 present in the environment (except ~~outside~~ in the effluent of our plants ~~where we know Aroclor 1242 is present~~). or in the streams and mud below our own plants at Anniston and Sauget

The seriousness of the problem can best be spelled out as follows:

1. Fish - Marine or aquatic species concentrate PCB in the fatty tissue. Toxic is small quantities (down to 5 ppb) to sensitive marine life such as shrimp.

2. Birds - Predatory species feeding on the marine or aquatic life can further concentrate PCB to possible harmful effects. Specifically in birds PCB can affect the calcium metabolism leading to egg shell imperfections which prevents proper hatch of the young. In fact, Monsanto has confirmed the eggshell by feeding chickens, a high order of the species, PCB's in controlled tests.

3. Man - There is no harmful effect known to man or other mammals after 40 years of production. Investigations are underway by various sources.

4. Political and Public Emotion - PCB's are falsely linked with DDT because PCB's show up in the analysis for DDT. PCB's are linked with other permanent type chlorinated hydrocarbon pesticides. This becomes particularly serious since about every article of food in the country is being examined for a trace of these materials.

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More than 50 samples and the majority of them have contained in anniston samples

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V. Effect on Monsanto

Business potential at stake on a worldwide basis:

Fluids	Plasticizers	Total/Year
70M lbs.	34M lbs.	104M lbs.
$16M	$6M	$22M
$6-8M G.P.	$2-3M G.P.	$8-11M G.P.

Already competition is using certain data against us in competitive situations.

A. Legal Liability

Direct lawsuits are possible. The materials are already present in nature having done their "alleged damage". All customers using these products have not been officially notified about known effects nor do our labels carry this information. These are only a few of the possible legal implications which would best be covered by the legal department.

B. Public Image

The corporate image of Monsanto as a responsible member of the business world genuinely concerned with the welfare of our environment will be adversely affected with increased publicity.

The evidence proving the persistence of these compounds and their universal presence as residues in the environment is beyond questioning. This combined with certain scare publications is certai to give an adverse image. Guilty by association (with DDT) will prevail as the background while actual facts may be sparse.

C. Customer Relations

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Some customers who presently use these materials will be "scared off" to other competitive products. Products associated with the same name or "trademark" will be adversely affected ie., Therminol, Pydraul and Aroclor. Competitors will use the information for an

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influence on Monsanto products.

Customers will seek other "outs" rather than become involved.

VI. Effect on Customers and Ultimate Consumers

One of the unique features of PCB's is their fire resistance. Here the basic decision whether to risk lives due to fire or risk extinction of, some species of birds. In this case the PCB would probably be accepted as a necessary pollutant and tolerated under controlled conditions.

A. Electrical Industry - Capacitors and Transformers use Aroclor because it is the best inexpensive dielectric fluid available.

B. Food Processing - Bulk "deep frying" units for potato chips, fish, and doughnuts use the fire resistance fluid as an indirect heating medium.

C. Die Caster -- and other hot metal working industries fire resistance fluids to protect the workers.

Affects a wide range of plastics and adhesives because the PCB serves as the plasticizer.

A wide range of paints and coatings are affected. The "Carbonless" carbon paper used so widely would disappear.

VII. Involvement With Other Producers

Although Monsanto is most probably responsible for the U.S. contamination and jointly responsible with MCL for the United Kingdom problem, we cannot accept responsibility for the world. There are five known producers in the free world, several possible producers behind the iron curtain and couple of additional companies making overtures about entering the business. Monsanto representatives have on one occasion discussed this problem with a couple of these producers but they expressed no great concern. In fact, it is highly possible that one of

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these manufacturers is dumping his waste into the Rhine River. Certainl any action taken by one producer will most assuredly affect the other. It is entirely possible that a joint plan of action could be developed but will most probably have to be spearheaded by Monsanto. It is also likely that producers of other chlorinated products used with PCB's will be dragged into the investigation.

VIII. Sources of Contamination

Although there may be some soil and air contamination involved, by far the most critical problem at present is water contamination. To our knowledge to date the contamination can be broken down into two general categories, open and indirect pollution.

A. Open Pollution - Our manufacturing facilities sewered a sizeable quantity of PCB's in a years time.

1. Fluids

Fluids are probably the most open source of pollution because of their mobility. They also may be the least serious because they are generally the lower chlorinated materials.

2. Electrical

Electrical customers have in the past sewered their wastes.

3. Heat Transfer

Heat transfer customers have sewered their objectionable and their spilled material.

4. Industrial

These fluids have generally been sprayed into drains, washed down sewers and generally regarded as very harmless.

All of the fluids have had the "pink" constituent dumped on dirt roads as a "dedusting agent" which inadvertently found its way back to the stream.

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5. Plastics

The plastics are not as mobile as the fluids so therefore they have not found and cannot find their way back to streams in open pollution.

B. Indirect

Shipping containers and the cleaning thereof for subsequent use a source of contamination.

1. Fluids

a. Electrical - Disposal of "burned out" transformer and capacitors may find its way back to streams. Scrap units (new) are generally disposed of in land fills but could possibly get back to the stream.

b. Heat Transfer - Leaks could contaminate.

c. Industrial - Cross product contamination carried out of an air compressor. Residual material carried on parts.

2. Plasticizers

a. Process Contamination from Washing

(1.) Environment Contamination

Swimming pool paints

Incineration of wax coatings

Traffic paints

(2.) Product Contamination

Coating for tank lining

Printing inks and paper coatings

Certain adhesives

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IX. Recent Technical Changes Which Have Bearing on the Contamination

A. Fluids

The sources of pollution were pointed out as they have been in the past because we are dealing with that quantity of material in the

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environment today which was deposited over the past forty years. We must state that responsible people throughout the industry have taken corrective action to reduce contamination in the last two years. There have also been technical advances which have brought about the use of lower chlorinated biphenyls which may be an advantage because to date the low chlorinated ones have not been identified present in nature.

1. Electrical - The large customers have established collect systems and the waste is recovered. Incinerators are being investigated and built for the disposal of the materials. There has been a shift away from the higher chlorinated types products and could probably shift almost entirely away from those products.
2. Heat Transfer - System have been tightened up and redesigned to confine the contents. Here, too, the trend has been to shift away from the higher chlorinated materials.
3. Industrial - Settling ponds have been built by the large manufacturers to catch the material and decant off the PCB for reprocessing. The trend here as the other fluid areas has been towards the lower chlorinated materials.
4. Plants - The plants effluent has been passed through limestone which provides surface to catch some of the material. But high concentrations can be found in our effluent (that is relative to those findings in nature causing the problem).

B. Plasticizer

Quite opposite to fluids the trend in plasticizer Aroclor has been to the higher chlorinated biphenyls. In plasticizers the lower chlorinated biphenyl will not be an acceptable solution however, the lower chlorinate terphenyls could offer a possible solution.

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X. Courses of Action

A. Do Nothing

We cannot deny the findings and the acquisitions by the various agencies. If we took no action we would likely face numerous suits. We would let government tolerances be based on public and political pressure along with any experimental or developed data which they may generate. We would most likely be forced out of this business. Other product areas would be adversely affected. We would project an image as an irresponsible member of the business world. Project poor customer relations. The only advantage to this technique offers is it reduces the cost but this too must be weighed against potential loss of business.

B. Discontinue Manufacture of All Polychlorinated Biphenyls (PCB)

Although we all realize this could be an eventually unfortunately the solution is not this simple. Assuming we did stop manufacture immediately, the pollutants are present in the environment, the liability is present and possibly by the shifting to the lower chlorinated materials and the recovery techniques the contamination may already be reduced to an acceptable level. Obviously the entire business would be lost without any or very few substitutes to be offered. Other product areas would be affected. Financial loss could be considered due to raw material contracts, customer contracts, and royalty -- secrecy contracts. Competition would take advantage on all fronts. We would be admitting guilt by our actions. Loss of capitol investment in the plant, associated utilities, and associated processes. We would possibly gain a little public image on this action.

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C. Respond responsibly, admitting that there is growing evidence of environmental contamination by the higher chlorinated biphenyls and take action as new data is generated to correct the problem.

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This approach would enable us to phase out the higher chlorinated materials in many applications where they are no longer necessary or really desired. Wecould maximize the corporate image by publicizing this act. We would reduce a known pollutant. Additionally we could gain precious time needed to develop new products and investigate further the lower chlorinated materials. As new research data is generated our course may be altered considerably. Certain limited actions may reduce or limit the problem.

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XI. Recommended Course of Action

Based on the information available today the only recommendation we can honestly make is respond responsibly admitting that there is growing evidence of environmental contamination by the higher chlorinated biphenyls and take action as new data is generated to correct the problem.

XII. Implementation of the Recommended Course of Action

A. Immediate (By 12-1-69)

1. Set up a task force under a project manager or the equivalent responsible for initiating, directing and implementing all action that Monsanto decides to take. This includes sufficient budget necessary to cope with the immediate problems. This task force should include representatives from Medical, Legal, Research and the two involved Marketing Groups and Public Relations and must conduct liaison with MCL and other locations involved in the problem.

2. Decide on timing and content of any public and/or customer notification of PCB problem.

B. Interim (Within 3 months)

Fluids	Plasticizers
1. Confirm Aroclor 1254/Aroclor 1260 are found in the environment.	1. Announce differential between fluids/plasticizer uses.
2. Publicize the difficult anal. tasks.	2. Announce safety of other PCB's/ chlorinated terphenyl.
3. Protect other PCB/chl. terph.	3. Educate customers on control of effluent for all products.
4. Announce plans to reformulate certain Therminols and Pydraul where control of the product is difficult.	4. Initiate program to develop A/ 1254 & 1260 substitutes

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5. Emphasize better control over other Aroclor 1254 & 1260 uses.

5. Investigate with manufacturer the feasibility of alternate products.

6. Initiate customer education or need for effluent control of all products.

~~6. Analyze 1242~~

7. Determine composition of all PCB's.

Develop a comprehensive Program

C. Short Term (within the next 12 months)

1. Research - Expand program for more meaningful biodegradation studies and confirming analytical results. Expand toxicity studies. Follow developments concerning publicity and those developments covering political implications of PCB contamination.

Medical

2. Marketing - Discontinue or substitute replacement products for those applications of Aroclors 1254 and 1260 where the Aroclor remains mobile.

Work with customers to clean up plants on other Aroclors. Report the habitual violators or "do nothings" to the product group.

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Reclaim or safely dispose of fluids.

Consider renaming products that do not contain PCB. Follow and report market developments such as customer disposal systems. Follow and report any political or public feedback which may affect the contamination problems and must be coordinated with Medical, Research and Legal.

3. Production - Clean up plants and stop gross contamination.

4. Legal - Define our present position, recommend reasonable action that will not unduely alarm the market but reduce the exposure in terms of liability. Coordinate recommendations with Marketing

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5. Public Relations - Publicize actions where believed advantageous Certainly discussions should be held with other producers within same period to determine their planned course of action, if any.

D. Long Range Tentative Outline (From 1 year to 3 years)

Realizing that the comprehensive program must be outlined the "Long Range Tentative Outline" is meant to serve as a guide: All aspects of this program should be reviewed quarterly by Organic Management.

1. Research-Medical

Continue biodegradation studies and analytical support

Isomer distribution

Toxicity and metabolism studies

Water soluble removal

Incineration analytical support

Confirmation analytical

Contract academic research for reference

Develop new and improved formulations

2. Manufacturing

a. Process Research and Development

(1.) Identification of typical Aroclor isomers

(2.) Develop control for effluent composition

(3.) Test substitute formulations, etc.

(4.) Develop new processes

b. Clean Up Plants

c. Modify processes to meet market needs

3. Engineering

a. Develop and set up on plant locations incineration systems

b. Design new processing equipment as necessary

4. Marketing

a. Specify alternates or changes

b. Customer liaison

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c. Set reclaim or disposal of fluids

d. Work on name association problems

5. Patent

Investigate trademarks registered

Cover with patents any work felt patentable

6. Environmental Control

Develop cheap disposal systems for customers

a. Incineration or pyrolysis

b. Biodegradation unit etc.

c. Consultants in pollution control

7. Legal

Investigate and define our position on Royalty secrecy agreements.

Contracts - Raw Material and Customer

8. Public Relations

Portray to public positive actions at correcting the contamination problem. Release periodical statements covering our position.

XIII. Probability of Success

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XIV. Cost of Program

Neither the program nor the costs have been clearly defined at this time However, a cost estimate of $220,000 for toxicological work alone has been presented. Tentative figures indicated under the worst conditions the entire program could run as high as $2.0-2.5M. At this stage it is very difficult if not impossible to develop a reasonable cost figure but one point is clear it will be larger than the normal research budget can handle. For this reason, assuming the approach is acceptable, we shall be forced to ask for additional appropriations to fund the program.

XV. Future

Follow developments on the problem as they unfold.

Develop an aggressive research program to confirm or deny findings and better understand the problem.

Develop costs for the duplementation of the Recommended course of action.

Develop specific actions with each department involved

Submit the actions with costs for approval

Develop a timetable to solve the overall problem.

Prepare for "precipitious pullout" or drastic legislative action althoug we do not feel this is a likely possibility.

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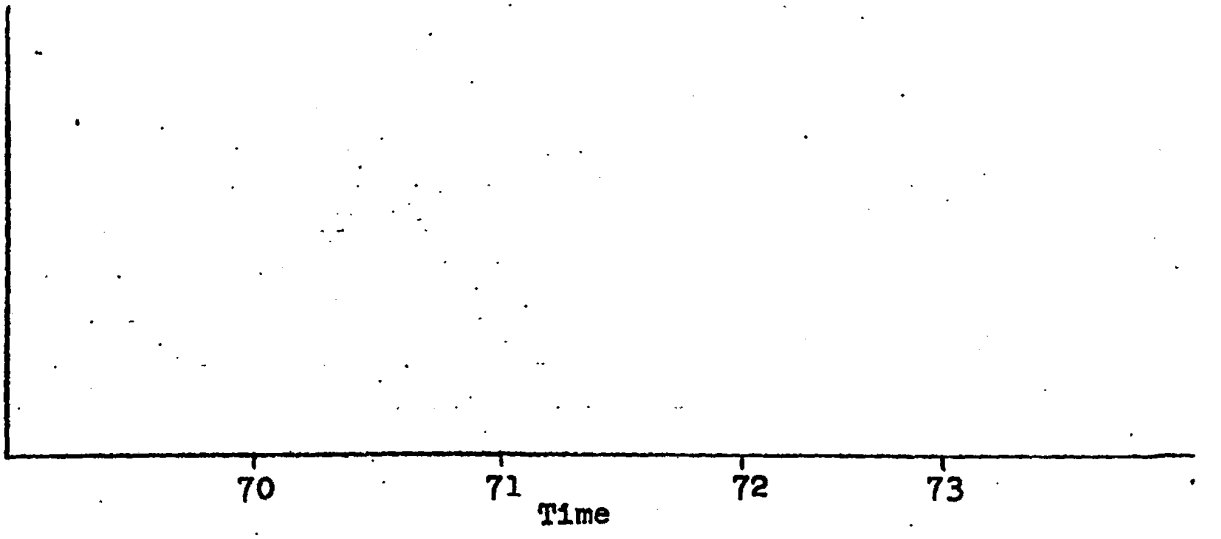
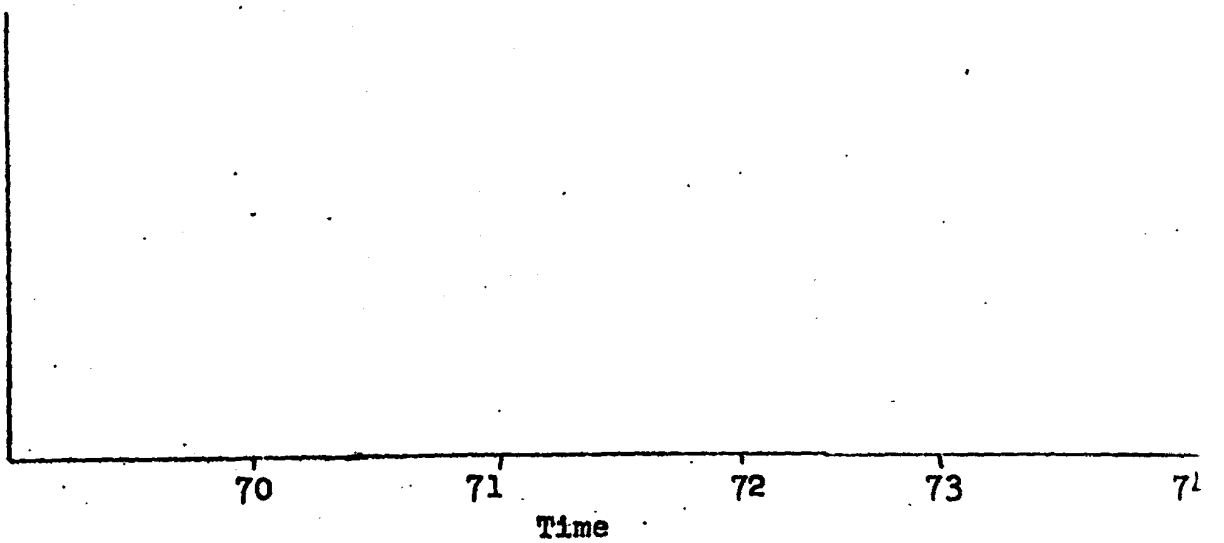
PROFIT AND LIABILITY VS. TIME

ACTION

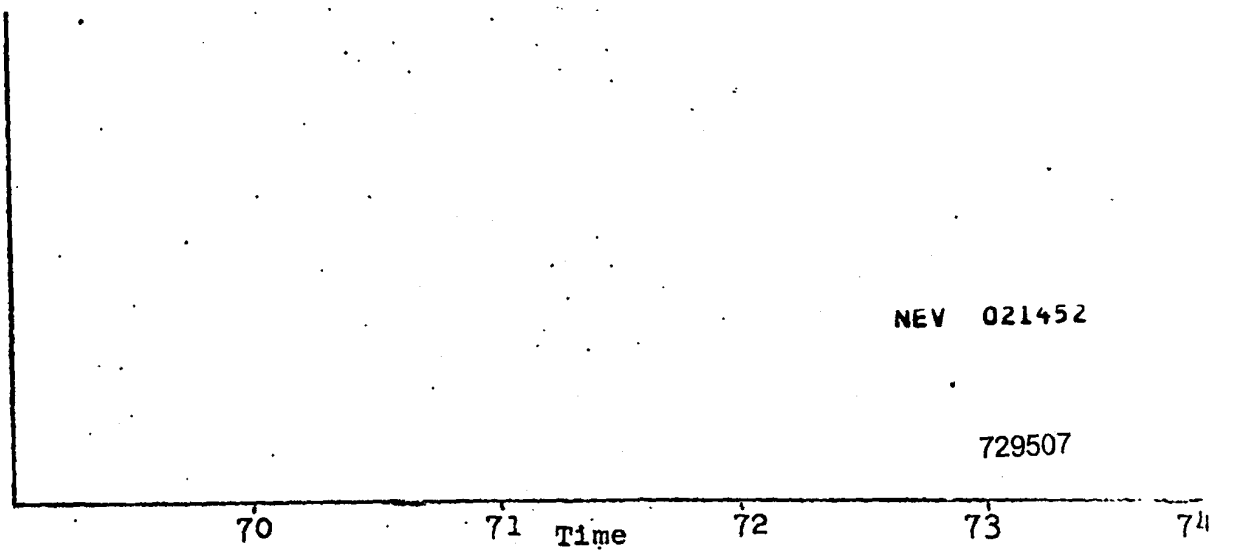
DO NOTHING



DISCONTINUE MANUFACTURE OF PCB



RESPONSIBLE APPROACH



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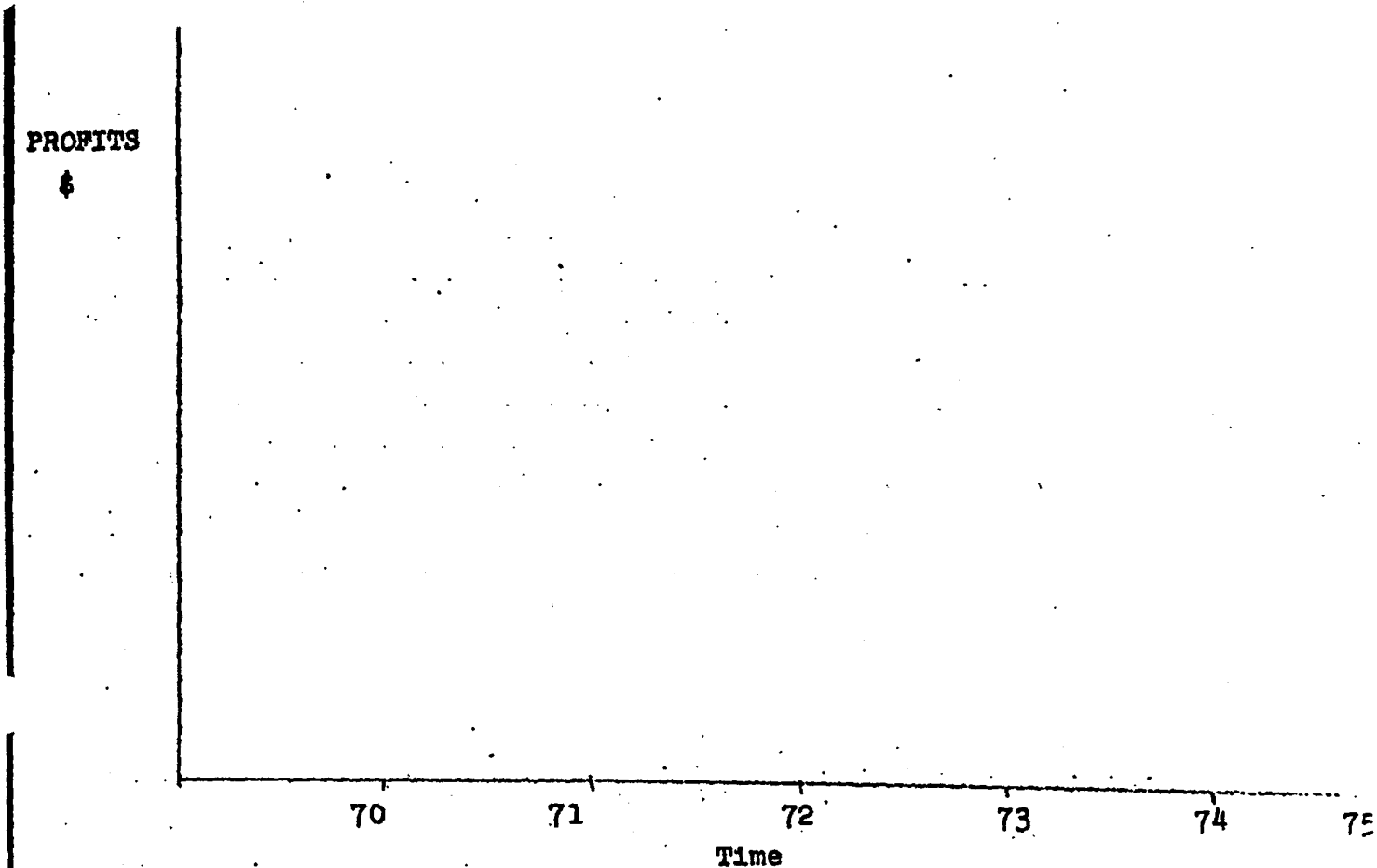
PROBABILITY OF SUCCESS



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PROFIT AND LIABILITY VS TIME

ACTION

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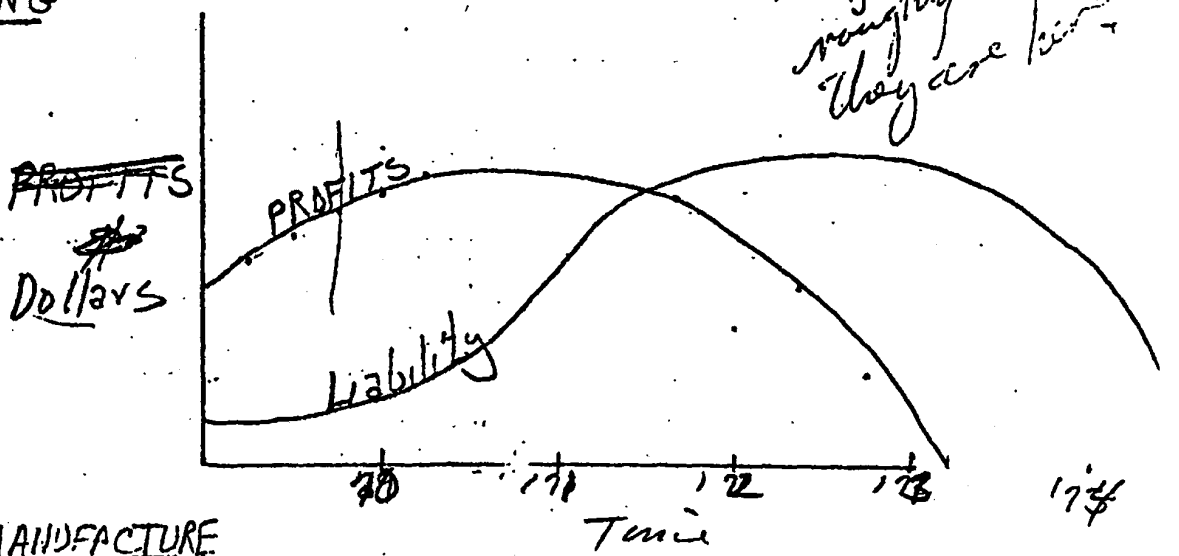
DO NOTHING



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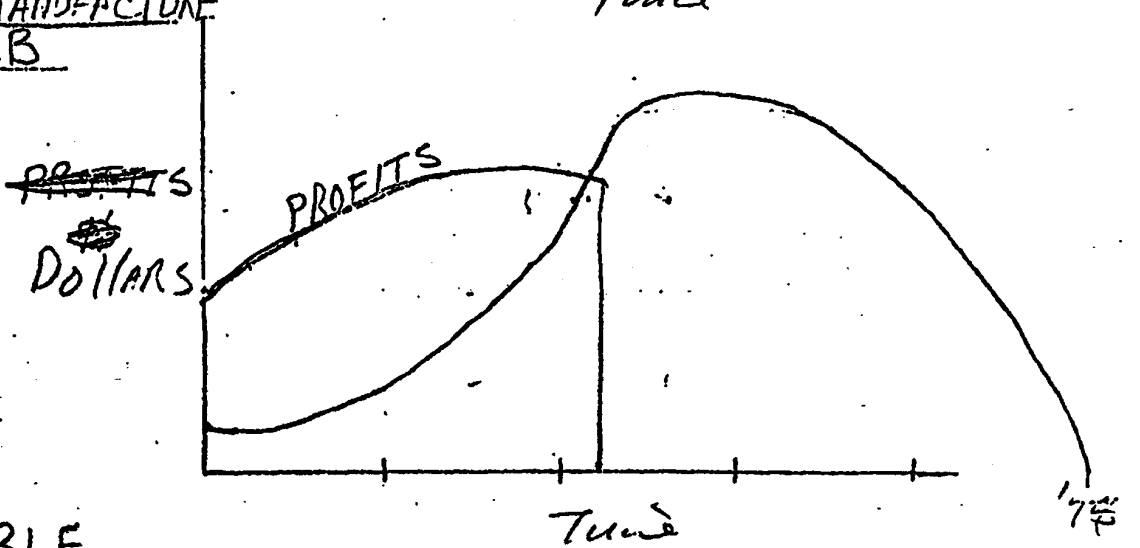
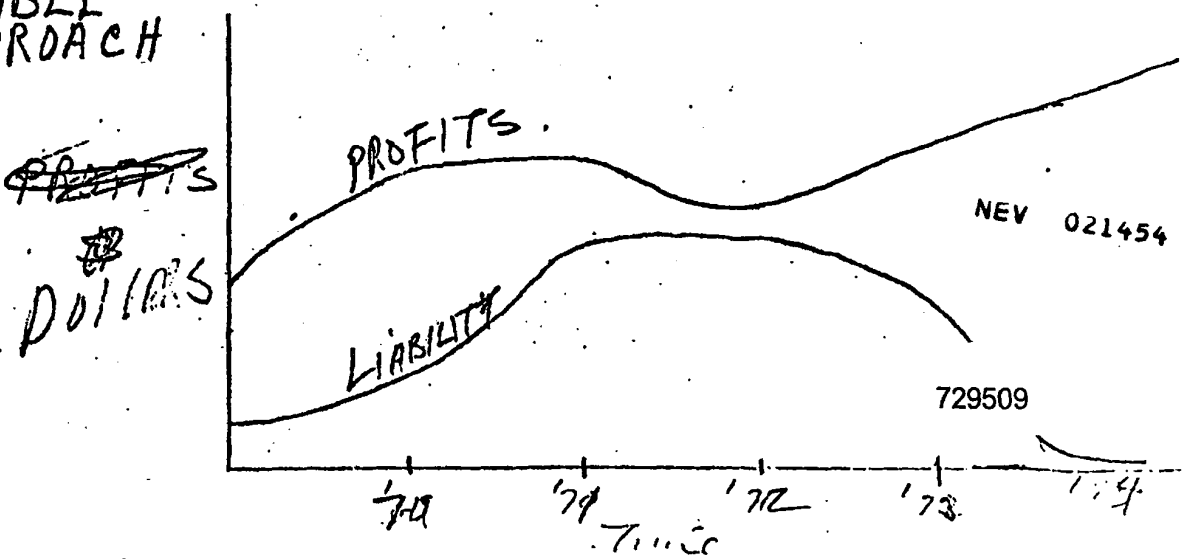


RESPONSIBLE APPROACH



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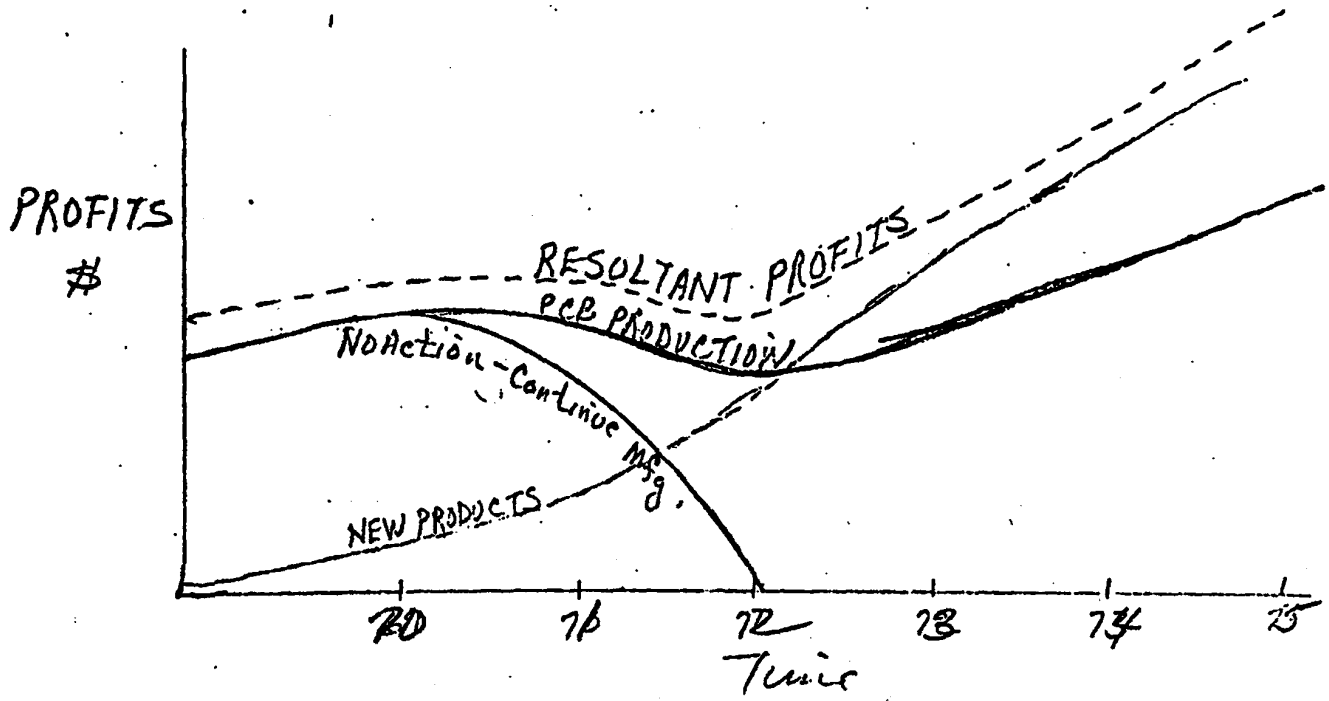
PROBABILITY OF SUCCESS



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XIII. Probability of Success

XIV. Cost of Program

$220,000 and bio with max. at $20-25M

XV. Future

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T.

AROCLOR BUSINESS TO BE DISCONTINUED IMMEDIATELY

APPLICATION	SALES M DOLLARS/YEAR	COMPLETION ~~TARGET~~ DATE
Pesticide Extender	$10	Completed
Medicinal, Dental, Cosmetic	90	June, 1970
Cutting Oils	50	June, 1970
Distributor Sales - Plasticizers		September, 1970

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FINAL REPORT OF THE
SUBCOMMITTEE ON THE HEALTH EFFECTS
OF
POLYCHLORINATED BIPHENYLS
AND
POLYBROMINATED BIPHENYLS

JULY 1976

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

WASHINGTON, D.C.

NEV 022886

PLAINTIFF'S EXHIBIT 1124

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SUBCOMMITTEE ON THE HEALTH EFFECTS OF POLYCHLORINATED BIPHENYLS AND POLYBROMINATED BIPHENYLS

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Food and Drug Administration

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SUBCOMMITTEE ON THE HEALTH EFFECTS
OF
POLYCHLORINATED BIPHENYLS
AND
POLYBROMINATED BIPHENYLS

Chairperson: A. C. Kolbye, Jr., M.D.

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I. Pomerantz, Chairperson
J. Roach
W. Trotter

2. Metabolism and Biochemical Toxicity

G. Fries
A. Gardner
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Y. Ku
H. Matthews, Chairperson
J. Moore

3. Animal Toxicity and Carcinogenesis

J. Buckley
L. Fishbein
G. Flamm
L. Kasza
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4. Human Exposure

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R. Rhoden
R. Shapiro

5. Staff Support

H. Gerstner
J. Moore
R. Shapiro

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Subcommittee on the Health Effects

of PCBs and PBBs

Purpose:

1. "Assemble, review and interpret data that assess the health significance of polychlorinated biphenyls."

2. "Formulate recommendations as to future research needs."

Specific Objectives:

1. Chemistry:

   Assess the impurities that may be found in PCBs and PBBs, the "hardness" of the data giving their potential for accumulating in the food chain.

2. Metabolism and Biochemical Toxicity:

   Assess the metabolism of PCBs and PBBs and the possible contribution of specific isomeric homologs to the observed toxicity; evaluate possible effects at the cellular level; and define existing dose-response relationships for the phenomena.

3. Animal Toxicity and Carcinogenicity

   Assess the short and long term effects, including carcinogenesis, of exposure to PCBs and PBBs in various animal models, their relationship to known human effects, and the establishment of dose-response curves.

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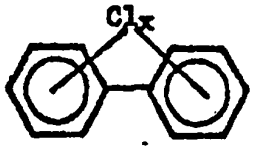
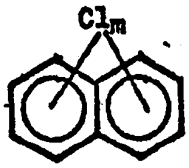
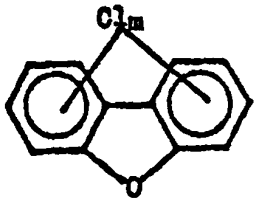
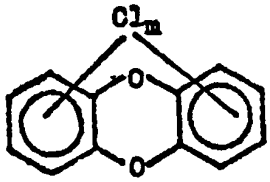
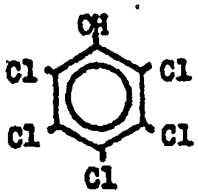
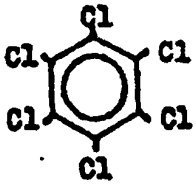
Appendix A
CHLORINATED AROMATIC COMPOUNDS
REFERRED TO IN CHEMISTRY REPORT

NAME	STRUCTURE	EXTENT OF CHLORINATION POSSIBLE	NUMBER OF CHLORINATED DERIVATIVES POSSIBLE
Chlorinated biphenyls		x= 1-10	209
Chlorinated naphthalenes		m=1-8	75
Chlorinated dibenzofurans		m=1-8	135
Chlorinated dibenzo-p-dioxins		m=1-8	75
pentachlorophenol		-	-
hexachlorobenzene		-	-

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4. Human Exposure

Quantify known human exposures, accidental pulsed, and long range, their relationship to possible overt symptomatology, and the establishment of possible dose-response curves.

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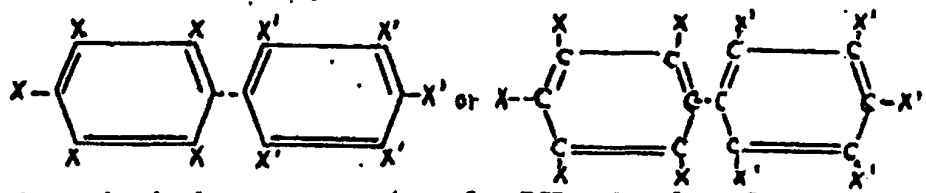
INTRODUCTION

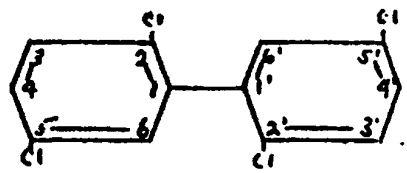
PCBs were reportedly first synthesized in 1881 by Schmidt and Schultz, but were not available commercially until 1930[1] (Hubbard, 1964). From 1930 until 1970, when their distribution in the U.S. was voluntarily restricted by Monsanto to closed systems, the use of PCBs in a wide variety of industrial applications had steadily increased.

---

1. Commercial PCBs are complex mixtures. Aroclor 1254, for example, contains 69 different molecules (Zitko, 1971), which differ in the number and position of chlorine atoms.



This is a chemical representation of a PCB molecule. C = carbon atom, X = Cl (chlorine atom) or H (hydrogen atom). The basic parent molecule contains two benzene rings connected by a carbon-carbon bond. When all the X' and X are hydrogen, the molecule is called biphenyl. When several of the hydrogen atoms are replaced by chlorine atoms, the molecule is called a PCB. X and X' are used to indicate that the chlorine atoms are on different benzene rings. For example, the chemical structure for 2,5,2',5'-tetrachlorobiphenyl is:



Positional isomers have the same number of chlorine atoms, but they are located at different positions on the ring. 2,5,2',5'-tetrachlorobiphenyl and 3,4,5',4'-tetrachlorobiphenyl (TCB) are isomers. They are different molecules with different chemical, physical, and biological properties. The chemical structure for 3,4,3',4'-TCB is:



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The problem of polychlorinated biphenyls (PCBs) became of national concern in 1971, when several accidental contaminations of foods were reported. In addition, the extent of the environmental contamination, and its persistence, were not precisely known. Subsequently, various regulatory actions were taken by the concerned agencies involved and, with the cooperation of the only U.S. producer, the situation was felt to be under control.

Then, in 1975, the reported high levels of contamination, with PCBs, of Hudson River fish, refocused national attention on this environmental contaminant. It was soon apparent that the actions and control measures of the early 1970's had not succeeded in totally reducing, or even substantially alleviating the problems associated with this environmental pollutant.

On November 17-19, 1975, a National Conference on Polychlorinated Biphenyls, sponsored by the Environmental Protection Agency in cooperation with the Department of Agriculture, Council on Environmental Quality, Department of Health, Education and Welfare and Department of the Interior, was held in Chicago, Illinois. This conference brought together the latest data, and scientific expertise, to consider all aspects of the various problems associated with PCBs, and the means for their possible resolution.

In his introductory remarks to the Session on Health Effects and Human Exposure, Dr. David P. Rall, Session Chairman, announced the formation of a Subcommittee on PCBs of the DHEW Committee to

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Coordinate Toxicology and Related Programs. The Subcommittee was given the charge to:

1. Assemble, review and interpret data that assesses the health significance of polychlorinated biphenyls.

2. Formulate recommendations as to future needs.

The accidental contamination of animal feeds with polybrominated biphenyls (PBBs), and consequent human exposures, that occurred in the State of Michigan, has been approached not only on its own basis, but in comparative relationship to the PCBs, as well. Therefore, the scope of this Subcommittee was expanded to the Subcommittee on the Health Effects of PCBs and PBBs. Members of this Subcommittee came from within the Department of Health, Education and Welfare, as well as including consultants from other Federal Agencies concerned with this difficult problem.

The report which follows represents the culmination of this Subcommittee's efforts.

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GENERAL
SUMMARY AND CONCLUSIONS

CHEMISTRY

The great complexity of PCB commercial mixtures has provided the difficult task of separating the components of these mixtures and determining the complete identity of the compounds. Efforts to define these mixtures have been quite successful over the past several years (Hutzinger et al., 1974). Identification of the component chemicals in PCB residues presents another difficult problem. Little progress has been reported in this area. Since the fate of components of commercial PCB mixtures entering the environment cannot be followed directly, inferences must be drawn about chemical alteration of chlorinated biphenyl compounds in the environment mainly based on laboratory studies.

The known resistance of aryl chlorides to chemical oxidation and hydrolysis presumably was a major factor in the promotion of PCBs for industrial uses. Exposure to non-metabolic environmental agents is unlikely to result in significant oxidation or hydrolysis of chlorinated biphenyls. However, since appreciable photoalteration of chlorinated biphenyls has been observed using either sunlight or sunlight-simulating lamps in the laboratory (Hutzinger et al., 1974) as energy sources, it is highly probable that photochemical changes occur in the environment. These photochemical studies have indicated that reductive dechlorination to biphenyls

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of lower chlorine content is a predominant alteration route although formation of more polar compounds, including a chlorinated dibenzofuran, has also been reported (Hutzinger et al., 1974; Crosby and Moilanen, 1973). The diverse conditions of the environment make it difficult to predict accurately the end products and rates of photoalteration of chlorinated biphenyls. From a comparison of carbon-halogen bond-energies, brominated biphenyls might be expected to be more readily altered by light than chlorobiphenyls. But because of the lower volatility and different end uses of bromobiphenyls, they may not be as readily exposed to light as the chlorinated analogs.

A typical PCB residue from fish resembles the Aroclor 1254 mixture more closely than it does other Aroclors (Zitko et al., 1972; Veith, 1975). Considering the major components of Aroclor 1254 (Sissons and Welti, 1971) it appears that penta-, hexa-, and heptachlorinated biphenyls tend to concentrate at this trophic level in the biosphere. It is of considerable interest, therefore, to carry out comparative accumulation, metabolism and toxicity studies emphasizing these higher chlorinated biphenyls using compounds of known chlorine substitution pattern. Individual chlorinated biphenyls are now quite accessible through synthesis and recent studies have begun to obtain these types of biological data.

Studies using a group of five symmetrical hexachlorobiphenyl isomers in chicks (McKinney et al., in press) and in mice (Biocca,

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1975) indicated that distinct difference in toxicity are possible and these differences could be related to structure. The isomers with chlorine substituents in the 4,4' positions appeared to accumulate more rapidly in adipose tissue, showed increased activity in the liver and greater overall toxicity (McKinney, 1975; McKinney et al., in press). Comparison of two pentachlorbiphenyls in laying chicks again indicated the one isomer with 4,4'-substitution to have greater toxic effects (Ax and Hansen, 1975; Ax et al., 1976). Structure-activity relationships, particularly for biphenyls known to be major components of commercial PCB mixtures, could be useful in assessing the potential hazard of these compounds.

A major part of determining human exposure to PCB residues in foods is evaluating the adequacy of the analytical methodology used and the significance of the data obtained. The methods applicable to PCB determination are complex and to be judged adequate should give acceptably reproducible results in the hands of experienced analysts. The degree of success of inter-laboratory collaborative studies helps measure the adequacy of a method.

PCB residues are multicomponent mixtures. Many common chlorinated pesticides are extracted from samples along with the PCBs. Procedures for separation of PCB residues from interfering pesticides therfore become important as a prerequisite to quantitation. Several different quantitation techniques have been used (Hutzinger et al., 1974). Comparison of PCB residue data is difficult where standardization of the quantitation procedure is lacking.

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It has been shown that recovery of PCB mixtures purposely added to food samples, using commonly applied analytical methodology, varies with the average level of chlorination. Recoveries tend to decrease with increasing chlorine level (Stalling et al., 1972).

Analytical procedures for determination of PCB and PBB (the latter is predominantly a hexabromobiphenyl) residues are essentially similar. They differ somewhat in cleanup of the extract and in the use of a higher column temperature for gas chromatographic determination of the PBB residue. The limit of quantitation for PCBs is generally 0.2 ppm for individual foods and about 0.05 ppm for Total Diet composites using Food and Drug Administration methodology. For PBB residues, the limit of quantitation is approximately 0.05 ppm in fats and 0.01 ppm in non-fatty foods. Interlaboratory studies of analytical methods for PBB determination have not been reported.

The chlorinated dibenzofurans (Cl-DBFs) have become a focus of concern as the class of contaminant compounds in commercial PCBs most likely to contribute significantly to the toxicity of the PCB mixture. This concern presumably stems mainly from the demonstrated toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin and the similarity in structure between dibenzo-p-dioxin and dibenzofuran (NIEHS Conference, 1973; also see Appendix of Chemistry Report) and from the little toxicity data that has been published for Cl-DBFs (Bauer et al., 1961). Recent data indicated

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the toxicity of 2,3,7,8-tetrachlorodibenzofuran approaches that of the analogous dibenzo-p-dioxin at least in chicks and in guinea pigs (Moore et al., 1976). If the chlorinated dibenzo-p-dioxins can serve as an example, chlorinated dibenzofuran toxicity can be expected to vary with number and position of chlorine atoms on the parent ring system. Relationships between structure and toxicity will emerge as more Cl-DBFs are synthesized and tested for toxicity.

A range of Cl-DBFs (from dichloro through hexachloro) have been reported in various Aroclors (Roach and Pomerantz, 1974b; Bowes et al., 1975a) and two specific compounds, the 2,3,7,8-tetrachloro- and 2,3,4,7,8-pentachloro-dibenzofurans, have been identified (Bowes et al., 1975b). Quantitation of Cl-DBF contaminants in PCB mixtures, a difficult procedure, suggests total Cl-DBF levels in the low parts per million range (Nagayama et al., 1975; Bowes et al., 1975a). The presence of Cl-DBF in a synthesized, individual, symmetrical chlorinated biphenyl has been reported (Moron et al., 1973). Chemical analysis of these individual chlorobiphenyls may be necessary prior to their use in toxicological and other biological studies.

There have been no published positive findings of Cl-DBFs in environmental samples or in foods other than rice oil. The finding of Cl-DBFs in such samples would not necessarily implicate commercial PCBs as the source of these contaminants since Cl-DBFs (generally the higher chlorine levels) have been reported in other

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industrial chemicals (Firestone et al., 1972; Schwetz et al., 1974; Villanueva et al., 1974). It is also possible that Cl-DBFs may be formed or altered in the environment.

METABOLISM AND BIOCHEMICAL TOXICITY

The effect of PCBs and PBBs on the hepatic mixed-function oxidase (MFO) enzymes has been the most thoroughly studied of any biochemical parameter that they are known to alter. On a molar basis, the PBBs are approximately five-fold more potent than the PCBs in inducing increased levels of the MFO enzymes (Farber and Baker, 1974). Among the PCBs it appears as if their potency increases with increasing chlorination and chlorine substitution in the para > ortho > meta positions respectively (Echobichon, 1975). However, this induction of the MFO enzymes is not unique to these compounds and the induction observed is well within the range observed with many other xenobiotics. The PCBs are somewhat unique as MFO inducers in that they induce the formation of both Type I and Type II P-450 (Alvares et al., 1973), but this induction may have been due to the fact that the commercial formulation used in the study was a mixture of twenty or more PCBs which were metabolized to an even greater number of metabolites. In addition, many, if not most commercial PCB formulations contain trace amounts of chlorinated dibenzofurans (Araki, 1974). These compounds may be up to 170 times more potent as MFO inducers than the PCBs. The chlorinated dibenzofuran concentration of American

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PCB formulations is usually quite low when they are produced, however, the effect of long-term is unknown. In any case, since induction of the MFO enzymes may result in increased hormone metabolism or carcinogen activation, exposure to the PCBs and PBBs should be limited on that basis alone.

PCBs and PBBs administered at relatively high concentrations, usually 50 ppm or higher in the diet, to laboratory animals have been shown to cause prophyria (Goldstein et al., 1975), disfunction of the thyroid (Bastomsky, 1974), inhibition of various enzymes (Pardini, 1971), changes in the liver to body weight ratios (Garthoff et al., 1975) various disorders of the liver (Kimbrough et al., 1975), and to alter the level or utilization of corticosteroids (Wasserman et al., 1973) and vitamins A, D and E (Cecil et al., 1973; Wong et al., 1974; Combs et al., 1975). Certain of the less chlorinated PCBs have also been shown to have a mild estrogenic effect when tested in the immature rat and mouse (Kihlstrom, 1973; Nelson, 1974). However, most of these parameters have not been studied in sensitive species or demonstrated at low exposure levels in laboratory animals.

The available data imply that the PCBs and PBBs containing six or fewer halogen atoms are readily absorbed from the gut of higher animals. The available data also imply that the PCBs are not excreted to an appreciable extent prior to metabolism to more polar compounds, and that long term PCB storage is in the skin and adipose tissue (Matthews and Anderson, 1975a). Studies of PBB

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metabolism are not yet available. Since tissue samples from birds and mammals with known exposures to PCBs usually contain only those PCBs with five or more chlorine atoms, it is assumed that the less chlorinated PCBs have been metabolized and excreted. On the other hand there is little evidence that fish can metabolize any PCB and an analysis of fish tissue usually shows a PCB pattern very similar to that to which the fish were exposed (Stalling and Mayer, 1972).

Laboratory studies have demonstrated that the rate of PCB metabolism and thus excretion is approximately inversely proportional to the degree of PCB chlorination so long as there are two adjacent unsubstituted carbon atoms on the biphenyl molecule. When two adjacent unsubstituted carbon atoms are not present the biological half-life of the given PCB may be a matter of years and accumulation of high tissue concentrations with continued exposure is inevitable (Matthews and Anderson, 1975a). It should be noted that the major constituent of Firemaster BP-6 does not have two adjacent unsubstituted carbon atoms and that the corresponding PCB has been shown to have an extremely long half-life in the laboratory rat and probably the human population as well.

It should also be noted that metabolism can also result in further complications of the PCB problem because those PCBs which are most readily metabolized and excreted are those which are most likely to be metabolized via arene oxide intermediates. And where as the reactivity of arene oxides varies greatly and often

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ultimately determines the toxicity, mutagenicity or carcinogenicity of the parent compound (Jerina and Daly, 1974), the PCBs offer such a range of degree and position of substitution that it would not be unlikely to find that one or more of these PCB metabolites would have the proper stability to be a mutagen or a carcinogen. Thus a move from the more highly chlorinated PCB formulations to the less chlorinated ones may help solve the long-term residue problem only to intensify other problems.

ANIMAL TOXICOLOGY

Gleaning the information that is now available on animal toxicology makes it obvious that different commercial mixtures of PCBs elicit different toxic responses in animals, and that different animal species vary in their susceptibility to the toxic effects of PCBs. Reproduction is severely affected in mink at a dietary level of 5 ppm Aroclor 1254, and a slight effect is still noted at a dietary level of 1 ppm (Ringer et al., 1972). In rhesus monkeys reproduction was reduced at a dietary level of 2.5 ppm of Aroclor 1248 (Allen 1975). In rats a dietary level of 20 ppm Aroclor 1254 depressed reproduction while in the same rat strain (Sherman), in a study conducted simultaneously in the same laboratory, a dietary level of 500 ppm Aroclor 1260 was necessary to reduce reproduction (Linder et al., 1974). In comparative studies done with European products, Phenoclor DB6 and Clophen A60, and the American product, Aroclor 1260, the

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European products were more toxic to chickens than the American product (Vos & Koeman, 1970). The difference in toxicity in this study was attributed to contamination of the European products with chlorinated dibenzofurans and perhaps chlorinated naphthalenes. However, if the differences in the effect on reproduction by the different Aroclors are compared, the contamination with chlorinated dibenzofurans may not be the decisive factor.

Hepatic porphyria has been produced in a number of species, namely the chicken, rabbit, Japanese quail and rat, by a number of commercial mixtures, such as Clophen A60, Phenoclor DP6, Aroclor 1016, 1242, 1254, and 1260 (Vos and Koeman, 1970, Vos and Beems, 1971, Iverson et al., 1975, Goldstein et al., 1974, 1975). It (hepatic porphyria) has not been reported in the monkey, mink or human (see Yusho) mammalian species quite susceptible to the toxic effects of PCBs in other ways. Aroclor 1254 and Aroclor 1242 produced hepatic porphyria in the female rat at doses lower than Aroclor 1016. Again, different commercial mixtures produce this toxic effect at different dosage levels. The hepatic porphyria occurs concomitantly with an increase in ALA synthetase in the liver. Mixed function oxidases are also induced in the liver and comparative studies with PCB isomers have suggested that if the 4,4' positions on the biphenyl ring are occupied by chlorine atoms the effect is most pronounced (Ecobichon and Comeau, 1975).

The liver is the primary target organ for PCBs in the rat. Early changes include hepatomegaly with a concomitant increase

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in smooth endoplasmic retiulum, lipid accumulation at higher dietary levels (20 ppm for Aroclor 1254 and 1260) and ultrastructural changes such as atypical mitochondria and the formation of "fingerprints" in the hepatic cytoplasm ("fingerprints" consist of concentrically arranged membranes surrounding lipid vacuoles). An increase in mitotic figures and cell breakdown are increasingly noted with either higher doses or longer exposure (Kimbrough, 1975). These changes are not as pronounced with Aroclor 1242 or 1016. Similar changes have been reported in the primate (Allen, 1975).

In the mouse, liver tumors have been produced with Aroclor 1254 (Kimbrough and Linder, 1974) and Kanechlor 500 (Ito et al., 1973) and in the rat with Kanechlor 400 (Kimura and Baba, 1973) and Aroclor 1260. Some tumors have also been produced with Aroclor 1242, 1254 and 1260 (Calandra 1976) in rats in a separate study. In one study with Aroclor 1260, some of the tumors were classified as hepatocellular carcinomas (Kimbrough et al., 1975). The dietary levels of the PCBs in all of these studies were 100 ppm or more, a high level when compared to the daily average human intake of PCBs but not very high for subgroups with a high intake of fish from polluted waterways or in some occupational situations. This is emphasized by the fact that the dietary levels which produce tumors and the relatively low dietary levels which affect reproduction (2.5 ppm in the monkey and 1 ppm in the mink) of some commercial PCB mixtures do not represent a no-effect level. It is presently not known what the no-effect levels are. Other uncertainties

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contribute to these problems. The Yusho oil which caused a poisoning outbreak in Japan was not only contaminated with PCBs but also with high levels of chlorinated dibenzofurans.

In the primate, in addition to the effect on the liver, the gastric mucosa (Allen and Borback, 1973), the skin, and the Meibomian glands are also affected at comparatively low dietary levels and the bone marrow is depressed (Allen 1975) while the gastric mucosa of the rat is only affected at exceedingly high doses (Kimbrough, 1974). Whether the dog also shows an effect on the gastric mucosa needs clarification. In the rabbit, atrophy of the thymus is a toxic manifestation in addition to liver pathology (Vos and Beems, 1971). Fluid accumulation occurs in primates, chickens, and finches. The lymphatic system is also affected in minks.

The few studies conducted with some hexachlorobiphenyl isomers demonstrated that the 3,4,5,3',4',5' hexachlorobiphenyl was the most toxic while 2,3,6,2',3',6' hexachlorobiphenyl was the least toxic isomer (Biocca et al., 1975). Penta-, hexa- and heptachlorobiphenyls are preferentially retained in mammalian adipose tissue for extremely long periods of time (Kimbrough, 1975) at fairly high concentrations in the rat for a recovery period of 16 months. Whether this has an influence on the toxicity of PCB mixtures has not been determined.

The toxic effects of the contaminants of PCBs have not been extensively studied. While it is assumed that chlorinated

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naphthalenes are toxic within the same dosage range as the chlorinated biphenyls, the chlorinated dibenzofurans probably have a greater toxicity. It is assumed that 2,3,7,8 tetrachlorodibenzofuran is the most toxic of this group of compounds. This compound also shows marked species variation. While the single oral LD_{50} in guinea pigs is between 5 and 10 ug/kg bodyweight, 1000 ug/kg TCDF given orally had no effect on rats. Mice are equally insensitive to the toxic effects of TCDF (Moore et.al., 1976).

For the brominated biphenyls limited toxicity data are only available on mixtures containing predominantly hexa- and octabromobiphenyl. Both mixtures differ sufficiently in isomeric composition so that their toxic effects may quantitatively be quite different and also different from the PCBs. Again the problem of toxic contaminants has not been resolved. If toxic effects are similar to PCBs then, at least in some species such as mink and monkey, longterm low level exposure should result in measureable toxicity. Additional animal studies are needed to resolve some of these problems. Poor metabolism and excretion of the brominated biphenyls may lead to long retention of these compounds predominantly in adipose tissue with accumulation to very high levels on continued exposure. Whether this would lead to sufficient recirculation of the chemicals to cause toxic effects on target organs in presently not known.

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HUMAN EXPOSURE

Several reports (Jelinek & Corneliussen, 1975; Humphrey, 1976; Kutz and Yang, 1975; Dennis, 1975; Kleinhert, 1975; Hesse, 1975; Yobs, 1972; Kutz and Strassmman, 1975) provide evidence that would indicate that a substantial proportion of the population of the United States has been exposed to PCBs. Minimal human exposure of the population to PCBs has occurred from food, air and water, while significant human exposure appears to be limited to sports fishermen consuming fresh water fish from contaminated streams and lakes, and to occupatibnal exposure in industrial workers.

Jelinek & Corneliussen (1975), in reviewing data from the FDA Total Diet Study (1971-1975) report that all food classes of the total diet have declined to no PCB occurrences except in these meat-fish-poultry composites. About 40 percent of these composites continue to contain detectable residues of PCBs, although only traces have been detected in the latter years. The fact that levels in these composites have declined to only traces further support the inference that the meat, poultry and eggs no longer contain detectable PCBs and that the low level findings are probably due to the fish in these composites. This would imply that the PCB levels in the diet may have "bottomed out" and may remain static until such time as there is a change in the PCB residues in fish.

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Data compiled from studies sponsored by the National Marine Fisheries Service (NMFS) also support the continuing presence of PCB residues in fish. A compilation of PCB data, representing the results of all the measurements known to NMFS on PCBs in fish used in the U.S. diet, indicates several important points: (1) while at one time or another, some PCB measurements have been made on many fish, there is an inadequacy of information on PCB residues in the most important fish items in the fish diet; (2) sampling and analysis have been sporadic and not designed to measure trends in human exposure; and (3) systematic surveys of neither the important items nor the species most likely to be contaminated have been undertaken.

However, these survey data do show that in general U.S. fish eaters include a wide variety of fish items in their diet and that some 93 percent of the U.S. population (197 million) consume fish, with the average annual consumption of fish being 15 pounds/year/fish eater.

At present, it is difficult to estimate all human exposure to PCB from eating fish, either from the population as a whole or subgroups at higher risk of consuming large quantities of fish with higher PCB residues. Fragmentary evidence from NMFS data suggests that the exposure of the population as a whole from PCB residues in ingested fish is probably well below 19 mcg/day/consumer, based on PCB levels which are estimated to be below 1 ppm and 19 g of fish consumed/day. This can be compared to

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the results of the FDA Total Diet Study where it has been estimated that the overall PCB daily intake is on the order of 5-10 mcg/day for the general population. The lower FDA estimate is based on the methodology of the Market Basket Survey where fish are purchased at the consumer level and would not be applicable to diets which include a high consumption of fish from certain areas with high PCB residues.

A recently completed study (Humphrey et al., 1976) has attempted to assess some of the consequences of human exposure to PCBs from the high consumption of fish from contaminated areas. The results of this study show that a group of sports fishermen consumed an average of 24-25 pounds of fish/person/year, with the highest individual exposure for a two year period reported as 180 pounds per year. PCB residues in cooked fish ranged from 0.36 to 5.38 ppm. Although there was a wide range of blood PCB levels for each quantity of fish consumed, there was a highly significant correlation between the reported quantity of Lake Michigan fish consumed and the concentration of PCB in the blood of study participants, with the higher reported fish consumption being associated with higher PCB blood levels. The blood values ranged from a low of 0.007 ppm in the control group (fish consumption less than 6 pounds/year) to a high of 0.366 ppm in the exposed group (fish consumption 24-25 pounds/year).

These investigators calculated that the amount of PCB ingested by the exposed group could average 46.5 mg/year and ranged from

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14.17 to 114.31 mg/year. While no systematic adverse health effects could be demonstrated in the exposed group when compared to controls, the investigators caution that any long-term chronic effects are unknown at the present time. Additionally, it can be concluded that exposure similar to those reported in this special group will continue and there is the likelihood that as sportsfishing becomes more popular, larger numbers of people may be exposed in a similar way.

Although human exposure to PCBs from air and water is probably minimal, there seems little question that such exposure does occur. Samples of ambient air collected in Florida, Mississippi and Colorado, show that PCBs were present at all locations. The average concentration at each of the three locations was approximately 100 nanograms per cubic meter of air. Studies of surface water from the major drainage basins of the United States report the widespread occurrence of PCBs in both surface water and bottom sediments. Mean residue levels of PCBs in the surface water ranged from 0.01 to 0.05 mcg/liter, with a maximum residue level of 20.0 mcg/liter.

In Wisconsin, effluents from cooling water in aluminum foundries contained PCBs ranging from 11.5 to 335 ppb. Effluents from paper mills ranged from 0.01 to 25 ppb. Analysis of snow melt water from Wisconsin cities showed PCB residue levels of 0.17 to 0.24 ppb, suggesting that fallout of PCBs from the air may be an important source of PCBs entering the waters of the state.

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In Michigan, testing of 900 samples of industrial effluents showed 22 percent had PCB residues greater than 0.5 mcg/liter, 8 percent greater than 1.0 mcg/liter, 6 percent greater than 10 mcg/liter and 2 percent greater than 100 mcg/liter.... With sludge disposal taking place by incineration, landfill and crop or pasture application, the continuation of PCBs in the environment seems obvious.

Adverse human health effects resulting from PCB exposure have come primarily from studies of occupational exposure and from human exposure through the ingestion of contaminated rice oil in Japan.

Schwartz (1936) provided some of the earliest reports of adverse health effects due to occupational exposure in the U.S., in which he described skin lesions and symptoms of systematic poisoning among workers who were reported to have inhaled chlorodiphenyls. There have been numerous reports over the ensuing years describing cutaneous eruptions and of systematic manifestations as well, among marine electricians, machinists, capacitor and transformer manufacturing workers, and others occupationally exposed to PCBs. The skin lesions described by Schwartz in 1936 have come to be designated as "chloracne." Part of the chloracne lesion resembles adolescent acne, but is generally more severe and the lesion distribution is inconsistent with adolescent acne.

Hara (1969) and Hasegawa et al., (1973) have reported dermatologic ailments which include "brown chromodermatosis" of the

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dorsal joints of the hands and purple-like eruptions of the face and neck. However, Hasegawa et al., (1973) performed a health survey of workers in carbonless copy paper factories, two years after the use of PCB in such processes had ceased, and reported no dermal effects nor liver function, urine or blood test abnormalities. PCB blood levels were reported as 0.01 - 0.02 ppm.

Typical clinical findings in the human exposure to PCB which occurred in Japan in 1968, and which resulted from the ingestion of rice oil contaminated with Kanechlor 400 included chloracne and increased pigmentation of the skin, increased eye discharge, transient visual disturbances, feeling of weakness, numbness in limbs and some disturbance in liver function. Adult Yusho patients had protracted clinical disease with a slow regression of symptoms and signs. In the dose-response epidemiologic study, the average cumulative intake of PCBs leading to overt symptoms was 2,000 mg, with the lowest dose leading to overt symptoms being 500 mg.

However, Kuratsune et al., (1975) have introduced a new factor into the Yusho incidence with the finding that the rice oil contained chlorinated dibenzofurans (Cl-DBF) at 5 ppm. Nagayama et al., (1975) reports that the toxicity of (Cl-DBF) is said to be from 200 to 500 times that of PCB. Whether or not the (Cl-DBF) contaminant is the crucial toxic substance producing the symptoms observed in the Yusho incident, or whether the exposure to the high levels of Kanechlor 400 produced the observed effects, or

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whether there was an inter-active process taking place is unknown.

The data necessary for determining reasonably accurate time and dose exposure to PBB in individuals in Michigan is either unavailable or non-existent. Attempts to secure accurate dietary intake with the PBB levels in food and the duration of consumption have been unsuccessful. It is hoped that data to be received from the Michigan Department of Public Health may provide some basis for crude estimates.

While there appears to be no evidence at the moment to indicate acute health effects from exposure to PBB, any chronic effects remain largely unknown. A large scale epidemiological study is expected to get underway shortly to identify all the farm family members from quarantined farms; a large group of study subjects secondarily exposed to PBB through the purchase of farm products on a regular basis from quarantined farms and a control group of individuals not exposed to PBB contamination. This study will continue efforts to identify any acute or chronic effects of PBB exposure through physical examination, biochemistry tests, and dietary histories. Efforts will continue to assess the original Firemaster BP-6 for the presence, if any, of chemical contaminants which might present human health hazards. In the meantime, a ten-fold safety factor for PBBs when compared to PCBs appears both reasonable and acceptable based on all currently available scientific data.

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Much work remains to be done concerning the toxicity of PCBs and PBBs and the association of these compounds with any demonstrable adverse human health effects. To accomplish some of these needs a list of recommendations follows.

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GENERAL RECOMMENDATIONS

More complete and additional metabolism studies with various individual PCBs and PBBs should be undertaken. Attention to the formation of possible toxic metabolites of these compounds should be considered, as well as detecting and quantifying any specific biochemical parameters which may be affected as a result of such exposures. Based on the above, lifetime feeding studies should be conducted with selected commercial PCBs and PBBs mixtures, as well as selected individual PCBs and PBBs.

Why some species seem to be more susceptible to the toxic effects of PCBs, and which are most closely related to man in their response should be determined. In addition, more experimental data is needed for the occupational PCBs settings; i.e., via the respiratory or dermal route. Additional toxicological evaluations should be made of fish and other foods which contain high levels of environmentally accumulated PCBs and other contaminants. Appropriate toxicological studies should be undertaken with PBBs in order to be able to make some predictions on possible human effects.

The quantitative evaluation of halogenated biphenyl exposure to man with respect to blood and body fat levels, and any possible health effects, needs further study. With respect to PCBs, this may be accomplished by identifying a population of individuals consuming large amounts of fish contaminated with high levels of

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PCBs. In addition, those exposed industrially should be included in these efforts. With respect to PBBs, appropriate studies should be initiated with Michigan farm families exposed through consumption of contaminated meat and dairy products.

Individual chemical components of PCB residues should be qualitatively identified and procedures for improving quantitation of these residues should be investigated. Commercial PCB (and PBB) mixtures need to be analyzed further to determine which chlorinated dibenzofurans (or, in the case of PBBs, whether any brominated dibenzofurans) are present as contaminants. Specific chlorinated dibenzofuran compounds must be synthesized for use in development of analytical procedures and to aid in identification of contaminants. Analytical procedures are needed to permit examination of foods for presence of chlorinated dibenzofurans. Toxicological studies should be carried out on chlorinated dibenzofurans and brominated dibenzofurans.

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DETAILED RECOMMENDATIONS

CHEMISTRY

Investigate procedures (such as Webb and McCall's, J. Chromatog. Sci. 11, 366-373 (1973)) for possible improvement of the quantitation step in the analysis of PCB residues.

Present procedures for analysis of PCBs yield a "PCB residue" that is commonly examined using electron capture GC. Individual components of this residue should be identified and it should be determined whether any of the electron capture GC peaks can be attributed to Cl-DBFs or Cl-naphthalenes.

Analyze commercial PCB mixture (e.g. Aroclors) to determine which Cl-DBFs are present as contaminants. Qualitative and where possible, quantitative studies should be carried out.

Synthesized, individual chlorobiphenyls should be examined for presence of chlorinated dibenzofurans before metabolism or toxicity studies are carried out with the biphenyl. (The importance of this is shown by the reported formation of 2,3,7,8-Cl_4 DBF as a side-product in the Ullmann coupling reaction used to synthesize the symmetrical 2,2',4,4',5,5'-hexachlorobiphenyl.)

Synthesize, purify and characterize by physical and chemical means a range of Cl-DBFs to be used for analytical procedure development as reference standards for confirmation purposes and for suitable toxicological studies.

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Develop a suitable procedure for analysis of edible fish for Cl-DBFs, emphasizing recovery and quantitation of 2,3,7,8-tetrachlorodibenzofuran.

Analyze a commercial mixture of brominated biphenyls (Firemaster BP-6) for brominated dibenzofuran content.

Analyze long-used heat exchange, transformer and capicitor fluids for chlorinated dibenzofurans.

Synthesize specific ^{14}C or tritium radiolabeled chlorinated biphenyls that may be needed for toxicity and metabolism studies.

Study the reported conversion of certain chlorinated biphenyls to Cl-DBFs under sunlight or sunlight-simulating conditions. If feasible, extend the work to additional Cl-biphenyls.

Simulating conditions applicable to heat exchange units and/or transformers, determine whether Cl-DBF content of PCB mixtures increases when the PCBs are heated and/or exposed to air.

Carry out laboratory studies, simulating environmental conditions, to determine alteration products from Cl-DBFs when irradiated or heated.

METABOLISM AND BIOCHEMICAL TOXICITY

Long-term feeding studies approaching life-time should be conducted with the less chlorinated PCB formulations. These

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studies should include at least two of the less chlorinated PCB formulations and a series of carefully selected individual PCBs.

Further and more complete metabolism studies should be done with the more highly chlorinated PCBs, for comparison with those done with PCBs having five or less chlorine atoms.

The effect of chlorine position on PCB metabolism and arene oxide formation should be further elucidated.

The formation of specific chlorinated dibenzofurans as possible PCB metabolites should be studied, their biochemical toxicity in mammalian species determined and the magnitude of their toxicity ascertained. These studies will also include those specific chlorinated dibenzofurans identified in new and used PCBs.

If possible, arene oxide metabolites of several PCBs should be synthesized and their toxicology investigated.

Within an isomeric series of PCBs, (e.g., tetra or hexa), metabolism of the more toxic members should be compared to those which are less toxic.

Metabolism of individual PBBs, comparable to those for PCBs, should be studied. These data should be related to known toxicities.

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The toxicology of known PCB metabolites should be studied.

Porphyrin excretion by the people and animals exposed in the Michigan PBB incident should be checked.

People who are suspected to have received high exposures of PCBs or PBBs should be checked for any changes in enzyme levels—e.g., protein-bound iodine, antipyrene metabolism, serum cholesterol, etc.

The adsorption, distribution and excretion studies of halogenated dibenzofurans and PBBs should be studied.

Further studies of possible PCB metabolism by fish.

Study the degree of chlorination and length of exposure on the estrogenic effects and reproductive organs with particular emphasis on the lower chlorinated PCBs (e.g., 1016).

ANIMAL TOXICOLOGY

Inhalation studies with "heated" PCB mixtures simulating occupational exposure and dermal toxicity studies should be conducted.

Studies as to why some species seem to be more susceptible to the toxic effects of PCBs than others and of these species, which are most closely related in their response to humans should be undertaken.

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Subacute and chronic toxicity studies should be conducted with hexabromobiphenyl (Firemaster FF-1) in order to be able to make some predictions on human PBB toxicity.

The toxicity of fish containing high levels of PCBs which have been accumulated by environmental exposure should be evaluated. It should be established whether and which toxic impurities are present in used PCBs, such as transformer oil and capacitor fluid.

Long-term feeding studies, approaching life-time, should be conducted with laboratory animals and selected commercial mixtures of PCBs and PBBs as well as selected individual PCBs and PBBs.

Further and more complete metabolism studies should be done with individual PCBs and PBBs. The formation of toxic metabolites of these compounds should be considered and carefully investigated.

Efforts to detect and quantitate specific biochemical mechanisms which are affected or altered by exposure to PCBs or PBBs should be continued.

HUMAN EXPOSURE

Polychlorinated biphenyls

Recommend that a population of fish eaters be identified who are consuming substantial amounts of fresh water fish with high levels of PCBs. This study population should be followed prospectively with adequate dietary histories, blood and body fat levels

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of PCBs, a health questionnaire, liver function tests and other biochemical studies.

Recommend a similar study be carried out in an industrial population exposed to PCBs.

Systematic studies to identify sub-groups of the total U.S. population who consume high levels of fish with more accurate measures of PCB exposure.

Polybrominated biphenyls

Recommend that a large scale epidemiological study be carried out to (1) identify all farm family members from quarantined farms in Michigan, (2) identify those individuals with secondary exposure to PBB contamination through the purchase of dairy products from quarantined farms on a regular basis, and (3) a suitable control group of non-exposed farm families. These groups should be followed to assess any short and long term adverse health effects related to PBB exposure.

Subgroups of these farm families from quarantined farms should be studied by:

1. Repeat PBB blood levels.
2. Matched blood-body fat PBB levels.
3. Pregnant female-infant studies.
4. A battery of biochemical studies.

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Ancillary Studies

Toxicology studies in non-human primates and rodents with hexabrominated biphenyl and any brominated contaminants of hexabrominated biphenyls.

Toxicology studies in several animal species (mice, rats, dogs, non-human primates) using hexabrominated biphenyl and several PCBs to determine species differences in response to the effects of these compounds.

Toxicology studies feeding hexabrominated biphenyls and selected PCBs singly and in combination to determine if there are different or additive effects when fed in combination.

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CHEMISTRY OF PCBs AND PBBs

I. Introduction

A recent book by Hutzinger et al. (1974) reviews the chemistry of chlorinated biphenyls through the end of 1973. This wide-ranging review also includes discussions of metabolism and determination of chlorinated biphenyls.

The present report reviews areas of chlorobiphenyl and bromobiphenyl chemistry held to be pertinent to the Subcommittee's concern for possible health effects of these types of compounds. No attempt at complete coverage of these subject areas is claimed. Findings reported since 1973 are particularly stressed.

Non-metabolic alteration of the halogenated biphenyls is considered in terms of agents most available to induce chemical change in the environment. Expected differences between chlorinated biphenyls and brominated biphenyls in their environmental chemistry are commented on.

It is possible that certain of the chlorinated biphenyl compounds will be shown to have relatively greater potential hazard for health. Therefore, occurrence and fate in the environment and metabolism and toxic effects in animals are related to chemical structure of the biphenyls.

For the general public, food is presumed to be the major

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source of chlorinated biphenyl compounds. The important concepts related to analytical methodology for PCB (and PBB) residues, particularly in foods, are reviewed. Alternative means of quantitation of these residues and problems in the quantitation techniques are discussed.

The pertinent aspects of chlorinated dibenzofurans, as known contaminants in commercial PCBs and as potentially significant environmental contaminants, are reviewed.

In reviewing the chemistry related to health effects of the PCBs and PBBs, it must be remembered that environmental contamination by these two commercial chemical mixtures is vastly different in magnitude. The former have been steadily released into the environment, in many countries, presumably over decades, and are now found to be a pervasive, world-wide contaminant. The number of chlorinated biphenyls reaching the environment probably number nearly 100 different compounds. The PBBs, encompassing a small number of chemical structures to begin with, are of concern due to a single, fairly recent contamination incident, apparently limited to the State of Michigan.

II. Chemistry of Chlorinated Biphenyls

A. Synthesis and analysis of Commercial Mixtures

Commercial preparation of mixtures of chlorinated biphenyls by reaction of biphenyl with chlorine has been described by Hubbard (1964). A more recent discussion of this subject,

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including the newer preparation designated as Aroclor 1016, is now available (Mieure et al., 1976). Analysis of the chlorinated biphenyl content of various American commercial PCB mixtures (Aroclor) has been reviewed by Hutzinger et al. (1974). An estimated 40 to 60 different chlorinated biphenyl compounds are present in each of the higher chlorinated commercial mixture. (There are 209 possible compounds obtainable by substituting chlorine for hydrogen on from one to ten different positions on the biphenyl ring system; see Appendix.) PCB commercial mixtures produced in the U.S. and elsewhere have been shown to contain classes of compounds other than the chlorinated biphenyls: chlorinated napthalenes and chlorinated dibenzofurans (Cl-DBFs), for example (Vos et al., 1970; Roach and Pomerantz, 1974 a,b; Bowes et al., 1975a). The possibility that naphthalene and dibenzofuran contaminate the technical biphenyl feedstock used in preparation of the commercial PCB mixtures has not been excluded.

Available toxicity information indicates that, of the identified types of contaminants in commercial PCB mixtures, Cl-DBFs pose the greatest potential hazard (See Section II.E on Chlorinated Dibenzofurans). As a result, the Cl-DBFs have become the focus of studies on contaminants in these mixtures. No report has appeared of an attempted complete content analysis of the trace impurities in a commercial PCB mixture.

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B. Non-metabolic Alteration of Chlorinated Biphenyls

Chlorinated biphenyls, as is typical of aryl chlorides generally, are quite stable to chemical alteration. Consideration of possible non-metabolic alteration routes for these compounds in the environment suggests air oxidation, aqueous hydrolysis, and photoalteration in sunlight as potential reactions to be investigated. (Thermal decomposition would be of concern in connection with incineration conditions meant to destroy waste chlorinated biphenyls). Study of these reactions under the complex and variable sets of conditions existing in the environment is difficult. Chemical reactivity of chlorinated biphenyls has therefore been studied almost entirely under the more controlled conditions of the laboratory.

Oxidation

PCBs are fairly stable to oxidation under moderate conditions. PCBs are stable under conditions which easily oxidize DDE, and can be separated from DDE by oxidizing DDE to the more polar dichlorobenzophenone prior to column chromatographic separation (Trotter, 1975). To effect the oxidation of DDE, the PCB-DDE solution is refluxed in 2.5% chromic acid-acetic acid on a steam bath. Some of the lower chlorinated biphenyls, however, are not recovered after the oxidation. It is reported (Weingarten, 1961) that mono-, di-, and trichlorobiphenyls are oxidized in 7.5%

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chromic acid-acetic acid to their respective (chloro-) benzoic acids. With vigorous oxidizing conditions in the environment, some PCB oxidation, especially of the lower chlorinated biphenyls may occur. It is difficult, however, to assess the total extent of possible environmental oxidation of PCBs.

Hydrolysis and Alcoholysis

PCBs are fairly stable to hydrolysis under moderate conditions. When refluxed with 2% KOH in ethanol, PCBs are stable (Trotter, 1975; Young and Burke, 1972). A halogen on a chlorobiphenyl molecule is not easily displaced in a nucleophilic substitution reaction. Under vigorous conditions the 4 and the 4,4' positions of decachlorobiphenyl are found to be the most susceptible to chlorine displacement by hydroxide and methoxide ions. Decachlorobiphenyl can be hydrolyzed to octachloro-4,4'-biphenylol when treated with aqueous alkali at high temperatures in an autoclave (Smith, 1948; Societe d'Electro Chimie, 1962). Heating 2,5-dichlorobiphenyl with sodium methoxide produces 2-chloro-5-biphenylol (deCrauw, 1931). Decachlorobiphenyl when treated with sodium methoxide in pyridine yields the 4-methoxy- and 4,4'-dimethoxy-chlorobiphenyl (Binns and Suschitzky, 1971). It is probable that the non-metabolic hydrolysis or alcoholysis of PCBs in the environment is limited.

Photochemistry

Exact environmental conditions for the photochemistry of

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environmental contaminants, including PCBs, are sometimes difficult to simulate in the laboratory. Limited understanding exists concerning the parallel of laboratory photoreactions and reaction rates under non-environmental conditions and possible environmental photolyses. The exact environmental conditions under which residues may photoreact can be diverse and difficult to evaluate. Unknown or discounted factors in the environment, such as possible sensitors or quenchers, may be important. The frequency (energy) and intensity of a laboratory photolysis light may not be comparable with environmental conditions. 3000 Å probably represents the practical lower limit of the ultraviolet (UV) portion of sunlight (Crosby, 1969). The residue must be exposed to sufficient light to react appreciably. It is necessary to consider the physical state of the residue exposed to light in the environment. The residue may exist as a solid or liquid (e.g., a film), a solution or a vapor. In photolyzing solutions the solvent can have an important effect. Photoreactions which proceed in one solvent may not proceed or may proceed at a different rate in another solvent. A muddy river containing a residue may yield different results compared to a laboratory photolysis in hexane. Laboratory photolyses under a variety of conditions which simulate most, if not all, of the environmental conditions of photolysis could be extremely significant and relevant. In the absence of these, we must rely on the questionable extrapolation of laboratory photolyses under non-environmental conditions.

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The photochemistry of PCBs has been described by Hutzinger, et al.,(1972; 1974). In contrast to oxidation and hydrolysis, PCBs are fairly easily photoreacted under certain laboratory conditions. PCB photochemistry has been studied in various solutions, as a thin film, and as a vapor. In hydrocarbon solvents progressive reductive dechlorination of the PCB is the predominant photochemical reaction (Hutzinger et al., 1974). Irradiation of solutions of chlorobiphenyls (Hutzinger et al., 1972) and trapped gas liquid chromatographic (GLC) effluents (Hannan, et al.,1973) have shown that PCBs with higher chlorine content dechlorinate more readily. 0.1% hexane solutions of 2,2',5,5'-tetrachlorobiphenyl and 2,2',4,4',5,5'-hexachlorobiphenyl were each irradiated with 3100 Å light in a Rayonet reactor (Hutzinger et al., 1972). After 24 hours of irradiation, 33% of the 2,2',5,5'-tetrachlorobiphenyl was unreacted while < 1% of the 2,2'4,4',5,5'-hexachlorobiphenyl remained. In dechlorinating PCBs by photoexcitation, ortho chlorines preferentially cleave (Ruzo et al., 1974). With PCBs containing only meta and para chlorines, meta chlorines are lost preferentially. The rate of dechlorination is faster in alcohol solvents, such as methanol (Hustert and Korte, 1972) than in hydrocarbon solvents. Irradiation of 2,2',4,4',5,5'-hexachlorobiphenyl in methanol yields, in addition to reductive dechlorination, ring methoxylation (Ruzo et al., 1974). Photochemical studies of PCBs in aqueous solutions may offer a significant relevance to environmental PCB photochemistry. A 0.4% Aroclor 1254 suspension in water-dioxane (7+3) in the presence of sodium bicarbonate with

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air bubbling through the mixture was irradiated with 3100 Å light. Two thin layer chromatographic fractions of the Aroclor 1254 after irradiation corresponding to the "addition of water to chlorobiphenyls" and a "carboxy fraction" were found (Hutzinger et al., 1972). Presumably PCBs formed by reductive dechlorination were also produced. Black light irradiation of Aroclor 1254 as a thin layer film in the presence of water yields a "carboxy fraction" and a fraction whose mass spectrum indicates hydroxychlorobiphenyls (Hutzinger et al., 1972). Sunlight irradiation of certain chlorobiphenyls as a thin film without the presence of water gives reductive dechlorinated products (Hutzinger et al., 1974). Chlorinated terphenyls and quaterphenyls are also produced by the black light and sunlight irradiation of certain chlorobiphenyls as a thin film (Hutzinger et al., 1974). Vapor phase photolysis of PCBs may be extremely relevant especially for the more volatile components of Aroclors with low chlorine content. Sunlamp irradiation of the vapor phase of a refluxing suspension of 2 2',5,5'-tetrachlorobiphenyl and water yields "carboxy" products (Hutzinger et al., 1972).

These laboratory photoreactions represent chemical conversions which may proceed in the environment. The photoreaction rates under diverse environmental conditions and the extent of PCB degradation or reaction in the environment are extremely difficult to assess.

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The reported low-yield conversion of certain chlorinated biphenyls to Cl-DBF is discussed under Chlorinated Dibenzofuran, Section II.E.

C. Chemical Structure Related to Occurrence, Fate and Effects of Chlorinated Biphenyls

The physical and chemical properties of chlorinated biphenyl compounds and commercial mixtures of PCBs vary greatly depending on the degree and position of chlorine substitution on the biphenyl ring system. Of particular importance to their environmental occurrence and fate are the properties of volatility, water solubility, bioaccumulation, biodegradability and photostability. Volatility, water solubility and bioaccumulation are of more importance as mechanisms of introduction into and transport within the environment. Biodegradation and photodegradation are more important as mechanisms of removal.

There are data (Mieure et al., 1975) which indicate that the higher chlorinated biphenyls are less volatile and less water soluble than the lower chlorinated biphenyls. These two factors would tend to enhance the ratio of lower to higher chlorinated biphenyls in the environment. There are no clear data to assess the involvement of chlorine position in volatility and water solubility, but is likely to be of less importance. Therefore, the lower chlorinated biphenyls are more likely to volatilize into and be selectively transported in the aqueous environment.

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The relationships between structure and bioaccumulation factors for PCB isomers are only beginning to be assessed (McKinney, 1975; Sugiura et al, 1975) with the availability of purified specific isomers for study. However, it appears (Zitko et al., 1972; Veith, 1975) that the peak patterns from gas chromatography found in environmental samples representing the biosphere most closely resemble the higher chlorinated commercial mixture, Aroclor 1254. This suggests a selective accumulation of the mores highly chlorinated components of the commercial mixtures in biological material. This also indicates that the higher chlorinated biphenyls are able to find their way into the environment in spite of their poorer volatility and water solubility. Pharmacokinetic studies (Matthews, 1975) with selected radiolabeled chlorinated biphenyl compounds have confirmed the trend toward increasing biological half-life with increasing chlorine number. However, these findings may be the result of both higher accumulation rates and lower elimination rates for the higher chlorinated biphenyls. It may be of interest to note that fish from lower and intermediate levels of the food web have been found (Zitko et al., 1972) to contain lower amounts of hexa and higher amounts of tetra and penta than higher trophic level white and silky sharks and aquatic birds This suggests that selectivity in bioaccumulation is also a function of biospecies.

Again the effects of varying chlorine position are less

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clearly understood, and the best assessment of this comes from study of two or more members of an isomeric series of the chlorinated biphenyls. Recent work with five symmetrical hexachlorobiphenyl isomers in chicks (McKinney et al., in press; Goldstein et al., in press) and subsequently in mice (Biocca, 1975) has demonstrated that separate and distinct differences in isomer toxicity are possible and that the differences are related to chemical structure via effects of varying chlorine substitution on compound lipophilicity and metabolism. The hexachloro isomers studied were 3,4,5,3',4',5'-; 2,4,6,2',4',6'-; 2,3,4,2',3',4'-; 2,4,5,2',4',5'-; 2,3,6 2',3',6'- and 2,3,5 2', 3',5'-. Those hexa-isomers with 4,4'-substitution appear to be more rapidly accumulated and may be more slowly metabolized, i.e., these isomers showed greater accumulation in adipose tissue and increased activity in the liver and overall greater toxicity. These differences are believed to be associated with differences in molecular polarizability and to be measureable by spectroscopic and chromatographic techniques.

Other workers (Ax et al., 1976; Ax and Hansen, 1975) have compared the toxicity of two pentachlorobiphenyls in laying chicks. The isomer with 4,4'-substitution (2,4,5,3',4') showed higher average embryonic mortality and teratogenicity in unhatched eggs but lower decreased fertility in the chick than 2,3,6,2',3' the isomer not chlorinated in the 4-position. Although it is difficult to assess the role of metabolism here, the data would suggest a

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more rapid accumulation of the 2,4,5,3'4'-isomer in the egg. Other workers (Bush et al., 1974) have already observed a correlation between PCB content of eggs and embryo mortality and teratogenicity.

Various other workers (Ecobichon and Comeau, 1975; Johnstone et al., 1974; Hill et al., 1974) studying a range of chlorinated biphenyls have generally observed the importance of degree of chlorination as well as position of chlorine substitution (especially 4,4'-substitution) in overall biological effectiveness. Although some of the compounds studied are unrealistic as components of commercial PCB mixtures, they have served as models to demonstrate the importance of chlorine number and position. Nevertheless, of 50 possible components of Aroclor 1254 identifed by Sissons and Welti (1971) as many as 19 (38%) could have 4,4'-substitution. It is of interest to note here that one of the possible persistent isomers found in Yusho patient tissue has been tentatively identified (Kuratsune, 1975) as the 2,3,4,5,3',4'-heptachlorobiphenyl. This isomer has been prepared (McKinney, personal communication) and its toxicty will be determined especially in relation to the highly toxic 3,4,5,3',4',5'-hexa isomer previously tested.

It has been only recently that hydroxylated metabolites of PCBs have been isolated and identified (Jansson et al., 1975) in environmental samples. The study of the metabolism of the commercial mixtures (deFreitas and Norstrom, 1974) themselves has

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received little attention for obvious reasons. Recently, the metabolism of purified chlorinated biphenyls, some radiolabeled for quantitation purposes, has been studied in a number of biological systems. Although there are a large number of publications in the literature on this subject, this report will concern itself with those studies which seem to support generalities in terms of the effects of varying chlorine number and position on metabolism with particular reference to mammalian systems and to realistic components of Aroclors.

The distribution and excretion of a series of four radiolabeled (^{14}C) chlorobiphenyls which have degrees of chlorination similar to and are themselves constituents of Aroclors 1221, 1242, 1254, and 1260 have been studied (Matthews, 1975) in the male rat. These studies have clearly shown an increasing biological half-life with increasing chlorine number for the series (4-; 4,4'-; 2,4,5,2',5'- and 2,4,5,2',4',5'-) which is believed to be related to the rate of metabolism and the ease of formation of the arene oxide intermediate. These compounds were also dosed at realistic exposure levels (0.06 to 6.0 mg/kg) which showed that little if any of the chlorobiphenyl is excreted in unchanged form. Most other metabolic studies (Hutzinger et al., 1974) with selected chlorobiphenyls have dealt with much higher dose levels (generally resulting in excretion of much unchanged biphenyl) and unlabeled compounds which are of little quantitative value in assessing the effects of chlorine degree and position.

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There has been no similar study with selected chlorinated biphenyls within an isomeric series to assess the effects of chlorine position on metabolism with the possible exception of an incomplete study (Hass et al., unpublished) on the identification of metabolites from the excreta of chicks (and mice) fed symmetrical hexachlorobiphenyl isomers. It is essential that this be done with symmetrical isomers (in order to simplify the problem of interpretation) and preferably in two or more isomeric series (tetras and hexas).

The various metabolism studies have generally shown the occurrence of polar hydroxylated compounds as major components of the metabolite mixture. As the degree of chlorination increases, hydroxylation can be concurrent or concomitant with dechlorination (Hutzinger et al., 1974). There is also evidence for the formation of methyl ethers (Safe, 1975) and methylchlorobiphenyls (Hass et al., unpublished) as metabolites.

There is an increasing body of evidence (Safe et al., 1975) to support the arene oxide intermediate in hydroxylation, especially (Chen et al., Division of Nutrition and Disposition, in press) in cases where vicinal (1-2,-adjacent) unsubstituted carbons are found in the molecule. The corresponding dihydrodiol and/or catechol generally occur along with the phenolic metabolites.

Althought it has not been studied in mammalian systems, there is at least one report (Baxter et al., 1975) that studies of

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individual chlorinated biphenyls do not accurately predict the rates of metabolism of the same compound in simple mixtures. Therefore, the overall problem of metabolic degradation of the commercial mixtures may be complicated by the possibility that certain PCBs are potent enzyme inducers but poor substrates and vice versa with various degrees in between. This is further complicated by the fact that certain chlorinated biphenyls occur in optically active forms and only one enantiomer may be biologically active and undergo enzyme interactions. The existence of nine of the major, and ten of the minor, constituents of Aroclors 1242, 1254, and 1260 in optically active forms has been predicted (Kaiser, 1974).

D. Determination of PCB Residues

The determination of PCB residues has been reviewed in detail by the WHO Task Group report on "Environmental Health Criteria for Polychlorinated Biphenyls and Terphenyls" (WHO Task Group, 1975) and in "Chemistry of PCBs" (Hutzinger et al., 1974).

PCBs are lipophilic, quite similar in this respect to DDE, the metabolite of DDT. Analysis for PCB residues follow procedures the same as or similar to those used for multiple residues of organochlorine pesticides (WHO Task Group, 1975; Hutzinger et al., 1974; Food and Drug Administration, 1968-1975, Horwitz, 1975; Hearing Clerk, Dept. HEW, 1973). The individual steps that follow sampling are extraction of residues from the sample, isolation of residues from coextractives (cleanup),

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separation of PCBs from interfering chlorinated hydrocarbon pesticides, quantitation, and confirmation of identity. In general analytical methods capable of completely extracting residues of organochlorine pesticides from sample substrates and of quantitatively recovering the pesticides through subsequent cleanup procedures are also capable of achieving quantitative analysis for PCBs. The lipophilicity of chlorobiphenyls which increases with increasing chlorine content may influence their recovery through some analytical methods (Stalling et al., 1972). For example, recoveries through the frequently used cleanup step, partitioning of PCB from a petroleum ether or hexane solution of fat or oil to acetonitrile, exceed 95 percent for Aroclor 1242 but drop to 75-80 percent for Aroclor 1260 (Hearing Clerk, Dept. HEW, 1973). Overall ability of typical analytical methodology to recover PCBs added in vivo to food samples is shown by two interlaboratory studies conducted within the Food and Drug Administration (FDA) and one study conducted for the Association of Official Analytical Chemists (AOAC) (Food and Drug Administration, 1971; Burke, 1972; Food and Drug Administration, 1973; Sawyer, 1973). Using methodology described in the FDA Pesticide Analytical Manual and in the Book of Official Methods of the AOAC, average recoveries and coefficients of variation for determination of Aroclors added as unknowns to different foods were: Aroclor 1254-fish, 74 ± 9 percent; Aroclor 1254-infant chicken, 89 ± 22 percent; Aroclor 1242-chicken fat, 101 ± 13 percent; Aroclor 1248-chicken fat, 96 ± 9

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percent;Aroclor 1254-fish, 75 ± 14 percent; Aroclor 1260-fish, 75 ± 15 percent. The three studies involving fish required separation of the PCBs from the DDT group before quantitation.

Gas chromatography with electron capture detection is the most widely used procedure for determination of PCB residues. Gas chromatographic columns with methyl silicone liquid phases are widely used under conditions that typically separate the Aroclors and PCB residues into about 15 peaks (Fishbein, 1972). The 10 percent DC-200 (or OV-101) column described in the FDA Pesticide Analytical Manual separates Aroclor 1254 into 14 peaks (Armour, 1972). These analytical columns do not give a highly defined representation of the Aroclor or PCB residue; several of the peaks in Aroclors result from mixtures of more than one chlorobiphenyl (Sissons and Welti, 1971; Stalling and Huckens, 1971; Webb and McCall, 1972; Webb and McCall, 1973). A column prepared from purified Apiezon L has been shown to separate a 54 percent chlorine PCB mixture into over 40 peaks (Jensen and Sundström, 1974). Separation of the PCB residue into three fractions by chromatography on charcoal prior to examination on the Apiezon L column has made it possible to characterize and quantitate nearly 60 technical PCB components. This method provides a way to get much needed, more detailed information on the compositon of PCB residues and might be used in special studies. The increased time and complexity of this approach would probably limit its application in regular monitoring analysis.

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The need to confirm residue identity and the procedures available are similar for PCBs and pesticides. The multipeak gas chromatographic pattern of a PCB residue may be very similar to that of a commercial Aroclor or, as in most biological samples, the residue peak pattern may be changed to varying degrees from that of a given Aroclor. The use of column chromatographic or chemical reaction procedures to separate PCBs from organochlorine pesticides increases the certainty of the gas chromatographic identification. Procedures readily available to the residue laboratory for confirming the identity of PCBs include: halogen specific gas chromatographic detectors (Hearing Clerk, Dept. HEW, 1973), stability of the residue peak pattern after refluxing the extract with alcoholic alkaline solution (Young and Burke, 1972), perchlorination of the residue to the decachlorobiphenyl derivative (Berg et al., 1971; Armour, 1973), and thin layer chromatography (Fehringer and Westfall, 1971; deVos and Peet, 1971). Mass spectrometry is not readily available to many laboratories conducting analyses for PCBs nor would the expense justify regular use in monitoring programs. However, the use of mass spectrometry is encouraged for residues and samples which are unusual or significant and for the occasional examination of a so-called routine sample.

Two especially critical considerations are associated with the determination of PCB residues: (1) their separation from potentially interfering organochlorine pesticides, particularly

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DDT, TDE, and DDE or the multicomponent chlordane or toxaphene, and (2) quantitative measurement of the multicomponent PCB residue which, in biological organisms, is usually changed in relative amounts of chlorobiphenyl components from commercial Aroclors or which may result from mixture of PCB from different sources. To achieve reliable residue results it is essential that the analyst correctly make critical judgements and interpretations in dealing with mixed residues of PCBs and organochlorine pesticides and in quantitation of the multicomponent PCB residue. There is no substitute for analyst experience in this analysis.

PCBs are separated from certain pesticides in the usual cleanup procedures, e.g., adsorption chromatography on Florisil or alumina or by gel permeation chromatography (Food and Drug Administration, 1968-1975; Stalling et al., 1972; Holden and Marsden, 1969). When DDT, TDE, DDE, chlordane, or toxaphene are present, ancillary procedures designed to separate these chemicals from PCBs must be used. The DDT analogs, particularly DDE, are the pesticide residues most frequently encountered in samples and DDE is the most difficult to separate from the PCBs. The effective electron capture gas chromatographic response for DDE is 20-30 times greater than for an equal weight of Aroclor 1254 and the response for DDT is only slightly less than that for DDE (Food and Drug Administration, 1968-1975). Without proper treatment these pesticides can readily interfere in the determination of PCBs. Some procedures utilizing column chromatography

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on alumina or Florisil separate DDT and TDE and intentionally collect DDE and PCBs in the same fraction (Holden and Maraden, 1969; Reynolds, 1969), which is analyzed. In these cases the analyst must exclude the DDE region of the gas chromatogram from the quantitative measurement of PCBs. Column chromatography on charcoal also has been proposed for separation of PCBs from DDE, DDT, and other organochlorine pesticides (Berg et al., 1971). Column chromatography on silicic acid is probably the most widely used procedure for separating PCBs from DDT and analogs (Food and Drug Administration, 1968-1975; Armour and Burke, 1970). The technique is fairly lengthy and difficult to reproduce, requiring empirical standardization in each laboratory (Sawyer, 1973; Masumoto, 1972; Edwards, 1974). The separation of DDE is probably not 100 percent effective but under ideal conditions practically all DDE can be separated; the usual inconsistency is for a portion of the DDE to be eluted from the column with the PCBs, requiring allowances to be made in PCB quantitation. The lower chlorinated PCBs present the greatest difficulty in separation from the DDT group by column chromatographic procedures. DDE can also be separated from PCBs by oxidation to the dichlorobenzophenone, followed by a chromatographic separation of this more polar derivative from PCBs. DDT and TDE may be dehydrochlorinated to their respective olefins and similarly separated along with DDE (Mulhern et al., 1971; Collins et al., 1972; Trotter, 1974). This technique has not received as much application as the chromatographic procedures, probably because pesticides and lower

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chlorinated biphenyls are destroyed or changed, preventing their determination. A variation on this approach used sodium dichromate plus a minute amount of sulfuric acid, rather than dehydrochlorination followed by oxidation with chromium trioxide in acetic acid. The dichromate reagent is reported to convert DDE quantitatively to the dichlorobensophenone without affecting DDT, TDE, or any of the chlorobiphenyls (Jensen and Sundström, 1974).

Quantitation of PCB residues is done in most laboratories by comparison of measurements made on the multicomponent electron capture gas chromatograms of the residue and a known quantity of reference material. The PCB residue in biological samples, as mentioned earlier, is very likely to be changed in the relative amounts of chlorobiphenyl components from any one Aroclor or the residue may be a mixture of PCBs from different sources (Food and Drug Administration, 1968-1975; Jensen and Sundström, 1974; Cook, 1972). The response of the electron capture detector varies with the number and location of chlorine atoms in the biphenyl molecule (Gregory, 1968; Zitko et al., 1971). With the electron capture system described in the FDA Pesticide Analytical Manual, the response/unit/weight increases about 6 fold from Aroclor 1242 to Aroclor 1260 (Hearing Clerk, Dept. HEW, 1973). The halogen specific microcoulometric and electrolytic conductivity detectors respond proportionally to the weight of chlorine present and in theory could provide a more accurate measurement of a PCB residue that is not exactly the

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same composition as the reference (Hearing Clerk, Dept. HEW, 1973). However, lower sensitivity, difficulty in maintaining optimum performance, and limited availability in residue laboratories has limited the use of these detectors. Unless the PCB residue and reference Aroclors are exactly the same in chlorobiphenyl composition, the gas chromatographic determination cannot be considered accurate; the greater the difference between residue and reference composition, the greater the deviation between determined and the true residue level (Hearing Clerk, Dept. HEW, 1973; Beezhoold and Stout, 1973). The most frequently used approaches to quantitation have been selected for the reference the Aroclor with the most similar gas chromatographic pattern to the residue and: (1) compared the response of a single peak in the residue with the response of the counterpart peak in the Aroclor reference; or (2) compared the total response for several peaks from the residue to the total response for the counterpart peaks in the reference; or (3) compared the total response for all peaks in the residue with the total response for all peaks in the reference; or (4) in a greater effort to duplicate the residue peak pattern, prepared a reference made up of one or more Aroclors to simulate the gas chromatographic pattern of the residue, and compared the total response for all peaks of the residue to the total response for all peaks in the reference (Sawyer, 1973; Beezhold and Stout, 1973). Response has been measured in terms of both peak height and area (Sawyer, 1973). The latter approach which utilizes an Aroclor or a mixture

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of Aroclors to duplicate the residue peak pattern is recommended by the AOAC for quantitation of PCB residues in certain foods (Horwitz, 1975). This is a currently accepted and practical way to quantitate PCB residues. Perchlorination of PCBs to decachlorobiphenyl has been suggested as a means to improve precision and consistency in PCB determination (Berg et al., 1971; Armour, 1973). This approach will not improve the accuracy of quantitation, however, because proportions of individual chlorobiphenyls in the PCB residue remain unknown; equal weights of individual chlorobiphenyls of different chlorine content result in different weights of decachlorobiphenyl. Contaminations found in antimony pentachloride, the perchlorination reagent, also detract from this procedure for quantitation purposes (Trotter and Young, 1975). An approach to quantitation which appears to have practical merit as well as offering improved accuracy in quantitation has been advanced by Webb and McCall (1973). The PCB residue is quantitated peak by peak in comparison to reference Aroclors which have been characterized as to the number of chlorines and the fraction of total Aroclor weight represented by each electron capture peak after separation on a widely used (methyl silicone liquid phase) gas chromatographic column. The availability of carefully characterized Aroclors and evaluation in practice are required to fully evaluate the merits of this procedure.

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Precision in the interlaboratory determination of PCBs is slightly less than with the common organochlorine pesticides. In several interlaboratory studies involving biological samples and paperboard containing either added Aroclors or actual residues of PCB the coefficients of variation are about ± 20 percent. The results of studies conducted by the AOAC and the FDA involving samples containing added Aroclors have been mentioned above (Food and Drug Administration, 1971; Burke, 1971; Food and Drug Administration, 1973; Sawyer, 1973); the recoveries of added Aroclors ranged from 74 to 101 percent and coefficients of variation from 9 to 15 percent. The levels of Aroclors added in these studies ranged from about 2 to 8 ppm with the exception of 0.2 ppm Aroclor 1254 added to chicken infant food. With samples containing actual residues, 9 laboratories in the AOAC study reported 9.2 ppm ± 8 percent for a residue in chicken fat and 4.5 ppm ± 20 percent for a residue in Lake Michigan chubs. The residue in the chubs was determined after separation of DDE, DDT, and TDE by column chromatography on silicic acid. In a study by 8 laboratories in cooperation with the International Council for the Exploration of the Sea, PCB residues determined in a fish oil averaged 1.97 ppm ± 47 percent. A much better coefficient of variation, about ± 11 percent, was obtained when the same fish oil was fortified with an additional 10 ppm PCB (International Council for Exploratoin of the Sea, 1974). In an AOAC study of the method for PCB in paperboard 11 laboratories analyzed a paperboard sample manufactured to contain Aroclor 1242 and reported 5.6 ppm ±

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16 percent (Finsterwalder, 1974). The inter- or intra-laboratory precision of the determination of PCB in any sample type is improved by use of the same analytical procedures, especially in quantitation of the residue.

The lower limit of quantitation for PCB residues will vary among laboratories depending upon the objectives of their analyses and upon the particular details of the analytical methods, especially the sensitivity of gas chromatographic detection and the sample size. The quantitation limit achieved will be higher than for organochlorine pesticides because of lower effective detector response to the technical PCB mixtures; 20-30 times more Aroclor 1254 or 30-50 times more Aroclor 1242 than DDE is required for the major peaks to produce the same peak height as DDE in electron capture gas chromatography (Food and Drug Administration, 1968-1975). Other factors which may restrict the attainment of low limits of quantitation and affect analytical reliability are interfering residues in the sample and laboratory contamination. Fish from some locations contain residues of organochlorine pesticides and possibly other contaminants at levels that would cause increasing difficulty as the PCB residue decreases below about one ppm. Contamination of laboratory equipment, reagents, and samples with PCB from containers, previous samples, control runs, and unknown sources, must be carefully guarded against in analyses where a low level of quantitation is necessary, for example with human blood or certain

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environmental samples (Trotter, 1975; Jensen et al., 1972; Giam and Wong, 1972). Perchlorination of the PCB residue to decachlorobiphenyl offers the possibility of about 25 fold increase in sensitivity in the gas chromatographic determination (Armour, 1973). However, contaminants present in antimony pentachloride severely restrict or prohibit application of this procedure to determination of low levels of PCBs (Trotter and Young, 1975). Analytical methods used by the FDA for PCB residues also recover chlorinated napthalenes (Armour and Burke, 1971). If present alone, chlorinated naphthalenes would be recognized by the analyst. However, their presence in admixture with PCBs would probably go unrecognized unless amounts were greater than PCBs or the residue was examined by mass spectrometry. Chlorinated naphthalenes are oxidized by procedures used to differentiate DDE in the presence of PCBs and could be removed from interfering in the PCB determination (Holmes and Walden, 1972).

From examination of procedures used to analyze for chlorinated dibenzofurans in commercial PCB formulations and from analytical studies with chlorinated dibenzodioxins it can be inferred that some chlorinated dibenzofurans may be recovered along with PCBs through analytical methods using Florisil and column chromatography (Vos, et al., 1970; Roach and Pomerantz, 1974; Bowes, et al., 1975; Porter and Burke, 1971). The chlorinated dibenzofurans have gas chromatographic properties similar to the PCBs (Bowes, 1975).

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It is very doubtful, however, that a relatively small amount of chlorinated dibenzofuran in the presence of PCBs would be recognized in the usual analysis for PCBs.

Little study has been made of residue analytical methodology for chlorobiphenylols (hydroxylated chlorinated biphenyls). Procedures used for their determination differ substantially from those used for PCBs (Bache and Lisk, 1973; Zitko et al., 1974). It is not likely that chlorobiphenylols would be recovered through column chromatographic and separation procedures used for PCBs.

In the discussion of PCB residues in foods given in the report of the Human Exposure Group a large share of the information comes from the FDA's surveillance programs. The analytical methodology used in the analyses is described in the FDA Pesticide Analytical Manual, Vol. I, and in Official Methods of Analysis of the AOAC. Quantitation of PCB residues is by gas chromatography with electron capture or halogen specific electrochemical detectors. The total response (area or peak height) for the PCB residue is compared to the total response for the Aroclor reference (or mixture of Aroclors) having the most similar gas chromatographic pattern. Aroclor reference materials are each from a single master lot. Results are reported as ppm of the Aroclor(s) used for the quantitation reference. With certain exceptions the limit of quantitation for PCBs (based on the electron capture detector response to Aroclor 1254) is

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about 0.2 ppm for individual foods and about 0.05 ppm for Total Diet composites. Fish from certain fresh water locations are the food most frequently and consistently found to contain PCB residues. The residues in fish are most often similar in gas chromatographic peak pattern to Aroclor 1254 but usually with higher concentrations of the late eluting (higher chlorination) chlorobiphenyl components.

E. Chlorinated Dibenzofurans

(See Appendix for structural information and definitions)

In considering the potential hazard to humans of the commercial chemical mixtures of chlorinated biphenyls called PCBs, one must consider which if any identified trace contaminant in these complex mixtures might contribute significantly to the overall hazard potential of the mixture. Although there is evidence for the presence of chlorinated napthalenes and possibly chlorinated terphenyls in PCBs, the chlorinated dibenzofuran (Cl-DBF) contaminants are regarded as a greater potential danger for several reasons. In using a chick bioassay to monitor fractionation of commercial PCB mixtures, it was found (Vos et al., 1970) that the fraction most toxic to chicks, and far more toxic than the other fractions, contained Cl-DBFs and chlorinated naphthalenes. What limited toxicological information there is available on these halogenated naphthalenes, terphenyls and dibenzofurans suggests that only the Cl-DBFs may be more toxic than chlorinated biphenyls by orders of magnitude (Bauer et al., 1961; Moore et al., 1976).

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The extremely high toxicity of some of the chlorinated-dibenzo-p-dioxins (NIEHS Conference 1973; Schwetz, et al., 1973) a class of organic chemicals very similar in structure to the Cl-DBFs, also suggests the latter are likely to be highly toxic. Knowledge of the chemistry and toxicity of various chlorinated dibenzo-p-dioxin structures and the relationship between toxicity and structure, although recently developed, is more complete than for Cl-DBFs. Therefore, findings in the chlorodioxin field provide indicators to assess the difficulties likely to be encountered in the study of Cl-DBFs.

Chlorinated dibenzofuran contaminants have been reported and confirmed in PCB mixtures manufactured in Germany and France (Vos et al., 1970; Bowes, et al., 1975a) in Japan (Roach and Pomerantz, 1974a; Nagayama, et al. 1975) and in the United States (Aroclors) (Roach and Pomerantz, 1974b; Bowes, et al., 1975a). An additional claim that a cl-DBF contaminated an Aroclor was not sufficiently supported by the evidence presented (Curley et al., 1975). In the PCBs of U.S. manufacture, the range of Cl-DBFs found was from dichloro through hexachloro (see references cited above) and sufficient evidence was obtained to show that 2,3,7,8-tetrachloro and 2,3,4,7,8,-pentachlorodibenzofuran are present in Aroclors (Bowes et al., 1975b). That the Cl-DBFs reported were actual contaminants and not artifacts resulting from the experimental procedures used, was considered in two instances (Roach and Pomerantz, 1974b; Nagayama et al., 1975).

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Proper quantitation of the individual Cl-DBF contaminants is very difficult. It requires full structural identification of the Cl-DBF contaminant, availability of the contaminant as a highly purified reference standard for quantitation purposes and evaluation of the procedure used to concentrate and separate the Cl-DBFs, (e.g. from chlorobiphenyls) to determine the capability of the procedure to recover the specific Cl-DBFs in the PCB mixture. Reported attempts to quantitate the Cl-DBFs in PCB suggest contamination levels in the low parts per million range for total chlorinated dibenzofurans (Bowes et al., 1975a; Nagayama et al., 1975). Many of the reported values probably can be taken as minimal in the absence of recovery data.

Although the source of the Cl-DBF contaminants in commercial PCB mixtures has not been determined, several possibilities may be considered. The simplest explanation would be the likely presence of dibenzofuran (parent compound) in the technical grade biphenyl subjected to the chlorination process. From a consideration of the procedures used in the commercial synthesis of PCBs (Hubbard, 1964) various chlorinated biphenyls, if substituted in the ortho and ortho-prime positions with hydroxy groups and/or chlorine atoms, might ring close to form the furanoid ring by dehydration or dehydrochlorination.

It is important to recall that Cl-DBFs have been reported as contaminants also in other chemicals of commercial importance. Samples of pentachlorophenol (Schwetz et al., 1974) as well as

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lower chlorinated phenols (Firestone et al., 1972) and hexachlorobenzene, (Villanueva et al., 1974) have been found to contain a range of Cl-DBFs. The ppm level of Cl-DBFs in certain pentachlorophenols examined by Schwetz and co-workers (1974) was considerably higher than the highest level thus far reported in commercial PCB mixtures; the chlorine level in the reported dibenzofuran contaminants of pentachlorophenol ranged from hexa to octa.

It is now known that "PCB residues" obtained from environmental samples usually do not simply represent an easily identified original commercial PCB mixture. For example, there is evidence from the study of electron capture gas chromatograms that certain chlorinated biphenyl compounds are preferentially lost or concentrated in passing through environmental media. This has led to recent studies of the toxicity, metabolism and physiological effects of specific, individual chlorinated biphenyl compounds, synthesized by routes intended to yield a single compound of known structure. In addition to permitting the development of structure-activity correlations, these studies presumably were intended to avoid complications in interpreting results from the testing of the commercial chlorinated biphenyl mixtures (Vos and Notenboom-Ram, 1972), now known to contain toxic Cl-DBFs as contaminants. Interpretation of results from the testing of individual chlorinated biphenyl compounds, however, may not be entirely straight forward. In the Ullmann coupling reaction of

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2,4,5-trichloroiodobenzene, it has been reported that the highly toxic 2,3,7,8-tetrachlorodibenzofuran is formed in 3% yield in addition to the expected 2,2'4,4',5,5'-hexachlorobiphenyl product (Moron, et al., 1973). This hexachlorobiphenyl is a significant constituent of PCB mixtures (Sissons and Elti, 1971; Tas and Kleipool, 1972; Jensen and Sundström, 1974) and has been singled out for biological studies by several workers (Vos and Notenboom-Ram, 1972; Johnstone et al., 1974; Hansell and Ecobichon, 1974). Careful purification and, if necessary, chemical analysis of symmetrical chlorobiphenyls prepared by the Ullmann coupling reaction (for dibenzofuran content) is suggested as a prerequisite to biological testing of the biphenyl.

There are two other aspects of the chemical relationship betwen chlorinated biphenyls and Cl-DBFs that need to be mentioned. Both deal with possible environmental alteration. Evidence has been obtained for photochemical conversion of certain chlorinated biphenyls to Cl-DBFs in very low yields (Crosby and Moilanen, 1973). Although the scope of this study was limited, formation of Cl-DBF was shown to occur under conditions of sunlight irradiation and in the laboratory using sunlight-simulating conditions. Two different ortho-chlorinated biphenyls (the 2,5-dichloro and 2,2',5,5'-tetrachloro) were claimed to produce approximately 0.2% steady-state yields of a monochloro DBF. The limited reports regarding the photochemical decomposition of Cl-DBFs (Crosby and Moilanen, 1973; Hutzinger et al., 1973) indicate relatively

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rapid destruction of the compounds may take place in the environment. Since reductive dechlorination is a major route of photochemical alteration of Cl-DBFs, the possibility of dechlorination of highly chlorinated DBFs to more toxic DBFs of lower chlorine content must be considered. The extent to which specific chlorinated biphenyls, found as major constituents of commercial PCB mixtures, can be photochemically converted to Cl-DBFs can only be determined by further experimental studies.

Analysis of the Yusho oil (the rice oil contaminated by PCB-containing heat exchange fluid implicated in the Japanese "Yusho" poisoning incident) by Nagayama et al., (1975) for Cl-DBF content, led to a value of 5 ppm Cl-DBFs. This value is about 300 times the Cl-DBF level expected in the Yusho oil if one simply assumes contamination of the oil by Cl-DBFs to be proportional to the Cl-DBF level found in unused Kanechlor 400 (the Japanese PCB mixture claimed to have been used as the heat exchange fluid) and to the level of PCB in the Yusho oil. This led Kuratsune et al., (1975) to suggest that Cl-DBF levels increased in the heat exchange fluid through use. Going a step further, these questions may be raised: Is Cl-DBF concentration increased, generally, in PCB-containing heat exchange fluids through use? Does such increase occur in PCB-containing transformer fluids or electrical capacitors through use?

A critical review is needed of the published data upon which Kuratsume's suggestion is based (Nagayama et al., 1975), particularly

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since the results from a recent analysis of a portion of Yusho oil (Trotter, 1976) raises questions about the concentration of chlorinated biphenyls in the Yusho oil. Further laboratory studies suggested by such a review and analyses of selected, used PCB-containing industrial fluids might help to answer the above questions.

Considering the Cl-DBFs as the toxicologically most significant class of chemical impurities in the PCB mixtures, the questions may be asked: what portion of the observed effects from animal and human exposure to PCB mixtures can be attributed to the Cl-DBFs? It is doubtful this question can be answered in any quantitatively explicit way. There are analytical problems in identifying and measuring accurately the amounts of chlorinated dibenzofurans in various PCB mixtures. Even though only a relative few of the 135 possible chlorinated dibenzofurans may be identified in PCB mixtures, the toxicity of these compounds can be expected to vary with both number and ring position of chlorine atoms in the Cl-DBF molecule. Toxicity data on specific, high purity Cl-DBFs is very limited because the compounds themselves are not readily available. In addition to these essentially chemical, difficulties, toxicological judgements would be difficult to make. To begin to evaluate the toxicological "burden" to be placed on Cl-DBF contaminants in commercial PCB mixtures, a practical approach would be to use analytical procedures that can recover and quantitate specific Cl-DBF compounds known to be highly toxic. For example, 2,3,7,8-tetrachlorodibenzofuran, already reported by Bowes (1975b) as

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present in PCBs, can serve as a measure of potential hazard until further toxicity data for Cl-DBFs become available.

To date, there have been no published, positive findings of Cl-DBFs in environmental samples or in foods. Analytical procedures to detect Cl-DBFs in such samples should be developed, tested and applied to appropriate samples. If chlorinated dibenzo-p-dioxin residue analytical findings can be taken as an indicator, procedures suitable for parts per trillion detection of Cl-DBFs will be required and quantitation will be difficult.

No clear evidence for the presence of chlorinated dibenzo-p-dioxins in commercial PCB mixtures has been reported. A recent publication suggesting the presence of such contaminants in some PCBs and in a synthesized chlorinated biphenyl (Ax and Hansen, 1975) almost certainly misinterpreted the significance of the experimental finding related to the dioxins.

III. Chemistry of Brominated Biphenyls

A. Comparison of Brominated Biphenyls with Chlorinated Biphenyls

Unlike PCBs, the chemistry and stability of PBBs have not been well studied and documented in the literature. It is difficult to assess the stability and the extent of possible chemical conversion of PBBs in the environment. PBBs can be compared chemically to the PCBs. Since both bromine and chlorine are

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halogens, PBB and PCB chemistry should be similar in some respects. Bromine, however, is a better leaving group in chemical reactions than chlorine. The described laboratory experiments concerning PBB alkaline hydrolysis and photolysis show that bromine is more labile than chlorine under comparable reaction parameters. PBBs may, therefore, be less stable in the environment if PBBs were under the same physical reaction parameters in the environment as PCBs. The physical state and other physical reaction parameters of PBB and PCB residues in the environment can determine reactivity. Liquids and vapors often react more readily than solids. Aroclors are liquids, though some Aroclors are extremely viscous at room temperature. Some PCBs, especially the lower chlorinated components, are volatile. FireMaster BP-6, however, is a solid and has an extremely low vapor pressure. The production, distribution, and usage of PBBs has not been as wide spread as PCBs. PBBs, unlike PCBs, may not be physically located in a position for chemical reaction. FireMaster BP-6 has been extensively used, for example, in thermoplastics, such as typewriter and business machine housings (Kerst, 1974). FireMaster BP-6 has little tendency to migrate from the thermoplastic into which it is incorporated. The major portion of the products into which FireMaster BP-6 is incorporated is assumed to be buried eventually in refuse dumps. PCBs, on the other hand, are often used in transformers and capacitors and can be exposed to high temperatures which can accelerate possible chemical reactions. PCB residues are found in many diverse locations

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throughout most of the world. Many of these locations may offer conducive settings for chemical and metabolic conversions. PCB residues in a body of water may react photolytically, whereas PBB residues buried in a refuse dump would not be in a position to absorb light.

B. Non-metabolic Alteration of Brominated Biphenyls

Oxidation and Hydrolysis

The stability of PBBs to oxidation has not been studied and documented in the literature. FireMaster BP-6 is unstable to alkaline hydrolysis. After refluxing FireMaster BP-6 with 2% KOH in ethanol, GLC chromatograms show erratic degradation of hexabromobiphenyl (DET,DO,DCT,DCH,1976), the major component of FireMaster BP-6. The possible rate of PBB hydrolysis in the environment under milder conditions is not known.

Photochemistry

Recent analysis of FireMaster BP-6 by GCMS using an OV 101 column demonstrated 12 peaks whose mass spectrum corresponds to 2 pentas, 4 hexas, 4 heptas and 2 octas. However, about 50 percent of the material is 1 hexa isomer with the next most abundant component being the hepta isomer at about 20-25 percent. Nuclear magnetic resonance and chemical studies have identified the principal component of Firemaster BP-6 as 2,2'4,4'5,5'-hexa-bromobiphenyl (Anderson et al., 1974; Sundström et al., 1976).

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The photolytic rates of reactivity of FireMaster BP-6 and 2,2'4,4'5,5'-hexachlorobiphenyl in methanol solutions irradiated with 3000 Å light were compared (Ruzo and Zabik, 1975). The rate of reaction of FireMaster BP-6 was determined presumably by the decrease in the GLC peak of hexabromobipenyl. Hexabromobiphenyl was found to be seven times as reactive as the corresponding PCB. Hexabromobiphenyl was found to undergo photolytic reductive debromination in methanol yielding penta- and tetrabromobiphenyls and also > 1% methoxylated product. Dimethoxy tetrabromobiphenyl was identified as a product by mass spectrometry. The highly efficient photoreactivity of PBB may be due to: 1. enhanced intersystem crossing to a triplet state due to vibronic coupling with the bromines, 2. steric interference due to the bromines, and 3. the relatively low carbon-bromine bond energy. The aromatic carbon-bromine bond energy is 71 kcal/mole vs the aromatic carbon-chlorine bond energy of 86 kcal/mole (Kerst, 1974). As with PCBs (Ruzo, et al., 1974), presumably ortho halogens preferentially cleave in PBBs upon photoexcitation.

The possible rates and extent of photolytic reactivity of PBBs in the environment are not known. The photochemistry of PBBs has not been studied in the vapor or solid states. Since FireMaster BP-6 has an extremely low vapor pressure, vapor state photochemistry in the environment would be extremely limited. The extent of thin film PBB photochemistry in the environment may also be limited. PBB contamination and resulting

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photochemistry in river waters, except in the vicinity of PBB production facilities, may be limited. PBBs incorporated into thermoplastics, which are presumably buried eventually in a refuse dump, are not likely to absorb much light for photolytic reaction.

C. Brominated Biphenyls: Determination of Residues

Polybrominated biphenyl (PBB) residues are analyzed for in foods by methods quite similar to those used for organochlorine pesticides and polychlorinated biphenyls (PCBs) (Food and Drug Administration, 1968-1975; Fehringer, 1975; Food and Drug Administration, 1976). Recoveries of PBB added to samples in vivo through these procedures is over 80 percent. A method to improve extraction efficiency of PBB residue from dry, high fat animal feeds has been reported (Fehringer, 1975).

The major difference from methods for organochlorine pesticides is in the gas chromatographic determination which is done at higher temperatures or on columns with low liquid phase loads because of the lower volatility of PBBs. Methyl silicones or Silar-10C, the liquid phases most frequently used, separate the technical PBB, FireMaster BP-6, into 3-9 peaks depending on the chromatographic conditions selected. PCBs and organochlorine pesticides which would be recovered through extraction and cleanup procedures together with PBBs have earlier retention times under these conditions and are separated from the

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major PBB constituent, hexabromobiphenyl. The retention times of hexabromobiphenyl and decachlorobiphenyl are not greatly different on methyl silicone liquid phases but are widely separated on Silar-10C. Elution of the Florisil column used for cleanup of extracts with petroleum ether rather than a mixture of petroleum ether and ethyl ether separates PBBs from most organochlorine pesticides prior to gas chromatography and improves cleanup for the PBB determination.

PBB residues are detected and quantitated with the electron capture gas chromatography detector. Quantitation is based on comparison of the size of the hexabromobiphenyl peak in the residue to the size of the hexabromobiphenyl peak in a known weight of the reference material, FireMaster BP-6. FireMaster BP-6 is a technical mixture containing 60-70 percent hexabromobiphenyls (Sundström and Hutzinger, 1976). The accuracy of residue quantitation is affected by any change in the composition of the residue from that of the reference technical PBB mixture. The identity of PBB residues can be confirmed by thin layer chromatography, photochemical alteration, halogen-specific gas chromatographic detection, and by different retention times on Silar-10C and methyl silicon gas chromatographic columns (Food and Drug Administration, 1976; Fehringer, 1974; Fehringer, 1975; Erney, 1975). Mass spectrometry has also been used to confirm the identity of the PBB residue (Ayers, 1975).

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The limit of quantitation for PBB residues, including capability for residue identity confirmation, is about 0.05 ppm in fats and 0.01 ppm in non-fats (Food and Drug Administration, 1976). Formalized interlaboratory studies have not been reported for analytical methods for determination of PBB residues.

D. Possibility of Brominated Dibenzofurans in Commercial PBB Mixtures

There has been no report, so far, of the finding of brominated dibenzofuran (Br-DBF) compounds in commercial PBB mixtures. Examination of FireMaster BP-6 for possible contamination by Br-DBF is in progress in several laboratories.

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METABOLISM AND BIOCHEMICAL TOXICITY OF PCBs and PBBs

I. Effects of PCBs on Biochemical Functions

One of the major biochemical effects of PCBs is the induction of microsomal enzymes in the liver. Risebrough et al., (1968) suggested that PCBs have the capability to induce the activities of microsomal enzymes. Subsequently, Street et al., (1969) demonstrated the induction of liver enzymes in rats by PCBs. Since then, a great number of articles have been published on this subject.

The enzyme systems studied have included mainly hydroxylases, N- and O-demethylases and nitroreductases, and to a lesser extent nonspecific carboxylesterase, bromosulphophthalein-glutathione conjugating enzyme, p-nitrophenol UDP-glucuronyl transferase and EPN-detoxification systems.

The induction of microsomal enzymes by commercial PCBs has been demonstrated perorally in rabbits (Villeneuve et al., (1971), rats (Litterst et al., 1972a) and primates Allen et al., 1974) and via intraperitoneal injection (Bickers et al., 1972) and skin application in rats (Bickers et al., 1975). Values reported for the threshold of enzyme induction by PCBs vary between 0.5-25 ppm. (Litterst et al., 1972b; Villeneuve et al., 1971; Turner et al., 1974).

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The time-course of microsomal eyzyme induction was studied by Litterst et al., (1974) in rats. They found that significant levels of enzyme induction occurred after 7 days of feeding PCBs

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in the diet. A single oral dose in rats resulted in maximum enzyme activities at 24 hours. Bickets et al., (1974); 1975) have shown that maximum induction occurred within 2-6 days in rats after cutaneous exposure to Aroclor 1254 or microscope immersion oils containing 30-45% chlorine.

In order to study the effect of chlorine content of PCB's on enzyme induction, different commercial PCBs were investigated. Litterst et al., (1972b) studied PCBs with chlorine contents from 42 to 60%. In rats the maximum activity of demethylase was observed with the 54% chlorine PCB's; maximum activity for nitroreductase was obtained with the 60% chlorine PCBs. Chen et al., (1973) reported that 54% chlorinated PCBs. gave maximum response of demethylase in rats. Similar results were reported by intraperitoneal injection of various PCBs in rats (Ecobichon et al., 1974). Goldstein et al., (1975) and Iverson et al., (1975) studied the effects of Aroclor 1016 and Aroclor 1242 on enzyme induction in rats. Both PCBs have approximately 42% chlorine, but the content of the penta-, hexa-, and hepta-chlorine isomers of Aroclor 1016 is reduced to 10% of that in Aroclor 1242. Their results showed that Aroclor 1242 was a much more potent inducer than Aroclor 1016 in female rats. In comparing Aroclor 1232, Aroclor 1248 and Aroclor 1260, Schmoldt et al., (1974) found that Aroclor 1260 was the most potent enzyme inducer in rats.

The synthetic and isomerically pure PCBs have been investigated for enzyme induction, Chen et al., 91973b) found that both

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2,3,4,5- and 3,5,3',5'-tetrachlorobiphenyls induced enzyme systems in male rats, but no significant differences were found between the two isomers. Johnstone at al., (1974); Ecobichon et al., (1975); Ecobichon (1975) compared the effects of position of chlorine atoms on the ring. They found that enhanced induction of mono-oxygenases was observed for PCBs having chlorine atoms substituted at the 4- and 4'- positions irrespective of chlorination at other positions. Substitution at the 2-position was next in importance followed by substitution at the 3-position. They concluded that the position of chlorination was as important as the degree of chlorination.

There are two types of enzyme inducers being reported in the literature. One group to which phenobarbital belongs resulted in increased cytochrome P-450 content, as well as increased benzopyrene hydroxylase and ethylmorphine demethylase activities in the liver. The second group includes polycyclic hydrocarbons. This group stimulates the formation of cytochrome P-448 and an increase in hydroxylation but not demethylation. Alvares et al., (1973) reported that rats treated with PCBs produced an increase in cytochrome P-448, hydroxylase, as well as demethylase. Therefore, it appears that PCBs display induction behavior typical of both groups.

Most of the enzyme induction studies were evaluated <u>in vitro</u>. Several workers indeed have observed enzyme induction effects <u>in vivo</u> by demonstrating shortened barbiturate sleeping times (Bickers et al., 1972; Johnstone et al., 1974; Villeneuve et al., 1972):

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Commercial PCBs are known to contain small amounts of dibenzofurans (DBF). DBFs were found to be 170 times as potent as PCBs in inducing enzymes.

Alvares & Kappas (1975) reported the induction of hydroxylase and demethylase in placenta, as well as in the fetus, when pregnant rats were treated with PCBs. Vainio (1974) reported that Clophen A50 enhanced hydroxylase 5-fold in the lung and 8-fold in the kidney microsomes, whereas the microsomes from duodenal mucosa exhibited no enhancement. Benzopyrene hydroxylase activity in skin was also increased by PCBs (Bickers et al., 1975).

Vos and Koeman (1970) found that several tissues of PCB-treated chickens were strongly fluorescent under ultraviolet light. They suggest that PCBs could induce chemical porphyria in chickens. Later, they demonstrated that mitochondrial ALA Synthetase activity increased 20-fold and fecal porphyrin levels were significantly increased in Japanese quail treated with PCBs (Vos, 1971; Vos et al., (1972). They suggested that the porphyria caused by PCBs is due to the increase of ALA synthetase, followed by overproduction of porphyrins. Similar results in rats were obtained by Goldstein et al., (1974), and Bruckner et al., (1974). Goldstein et al., (1974) suggested that the induction of ALA synthetase is probably not the primary cause of PCB-induced porphyria because of the delayed onset of porphyria as compared with ALA synthetase induction. They suggest that the ALA synthetase in the liver may be related to the increase of cytochrome P-450 content. This

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idea was supported by Grote et al., (1975). Aroclor 1242 was found to be a more potent inducer of liver porphyria than Aroclor 1016 (Goldstein et al., 1975). Both Aroclors have similar chlorine content, but Aroclor 1242 contains 9% homologs with five or more chlorines while Aroclor 1016 contains only 1% of such homologs. Sinclair and Granick (1974) showed that cultured liver cells respond rapidly to PCBs in accumulation of uroporphyrin. Simon et al., (1974) suggested that porphyria may be due to the destruction of the phospholipid structure of cell membrane, resulting in increased permeability of the substrate. Hirayama et al., (1974) observed hypo-bilirubinaemia in Yusho patients and suggested that the induction of bilirubin UDP-glucuronyltransferase may be responsible for the low plasma bilirubin content. However, recently Bastomsky et al., (1975) showed that the lowering of serum bilirubin concentration by PCBs is due to the reduced binding of bilirubin to plasma protein rther than to the enzyme induction. Wit (1972) has shown that PBBs which are similar to PCBs are potent heptoporphyrinogenic chemicals.

The chemical and structural similarity of DDT to PCBs led Jefferies et al., (1972) to study the effects of PCBs on thyroid functions. They found an increase in thyroid weight in PCB-treated black-backed gulls as compared to controls. Hurst et al., (1974) found no clear-cut effect of PCBs on thyroid gland size in quails. Byrne et al., (1975) reported that PCBs increased

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thyroxine levels in the blood and also promoted peripheral degradation of thyroxine in female minks. Bastomsky (1974) found a 4 to 5-fold increase of biliary excretion of thyroxine in rats treated with PCBs. PCBs also elevated iodine uptake by the thyroid and reduced serum PBI concentration. Recently Bastomsky and Wise, (1975) showed similar results in rats due to either intraperitoneal injection or skin application of microscope immersion oil. Walker (1975) found that inclusion of Aroclor 1254 in fish food resulted in an increase in fish thyroid activity.

The effects of PCBs on ATPase and oxidative phosphorylation have been examined by a number of investigators. $Na^{+}K^{+}$-ATPase and Mg^{++} ATPase from several fish tissues were found to be inhibited by PCBs. (Yap et al., 1971; Cutkomp et al., 1972; Desaiah et al., 1972; Koch et al., (1972). Further study showed that in vitro data were not in agreement with the in vivo data (Yap et al., (1974). The inhibition of ATPase in fishes by PCBs was also reported by Kinter et al., (1972) and by Davis et al., (1972).

Sivalingan et al., (1973) investigated the effects of PCB on the oxidative phosphorylation of rat liver mitochondria. They showed that the mode of inhibition appears to be different with PCBs of different chlorine content. PCBs with low chlorine content inhibited energy and electron transfer but PCBs with high chlorine content not only inhibited energy and electron transfer but also had an uncoupling effect. LaRocca et al.,

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(1975) showed that the administration of commercial PCBs, as well as purified isomers to rats inhibited the total ATPase activity in liver, kidney and brain tissues.

Pardini (1971) has demonstrated that a marked inhibition of respiratory enzyme systems occurred when heavy beef heart mitochondria were exposed in vitro to numerous PCBs. Chesney and Allen (1974) showed that the addition of PCBs to rat liver mitochondria in vitro caused an inhibition of oxidative phosphorylation and respiration. Feeding rats with PCBs at the 1000 ppm level increased the oxidative phosphorylation in liver mitochondria; however, no effect was seen at the 100 ppm level.

Sharp et al., (1974) reported that the inhibition of beef brain and rabbit kidney $Na^{+}K^{+}$-ATPases can be reversed or prevented by phosphatidylserine or phosphatidylinositol, but not by phosphatidychloline and phosphatidylethanolamine. They suggested that acidic phospholipids are required to stabilize the enzyme and thereby overcome the effect of PCBs.

Risebrough et al., (1968) suggested that PCBs had the capacity to enhance steroid-hydroxylating enzyme activity, thus affecting estradiol metabolism. In addition, certain low chlorine containing PCBs have estrogenic activity which is reflected by an increase in glycogen content of the uterus of immature rats (Bitman and Cecil, 1970). Similar results were obtained by Fumiko (1972) in rats (Bitman and Cecil, 1970). Similar results were obtained by

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Fumiko (1972) in rats and by Orberg, and Kihlstrom (197) in mice. Orberg et al., (1972) found that the estrus cycle of the mouse increased in length after a single injection of PCBs. Lincer and Peakall, (1973) reported an increased rate of metabolism of estradiol in vitro in the liver of American kestrels after the feeding of PCBs. Similar results were also reported in white leghorn cockerels and pullets (Nowicki and Norman 1972). Platonow and Funnell (1971) demonstrated that feeding PCBs to cockerels resulted in a decrease in testicular and comb growth. Decreased urinary excretions of estrogen and dehydroepiandrosterone were also observed in cockerels when PCBs were administered in high doses (Platonow et al., 1972). Ecobichon and Mackenzie, (1974) studied the uterotropic activity of commercial and isomerically pure PCBs in rats. They found significant changes with a number of PCB mixtures but experiments with the isomerically pure PCBs were inconclusive. Changes were observed with 2-chloro and 2,2-chlorobiphenyls. Nelson (1974) reported that PCBs are effective inhibitors of the binding of ^{3}H-estradiol to the rat uterus cytosol fraction in vitro. Recent data showed that PCB feeding caused neither significant chromosomal damage nor arrest in the rate of spermatogenesis in male rats (Dikshith et al., (1975).

Flick et al., (1965) noted enlarged adrenals and small spleens in PCB-treated white leghorn cockerels. Wassermann and Wassermann (1972) and Wessermann et al., (1973) reported that rats receiving 200 ppm PCBs showed an increase in plasma corticosterone levels.

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These changes were concomitant with morphological changes in the zona fasciculata of the adrenal gland which indicated increased activity. Sanders, et al., (1974) have shown similar increases in serum corticosterone in mice fed 60 to 1000 ppm PCBs.

It is known that DDT decreases the utilization of dietary carotene and liver storage of vitamin A in rats and cattle (Phillips, 1963; Phillips, and Hidiroglou, 1965). Villeneuve et al., 1971) reported that Aroclor 1254 but not Aroclor 1221 reduced the liver concentration of vitamin A in pregnant rabbits. Decreased liver vitamin A concentrations were found in male and female rats and also Japanese quail after PCB feeding (Cecil et al., 1973). However, the laying female quail did not appear to be affected.

The effects of PCBs on vitamin E have been studied by Combs et al., (1975). Their results indicated that dietary PCBs increased the incidence of exudative diathesis in chicks and that this increase can be overcome by increasing dietary vitamin E or selenium. The vitamin D mediated calcium metabolism was found to be altered by the oral administration of PCBs to chickens (Wong et al., 1974).

II. The Comparative Biochemical Toxicity of Aroclor 1254 and Firemaster BP-6

PCBs have been reported to affect a large number of biochemical systems. To the extent that it has been reported, PBBs

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affect most of these same systems in a similar fashion. However, quantitative and possibly qualitative differences do not appear to exist in the response of some biological parameters. These include thyroid hyperplasia (Norris et al., 1973) and microsomal enzyme induction (Farber and Baker, 1970).

A preliminary study was conducted to compare the relative effect of Aroclor 1254 (Aro) with Firemaster BP-6 (FM) (Garthoff et al., 1975). This was set up as a broad survey to give an estimate of the relative biological activity of these chemicals in many different systems and pin point areas where further more definitive work should be done.

Table 1 summarizes the time sequence of the various parameters studied. Adult male rats were fed either 0, 5, 50, or 500 ppm Aroclor 1254 or Firemaster BP-6, mixed in the diet, for 2, 3, or 5 weeks.

Due to the large number of parameters examined and the time restraints placed on the study, the experimental design did not permit a totally unambiguous comparison between all of the effects caused by Aro and FM. Some apparent differences in biochemical responses determined at sacrifice may have been partly due to the fact that, for the three-week study, rats were exposed to FM for 48 hours longer than rats were exposed to Aro. Although it is felt that under the experimental conditions, this effect should be small, critical comparison of Aro and FM toxicity should be

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considered tentative until similar experiments are conducted which can eliminate this difference in exposure time. The following evaluations were made based on the assumption that this two day difference had no effect.

Some parameters showed no consistent or dose related change with either chemical at any level. These included relative kidney weight and testes weight, hematology, SGPT, SGOT, plasma BUN, plasma corticosterone, the rate of liver protein synthesis per g tissue, liver dry weight, lyophilizable kidney, liver, or testes, the incidence of chromosome abnormalities and the number of cells in mitosis from bone marrow of spermatogenial cells.

Growth and adipose tissue weight were equally depressed by Aro and FM when fed over a three week period at 500 ppm. The growth effect appeared to be due primarily to decreased food efficiency.

Three parameters were more sensitive to Aro than to FM. These included the decreased liver protein and liver RNA per g tissue and the decreased plasma glucose.

On the other hand, six parameters were more sensitive to FM. These included liver growth, increased liver lipid (total lipid, cholesterol, phospholipid, and neutral lipid), elevated plasma cholesterol, increased microsomal enzyme activities, impaired mitochondrial function, and decreased liver RNA synthesis.

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Disruptions of the redox and energy states of the cell were produced by dietary exposure to Aro or FM. These effects were indicated by studies with isolated mitochondria and frozen clamped liver. In the latter case the concentrations of adenine nucleotides, pyridine nucleotides, and glycolytic intermediates were determined. On a molar basis, hexabromobiphenyl was reported to be about five times more potent than Arochlor 1254 in causing some increased microsomal enzyme activities (Farber and Baker, 1974). A three-fold difference was observed between Firemaster BP-6 and Arochlor 1254 (Table 3).

A pathology team autopsied rats after both three and five weeks exposure to Aro and FM (Kasza et al., 1975). Pathological analysis of the liver of rats fed Aro or FM for three weeks showed no abnormalities on gross observation. No histopathological lesions were seen in controls, Aro groups, or the 5 and 50 ppm FM groups, after three weeks. In the 500 ppm FM group, minimal vacuolation and focal hepatitis were each seen in one rat. After five weeks exposure, gross observation of the liver indicated an increasing incidence of enlargement, friability, and prominent lobular pattern with increasing dose of both chemicals. Microscopically the 5 ppb Aro group appeared normal while 2/7 rats fed 5 ppm FM had minimal cytoplasmic degeneration. All rats had this lesion at 50 and 500 ppm Aro or FM, with increasing cellular lipid. This lesion was recent, centrilobular and coalescing with no change in fibrous tissue or glycogen. The histopathology was qualitatively similar but slightly more severe in rats fed FM

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than in those fed Aro and is consistent with biochemical findings. The biochemical findings were all made after three weeks exposure at which time histopathological changes were not evident. Even at five weeks the histopathology was not severe enough to alter most of the clinical chemistry in the rat.

In most parameters evaluated, FM either caused an effect at a lower dose level or caused an effect in a shorter time or caused a greater effect at the same dose level, expressed as ppm in the diet, as Aro. When expressed on a molar basis FM becomes even more effective than PCB. Exceptions to this observation were noted at the 500 ppm dose level where differential effects of Aro and FM were often eliminated.

A summary of the major effects seen are found in Tables 2, 3, and 4. In all but one case the maximum response of a parameter occurred at the highest dose level. Microsomal enzyme activities were, in general, greater at the 50 ppm level and the decline at 500 ppm relative to the 50 ppm level was more marked with FM.

III. Metabolism of PCB and PBB Mixture

Generally, the tissues from animals and man containing PCB from environmental exposure have GLC patterns resembling those of PCB mixtures with more than 50% chlorination. This is in marked contrast to the major manufactured products that generally contain 42% or less chlorine. While one cannot rule out the possiblity that differential uses favored introduction of more highly

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TABLE 1

PARAMETERS EVALUATED IN STUDY

EXPOSURE TIME

(WEEKS)

PARAMETERS	TWO	THREE	FIVE
Body weight	x	x	x
Liver weight	x	x	x
Other tissue weights		x	
Mitochondrial respiration	x		
Liver composition		x	
Liver protein synthesis		x	
Liver RNA synthesis		x	
Liver Microsomal enzyme activities		x	
Liver intermediary metabolites		x	
Serum cholesterol		x	
Serum enzymes		x	x
Plasma corticosterone		x	
Plasma protein		x	
BUN		x	x
Gross pathology		x	x
Histopathology		x	x
Cytogenetic analysis			x

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TABLE 2

RELATIVE BIOCHEMICAL RESPONSE TO Aro AND FM AFTER TWO WEEKS DIETARY EXPOSURE

	LEL[1] ppm		Maximum Effect % Control	
	Aro	FM	Aro	FM
PARAMETERS				
Liver weight / Body weight	500	50	170	183
Mitochondrial respiration	500	500	152	192

[1]LEL = lowest effective level that showed a dose-response relationship.

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TABLE 3

RELATIVE BIOCHEMICAL RESPONSE TO Aro AND FM
AFTER THREE WEEKS DIETARY EXPOSURE

	LEL[1] ppm		Maximum Effect % Control	
	Aro	FM	Aro	FM
PARAMETERS				
Body weight gain	50	500	52	52
Liver weight / Body weight	50	50	203	214
Liver dry wt.	NE[3]	50	NE[3]	107
Liver lipid	50	5	138	156
Liver cholesterol	500	50	226	232
Liver protein	500	NE	84	NE
Liver RNA	5	50	79	84
Liver DNA	5	5	58	60
Liver RNA synthesis	500	5	78	86

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TABLE 3 (Cont'd)

	LEL[1] ppm		Maximum Effect % Control	
	Aro	FM	Aro	FM
PARAMETERS				
para-Nitrobenzoate reductase activity	50	5	288[2]	520[2]
Plasma glucose	50	NE[3]	79	NE[3]
Plasma cholesterol	500	5	178	256

[1]Lowest effective level that shows a dose response relationship.

[2]Maximum effect occurred at 50 ppm dose.

[3]NE = No effect

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TABLE 4

RESPONSE OF RELATIVE LIVER WEIGHT TO Aro AND FM AFTER FIVE WEEKS DIETARY EXPOSURE*

PARAMETER	LEL ppm		Maximum Effect % Control	
	Aro	FM	Aro	FM
Liver weight / body weight	500	50	171	216

* Legend - see Table 3.

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chlorinated materials in the environment, the observation has led to the general belief that the less chlorinated components are more readily metabolized.

The environmental observations have been confirmed in a large number of experimental feeding studies in a number of mammalian and avian species. The absence or diminished concentration of the early eluting peaks have been reported in rats (Grant et al., 1971a, Curley et al., 1971), rabbit (Grant et al., 1971b), cow (Fries et al., 1973a), quail (Bailey and Bunyan, 1972), and hens (Fries et al., 1973b).

The peaks not present in tissues and products generally are the early eluting peaks that correspond to the PCBs with lower degrees of chlorination. The observations are consistent with the belief that the rate of metabolic attack on PCBs decreases with increasing chlorination. Studies of the single PCB homologs of various degrees of chlorination have shown that those with five or less chlorine atoms are more readily metabolized and excreted than the PCBs with higher chlorination (Berlin et al., 1975; Hutzinger et al., 1972; Melvas and Brandt, 1973). The position of chlorine substitution also affects the retention and elimination of single homologs (de Freitas and Norstrom, 1974). Metabolism of individual PCBs will be discussed more thoroughly in another section.

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Among the various food species there appears to be one exception to the general rule that the less chlorinated PCBs are hydroxylated. The PCB residues in fish closely resemble the PCB to which the fish was exposed. There was little change in the relative concentrations of the various homologs (Stalling and Mayer, 1972). Consistant with this observation it has been found that mono-, di-, and tetrachlorobiphenyls are not metabolized by trout (Hutzinger et al, 1972).

Among the food producing animals (cattle, chickens) concentrations of PCB residues in milk and eggs reach a "steady state" after approximately 8 to 12 weeks of continuous intake (Fries et al., 1973a; Fries et al., 1973b). The ratio of residue levels in food products to levels in the animal's diet are greatest with PCBs of 54% chlorination. The residue levels in milk are approximately 4 times the residue level in the cow's diet. In hens, residue levels in eggs are approximately equal to the diet while residue level in the body tissue (fat basis) is approximately 6 times the dietary level. The ratio of residue level in product and tissues to intake is lower with PCBs of greater than 54% chlorination. Since it is unlikely that there is greater metabolism of the most highly chlorinated PCBs, the results suggest that the absorption for the GI tract is lower for the more highly chlorinated PCBs (Smith et al., 1976). PCBs of four or fewer chlorines rarely occur in animal products when the animals are fed environmentally realistic levels.

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Much less is known about the metabolism of PBB than PCBs. However, the observations that have been reported tend to be consistent with the reports on PCB metabolism.

While the PBB of most immediate concern for human health (BP-6, Michigan Chemical Co.) is a multicomponent mixture like the PCBs, it is much simpler than the ordinary commercial PCB mixtures. The major component is a single hexabromobiphenyl accounting for over 60% of the total material. The only other component occurring in significant amounts is a single heptabromobiphenyl.

In general, the measures of retention in edible tissues and excretion in edible products are similar for the hexabromobiphenyl and the hexachlorobiphenyls (Fries et al., 1976; Fries and Marrow, 1975). Heptabromobiphenyl retention and excretion is only 1/10 of that of the hexabromobiphenyl. In cattle that have been heavily contaminated with BP-6, the heptabromobiphenyl was barely detectable (milk or tissues) 6 to 8 months after the time of ingestion even though the hexabromobiphenyl level was over 1000 ppm (Fries et al., 1975). Since the heptabromobiphenyl is not more likely to be metabolized by the animal than the hexabromobiphenyl, it is reasonable to assume that its absorption is lower or its elimination through bile is greater than the hexabromobiphenyl component. Over 60% of octabromobiphenyl is excreted in the feces as the parent compound when it is fed to rats (Norris et al., 1974). This observation supports the conclusion that there is less absorption with increasing halogenation.

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IV. The Metabolism of Individual PCBs

Quantitative studies of the distribution of PCBs indicate that most, if not all, PCBs which contain six or fewer chlorine atoms are efficiently absorbed from the gut of higher animals (Albro and Fishbein, 1972; Matthews and Anderson, 1975a; Van Miller et al., 1975). Furthermore, only about one-tenth of the absorbed dose is excreted prior to metabolism to more polar compounds (Matthews and Anderson, 1975a; Van Miller et al., 1975; Balin et al., 1975). A number of the less chlorinated PCBs (i.e., mono-, di-, tri-, and tetrachlorobiphenyls) are readily metabolized and excreted by birds and mammals. There is little evidence that fish can metabolize any PCB.

It has been adequately demonstrated that a number of mammalian species and the pigeon can readily degrade and excrete monochlorobiphenyls, primarily 4-chlorobiphenyl (Matthews and Anderson, 1975a; Block and Cornish, 1959; Hutzinger et al., 1972; Safe et al., 1975a,b,c). However, the rate of metabolism drops sharply as the number of chlorines per molecule increases. For example, the rate of metabolism and excretion of several PCB isomers has been shown to decrease as the number of chlorines increases in the following order: 4-chlorobiphenyl 4,4'-dichlorobiphenyl 4,4'-dichlorobiphenyl 2,5,2',5'-tetrachlorobiphenyl 2,4,5, 2',5'-pentachlorobiphenyl (Matthews and Anderson, 1975a; Van Miller et al., 1975; Matthews and Anderson, 1975b). The rate

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of metabolism and excretion of 4,4'-dichlorobiphenyl is approximately one-half that of 4-chlorobiphenyl. In each case the PCBs are metabolized primarily by hydroxylation and conjugation with glucluronic acid (Matthews and Anderson, 1975a; Balin et al., 1975). The importance of the route of excretion, i.e., urine or feces, is determined primarily by the degree of chlorination. Approximately 60, 30, and 7 percent of a single dose of a mono-, a di-, and a pentachlorobiphenyl, respectively, were excreted in the urine of rats. The remainder of the dose was excreted in the feces (Matthews and Anderson, 1975a).

Once the number of chlorine atoms on the biphenyl molecule reaches four, the position of the chlorine atoms becomes a more important factor in determining the rate of metabolism and excretion (Matthews and Anderson, 1975a; De Freitas and Norstrom, 1974). As was observed with the chlorinated benzenes (Jondorf et al., 1955; Jondorf et al., 1958) those PCBs which have two adjacent unsubstituted carbon atoms are metabolized and excreted more rapidly than PCBs having the same degree of chlorination, but which do not have two adjacent unsubstituted carbon atoms (Matthews and Anderson, 1975a). It is also likely that, as with the chlorinated benzenes, the absence of two adjacent unsubstituted carbon atoms has a greater effect as the degree of chlorination increases. For example, the initial half-life of 3,5,5',5'-tetrachlorobiphenyl is only about two-fold greater

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in the rat (Matthews and Tuey, 1976) than that of 2,5,2',5'-tetrachlorobiphenyl in the same species (Van Miller et al., 1975). On the other hand, the initial half-life of 2,4,5,2',4',5'-hexachlorobiphenyl appears to be infinite, whereas the initial half-life of 2,4,5,2',5'-pentachlorobiphenyl is only about two days (Matthews and Anderson, 1975a). This particular hexachlorobiphenyl has been shown to be in the highest concentration of any PCB found in the adipose tissue of the Swedish population (Jensen et al., 1974).

The importance of two adjacent unsubstituted carbon atoms to the metabolism of PCBs may be derived from their effect on the formation of arene oxide intermediates during the metabolism of these compounds by the hepatic mixed-function oxidases. Evidence for the formation of arene oxide intermediates in PCB metabolism was first provided by Gardner et al., (Gardner et al., 1973) in their study of the metabolism of 2,5,2',5'-tetrachlorobiphenyl and in a later study of 4-chlorobiphenyl metabolism by Safe et al., (1975c) which was specifically designed to provide evidence of an arene oxide intermediate. Metabolism of PCBs which do not have two adjacent unsubstituted carbon atoms by hepatic mixed-function oxidases, via direct hydroxylation of the biphenyl molecule and/or the formation of an arene oxide between a chlorinated and an unsubstituted carbon atom could occur, but each of these mechanisms would be expected to be slower than arene oxide formation between two unsubstituted carbon atoms (Daly et al., 1972; Jerina and Daly, 1974). The latter mechanism would be expected

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to result in dechlorination and/or shifting of a chlorine atom (Daly et al., 1972). The metabolism of selected hexachlorobiphenyls has been reported (Jensen and Sundstrom, 1974; Hutzinger et al., 1974; Hass, unpublished), and in two incidents (Hutzinger et al., 1974; McKinney et al., unpublished) dechlorination and/or chlorine shifting was observed, but in all cases the rate of metabolism was quite slow.

Thus, those PCBs which are more readily metabolized and excreted may also more readily form arene oxides. Certain arene oxides have been implicated as potential carcinogens (Daly et al., 1972; Jerine and Daly, 1974) as have certain PCB formulations (Ito et al., 1973; Kimbrough and Linder, 1973; Kimbrough et al., 1975), but there is no published evidence which indicates that the less chlorinated PCB formulations have been so rigorously tested.

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ANIMAL TOXICOLOGY

Introduction

A number of reviews on different aspects of the toxicology of the PCBs have been written recently and no effort has been made in this report to give a complete outline of the animal toxicology (Kimbrough, 1974; Peakall and Risebrough, 1975; Nelson et al., 1972; Fishbein, 1974).

The material summarized in this report consists predominantly of more recently published information on toxic effects of PCBs in mammals and experimental studies in birds. Since Nelson et al. (1972) discussed extensively the toxic effects produced in fish by PCBs, the reader is referred to this and the other reviews cited above for information on toxicity of PCBs in this species.

The emphasis of the present review was placed on chronic toxic effects wherever possible. Unfortunately, very little information was available for halogenated dibenzofurans and the brominated biphenyl mixtures.

Acute Toxicity

Polychlorinated Biphenyls (PCB)

The acute oral LD_{50} of the PCBs in rats, rabbits and mice ranges from 1 to 10 g/kg body weight (Tables 5,6). There is some indication that young animals may be more sensitive than adults,

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and females more sensitive than males (Table 5). According to the classification used by the American Industrial Hygiene Association (Hodge & Sterner, 1949), the acute toxicity of the PCBs can be classed as slightly toxic (0.5 to 5 g/kg body weight) to practically non-toxic (5-15 g/kg body weight).

The symptoms associated with administration of a toxic dose of PCB (Aroclor 1242) in rats consist of diarrhea, diminished exploratory behavior, decreased response to pain stimuli, chromodacryarrhea, adipsia, oliguria, anorexia, erythema of limbs, followed by ataxia, coma and death. Death occurred up to 14 days following administration of the toxic dose. 24 hours after administration of a single toxic dose of Aroclor 1242, gross pathology indicated all organs appeared normal except the liver and kidneys. No inflammation was observed in the abdominal and intestinal mucosa. Histopathological findings showed large discrete sudanophilic vacuoles in the hepatocytes. Widely scattered foci of tubular epithelial cells were present in the kidneys (Bruckner, et al., 1973). However, Kimbrough (1974) reported ulceration of the gastric and duodenal mucosa in rats after single oral doses of 3,000 mg/kg Aroclor 1254 or 1260.

Only one metabolite of PCB is known to have been tested for the acute LD_{50}. The 5-OH metabolite of 2,4,3'4'-tetrachlorobiphenyl was known to be more toxic than the parent compound (0.43 g/kgBW/2.15 g/kgBW (Table 5). Dermal toxicity of PCB is summarized in Table 7.

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Polybrominated Biphenyls (PBBs)

Polybrominated biphenyls show a low order of acute toxicity to the rat (Table 8). In the case of chicks, a 37% mortality was reported when PBB was administered in the diet at a level of 400 ppm, for 15 days. Seven out of eight guinea pigs fed 50 ppm dietary PBB died (Vos and VanGerderen, 1973). Effects noted included cortical atrophy of the thymus, adrenal enlargement, marked depletion of the follicles and periarteriolar lymphocytes sheath of the spleen.

Chlorinated Dibenzofurans

See subacute toxicity.

Chlorinated Napthalenes

See end of chapter.

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TABLE 5

Compound Tested	Species	Route	g/kg body wt. LD_{50}	Reference
Aroclor 1254	Rat(Adult-Sherman Strain)	oral	4-10	Linder, et al. (1974)
" 1260	Rat(Adult-Sherman Strain)	oral	4-10	"
" 1254	Rat(weanling " ")	oral	1.295	"
" 1260	Rat(weanling " ")	oral	1.315	"
" 1254	Rat(female " ")	Intravenous	0.358	"
" 1221	Rat(female " ")	oral	4.00	Panel on Hazardous Trace Substances (1972)
" 1262	Rat(female " ")	oral	11.3	
" 1240	Rat	oral	4.25	Bruckner, et al. (1973)
" 1254	Rat(Wistar-30-day-old M-F)	oral	1.3	Grant & Phillips (1974)
" 1254	Rat(Wistar-60-day-old M-F)	oral	1.4	"
" 1254	Rat(Wistar-120-day-old M)	oral	2.0	"
" 1254	Rat(Wistar-120-day-old F)	oral	2.5	"
Kaneclor-400	Rat(Wistar Strain - Male)	oral	1.30 (ml/Kg)	Ikeda, et al. (1970)
Kaneclor-400	Rat(Wistar Strain - Female)	oral	1.14 (ml/Kg)	
Kaneclor-400	Mice(CFI Strain - Male)	oral	1.875 (ml/Kg)	
Kaneclor-400	Mice(CFI Strain - Female)	oral	1.57 (ml/Kg	
Kaneclor-300	Rat(Wistar Strain - Male)	oral	1.15	
Kaneclor-300	Rat(Wistar Strain - Female)	oral	1.05	
BP-200 (biphenyls of dicloride and below	Mice(dd-strain-female)	oral	6.36	Kitamura (1972)
2,4'-dichlorobiphenyl	Mice(dd-strain-female)	oral	7.86	"
trichlorobiphenyl	Mice(dd-strain-female)	oral	3.06 - 4.25	
biphenyl of trichloride and below	Mice(dd-strain-female)	oral	9.27	"
2,4,3',4'-tetrachlorobiphenyl	Mice(CFI strain)	Intraperitoneal	2.15	Yamamoto & Yoshimura (1973)
5-OH derivative of 2,4,3'4'-tetrachlorobiphenyl	Mice(CFI strain)	"	0.43	"
2,3,4,3'4'-pentachlorobiphenyl	Mice(CFI strain)	"	0.65	"

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TABLE 6

Oral LD_{50} (Rat) (Panel on Hazardous Substances, 1972)

Compound Tested		g/Kg body wt.
Aroclor 1221	(undiluted)	3.98
Aroclor 1232	(undiluted)	4.47
Aroclor 1242	(undiluted)	8.65
Aroclor 1248	(undiluted)	11.0
Aroclor 1260	(50% soln in corn oil)	10.0
Aroclor 1262	(50% soln in corn oil)	11.3
Aroclor 1268	(50% soln in corn oil)	10.9

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TABLE 7

Skin MLD_{50} Rabbits (Panel on Hazardous Substances, 1972)

Compound tested		g/Kg body wt.	
Aroclor 1221	(undiluted)	>2.000	<3.169
Aroclor 1232	(undiluted)	>1.26	<2.0
Aroclor 1242	(undiluted)	> .794	<1.269
Aroclor 1248	(undiluted)	> .794	<1.269
Aroclor 1260	(50% soln in corn oil)	>1.26	<2.0
Aroclor 1262	(50% soln in corn oil)	>1.26	<3.16
Aroclor 1268	(33.3% soln in corn oil)	>2.5	

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TABLE 8

LD_{50} Polybrominated Biphenyls

Compound	Species	Route	LD_{50}	Reference
Firemaster BP6	Rat	Oral	21.5 g/Kg	Hill Top Research, Inc. (1970) for Michigan Chemical Company
Octabromobiphenyl	Rat	Oral	More than 2 g/Kg	Aftosmis, et al., 1972
Octabromobiphenyl	Bobwhite Quail	Oral	More than 12.5 g/Kg	"
Hexabromobiphenyl	Rabbit	Dermal	More than 5 g/Kg	"
Octabromobiphenyl	Rabbit	Dermal	More than 10 g/Kg	"

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SUB-ACUTE AND REPRODUCTIVE EFFECTS OF PCB'S, PBB'S AND CHLORINATED DIBENZOFURANS

A. Mammalian Sub-acute Effects of PCBs

In contrast to the acute toxicity (oral and dermal) of the PCBs which is of relatively low order when the substances are administered as a single dose, aspects of sub-acute toxicity of both the PCBs and individual chlorinated biphenyls appear to be of far greater concern, exhibiting species sensitivity and cumulative toxic effects following continuous exposure at low levels.

When groups of mice were given toxic rice bran oil containing 1,600 ppm PCBs or 5000 ppm of PCB mixture with 48% chlorine, the toxicity response was similar in the two groups (Nishizumi 1970).

In a group of rats fed 2000 ppm of Phenochlor DP-6, deaths occurred between the 12th and 26th days with enlarged livers, atrophy of the spleens and a progressively induced hepatic porphyria was noted (Vos and Koeman, 1970). Administration of 1000 ppm of Arochlor 1254 in the diet of rats resulted in deaths between the 28th day and 53rd day (100% mortality) of feeding (Tucker and Crabtree 1970), 50% mortality at the same dosage in an 8-month study was reported by Kimbrough et al. (1972).

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Two groups of 52 male Sherman strain weanling rats were fed 100 ppm Aroclor 1242 (6.6-3.89 mg Aroclor/kg body weight) and 100 ppm Aroclor 1016 (6.9-3.5 mg Aroclor/kg body weight) respectively for 6 months and 54 rats were fed ground chow. Groups of 4 rats were sacrificed at intervals. Microscopic examination of the liver showed evidence of lipid accumulation, enlarged liver cells, inclusions in a number of livers and hemorrhage and necrosis in one animal per experimental group each. No difference in effect between the two compounds was noted (Burse et al., 1974).

Rats given 100 mg Aroclor 1242/kg body weight by stomach tube every other day for 3 weeks showed histopathological changes only in the liver and kidneys as foci of sudanophilic vacuolation but no overt sign of toxicity (Bruckner et al., 1973).

Rats (Sprague-Dawley) given 100 ppm of 2,5,2', 5'-tetrachlorobiphenyl in the diet for 3 weeks showed less liver hypertrophy and fewer biochemical changes than rats given a similar dose of Aroclor 1248 (Allen et al., 1975).

Administration of 100 mg/kg body weight of Aroclors 1242, or 1254 orally to rabbits once a week for 14 weeks resulted in enlarged livers with apparent destruction of the rough endoplasmic reticulum and atrophy of the uteri, while Aroclor 1221 did not cause this effect (Koller and Zinkl, 1973).

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The unusual sensitivity of mink to PCBs was reported by Aulerich et al., (1973) who noted 100% mortality within 6 months following administration of 30 ppm PCB (10 ppm each of Aroclor 1242, 1248 and 1254) to adult mink. Feeding of Aroclor 1254 at levels of 5 and 10 ppm in the diet for 4 months led to a dose-dependent retardation of weight gain of growing female mink. Platonow and Karstad (1973) produced 100% mortality in mink when they fed this species 3.6 ppm Aroclor 1254 in the diet for 105 days.

Rhesus monkeys are also very sensitive to PCBs (McNulty, 1975). For example, adult female rhesus monkeys (Macaca Mulatta) have been fed diets containing 2.5, 5.0 and 25.0 ppm of Aroclor 1248 over periods ranging from 2 months for the higher PCB levels to 1 year for the two lower doses (Allen et al., 1974; Barsotti and Allen, 1975). Animals on the 25 ppm dose developed facial edema, alopecia and acne within 1 month, and 1 of 6 animals had expired as a result of PCB intoxication 2 months after removal from the diet. The total intake of PCBs ranged from 250 to 400 mg/animal. As was the case with the higher doses, these animals developed anemia, hypoproteinemia, bone marrow atrophy and severe hypertrophic hyperplastic gastritis. PCB concentrations in subcutaneous adipose tissue averaged 127 ppm at termination of experimental diet and 34 ppm 8 months later. Surviving animals continued to show clinical signs and lesions of PCB intoxication 2 years following PCB exposure (Allen, 1975).

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When adult rhesus monkeys were fed diets containing 2.5 and 5.0 ppm Aroclor 1248 for 1 year, the females of the group developed periorbital edema, alopecia, erythema and acne from lesions that involved the face and neck within 1 to 2 months (Allen et al., 1974; Allen, 1975). Although males consumed more PCB, they exhibited only moderate periorbital edema and erythema. An abnormal dysplastic growth pattern of the gastric mucosa was also noted in male rhesus monkeys fed 300 ppm Aroclor 1248 for 3 months (Allen and Norback, 1973).

Cygomegalous or squirrel monkeys fed different dietary levels of Kanechlor 400 showed weight loss, palpebral edema, enlargement of the liver and pneumonia. The lowest effective total dose was 300 mg/kg bw given over 20-32 weeks (Nishizumi, 1970).

A rhesus monkey fed 3 ppm Aroclor 1242 for 8 months died spontaneously and on autopsy was found to possess a gastric lesion manifested by extensive down growth of the epithelium deep into the subserosa and into the muscular wall of the stomach itself (McNulty, 1975).

One monkey fed 2,4,4'-trichlorobiphenyl and another fed 2,4,5,4'5'-pentachlorobiphenyl at 10 ppm for 90 days were reported clinically well and autopsies showed no positive findings (Oregon State University, 1975; McNulty, 1975).

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Third-litter sows received feed containing Aroclor 1242 at a concentration of 20 ppm throughout gestation and nursing. Treated sows differed significantly from control sows in the number of live pigs farrowed. Treated sows also had more mummified fetuses. Performance of live-born pigs was not affected by feeding PCB to the sows during nursing. Pathologic changes in the sows included hypertrophy of the liver and erosion of the stomach. Slight atrophy of the spleen and thyroid gland were observed in pigs from treated sows (Hansen et al., 1975).

Dermal toxicity studies in rabbits of technical PCB samples that contain an average of 60% chlorine (Phenoclor DP6, Clophen A60, and Aroclor 1260) as well as fractions containing tetra and pentachlorodibenzofuran have been recently described by Vos and Beems (1971). PCB-induced skin lesions were hyperplasia and hyperkeratosis of the epidermal and follicular epithelium following application of 118 mg of the three PCBs (5 times per week for 38 days) in the back skin of adult female New Zealand rabbits. Histopathology of the liver included centrolobular degeneration, centrolobular liver cell atrophy, focal necrosis, and cytoplasmic hyalin degeneration. PCB-induced kidney lesions were hydropic degeneration of the convoluted tubules and tubular dilation with the presence of casts. Definitive hyperplasia and hyperkeratosis of the follicular epithelium of the ear skin were seen after the topical application of fractions of Phenoclor and Clophen, while the fraction from Aroclor caused a minimal hyperplasia and hyper-

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keratosis of the follicular epithelium. Other effects elicited by the dermal application of the PCBs including thymus atrophy and lymphopenia as well as elevated excretion of fecal coproporphyria and protoporphyria.

From the response of the back skin and the liver of the rabbit to the three PCB mixtures, and from the response of the ear to the 25% diethyl ether-hexane fractions it was concluded that there were definite quantitative differences in toxicity, at least between the samples used in the above study and prior studies. The extent to which these samples are representative of the normal commercial output has not been established and emphasizes the difficulty in the evaluation of toxicity data of PCBs in which the samples may differ in the amount and nature of toxic impurities.

Vos & Notenboom-Ram (1972) compared the toxicity of Aroclor 1260 with a single isomer 2,4,5,2',4',5'-hexachlorobiphenyl in New Zealand rabbits. Dermal applications of a total 120 mg Aroclor 1260 (5 times/week for 28 days) resulted in early macroscopic skin lesions. The lesions in a 2,4,5,2',4',5'-hexachlorobiphenyl group of rabbits treated similarly appeared later and were less severe.

When groups of 5 male mice were fed dietary levels of 10, 30, 100 and 300 ppm of the PCB isomers 3,4,5,3',4',5'-hexachlorobiphenyl, 2,4,5,2',4',5'-hexachlorobiphenyl and 2,4,6,2',4',6'-hexachlorobiphenyl

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for 4 weeks it was noted that the 3,4,5,3',4',5', isomer of hexachlorobiphenyl caused death in mice at a dietary intake of 10 ppm (2.1 mg/kg bw) within 36-47 days of exposure while consumption of the other two isomers only resulted in death at a dietary level of 300 ppm (64.3 mg/kg bw). Body weight was reduced at the lowest dose for the 3,4,5,3',4',5', isomer and only at the highest dose for the other two isomers. Atrophy of the thymus and hepatomegaly was noted at the lowest dose in the mice receiving the 3,4,5,3',4',5', isomer and only this isomer produced experimental porphyria.

B. Avian subacute toxic effect of PCBs.

Chickens fed 10 ppm Aroclor 1242, or 100 ppm Aroclor 1254 showed diminished growth but a dietary level of 100 ppm Aroclor 1260 did not produce this effect (Keplinger, et al., 1971).

Symptoms of PCB poisoning in birds consist of tremor, ataxia, ruffling, loss of feathers. Edema of the subcutaneous tissues, and fluid accumulation of the abdominal and thoraxic cavities are characteristic signs at autopsy. These findings are responsible for this disease being designated chick edema disease. Several outbreaks of chick edema disease caused by PCBs have been reported (Firestone 1973, Kohanowa 1969a, 1969b).

Chicks (one day old white leghorn cockerels) were fed the following PCB isomers: 2,3,6,2',3',6'- hexachlorobiphenyl 2,4,6,2',4',6' hexachlorobiphenyl, 2,3,4,2'3',4'-hexachlorobiphenyl,

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2,3,6,2',3',6', hexachlorobiphenyl and 2,4,5,2',4',5' hexachlorobiphenyl for 21 days at a level of 400 ppm. The isomer 2,4,5,2',4',5' hexachlorobiphenyl was also fed at the dietary level of 100 ppm. The 3,4,5,3',4',5' isomer was the most toxic causing death of all chicks within 11 days after onset of exposure. These chicks had chick edema disease, atrophy of the thymus and loss of subcutaneous and visceral adipose tissue. The other isomers also caused weight loss the 2,4,6,2',4',6' isomer being the least effective. Liver enlargement was noted for all groups the 2,3,6,2',3',6' being the least effective and the 2,4,6,2',4',6' the most effective. The microscopic findings made in the liver were most pronounced in the group fed the 2,4,6,2', 4',6' isomer. (Since the chicks fed the 3,4,5,3',4',5' isomer died relatively early in the experiment pathological findings in the livers of these chicks are not comparable to those made for the other isomers.)

When chicks were fed 5% rice oil which had produced Yusho they developed chick edema in 17 days. Similar symptoms were produced when chicks were fed 400 ppm Kaneclor 400 (Goto et al., 1969).

C. Mammalian Reproductive Effects of PCBs

Oral administration of 0.025 mg/day of Clophen A60 in peanut oil to NMRI-mice for 10 weeks lengthened the estrus cycle from 6.6 ± 2.5 days to 8.7 ± 4.3 days (Orberg and Kihlstrom, 1973; Kihlstrom et al., 1973). Females treated analogously for 62 days

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and mated with untreated males exhibited a significant decrease in the implantation rate from 87.0% in the controls to 79.5%. Male castrated mice were given 0.25 gm PCB (Clophen A 60) in peanut oil/day by stomach tube for 28 days and 70 µg testosterone propionate daily on days 19-28. The dry weight of the seminal vescicles after this treatment period was compared to castrated male mice given testosterone but not PCB and was found to be significantly reduced.

Groups of 10 NMR I female mice were injected subcutaneously with 50 mg/kg body weight of Clophen A 60 in peanut oil or only the vehicle on the day of parturition and thereafter once weekly for 3 weeks. The 209 offspring were bred when reaching sexual maturity by mating them in pairs as follows: 17 pairs of controls, 19 pairs where the males had received Clophen A 60 as a suckling, 23 pairs where the female had received Clophen A 60 as sucklings and 23 pairs were both sexes had received Clophen A 60 as sucklings. The controls had an average of 11.5 offspring per litter while the parents where both mates received PCBs as sucklings had 8.8 offspring per litter. The resorption rate for both groups was the same but the number of implantations were reduced. Reproduction was not affected where only one mate received the PCB (Kihlstrom et al.,1975).

Keplinger et al.,(1972) reported low mating indices and decreased survival of pups for rats receiving Aroclor 1242 at 100 ppm, and decreased survival of pups receiving Aroclor 1254

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at 100 ppm. No reproductive effects were found with Aroclor 1260 at 1, 10, or 100 ppm, or with Aroclor 1242 or 1254 at 1 or 10 ppm. These studies suggest that in mammals reproductive effects decrease with increasing chlorination.

Sherman rats were exposed to polychlorinated biphenyls, Aroclor 1254 and Aroclor 1260. Rats exposed to Aroclor 1254 at dietary levels of 20 ppm or more had fewer pups per litter than the controls in the F1b and F2 generations (Linder et al., 1974). The 100 ppm exposure level of Aroclor 1254 increased mortality in the F1b offspring and markedly decreased mating performance of the F1b adults. The 500 ppm dietary level of Aroclor 1260 reduced litter size and decreased survival in the F1 litters. Dietary levels of 5 ppm Aroclor 1254 and 100 ppm Aroclor 1260 had no effect on reproduction in rats exposed through two generations. Liver weights were increased in 21-day-old F1 male weanlings at the 1 ppm level of Aroclor 1254 and in either sex of F1 and F2 weanlings at 5 ppm or higher levels of both Aroclor 1254 and 1260. Histological changes in the liver and increased liver weights were observed in adult rats exposed to the higher levels. Pregnant rats given Aroclor 1254 at the rate of 100 mg/kg/day on days 7-15 of gestation produced grossly normal litters, but only 30.1% of the pups survived to weaning. Reproduction and pup survival were not affected at dosage rates of 50 mg Aroclor 1254/kg bw/day or 100 mg Aroclor 1260/kg bw/day.

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Rabbits have been found to be more sensitive to PCBs than rats in regard to fetotoxic and reproductive effects (Villeneuve et al., 1971). In rabbits, no effects were reported at dosages of 6.25 or 10 mg Aroclor 1254 /kg/day, but at dosages of 12.5 to 50 mg/kg/day, fetotoxic effects were noted. Abortions, maternal death and stillborns occurred, but no consistent skeletal abnormalities were found.

Ringer et al., (1972) found that 1 ppm of Aroclor 1254 caused a slight reduction in reproductive success in mink, but at 5 ppm Aroclor 1254 complete reproductive failure was noted. In the same study 12 mink were fed a diet containing 30% Coho Salmon from Lake Michigan. None of the mink whelped while 11 of 12 controls whelped.

Female adult rhesus monkeys fed Aroclor 1248 at a level of 25 ppm for 2 months noted at beginning of the 5th month experienced either fetal resorption or abortion during their second month of pregnancy (evidenced by regression in uterine size and reestablishment of menstruation (Allen et al., 1974). A third animal carried her fetus to term. This infant's weight was considerably lower than the average rhesus infant (375g vs 544 $\pm$ 101g) and had 25 μg PCB/g/(ppm) of adrenal and adipose tissue. Adult female rhesus monkeys fed 2.5 and 5.0 ppm Aroclor 1248 were bred to control males following the establishment of a relatively steady tissue level of PCB at 6 months. Following 3 matings, 12.5% of the 5 ppm group and 37.5% of the 2.5 ppm group was pregnant

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compared to 90% in the control group (Allen, 1975). The conception rate of females bred to PCB-fed males was equally as great as that in females bred to control males.

D. Mammalian Sub-Acute and Reproductive Effects of PBBs

Male Sprague Dawley rats maintained on diets containing 0, 0.1, 0.01 or 1% octobromobiphenyl for 30 days did not exhibit overt toxicity during this period. Gross pathological studies revealed enlarged livers and some kidney changes (petechial hemorrhage, enlargement), while histopathological changes in the 1% group included liver lesions consisting of centrilobular cytoplasmic enlargement and vaculation and kidney lesions consisting of hyaline degenerative cytoplasmic changes (Aftosmis et al., 1972). Thyroid hyperplasia was observed in all rats in all test groups.

Rats were fed 100 and 1000 ppm octabromobiphenyl in their diets and then a number were sacrificed after 2 and 4 weeks of feeding and after 2,6 and 18 weeks of recovery on an octabromobiphenyl-free diet. The hepatocytes were markedly enlarged in rats fed 100 ppm and 1000 ppm of the PBB after 2 weeks of treatment. Histopathologic changes were characterized by hepatocellular hypertrophy with the pathologic changes localized mostly in the centralobular zone (Aftosmis et al., 1972b). The cytoplasmic inclusions were more pronounced in the livers of rats fed 1000 ppm than 100 ppm of the PBB. There was some evidence of recovery since the livers of the 100 ppm level animals returned almost to normal 2 weeks after

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withdrawal of the compound.

Preliminary 28-day feeding studies in rats with octabromobiphenyl at 100 and 1000 ppm demonstrated liver enlargement, hepatocellular alterations with cytoplasmic inclusions and accumulative effects of bromine in the fat, liver and muscle (Aftosmis et al., 1972).

Norris et al., (1974) demonstrated hematological changes, liver enlargement and liver and kidney lesions at all levels of octabromobiphenyl (10, 100, 1000 and 100 ppm) in the diet of rats. When three groups of primagravid rats fed diets containing 100, 1000 or 10,000 ppm of octabromobiphenyl (BB-8) from day 6 through 15 of pregnancy and the pups delivered on day 20, anasarca was observed in one fetus at each of the two highest levels and gastroschisis was observed in another fetus at each of these levels. No other gross effects were observed in either the mothers or the pups and dose-related levels of bromine were found in the fetuses (Aftosmis et al., 1972a).

When 1 g/kg of octobromobiphenyl was applied in corn oil under occluded conditions to rabbits for 5 hrs/day for 10 days over a 2-week period, liver enlargement was found while at 0.1g/kg no enlargment was found (Aftosmis, et al., 1972b).

Hexabromobiphenyl (Firemaster BP-6) fed to pregnant Sprague-Dawley rats and Swiss/ICR mice (100 and 1000 ppm) resulted in a dose dependent decrease in mean fetal weight. (Number of pregnant

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mice: 16 controls, 9 received 100 ppm and 12 received 1000 ppm. Number of pregnant rats: 12 controls, 7 received 100 ppm and 6 received 1000 ppm). Exencephaly was produced in the offspring of the mice that received both 100 (3/121)and 1,000 ppm (2/174 dosages while cleft palate (4/87) and defective kidneys (2/87) were noted in offspring at the 1,000 ppm level. Nonpregnant mice fed 1,000 ppm PBBs for 11 days showed marked increase in liver size and weight (Corbett et al., 1975).

Cows from the Halbert herd received feed containing PBB at a level of 2914 ppm at a consumption rate of approximately 15 lbs/head/day (200 cows) or 8 lbs/head/day (200 cows) for a period of approximately 16 days. Early signs of toxicity included anorexia, decreased milk production, increased frequency of urination, lacrimation, some lameness, and shrinking of the udder of recently freshened cows. Upon removal of the contaminated feed appetite improved. Cows bred 4-6 weeks prior to onset came back in heat suggesting early resorptions.

Later signs exhibited by the cows included hematomas, abscesses, weight loss particularly in high producing cows, abnormal hoof growth, rough hair coat, alopecia, thickening of skin, dystocia, lack of udder development at freshening, metritis, and negligible milk production in cows freshening 3-4 months post-exposure. Cows also exhibited a lack of wound healing, general weakness and were highly susceptible to stress. Six months post-exposure non-lactating cows showed depression of

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appetite, prepartum weakness, failed to develop signs of labor and died without calving. Gross pathology included liver and renal degeneration, and hematomas and abscesses in the peritoneal and thoracic cavities.

Twelve 6 to 18 month-old heifers and bulls were offered the contaminated feed ad libitum. Five of the animals were dead within 6 weeks. Younger animals became prostrate, went through a short period of coma and died. Signs and lesions included testicular atrophy, abdominal adhesions, and massive liver abscesses. At 5 months only 2 animals remained alive. These became anorexic, would consume only milk and developed signs of hyperkeratosis over the entire body (Jackson and Halbert, 1974; Welborn, 1975).

The health status of 16 herds of dairy cattle exposed to low levels of polybrominated biphenyl (PBB) was compared with that of 15 control herds. Milk production of the contaminated herds was not significantly changed in 1972, 1973, and 1974, and was not significantly different from that of control herds in the same years. Mortality of adult cows and calves, the percentages of cows culled from the herds because of old age and low production, disease, or sterility, and the general health conditions were similar in the two groups. Serum concentrations of calcium, glucose, and cholesterol in contaminated herds were significantly different from those of the control herds, but the relationship to PBB exposure needs further investigation (Mercer et al., 1976, In Press).

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A study consisting of an investigation of records and herd history of herds accidentally exposed to PBBs was also done. Significant findings included a decrease in production of 20 to 50%; severe weight loss at calving time; sterility; decreased growth rate in young animals; evidence of soreness and stiffness; poor response to therapy of common diseases; prolonged wound healing; abnormal hoof growth; calf losses; and malformed calves. (Deming, 1975).

Polybrominated biphenyl was administered to four cows at a dose rate of 10 mg/head/day for 60 days. Although the study was not designed as a toxicology study, retrospective evaluation of the data provided no evidence of clinical problems among test animals during the period of exposure to PBB nor for a year thereafter (Fries and Marrow, 1975).

E. Chlorinated Dibenzofurans - Mammalian Toxicity

It is presently assumed because of our experience with the chlorinated dibenzodioxins, that the 2,3,7,8-tetrachlorodibenzofuran is the most toxic compound of this group of chemicals, while the dibenzofuran itself or the octadibenzofuran have little inherent toxicity on an acute basis (Kimbrough, 1974).

Bauer et al., in 1961 demonstrated the toxicity of mixtures of tri and tetrachlorodibenzofurans. A single dose of 1 mg or 0.5 mg/kg body weight given orally to rabbits caused severe and often fatal liver necrosis. Application of this material to the rabbit

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ear caused severe hyperkeratosis at the application site.

The single oral LD_{50} for tetrachlorodibenzofuran for guinea pigs is between 5 and 10 μg/kg. Symptoms of toxicity were severe weight loss, atrophy of the thymus and spleen. Hemorrhages were observed in the adrenals, urinary bladder and single cell necrosis was noted in the liver. C. D. Strain rats given as much as 1000 μg/kg bw of the TCDF failed to show any symptoms of toxicity and microscopic examination of their tissues did not reveal any abnormalities. Similarly oral single doses of up to 6000 μg/kg body weight of TCDF failed to elicit any toxic effect in C57Bl mice. A subcutaneous dose of 6000 μg/kg bw given to these mice produced weight loss, hepatomegaly and atrophy of the thumus but no fatalities (Moore et al., 1976).

While these findings indicate that in mice TCDF is 30 fold less toxic than TCDD, the overall estimated difference in toxicity between TCDD and TCDF is about tenfold (Bauer et al., 1961; Kimbrough, 1974; J. G. Vos, personal communication).

F. Chlorinated Dibenzofurans - Avian Toxicity

When 1 day old chicks were started on daily oral doses of 5 μg/kg TCDF daily most of them died within 11.5 days. One of 6 chicks died given daily oral doses of 1 μg/kg bw. Symptoms of toxicity at the low as well as the high doses consisted primarily of weight loss, decreased food consumption and general unthriftyness. At autopsy the most striking findings were subcutaneous edema, ascites and hydropericardium and atrophy of the thymus.

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An inflammatory exudate was noticed on microscopic examination in the lung and the pericardial surface of the heart showed inflammatory changes. Congestion and hemorrhage into the gastrointestinal tract was also observed (Moore et al., 1976).

G. Brominated Dibenzofurans - Mammalian Toxicity

When daily doses of 4 µg/rabbit of 2,3,7,8-tetrabromodibenzofurans were applied to the rabbit ear for 5 days giving a total dose of 20 µg/rabbit or about 5-6 µg/kg bw, the rabbits (4) developed hyperkeratosis of the treated ear and areas of liver cell necrosis (Kimbrough, personal communication). No other information is presently available on the toxicity of brominated dibenzofurans.

H. Longterm Toxicity Including Tumorogenesis

Chlorinated biphenyls

Mice

When male BALB c/J mice were fed Aroclor 1254 for 11 months at a dietary level of 0 or 300 ppm (49.8 mg/kg body weight) 22 of 50 mice in the experimental group and 24 of 50 in the control group survived. The livers of the test animals were markedly increased in size, and showed a qualitative increase in porphyrin. A total of 9 experimental mice showed 10 neoplastic nodules (hematomas, hyperplastic nodules) in their liver ranging in size from 0.1 - 0.5 cm in diameter. Other morphological changes observed in the livers of the experimental group including pleomorphism,

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areas of necrosis, and foci of adenofibrosis. (Kimbrough and Linder, 1974). Neither tumors nor the other morphological changes were noted in the controls. Only one of 24 surviving male BALB c/J mice fed Aroclor 1254 for 6 months followed by a control diet for 5 months had a hepatoma (neoplastic nodule) measuring 0.3 cm in diameter.

Ito et al., (1973) fed male dd mice 500, 250, 100 and 0 ppm Kanechlor 500, 400 and 300 in the diet respectively. After one year, hepatocellular carcinomas were observed in 5/12 mice fed Kanechlor 500 at a dietary level of 500 ppm, the other 7 mice in this group had nodular hyperplasia (neoplastic nodules). No metastases were observed. Feeding α, B, or Y hexachlorocyclohexane (BHC) isomers with or without Kanechlor 500 at a dietary level of 250 ppm to mice for 24 weeks did not produce any tumors in the liver of animals receiving only the PCB (Ito et al., 1973). Liver tumors were observed in mice receiving 250 ppm α BHC alone or 250 ppm PCB and either 100 or 50 ppm α BHC or 250 or 100 ppm B BHC. Thus PCBs enhanced the tumor development of liver tumors of α or B BHC isomers.

Rats

Dietary exposure of male Sherman strain rats to levels of 500 ppm Aroclor 1254 (36.4 mg/kg body weight) for 6 months resulted in pronounced lipid accumulation in the liver which persisted for a 10 months observation period following the discontinuation of

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the dietary exposure to PCBs. Adenofibrosis (cholangiofibrosis) which was observed in the livers of rats ingesting the PCB for 6 months was still present 10 months later. Whether this lesion is persistent could not definitely be determined since high levels of the higher chlorinated biphenyl isomers were still present in adipose tissue and liver (Kimbrough, et al., 1973). Adenofibrosis is a focal proliferation of glandular epithelium forming ducts often surrounded by extensive fibrosis. This lesion usually occurs concomitantly in rat livers with hepatocellular carcinomas and has been produced by many known hepatocarcinogens. It was first described by Edwards and White (1941). The extremely long retention of some PCB isomers in rats was again noted when male Sherman strain rats were fed 100 ppm Aroclor 1254 for 6 months and then allowed to recover for 16 months. 4.4 ppm of PCB derived material was present in the liver and 152 ppm in adipose tissue on a wet weight basis (Kimbrough, 1976).

Continued dietary exposure to commercial PCB mixtures in mammals results in their storage in adipose tissue and over an extended period high levels may be attained (Curley, et al., 1971; Burse, et al., 1974). Blood levels are more a function of the dose, the rate of metabolism, availability of binding sites in blood, chemical characteristics of the compound given, rather than the amount stored in adipose tissue (Smrek, et al.; in preparation).

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In another study, 200 experimental female Sherman strain rats were fed 100 mg/kg Aroclor 1260 in the diet (11.6 - 4.3 mg/kg body weight) for approximately 21 months and 200 female rats were kept as controls. A total of 184 experimental rats and 173 controls survived to sacrifice at 23 months. Hepatocellular carcinomas were observed in 26/184 experimental rats and in 1/173 controls. None of the controls but 146/184 experimental rats had neoplastic nodules within the liver (hyperplastic nodules). Areas of hepatocellular alteration were noted in 28/173 controls and 182/184 experimental rats. The incidence of tumors in other organs was not altered by PCB ingestion and metatases from the liver tumors were not observed (Kimbrough et al., 1975). Adenofibrosis of the liver was also noted in this study. In reporting these liver tumors the classification developed in a rat liver tumor workshop was followed (Squire and LeVitt, 1975).

Liver tumors (multiple adenomatous nodules) were also induced in 6/10 female Donryu rats with Kanechlor 400 but not in male rats. The dietary exposure varied throughout the study from 38-616 ppm (Kimura and Baba, 1973). The induction of liver tumors by known carcinogens in Sprague Dawley rats such as 3'methyl-4-dimethylamino-azobenzene, N-2-fluorenyl acetamide and diethylnitrosamine was inhibited by Kanechlor 500 (Makiura et al.,1974).

Groups of 50 male and female Charles River rats were fed dietary levels of 0, 1, 10 and 100 ppm of Aroclor 1242, 1254, and 1260 respectively (Calandra, 1976). At 3, 6, and 12 months after

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onset of the experiment, 5 rats per each group and sex were sacrificed. The surviving rats were sacrificied 24 months after onset of the experiment. The only body weight depression noted was observed in the female rats fed Aroclor 1254. The author reported that important histopathologic changes were only noted in the rats fed the different Aroclors for 24 months.

The liver weights were increased in the male and female rats fed 100 ppm of Aroclor 1260 and 1254 and only in females fed Aroclor 1242 at a dietary level of 100 ppm.. It was noted that of a total of 20 surviving male and female rats (10 male and 10 female rats) fed 100 ppm Aroclor 1242 in the diet for 24 months 8/20 rats showed liver lesions called nodular hyperplasia, 2/20 had hepatomas and 1/20 had a cholangiohepatoma.

A total of 27 male and female rats (13 male and 14 female rats) survived to 24 months in the groups of rats fed 100 ppm Aroclor 1254 of these 13/27 had nodular hyperplasia of the liver 4/27 showed hepatomas and 2/27 showed cholangiohepatomas.

Similar findings were made in the total 27 surviving male and female rats fed 100 ppm Aroclor 1260 for 24 months. In these groups 7/27 male and female rats had nodular hyperplasia of the liver. 5/27 had hepatomas, and 2/27 had cholangiohepatomas.

Groups of 4 male and 4 female dogs were fed dietary levels of 0, 1, 10, and 100 ppm Aroclor 1242, 1254, and 1260 respectively for 2 years, 1 female fed 100 ppm Aroclor 1242, 1 male fed 10 ppm Aroclor 1242, 1 female dog fed 100 ppm Aroclor 1254, 1 female

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fed 10 ppm and 1 male and 1 female fed 100 ppm Aroclor 1260 died. At the dietary level of 100 ppm of either Aroclor 1254 or Aroclor 1260 the body weight gain was slightly decreased for both sexes. Aroclor 1260 also reduced the body weight gain in the females at the dietary level of 10 ppm. In the beagles fed Aroclor 1260 at a dietary level of 100 ppm, the liver weight was increased and the serum alkaline phosphatase was elevated. All but 1 dog that died had either chronic peritonitis or chronic pneumonitis. Many of the dogs fed 10 or 100 ppm of different PCBs showed chronic inflammation of a variety of organs. Male dogs fed Aroclor 1254 showed diffuse hyperplasia of the interstitial cells of the testes and aspermatogenesis (Monsanto, 1971).

Decachlorobiphenyl

No long term studies are available.

Polybrominated Biphenyls

No long term studies are available.

Chlorinated Dibenzofurans and Chlorinated Naphthalenes

No long term studies are available.

Immunosuppressive Effects of PCB and PBB

Polychlorinated biphenyls (PCB) have been implicated as immunosuppressants. Friend and Trainer (1970) found a decreased resistance to duck hepatitis virus in PCB exposed ducklings.

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PCB has been shown to produce lymphoid atrophy in rabbits (Street and Sharma, 1975; Vos and Beems, 1971), chickens (Flick et al., 1975; Vos and Koeman, 1970) and guinea pigs (Vos and DeRoij, 1972; Vos and van Genderen, 1973). In addition, PCBs were found to suppress humoral immune responses to several antigens in rabbits (Koller and Thigpen, 1973, Street and Sharma, 1975) and guinea pigs (Vos and DeRoij, 1972, Vos and van Genderen, 1973) and to suppress cell mediated immune reactions in guinea pigs (Vos and van Genderen, 1973). In all of these studies the PCBs studied have been commercial mixtures; the role of contaminants such as chlorinated dibenzofurans needs to be considered.

The effect of HBB on the immune system was studied in chickens and guinea pigs (Vos and van Genderen). In chickens the atrophy of the lymphoid tissue was observed in bursal follicles and in the spleen. It suppressed the humeral immune response in guinea pigs.

MUTAGENICITY AND TERATOLOGY

Polychlorinated Biphenyls

The mutagenicity and cytotoxicity of PCBs, Aroclor 1242 and 1254, were studied by Green et al., 1975, a, b. The lack of mutagenic activity as measured by the dominant lethal test was reported for male Osborne-Mendel rats subjected to four different dosage regiment: (1) single oral intubations of 625, 1250 or 2500 mg/kg (for Aroclor 1242); (2) five daily doses of 125 or 250 mg/kg (for Aroclor 1242), 75, 150 or 300 mg/kg (for Aroclor

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1254); (3) five daily doses of Aroclor 1254 at 150 mg/kg, then starved overnight prior to mating; (4) chronic feeding for 70 days at a dietary level of 25 or 100 ppm prior to mating (Green et al., 1975a). In a second study, bone marrow and spermatogonial cells were cytogenetically investigated from Aroclor-treated Osborne-Mendel rats. Aroclor 1242 was given orally at single doses of 1250, 2500, or 5000 mg/kg or as four daily doses of 500 mg/kg/day; Aroclor 1254 was administered orally as five daily doses of 75, 150, or 300 mg/kg/day. No statistically significant increases in chromosomal aberations were found for the Aroclor-treated rats. As indicated by Green et al., (1975 b), while these studies were negative in regard to chromosomal mutations, they do not entirely rule out the possibility that PCBs may induce point mutations. To date, there are no known reports in the literature concerning the induction of point mutations by PCBs in laboratory model systems. The observations of Nilsson and Ravel, 1974, in Drosophila where no chromosomal breakage was found among Clophen A30- or A50-treated flies, are fully consistent with those of Green et al., (1975, a, b).

TERATOLOGY

Female NMRI mice, orally administered 0.025 mg/day of Clophen 60, showed evidence of an increased estrus cycle from 6.6 $\pm$ 2.5 days to 8.7 $\pm$ 4.3 days and a decreased ova implantation rate from 87.0 to 79.5% (Orberg and Kihlström, 1973). Kihlström et al., (1974 a), also demonstrated a decrease in the frequency of implanted ova

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among young animals nursed on milk containing PCB (Clophen 60). Both the male and the female contributed to the magnitude of the reduction of implantations. The mechanism by which exposure of the developing male to milk containing PCB leads to a reduction in the precent of ova implanted is unknown but need not necessarily involve dominant lethal events.

No reports of frank terata were found, but a number of studies indicated the facility of PCBs for placental transport. Grant et al., (1971 b), showed that the concentration of PCB in fetal tissue from oral administration of Aroclor 1254 was dose-dependent and that accumulation occurred in fetal liver where higher concentrations were found than in maternal liver. Placental transport of PCB has been reported for the rabbit, rat, mouse, and cow (Grant et al., 1971; Platonow and Chen, 1972; Berlin et al., 1975; Melvas and Brandt, 1973; Brandt and Ullberg, 1973). Evidence of placental transfer was also observed among Yusho patients. While PCB has no known or clearly defined teratogenic effect in mammals, their easy passage across the placenta suggests the possibility of potential for some form of fetal toxicity.

Chlorinated Dibenzofurans

No information available.

Brominated Biphenyls

15 pregnant rats were force fed 100 mg hexabromobiphenyl/kg

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body weight on days 6, 8, 10, 12, 14 and 16 of pregnancy in corn oil. 14 control rats were given corn oil. The pups were obtained by cesarian on day 19 of pregnancy. No terata were observed and no difference between control and experimental rats was noted in any of the other parameters studied.
5 control and 6 PBB treated animals were treated with colchicine and bone marrow was studied cytogenetically. Animals treated with PBB and colchicine had higher metaphase and mitotic indices than non-treated animals. Chromosome aberrations were not noted (Fiscor and Werts, 1976).

Toxicity of Chlorinated Naphthalenes

The following information is derived from a review published by the EPA, namely Environmental Hazard Assessment Report 'Chlorinated Naphthalenes', EPA-560/8-75-001*. For literature references please refer to this report.

Animal Studies

The following tables summarize the available studies in laboratory animals. Three routes of exposure are reported.

*This document is available through the National Technical Information Service, Springfield, VA 22151. 'Preliminary Environmental Hazard Assessment of Chlorinated Naphthalenes, Silicones, Fluorocarbons, Benzenepolycarboxylates and Chlorophenols'. (NTIS accession number PB-238-074/AS)

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(a) Dietary Exposure

Compound	Species	Dose Level	Days Exposed	Effect Reported
Mono-			None reported	
Di-	Rat	5g/Kg feed	15	Increase in liver weight, growth impaired, rough coat.
Tri-	Mouse	2.5 mg/day	20	None.
Tri-	Rat	300 mg/day	9-136	Fatty infiltration of liver.
Tri/Tetra	Rabbit	15 mg/Kg body wt.	60	None.
Penta	Rat	50 mg day	63	Jaundice/fatty degeneration of liver.
Penta/Hexa-	Rat	300 mg/day	33	Death with yellow livers and extreme fatty degeneration.
Penta/Hexa	Rat	100 mg/day	55	Death with yellow livers and extreme fatty degeneration.
Penta-	Guinea pig	2.5 mg/Kg in oil	48	Death-Severe weight loss fatty degeneration of liver.
Hexa-	Rat	20 mg/Kg	84	Weight loss.
Hexa-	Rat	63 mg/Kg	84	Weight loss.
Hexa-	Rat	200 mg/Kg	84	Death.
Heptachloro-			None reported	
Octa-	Rabbit	1 g	Single dose	Death in seven days.
Octa	Rat	0.5, 2 or 5g/Kg	22	Decrease in liver but not plasma Vit. A.

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TABLE 10

(b) Inhalation Studies

Compound	Species	Dose Level	Days Exposed	Effect Reported
Tri-	Rat	0.05-0.2 mg/L	2 hr/day for 20 days	No toxic effect.
Tri-	Rat	1.31 mg/L	16hr/day for 134 days	No toxic effect.
Tri-	Rat	10.98 mg/L	16hr/day for 102 days	Slight liver discoloration, 5% rats showed increased fatty degeneration
Penta-	Rat	1.16 mg/L	16hr/day for 52 days	Jaundice, enlarged liver and 69% fatality.

No studies have been reported for the other chlorinated naphthalenes.

(c) Dermal Studies

Compound	Species	Conc Applied	Days of Application	Effect
Mono-	Rabbit(ear)	90 mg/g Acetone	5-7	Mild reddening.
Mono-	Rabbit(ear)	500 mg/g Acetone	5-7	Severe reddening, no decrease of sebaceous glands.
Tri-	Rat(skin)	Not given	2 hr/day/40-60 days	None reported
Tri-	Mice (skin)	Not given	2 hr/day/40-60 days	None reported
Penta-	Swine (skin)	60 mg/Lx3L	6 days/week-4 weeks	Slight hyperkeratosis.
Penta-	Rabbit(ear)	30 mg/g acetone/day	5	Mild dermatitis, hair folicular attenuation.
Hexa-	Rabbit(ear)	30 mg/g acetone	5	Decrease in sebaceous glands

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TOXICITY IN BIRDS

Turkey Poults

Penta/Hexachloronaphthalenes in the diet.

(a) 5 ppm for 40 days caused 23% reduction in weight gain with 6.5% mortality.

(b) 100 ppm - all poults died within 33 days. Histopathologic examination showed enlarged and darkened livers.

The LC_{50} was 20 ppm with an average decrease in weight of 51%.

Chickens

Penta/Hexachloronapthalene in the diet.

(a) No effects reported at dietary levels of 4 and 20 ppm (35 days).

(b) 100 ppm prevented egg production (35 days).

(c) 2550 ppm caused 100% mortality (14 days).

Effects reported included enlarged fibrous livers, lack of feather pigmentation and pericardial and peritoneal edema. A fourfold increase in Vitamin A in the diet decreased toxic effects.

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TOXICITY IN DOMESTIC ANIMALS

Ingestion is the most important route for exposure of domestic animals.

Cattle

Highly chlorinated naphthalene poisoning in cattle is known as bovine hyperkeratosis or X-disease. Detailed information on toxic doses is lacking. Penta/hexa mixture at a dose level of 5.5 mg/Kg body wt (orally) for 5 days caused a sharp drop in plasma Vit. A by the end of the third day and depressed plasma Vit. A for over 30 days. A single oral dose of 1 mg/Kg body wt of hexachloronaphthalene caused mortality within two weeks. The first effect of chloronaphthalene poisoning is an interference with the biotransformation of carotene to Vit. A. The Vit. A. deficiency is quickly followed by inflammation of the oral mucosa, lacrimation, excessive salivation and irregular food consumption. Gross physical effects that develop during the course of disease include a general thickening of the skin caused by over development of the skin's hairy layer with loss of hair (hyperkeratosis). There may be degeneration or irregular growth of the horns. Continued exposure results in anemia, dehydration, loss of weight, fever and death. There may be severe liver damage.

Swine

No toxic effects were observed at levels of 100 mg/Kg

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body wt of the chlorinated naphthalenes (degree of chlorination was not stated). 150 mg/kg body wt caused a marked depression of plasma Vit. A, and death occurred at a dose level of 198 mg/Kg body wt.

Sheep

Toxic effects are observed at doses of chlorinated napthalene 10 X that required to produce toxicity in cattle. Sheep do not show cutaneous hyperkeratosis or an excessive drop in plasma Vit. A as observed in cattle.

Effects reported include nasal discharge, weakness, loss of weight, loss of appetite, ascites, necrosis and cirrhosis of the liver and cardiovascular effects.

Toxicity in Man

The most important route for man's occupational exposure to chlorinated naphthalene is via the inhalation route. Dermal absorption route may also occur.

Penta/hexachloronaphthalene at a concentration of 30 mg/g acetone, applied to the backs of human volunteers for a period of six weeks caused typical chloracne.

Daily topical application of mono-dichlorinated naphthalene to the human ear in mineral oil suspension for 30 days caused no observable effect. Two clinically distinct but often concurrent syndromes have been described, namely, liver necrosis, and chloracne

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with itching. A number of deaths involving acute atrophy of the liver have been reported; with the course of the disease similar to other forms of severe liver damage. Autopsy of fatally exposed workers show severe yellow atrophy of the liver. Definite data relating to dose response effects are in general lacking. However, two dermal studies with man have been reported.

SUMMARY

The degree of toxicity of chlorinated napthalenes increases with the degree of chlorination. The higher chlorinated naphthalenes (especially hexa and penta) have been associated with chloracne and liver damage in man. Dose response effects have not been established.

Cattle are more susceptible to the effects of chlorinated naphthalene than other domestic animals. The effects observed include development of Vit. A deficiency, hyperkeratosis and liver damage.

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HUMAN EXPOSURE TO POLYCHLORINATED BIPHENYLS

I. Introduction

Although the polychlorinated biphenyls (PCBs) have been used in a wide variety of industrial applications in the U.S. from 1930 until 1970, when their distribution was voluntarily restricted to closed systems, there is scant information on human exposure to adverse human health effects in the U.S. In the U.S., minimal human exposure of the population to PCBs is limited to food, air and water, while significant human exposure appears to be limited to sports fishermen consuming fresh water fish from contaminated streams and lakes; and to occupational exposure in industrial workers.

II. Dietary Exposure to PCBs

The May 1972 Report of the Interdepartmental Task Force on PCBs summarized the findings in food sampling programs conducted by the Food and Drug Administration and the Department of Agriculture. Jelinek et al., (1975), have provided an update to that summary and evaluated trends which is presented below.

The 1972 Task Force report outlined three broad sources of food contamination. These are restated here in order to show which sources have been effectively controlled and which sources apparently persist, as reflected by results obtained in continued food sampling.

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1. Environmental contamination - background levels of PCBs in fish from lakes and streams.

2. Industrial accidents - isolated incidents involving direct leakage and spillage or contact of PCB fluids and other PCB containing materials on animal feeds, feed ingredients or food.

3. Food packaging materials - PCB migration to foods packaged in PCB contaminated paper products.

As discussed in the 1972 Task Force report, there were a number of other positive findings in foods which could not be traced to one of these broad sources prior to 1972 and the source of such occasional findings remain speculative. However, in more recent years, essentially all positive findings of PCBs in the food supply have been attributable to one or more of these three sources.

Jelinek and Corneliussen (1975) reported that for the 1969-1975 period, there has been a significant decrease in PCB levels in all foods with the exception of fish, where no particular trend has been noted. From that observation they concluded that procedures instituted to exclude the use of PCBs in "open" applications have been effective, but that more needs to be done to prevent their entry into the aquatic environment.

Jelinek and Corneliussen (1975) presented data on FDA's sampling program showing a very conclusive decline in the FYs 1973-1975

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period in terms of occurrence rate of PCBs and maximum levels found in milk, eggs, cheese, animal feeds and components, processed fruits, and baby foods. Except for fish, occurrence rates in FY'75 had dropped to zero or less than 1% for all categories, and there were no findings in excess of the existing temporary tolerances. Similar data were presented covering USDA's sampling of meat and poultry which also showed a decline, to 0.3% positive and only 0.6% above the temporary tolerance.

Jelinek and Corneliussen (1975) also reviewed FDA Total Diet Study findings (FY'71-75) which showed that all food classes of the total diet have declined to no PCB occurrence and no calculable daily intake of PCBs, except in the meat-fish-poultry composites. About 40% of these composites continue to contain detectable PCBs, although only traces have been detected in the latter years. The limit of quantitative detection in the Total Diet Study is about 0.05 ppm; positive findings below that level are generally reported as traces since they are not reliably quantitated.

Occurrence of PCBs ended in 1973 in all other categories, notably in dairy product composites and the composites of grain and cereal products. This probably reflects the control measures affected on animal feeds and on the control of ingredients in recycled paper used for food packaging. What remains, based on the total diet study, is a continued low level occurrence (about 40% positive and only at trace levels) in the meat-fish-poultry

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composites. The fact that levels in these composites have declined to only traces further supports the inference that the meat and poultry and eggs no longer contain detectable PCBs and that the low level findings are primarily due to the fish in those composites. This would imply that the PCB levels in the diet may have "bottomed out" and may remain static until such time as there is a change in the levels for fish.

Estimates of dietary intake of PCBs based on the Total Diet Study must be taken as gross estimates because only traces are currently found and some type of estimated value must be assigned to those traces to calculate microgram per day intakes of PCBs. Jelinek and Corneliussen used a set of consistent assumptions for those traces in computing the daily intakes for the FY-1971-75 period. Their calculations showed a steady decline from 15 mcg per day down to 8.7 mcg/day, with all of this coming from the meat-fish-poultry group in FY'74-75 (minor and declining portions attributable to other food classes in earlier years.)

Review of this information implies that, although the various assumptions for trace residue reportings and varying food consumption data have a significant effect on daily intake calculations, an overall estimate in the order of 5-10 mcg/day PCB dietary intake of PCBs for the general public seems reasonable. This figure would not be applicable to diets which may include regular consumption of fish from certain locations with high PCB levels.

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III. PCB Residues in Fish

Review of the data gathered by various agencies on fish residues indicates a serious incompatability of sampling programs for obtaining data which reliably define trends in PCB levels. The Food and Drug Administration's primary concern is the levels which exist in the edible portion of commercially imported fish which are marketed interstate. Therefore, in most cases, the heads, entrails, skin and fins are excluded. Furthermore, FDA sampling has not included fish which are caught and consumed locally (freshwater fish) and the sampling has dealt with the most important consumption species which are primarily of marine origin and which generally do not contain PCB levels as high as freshwater species from certain locations.

In order to determine the human exposure to PCBs through dietary fish, one must know the levels of PCBs residues in the edible portions of fish, and the amounts of the various kinds of fish consumed by the population at large, and by special subpopulations. During the past few weeks, information has been compiled by National Marine Fisheries Service-NOAA on the PCBs levels of these residues in marine and freshwater fish and shellfish, and on dietary habits.

Table 10 lists the 20 most important types of fish eaten in the U.S. today, and the mean daily amount of each type eaten by

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TABLE 10

Fish and Shellfish Consumption in the United States
(September 1973-August 1974)

	Rank	Amount (mill.) lbs/yr)	Percent of total by wt.	Number of Actual Users (millions)	Mean amoun per user (grams/day
Total		2957.	100.	197.	18.7
Tuna (mainly canned)	1	634	21.4	130.	6.1
Unclassified* (mainly breaded, incl. fish sticks)	2	542.	18.4	68.	10.0
Shrimp	3	301.	10.2	45.	8.3
Ocean Perch*	4	149.	5.0	19.	9.7
Flounder	5	144.	4.9	21.	8.6
Clams	6	113.	3.8	18.	7.6
Crabs/Lobsters	7	110.	3.7	13.	10.6
Salmon	8	101.	3.4	19.	6.7
Oysters/Scallops	9	88.	3.0	14.	7.8
Trout**	9	88.	3.0	9.	12.3
Cod*	11	78.	2.7	12.	8.1
Bass**	12	73.	2.5	7.6	12.0
Catfish**	12	73.	2.5	7.5	12.1
Ha[illegible]ock*	12	73.	2.5	11.	8.6
Pollock*	15	60.	2.0	11.	6.8
Herring/Smelt/ Sardines	16	54.	1.8	10.	[illegible].7
Pike**	17	35.	1.2	2.5	17.4
Halibut*	18	32.	1.1	5.0	8.0
Snapper	18	32.	1.1	4.3	9.3
Whiting	20	25.	0.9	3.2	9.7
All other classified		152.	5.1	n.a.	n.a.

* Mainly imports
** Fresh water

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the subpopulations of actual users. The Table includes all dietary fish, from sport fishing and from domestic and imported commercial fishing. These 20 items comprise 95% of the fish products eaten. The results are taken from information in a recent Seafood Consumption Study by the National Purchase Diary of Schaumburg, Illinois, sponsored by the Tuna Research Foundation, and National Marine Fisheries Service data on the amount of fish and shellfish processed and distributed in the U.S. Several items in the Table are worth noting for purposes of the present analysis. (1) Although ninety-three percent of the U.S. population (197 million) eat fish, the average annual per capital consumption of fish is small: 15.0 lbs/year--fish eater; (2) a large "Unclassified" fish fraction exists in the U.S. diet, ranking just below tuna in importance; (3) the major portion of many of our most familiar types of seafood is imported; and (4) freshwater species, led by trout, bass, and catfish, comprise about 9% of our total fish diet.

A compilation of PCB Data, representing the results of all the measurements known to NMFS of PCBs in fish used in the U.S. diet is presented in the Compendium of PCB data. It includes data from government reports, and state and private publications. An effort was made to include current, unpublished data from marine laboratories. The compilation includes the results of a comprehensive literature search by the NOAA-Environmental Data Service (EDS). An EDS-ENDEX data search for unpublished data

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and a EDS-OASIS search were made, crossing marine food species with PCBs.

Two significant sources of data--the 1975 FDA-Market Basket results, and the results of the extensive Fall 1975 New York State Department of Environment analyses were not available to NMFS at the time Compendium was published. However, FDA has indicated that the 1975 Market Basket results do not differ dramatically from 1973/4 data. Preliminary results of the New York Study are included in Table 12.

Table 11 summarizes the PCB information assembled in the Compendium relating to the 20 most important kinds of dietary fish identified in Table11. Although at one time or another, some PCB measurements have been made on many fish, Table 10 points out the inadequacy of information on PCB residues in the most important items in the fish diet. Sampling and analysis have been sporadic and not designed to monitor trends in human exposure. Systematic surveys of neither the important items nor the species most likely to be contaminated have been undertaken. Very few recent (1975) measurements have been reported.

However fragmentary the data on PCB levels may be, they do not include a single measurement exceeding 1 ppm in any of the ten most important fish foods, except for Dover sole and crab taken in the immediate vicinity of Los Angeles sewerage outfalls, and crab living on contaminated sediments in Upper Chesapeake Bay.

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TABLE 11

Maximum Reported PCB Residue Levels in
Fish Muscle (White Meat)

Rank#	Kind	Range and Max. Level Reported (ppm) (see Compendium)	Mean Level in the U.S. Diet
1.	Tuna	0-0.49 (1973)	Unknown*
2.	Unclassified (mainly breaded)	no data	Unknown
3.	Shrimp	0-0.167 (1971)	Unknown*
4.	Ocean Perch	0-0.25 (1974)	Unknown*
5.	Flounder/Sole	0.6.3[a] (1972)	Unknown*
6.	Clams	0-0.819 (1974)	Unknown*
7.	Crabs/Lobster	0-4.9[b] (1972)	Unknown*
8.	Salmon	0-0.5 (1974)	Unknown*
9.	Oysters, Scallops	0-0.43 (1974)	Unknown*
10.	Trout (excl. Lake Trout)	0-0.56 (1972)	Unknown*
11.	Cod	0-0.4 (1974)	Unknown*
12.	Bass	0.3-8.4[c] (1974)	Unknown*
13.	Catfish	0-4.4[d] (1974)	Unknown*
14.	Haddock	0-1.16 (1974)	Unknown*
15.	Pollock	0.0 (1974)	Unknown*
16.	Herring/Smelt/ Sardines (marine	0-1.6 (1974)	Unknown*
17.	Pike	0-0.65 (1974)	Unknown*
18.	Halibut	0-0.149 (1974)	Unknown*
19.	Snapper	0-0.1 (1974)	Unknown*
20.	Whiting	0.0 (1974)	Unknown*

These 20 items compose 95% of the fish in the U.S. diet.

* Probably well below 1 ppm

[a]Single Dover Sole taken near Los Angeles municipal sewerage outfall. The mean value of Sole samples taken in this vicinity was 1.3 ppm in 1975. Mean values of other samples taken away from outfalls were less than 1 ppm in 1975. In any case, although Dover sole is an important food fish in Northern California, it is not taken commercially in Southern California waters.

[b]Single yellowneck crab taken near Los Angeles outfall-mean of group including this crab was less than 1 ppm. A composite of Upper Chesapeake Bay crabs contained 1.2 ppm in 1974.

[c]Taken in 1974 from St. Croix River, Wisconsin--mean of 4 White Bass was 6.2 ppm.

[d]Taken from Mississippi River, Minnesota--mean of a sample of 5 catfish was 2.5 ppm.

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No more than 1.6 ppm has been reported in items 11 through 20 in importance, with the exception of freshwater bass and catfish living in river and lake areas known to be contaminated with PCBs. Nonetheless, as emphasized in the Table, there have been no PCB measurements on the important unclassified dietary fish items, and the analytical information is in no instance systematic enough to permit an estimate of the actual mean PCB values, hence human exposure. The strongest statement that can be made, based on the incomplete data summarized in the Compendium, is that most of the important fish meat items eaten in the U.S. probably contain mean PCB residue levels well below 1 ppm.

Fragmentary evidence also leads to the conclusion that the PCB levels in fish liver, roe and oil are approximately ten times that in the edible muscle and the PCB concentrations are greatest in the older larger oily fish, especially those that spend part or all of their lives in contaminated lakes, rivers or estuaries.

Table 12 lists the location of the species where high PCB levels, exceeding the FDA 5 ppm guideline, have been reported. Although the trout, salmon and chub in Lakes Michigan and Ontario and the Hudson River bass, perch and eel constitute only a few percent at most of the national fish diet, in some areas they are a significant part of the fish diets.

In order to discover what is presently known about U.S. fish consumption habits, a wide range of government and private sources

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TABLE 12

Areas Where at Least One Example of High* PCB Residue Levels Have Been Reported in the Listed Species

Species	Location
Striped Bass	Hudson River, New Jersey
Chub	Lake Michigan
Carp	Mississippi River, Minn., Lake Onandaga, NY
Chain Pickerel, Alewife	Hudson River
Coho Salmon	Lake Michigan, Lake Ontario, Hudson River
Chinook Salmon -	Lake Michigan, Lake Ontario, Hudson River
Steelhead Trout	Lake Michigan, Lake Ontario
Lake Trout	Lake Michigan, Lake Ontario, Lake George, NY
Bass, Smallmouth	Lake Onandaga, Genessee River, NY Hudson River, Mohawk River, St. Lawrence River
White Perch	Lake Onandaga, Hudson River
Alewife	Hudson River
White Sucker	Hudson River, Mohawk River
Walleye	Hudson River, Mohawk River, Black River, NY
Bass, Largemouth	Hudson River, Mohawk River
Yellow Perch	Hudson River
[illegible]rican Eel, Crabs, Sturgeon	Hudson River
Rock Bass, Catfish	Hudson River
Bluefish	Long Island Sound (muscle from one large oily fish contained 8 ppm)

This Table includes recent data from New York State Department of Environmental Conservation not included in the NMFS Compilation.

The Hudson River above Fort Edward, New York, is not contaminated with PCBs and the residue levels in fish are quite low.

*Above the current 5 ppm FDA Guideline.

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were consulted. A number of pre-1970 studies are available, including a 1969 NMFS Survey of Fish Purchases and a 1968-70 HEW Ten State Nutrition Survey. In addition, a few specialized reports have been published, including annual FDA Regional Basket Surveys that do not include fish eaten in restaurants and institutions or by sport fishermen, and surveys by the Sport Fishing Institute and a 1974 Texas A&M Analysis of Seafood Consumption Patterns in Texas. However, the most up to date and comprehensive data are available in the previously mentioned 1973-74 Seafood Consumption Study by the National Purchase Diary.

Table 13 summarizes results of fish consumption demographic information that defines the number of U.S. consumers who would exceed an arbitrarily set dietary micro-constituent level. To date, this kind of information is available only for total dietary fish and one subcomponent, tuna. Table 13 indicates that 75 million U.S. consumers eat more than the national average of 18.7 grams of fish per day and 29 million would exceed the present dietary intake limit of PCB (175 mcg/day) if the 35 or more g/day of fish eaten was contaminated on average to 5 ppm, the current FDA guideline level. There is, of course, no evidence that the mean PCB level in fish is anywhere near 5 ppm. Nonetheless, should it in the future reach 1 ppm, then by an extrapolation from Table 13, an estimate can be made that about 200,000 U.S. consumers would be exceeding the 200 mcg/day FDA limit. As

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TABLE 13

Number of U.S. Consumers Who Eat More Than X

X (g/day)	Number (thousands of consumers) Total Fish	Tuna
0	197,000	130,000
18.7 (national avg.)	75,000	5,700
35	29,000	1,300
50	14,000	400
100	2,000	43
150	400	10

* Derived from graphs on pp. 21 and 23 of the Seafood Consumption Study, September 1973--August 1974 by the National Purchase Diary, Shaumburg, Illinois, 1975. Sponsored by the Tuna Research Foundation.

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another hypothetical case, if the PCB level in tuna should ever reach 1 ppm, then about 5,000 tuna fish consumers, those who eat in excess of 175 g/day, would exceed the 200 mcg/day limit from tuna alone.

Survey data do show that in general U.S. fish eaters include a wide variety of fish items in their diet. Thus, even if certain items contain toxic micro-constituents at or near FDA guideline level, the great majority of consumers would receive only a small fraction of their average dietary intake from these sources.

Clearly, there is a need for demographic information, similar to that available on total fish and tuna, on the other principal foodfish items in the U.S. diet; and a need to extend and better measure the high-consumption tail of the distributions, to get a correct picture of the number and type of consumers eating in excess of 100g/day of any single fish product.

IV. Conclusions

At present, it is difficult to estimate human exposure to PCB from eating fish, either for the population as a whole or for subgroups at higher risk. Fragmentary evidence suggests that the exposure to the population as a whole from PCB residues in ingested fish is probably well below 19 mcg/day-consumer, based on PCB levels which are probably well below 1 ppm and 19g fish consumed/day.

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Firemaster BP-6 has been used as a flame retardant in the manufacture of typewriter, calculator and microfilm reader housings, radio and TV parts, miscellaneous small automotive parts and small parts for electrical applications. The use of Firemaster BP-6 has been restricted to those applications where the end-use product is not exposed to either animal feed or food and there is no known use in flame retarding fabrics where human exposure would occur (1).

The ultimate disposition of Firemaster BP-6 upon burial is uncertain. The Michigan Chemical Corporation has stated that in their opinion this material will eventually undergo oxidative/biological degradation forming carbon dioxide, water and bromide ion (1).

II. Human Exposure

In October of 1973, adverse health effects were observed in cattle in several dairy herds in the State of Michigan. At that time, the cattle refused to eat manufactured feed; milk production decreased; there was a loss in body weight and the cattle developed abnormal hoof growth with lameness; cattle and swine aborted; and farmers reported the inability to breed heifers after they consumed feed manufactured by Farm Bureau Services. A herd of some 100 head of cattle sent to slaughter during this time period. exhibited enlarged livers.

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Although it is important to know the total population exposure, the first priority should be given to defining the dietary intake of PCBs in special subpopulations at high risk by reason of high consumption of fatty fish, or high sensitivity to the toxic action of PCBs. Such populations might include pregnant women and young children, dieters, low income groups and sport fishermen living in coastal and lake regions where there is known PCB contamination. Primate studies suggest that pregnant women and young children will be particularly sensitive to PCBs, and dieters, and in some areas low income groups may rely heavily on fish for food. For each subpopulation, the amount and kind of fish in the diet and the PCB residue levels in the fish eaten must be obtained in order to determine exposure. None of the necessary information to define the human PCB exposure in subpopulations is presently known.

The first priority in systematically monitoring and analyzing for PCB residues in fish should therefore be among the oily fish such as salmon, trout, mackerel, shad, sardines, herring, bluefin tuna, sable fish, white fish, striped bass, and bluefish, that have been identified as significant food items in the diets of special subpopulations of consumers.

Although only minimal dietary exposure to PCBs may occur through food, there is evidence of potentially significant exposure

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in those sub-groups of the population who regularly consume freshwater fish from waters which are contaminated with PCBs at levels which exceed the FDA temporary tolerances. These sub-groups of the population would include sports fishermen and others who consume locally caught freshwater fish.

In surveys conducted by the State of New York and FDA, samples of 17 species of fish were collected from 10 points on the Hudson River between Glens Falls and Alpine, 13 samples were collected at Glens Falls and 68 samples below Glens Falls. The data from these surveys indicate that 53 out of 68 samples of fish collected at or below Fort Edward (approximately 7 miles below Glens Falls) contained PCBs in excess of 5 ppm. The average level of PCB contamination in these 68 samples was 31.3 ppm. In contrast, only trace levels were found in the 13 samples obtained at Glens Falls. A high proportion of finfish and eels from all sampling points below Glens Falls contained PCB levels in excess of 5 ppm. The Fort Edward sampling point had the highest levels for the species examined, with individual samples ranging from 20.1 to 178 ppm.

Twenty-eight of the 33 samples of coho and chinook salmon from Lake Ontario exceeded 5 ppm, with a range from 21 ppm to 24.6 ppm. Of the 4 samples of lake trout tested, results were in the range of 10 to 15 ppm. All other species of fish sampled from Lake Ontario were at 5 ppm or less PCBs.

The Great Lakes represent another area of the nation contaminated with PCBs. The Michigan Water Resources Commission has reported

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that many surface water samples contained PCBs at concentrations above the detection limit of 10 ppt. Ten significant levels of PCBs have been found in rivers and streams discharging into the Great Lakes. Effluents from wastewater treatment plants servicing industrialized communities have been found to be highly contaminated.

Sampling surveys of Great Lakes fish have shown that most species tested contained detectable levels of PCBs and that residue levels were generally proportional to fish size (age) and highest in the predator species. Except for whitefish, the species of commercial or sport interest (trouts and salmons) from Lake Michigan were found to be highly contaminated with PCBs. Data obtained from lake trout collected from various areas of Lake Michigan show mean PCB levels ranging from 3.06 ppm to 11.93 ppm.

The Michigan Department of Public Health has recently completed a study (Humphrey et al., 1976) which attempted to assess some of the consequences of human exposure to PCBs from the consumption of sportsfish caught in different areas of Lake Michigan. The study included exposed and control subjects from five areas of Michigan bordering on Lake Michigan. Exposed study subjects were those individuals who consumed at least 24 to 26 pounds of Great Lakes fish per year. Control subjects were those individuals who consumed less than six pounds of Great Lakes fish per year.

A preliminary assessment of the findings in the study indicate that the most frequently recorded quantity of fish consumed by the

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study participants was in the 24-25 pounds per year range. The highest recorded fish consumption over the two year period of the study was 180 pounds per year and the highest single season consumption was 260 pounds. Mean PCB levels in whole Lake Trout are reported as 18.93 ppm in 1973 and 22.91 ppm in 1974, and 12.17 ppm in Coho Salmon in 1973 and 10.45 ppm in 1974.

However, comparisons of PCB levels in raw vs. cooked fish indicate that actual human exposure to PCB from fish consumption is less than might be expected from the raw fish data. This is not unexpected since preparation (trimming away fatty tissue) and cooking have been shown to decrease the concentration of PCBs. For example, the PCB level in cooked Lake Trout consumed by the study participants ranged from 1.03 ppm to 4.67 ppm; in cooked salmon from 0.48 ppm to 5.38 ppm; and in other cooked fish from 0.36 ppm to 2.06 ppm. These levels are decidedly lower than the level of PCB contamination reported in raw trout and salmon.

PCBs were found in 501 blood and breast milk specimens collected from study participants during the study. The values ranged from a low of 0.007 ppm in blood in the control group to a high of 0.366 ppm in the exposed group. Although there was a wide range of blood values for each quantity of fish consumed, there was a highly significant correlation between the reported quantity of Lake Michigan fish consumed and the concentration of PCB in the blood of study participants. Using a natural log transformation

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of PCB values, the correlation between amount of fish consumed and PCB blood levels was significant ($t=6.24$, $p= 0.0001$), with higher reported fish consumption being associated with higher blood PCB levels.

No annual variation in PCB blood levels in humans could be demonstrated. The mean PCB blood values for the control and exposed groups did not appear to change markedly from 1973 to 1974. In addition, abstinence from Lake Michigan fish consumption for a period of 90 days or more did not change the PCB blood levels significantly. PCB blood levels over the abstaining period shows variation but no steady decline in PCB. In fact, more subjects showed no change or a rise than showed a decline in PCB blood levels over time.

The calculated quantity of PCB ingested by eating Lake Michigan fish averaged 46.5 mg/year and ranged from 14.17 to 114.31 mg/year. PCB ingestion for each individual was determined by proportioning the reported annual fish consumption by frequency of species eaten and the cooked fish PCB levels for those fish. The community average for cooked fish was used in instances were cooked fish determination were not available for a study participant. Because fish consumption was found to vary from year to year the average annual consumption for each individual for the two baseline years of study was used in each case.

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Results from this study indicate the strong likelihood that the maximum allowable ingestion of 1 mcg/kg body weight/day recommended for protracted exposure to PCB is being exceeded by the majority of the exposed group participants, and by inference, by a substantial number of individuals participating in sport fishing and who consume quantities of contaminated fish. The calculated mean daily dose received by the exposed group is 1.7 mcg/kg/day and ranges from 0.49 mcg to 3.94 mcg/kg/day. If the average annual rate of PCB ingestion from fish indicated by these study results were continued over the years, and if net accumulation occurs, the average sports fisherman consuming contaminated fish could receive a total PCB dose equal to the 200 mg safety limit in approximately 4.3 years. Under the same set of assumptions, individuals consuming greater than average amounts of contaminated fish would reach the total dose level sooner.

No adverse health effects or group of symptoms could be identified in the exposed group that were clearly related to PCB exposure. This implies that exposure to PCBs from eating contaminated fish at the levels observed and the presence of PCBs in these exposed persons has not caused any observable adverse health effects at the time of the study. However this does not exclude the possibility that effects too subtle for detection are occurring or the possibility of long-term adverse health effects.

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Considerable scientific interest has centered on the Yusho incident in Japan where in 1968 human intoxication with Kanechlor 400, a PCB manufactured in Japan, was noted when a heat exchange leaked this PCB into rice oil ("Yusho" oil) which was consumed by Japanese families.

The typical clinical findings included chloracne and increased pigmentation of the skin, increased eye discharge, transient visual disturbances, feeling of weakness, numbness in limbs, headaches and disturbances in liver function. Most of the babies born to mothers with Yusho had skin discoloration which slowly regressed as the children grew in size. Adult "Yusho" patients had protracted clinical disease with a slow regression of symptoms and signs, suggesting a slow metabolism and excretion of the PCB in humans, probably resulting from a long biological half-life.

A review of the literature extent in 1972 led to the following facts with respect to this tragic incident in Japan:

1. The average PCB content of the rice oil in the dose-response epidemiologic study was 2,500 ppm.

2. In this dose-response epidemiologic study, the average cumulative intake of PCBs, leading to overt symptomatology, was 2000 mg. In this same study, the lowest dose leading to overt symptomatology was 500 mg.

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3. The toxicity seen was the result of the ingestion of the PCBs contaminant in the rice oil.

A summary updating of the "Yusho" incident was presented by Professor Kuratsune at the National Conference on Polychlorinated Biphenyls, Chicago, Illinois, November 19, 1975 (Kuratsune et al., 1976). This report affects the original conclusions enumerated above.

1. PCBs Content of "Yusho" Oil.

The first reported PCB determination was made on a canned contaminated rice oil produced on February 5, 1968, and whose consumption was associated with overt symptomology. One group of Yusho patients was associated with ingestion of this contaminated canned rice oil produced or shipped on February 5 and 6, 1968 (Kuratsune et al., 1972).

The detailed epidemiologic studies are given in the papers by Kuratsune et al., (1969) and Yoshimura (1971) and summarized in English by Kuratsune (1972), Kuratsune et al., (1971) and Kuratsune et al., (1972). Of 325 patients queried, 166 of 170 used canned rice oil produced or shipped on February 5 and 6, 1968, and 143 of 155 used bottled rice oil shipped from February 5 to 15, 1968. Tsukamoto et al., (1969) determined that the organic chlorine content of canned rice oils produced or shipped on February 5, 1968, was 1000 to 1500 ppm, by chemical and activation analysis. Since Kanechlor 400 had a 48 per

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cent chlorine content, if one attributed all the organic chlorine to this specific chlorinated biphenyl, then this canned rice oil contained, as an average, 2500 ppm PCBs. Kuratsune et al., (1969) reported that a qualitative GLC survey of 109 samples of bottled rice oil shipped between October, 1967, and October, 1968, showed "significant" PCBs content only in those samples between February 7 to 10, 1968. The largest amount was reported in the sample of February 7, 1968, but the quantity was not given. No bottled rice oil samples were available for February 5 and 6, 1968. However, in the paper by Kuratsune et al., (1971), the most marked contamination of bottled rice oil was for that shipped on February 7, 1968; and the maximum chlorine content was 462 ppm. One may assume that this number applies to the sample of bottled rice oil of February 7, 1968, giving this sample a PCBs content of 924 ppm. Kuratsune et al., (1976), reporting the work of Nagayama et al., (1975b), gives the PCBs analyses for three samples of toxic "Yusho" oil, used by three independent families with "Yusho", as approximately 800 to 1000 ppm. These were GLC/MS measurements. Nagayama, et al., (1975b), described these samples as follows:

> "Rice oil used by patients with Yuso ("Yusho oil"): 3 samples of rice oil used by 3 independent families with Yusho in 1968. These samples had been kept in glass bottles with glass stoppers at room temperature in our laboratory until 1974 when the analysis was made."

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Kuratsune (1976) pointed out that these three samples were canned oil and considered to have been produced and shipped on February 5 or 6, 1968. This is also suggested in footnote a, Table 5, in the paper by Kuratsune et al., (1976). It was reported previously that, based on organic chlorine determinations, Tsukamoto et al., (1969) reported an average PCB content of the canned oil of February 5, 1968, to be 2500 ppm. Now, based on BLC/MS, we have a PCB content of ca 1000 ppm for canned oil sample of February 5 or 6, 1968.

What are the possible explanations for this discrepancy in values? One possibility is based on the assumptions associated with the method of measurement by Tsukamoto et al., (1969); namely, determination of total organic chlorine. Thus, any orgnic chlorine present in the rice oil, which was not a chlorinated biphenyl, would be included in the PCB analysis. Some possibilities include: chlorinated dibenzofurans, chlorinated naphthalenes, chlorinated paraffins, other chlorinated aliphatics and non-biphenyl aromatics.

Another possibility is related to the distribution, with time, of the contaminated rice oil samples. February 5, 1968, occurred on a Monday. The first rice oil samples reported to contain PCBs were produced on this date (Tsukamoto et al.; 1969). If the leak first occurred sometime over the weekend (February 3 and 4, 1968), and

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production was resumed Monday morning, February 5, 1968, then one would expect the samples of this date to be higher in PCB content.

Therefore, one would expect the first batches Monday morning to be highest with a diminution of PCB content with time. Tsukamoto et al., (1969) reported the organic chlorine content of six canned oils produced Monday, February 5, 1968, as follows: 1020, 1170, 1070, 1080, 1030, and 1500 ppm. In the survey of bottled oils, Kuratsune et al., (1969) reported that for those samples where PCBs were found, the greatest amount was in the samples of February 7 (Wednesday); and after February 11. It was inferred from the paper by Kuratsune et al., (1971) that the PCB content of the bottled rice oil samples of February 7, 1968, was 924 ppm. In addition, in Table 5, Kuratsune et al., (1976) gave a value of 134 ppm PCB for a rice oil produced on February 10, 1968. Thus, the available data does confirm a diminution of PCB contamination of the rice oil with time. This is summarized below:

Date	Source	PCB content (ppm)	Method
Feb. 5, 1968	canned	2000-3000	organic Cl
Feb. 5 or 6, 1968	canned (?)	ca 1000	GLC/MS
Feb. 7, 1968	bottled	924	organic Cl
Feb. 10, 1968	bottled	134	?
After Feb. 11 1968	bottled	just detectable	GLC (?)

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The resolution of the varying PCB values for the canned oil cannot be made. However, Kuratsune (1976) confirmed that the production of rice oil had been suspended for an unknown period of time prior to February 6, 1968, when it resumed.

2. Dose-Response

There were 1291 "Yusho" patients as of April 30, 1975 Oeme, 1975). Of this total group, the dose-response relationship was developed from a detailed analysis of 146 patients (Yoshimura 1971; Kuratsune et al., 1972). These 146 patients all consumed contaminated canned rice oil produced on February 5, 1968 contained 2000 to 3000 ppm PCBs as Kanechlor 400 (Tsukamota et al., (1972) estimated that the lowest dose producing symptoms was 0.5 gm.

If the PCB content of this canned oil was ca 1000 ppm, as discussed in the previous section, then the average dose producing an overt effect was 0.8 gm. and the lowest dose producing an overt effect was 0.2 gm.

3. Causative Factors.

Originally, rice oil contaminated with a heat exchanger, Kanechlor 400, a polychlorinated biphenyl, was associated with "Yusho" symptomatology (see discussion in section

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1 above). PCBs were identified in the contaminated rice oil consumed and in the blood and tissues of Yusho patients. Therefore, the effects seen were attributed to PCBs.

In the review by Kuratsune et al., (1976), a new factor was introduced into the system; namely, the canned rice oil was also contaminated with chlorinated dibenzofurans to the extent of 5 ppm. In addition, in this same paper by Kuratsune et al., (1976), they presented data of Bagayama et al., showing polychlorinated dibenzofurans in the liver and adipose tissue of Yusho patients, while none was found in that of a control group. The ratio of PCBs to PCDFs in Kanechlor 400, a Yusho oil of February 5 or 6, 1968, in adipose tissue and liver from a Yusho patient were 50,000; 200; 144; and 4 respectively. Thus, relative to Yusho oil, the liver with a PCB/PCDF ratio of 4 to 1, appears to selectively concentrate PCDFs relative to PCBs.

Relative to PCBs, PCDFs are about 250 times higher in the rice oil than in Kanechlor 400 (Nagayama et al, 1975b; Kuratsune et al., 1976).[1] They also stated that PCDFs may be a factor in Yusho disease. In another

1) It should be noted that we are comparing chlorinated dibenzofuran content of an unused Kanechlor 400 to that after prolonged use in a heat exchanger.

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paper Nagayama et al., (1975a) reported that it "is said that the toxicity of PCDF is said to be from 200 to 500 times that of PCB". At the lower factor (200), contaminated rice oil would be expected to be twice as toxic as Kanechlor 400. Also, in this same paper they stated that the symptoms seen in Yusho patients seemed to be more severe than would be expected just from the PCB intake associated with the oil.

If PCDF is 200 to 500 times more toxic than PCB (Nagayama et al., 1975a), then contaminated rice oil would be 2 to 3.5 times more toxic than that expected from its PCB content, alone. Kuratsune et al., (1972), estimated that if the average amount of contaminated rice oil ingested by a "Yusho" exposed person, is related solely in terms of its PCB equivalent, then the amount of oil needed to be ingested, on that basis, would be 1600 ml to 2800 ml. At a PCB content of 2500 ppm, this is an ingestion of 4 to 7 gm of PCBs equivalent; whereas at a PCB content of 1000 ppm, this is an ingestion of 1.6 to 2.8 gm of PCBs equivalent.

Conclusion

The complexities and uncertainties associated with the most recent reports of the "Yusho" incident in Japan, make it extremely difficult to quantify possible human health effects resulting from exposure to PCBs alone.

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V. Occupational Exposure to PCBs

The earliest reports of adverse health effects due to exposure of workers to PCBs in this country are probably those of Schwartz (1936) who described skin lesions and symptoms of systemic poisoning among workers who were said to have inhaled chloro diphenyls; their complaints included digestive disturbances, burning of the eyes, impotence, and hematuria. Patch tests with the chlorodiphenyls were negative, and Schwartz speculated that mechanical plugging of the follicles of the skin as the fumes solidified on it were responsible for the skin lesions; the chlorine present in the products were thought to then exert an irritating effect on the plugged follicles, and to thus cause suppuration. No quantitative data were reported, but a number of preventive practices were recommended.

There have been numerous reports over the ensuing years (Schwartz and Bartow, 1942), (Greenburg et al., 1939), (Drinkes et al., 1937), (Good et al., 1943), (Schwartz, 1943) and (Meigs, et al., 1954) of cutaneous eruptions and of systemic manifestations (sometimes fatal) as well, among marine electricians, machinists, capacitor and transformer manufacturing workers, and others occupationally exposed to PCBs. However, in many of these reports the exposures are described as having been to mixtures of chlorinated hydrocarbons, quite often of chlorinated naphthalenes and PCBs.

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The skin lesions described by Schwartz (1936) have come to be designated generally as "chloracne." Chloracne can be produced by a number of chemical compounds, including chlorinated dibenzofurans and certain isomers of the chlorinated dibenzodioxins (Kimbrough, 1972). Oily skin and large pores seem to predispose to the disease, while the opposite is the case for smooth, tender skin (Kimbrough, 1974). Chloracne also has occurred among workers engaged in the production of 2,4,5-T (Poland et al., 1971).

Part of the chloracne lesion resembles adolescent acne, but it is generally more severe, and lesion distribution is inconsistent with, although it may be superimposed upon, adolescent acne. It is known that chloracne can be produced by either the systemic absorption of chlorinated biphenyls or the direct application of chloracnegenic compounds to the skin. Systemic effects sometimes result after occupational chloracne has manifested itself; these may include loss of appetite, nausea, edema of the face and hands, abdominal pain, vomiting, and burning and soreness of the eyes. No fully satisfactory explanations have been made of the development of chloracne. Chloracne is generally very persistent, and there is no preferred control measure. An excellent review of this subject is that by Crow (1970).

The U.S. occupational standards for PCBs are: 8-hour time-weighted average exposure limits of 1 mg/m^3 (skin) for the 42% chlorinated product, and 0.5 mg/m^3 (skin) for the 54% chlorinated product (CFR, Title 29, Part 1910.93). The National Institute for Occupational Safety and Health has under way the preparation of

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criteria for a recommended standard for occupational exposure to polychlorinated biphenyls. In addition to an environmental exposure limit, this document will provide comprehensive recommendations for medical surveillance, safe work practices, and engineering controls to ensure employee protection during occupational exposure over a working lifetime; it is scheduled for transmittal to the Department of Labor in late 1976 or early 1977. NIOSH also is undertaking certain studies of employee populations (mainly in U.S. capacitor factories) in order to better define the nature and extent of any chronic and/or life-shortening effects of exposure to PCB.

Practically all of the currently available information on worker health and PCB exposure is found in foreign literature. For example, Karppahen and Kolho (1974) reported on relationships between the concentration of PCB's in the blood of all, and in the adipose tissues of some, of 29 persons in "good health"* from

*Kolho has stated that the capacitor plant workers received quarterly health examinations, and, in addition to the clinical examination made at the time of the investigation, serum alkaline phosphatase, GOT, and GPT activities were determined; the 6 employees with the highest blood concentrations of PCBs also had BSP excretion tests performed. All results were normal.

In view of claims based on animal experiments that PCBs can induce liver microsomal enxyme activity, the authors also determined the half-time of antipyrin before and after phenobarbital induction (1 mg phenobarbital/kg body weight/day/3 days) for 6 capacitor plant employees and 6 controls; no enzyme induction was observed. Further, because of claims that PCB's have effects on steroid metabolism, 4 capacitor plant workers were tested for ACTH (serum, presumably); all results were reported to be within the normal range (letter from S. Hernberg to A. C. Kolbye, Jr., 12/23/75.

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three different employee groups in Finland. None of the employees had no history of occupational exposure to PCBs, six of them had handled PCB samples in an analytical laboratory, and the other eleven of them had been employed for 6 years in a capacitor factory where Aroclor 1242 was used as the impregnating fluid. It was stated that average PCB concentrations in the air of the capacitor factory had not exceeded "internationally accepted limits**," and that special attention had been given to skin protection.

Table 14 shows the observed tissue concentratins of PCB's; the authors were unable to detect any biological effects of the approximately 50-fold larger PCB concentrations in the blood of the capacitor plant employees, compared to the "unexposed" control group.

Ouw et al., (1974) conducted a survey to determine the degree of absorption and the health effects of exposure to "electrical grade" Aroclor 1242 (that "did not contain any impurities") for varying periods of time. PCB concentrations in the air of a capacitor factory in New South Wales, Australia*, were measured, and 34 occupationally exposed employees (15 males, 19 females, ranging in age from 33 to 55 years) were examined and compared with volunteer controls (23 males, 7 females ranging in age from 20 to 50

*The Joint ILO/WHO Committee on Occupational Health, in its sixth report (World Health Organization Technical Report Series No. 415, 1969), recommended for international adoption a "safe concentration zone" of 1 mg/m^3 for chlorinated derivatives of diphenyl.

**Aroclor 1242 is not manufactured in Australia (Ouw et al., 1974).

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TABLE 15

Concentration of PCB's

Subjects	In blood Fat basis mg/kg		In adipose tissue Fat basis mg/kg	
	Average	Range	Sample no	
Workers in capacitor factory	313	100-700	1	200
			2	11
			3	160
			4	285
			5	635
Persons handling PCB's in analytical laboratory	53	33-71	not analyzed	
Persons without any special exposure to PCB's	5.4	3.6-9.9	1	2.3
			2	1.5

From Karppanen and Kolho (1974)

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years) having no history of occupational exposure to PCB's. Study parameters included occupational and medical histories, PCB-in-blood concentration estimates, and liver function (serum bilirubin, alkaline phosphatase, total protein, and GPT, and BSP excretion) tests.

The authors noted that exposed workers tended to complain of eye, face, and skin "burning," that the PCB "'fume' ... has a pungent smell which often causes persistent body odour," and that the employees with higher blood concentrations of PCBs complained most often of the skin lesions (one case of chloracne, five cases of "an eczematous rash on" the legs and hands), although there apparently was poor correlation of blood PCB's with the severity of the complaints. No significant health effects were observed among those of the 34 workers whose blood PCB concentrations were below 200 ppb.

There was a statistically significant difference between the blood PCB concentrations of the exposed group and the control group (P less than 0.01). Table 15 shows the concentrations of Aroclor 1242 in the capacitor plant air prior to and after exhaust ventilation system "improvements" had been made. (The Australian National Health and Medical Research Council recommended (Atmospheric Contaminants, 1970) exposure limit values of 1.00 mg/m^3 for PCBs of 42% and 54% chlorine content, respectively). Table 16 shows that there was no lowering of blood PCB concentration among those workers tested two months after the installation of a more

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TABLE 15

Arocloro 1242 concentrations in the air inside capacitor plant before and after improvement of exhaust ventilation system

No.	Areas in the Impregnation Room	Aroclor concentration in mg/m^3	
		Before	After
1	Area in the unloading tank in front of exhaust register from operator's breathing zone	1.44	0.75
2	Area in the unloading tank not in front of exhaust register	2.22	0.7
3	General atmosphere near tank	1.08	0.18
4	Soldering area	0.32	0.08

From Ouw et al (1974)

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TABLE 16

Mean blood Aroclor 1242 levels before and after improvement of exhaust ventilation and the recommendation to use "suitable impervious" gloves.

Group	Mean blood Aroclor levels in ppb. Retention times relative to Aldrin I.		
	0.69	1.31	1.41
Before	281.6	135.1	58.41
After	477.2	225.4	524.7
Statistical differences	Not significant difference (P 0.01)	Not significant difference () 0.01)	Significant difference (P 0.05)

From Ouw et al (1974)

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efficient exhaust ventilation system and the concomitant recommendation to wear "suitable impervious gloves" in order to reduce PCB absorption through the skin. The authors suggested that a failure to adhere strictly to the glove recommendation might explain the continued elevation blood PCB levels. Another possibility might be that PCBs were continually mobilized from storage in adipose tissues.

The Japanese Ministry of Labor (Regulation for the Prevention of Disturbances due to Specified Chemical Substances, under the Act for Safety and Health of Workers, of April 28, 1971) established an occupational environmental exposure limit for PCBs of 0.5 mg/m^3 at 25° C, one atm (Ad Hoc Committee, 1974). Japanese importation of PCBs commenced around 1950, and early uses were as dielectrics in capacitors and transformers. In 1954, Kanegafuchi Chemical Industry Co., Ltd. started PCB production in Japan and it was at about this time that chloracne eruptions among workers were first reported. Slightly earlier (1953) incidents, however, were reported by Hara (1969), of changes attributable to PCBs. in blood and urine findings among capacitor factory workers.

According to an Ad Hoc Committee sponsored by the Japanese Environmental Agency (1974), PCB concentrations in the air of a Japanese capacitor factory (where the major PCB constituent was "diphenyl pentachloride") were found to range from 0.37 to 6.75 mg/m^3; this was between the years 1953 and 1957, and prior to the

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date when the aforementioned occupational exposure limit was promulgated. The highest concentration was measured where PCBs were heated to drive out entrained/dissolved air. Admittedly, the analytical methodology for PCBs in those years was not as refined as that now in use, but it is thought likely (authors) that some employees were exposed continually at concentrations of several milligrams per cubic meter.

The Janapese literature is said to have contained no further reports on PCB-in-air measurements until the spring of 1972, just prior to the suspension of their usage. The production of PCBs was discontinued in Japan in June 1972, and their importation was discontinued in the following September. At that time Hasegawa et al., (1973) reported PCB measurements in the air of one PCB (Kanechlors 200-600) production plant (0.005-0.02 ppm), four capacitor manufacturing plants (Kanechlor 300 used) (0.01-0.05 ppm), and one plant where PCBs (Kanechlor 300) were used as a heat exchange medium (0.002 ppm). Peak values of 0.17 ppm and 0.67 ppm, respectively, were found in a capacitor plant "air-riddance" process area and in a capacitor impregnating area where tank leakage had occurred. Estimated (presumably 8-hour workday) time-weighted average exposures of affected employees were 0.02-0.03 ppm. Airborne PCBs in the capacitor plants were reported to consist of 70-80% vapor for material corresponding to Kanechlor 200, and of particulates larger than 0.1 micron for Kanechlor 300. The authors attributed the 3/1 vapor/particulate mix to selective evaporation of low boiling components of Kanechlor 300.

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Although no measurements were available, Hasegawa et al., (1973) estimated that environmental conditions in carbonless copy paper manufacturing facilities (using Kanechlor 300) were roughly similar to those found in capacitor factories. Beginning in February 1971, PCBs were phased out as the microcapsular solvent in this process, being replaced by "SAS" or KMC-oil;" however, during the period from November 1972 to January 1973, when occupational health surveys were being performed relative to SAS or KMC-oil toxicity, PCB concentrations of 0.013-0.4 ppb were measured in the environments of these facilities. General environmental concentrations of PCBs at that time were less than 0.0005 ppb, and outdoor PCB concentrations around the facilities were 0.0043 ppb (Hasegawa et al., 1973) and 0.009 ppb (Sato and Hasegawa, 1974). In an office room where carbonless copy paper was used, an air concentration 1.1 mcg PCB/m^3 was measured, and in the carbonless copy paper storage area of a post office, PCB concentrations of 8.7-21.1 mcg/m^3 were detected (Nishiyama et al., 1973).

The Japanese Ministry, in its "Regulations for Physical Examinations for the Prevention of Disturbances due to Specific Chemical Substances," promulgated on October 14, 1971, advised PCB users to examine employees for dermal and hepatic "symptoms" and their anamnesis, "subjective symptoms" such as anorexia and asthenia, and urine urobilinogen, in the first (pre-employment?) physical examination, and to "survey" working conditions, blood tests and liver function tests in the "secondary" (periodic re-?)

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examination. A 1973 notice advised those users of PCB's as heat exchange fluids to perform comprehensive health surveillance (Environmental Agency of Japan 1974). Yamamoto (1974) reported "positive" findings in 37 employees of 323 (total employment = 706 in 51 establishments) who were given "special" physical examinations in 1971.

Hara (1969) reported a 20-30% incidence of dermal "symptoms," consisting of "distinctive hair follicles" in exposed areas such as the face, neck, and forearm, and pimple-like skin eruptions of the face and neck, among employees in a capacitor factory that had been in operation between 1953 and 1963 (pentachlorobiphenyls) 1953-1957; Kanechlor 300, 1958-onward). No other, e.g., hepatic, dysfunction was observed, and no quantitative information was reported in the reference from which the preceding report was obtained; however, in a follow-up survey of workers in capacitor factories, Hara et al (1974) reported that by one year after the suspension of PCB usage skin findings had become milder.

Hasegawa et al., (1973) reported on a 1972 survey of capacitor factories, in which they noted that persons working in environments that contained 0.2-0.3 mg PCB's/m^3 (0.02-0.03 ppm) showed dermatologic ailments that included "brown chromodermatosis" of the dorsal joints of the hands and fingers and nail bed, and "acneform examthema." Several cases of comedo or acneform exanthema of the jaw, back, and thighs were seen also. These signs were no longer observed one month after the cessation of the handling of PCB's.

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In a factory where Kanechlor 300 was employed as a heat exchange medium, the environmental concentration of PCB's was reported to be 0.02/mg/m^3, and no dermal manifestations were observed among its employees (Hasegawa et al., 1973). Nor did Hashimoto (1974) observe any abnormalities among 236 workers in such a facility, to whom he administered "examination centered around liver function tests."

In 1972, when Hasegawa et al., (1973) performed a health survey of workers in carbonless copy paper factories, i.e., 2 years after the use of PCBs in such processes had ceased, they noted no dermal effects, and no liver function, blood, or urine test abnormalities were seen, with the exception of "slight abnormalities in lipid metabolism". PCB levels in the blood of these workers were reported as "approximately 0.01-0.02 ppm," or what amounted to a decrease to 10% of the levels during the period of PCB usage. The authors' data indicated that PCBs collected from the work atmosphere had apparently degraded to a product containing one less chlorine atom than the average number of chlorine atoms in the PCBs handled in the factory, and that, conversely, the PCBs found in the workers' blood contained one more chlorine atom than did the PCBs handled in the factory, i.e., if the PCBs found in the workers' blood were inhaled at the workplace, it can be surmised that the di- and trichloro- biphenyls disappeared rapidly from the body, whereas the tetrachlorobiphenyl was metabolized slowly.

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Hasegawa et al., (1973) concluded that blood analysis is a feasible method for determining body burdens of PCBs, and "probably more useful than the technique presently used by extracting adipose tissue and using it for PCB;" urinalysis for PCBs did not appeal to them as a viable monitoring method. They noted, however, that there was no correlation between length of employment (and presumably, duration of exposure) and the amount of PCBs accumulated in the blood, i.e., with continued exposure, PCB levels in the blood did not increase linearly; in light of the demonstrated slow excretion rate of PCBs from the body, the authors conjectured that some different biotransformative mechanism comes into play after blood PCB levels exceed approximately 1 ppm (perhaps fat storage). This would seem to belie their confidence in blood analysis as a reliable index of exposure.

Kitamura et al., (1973) reported that the mean PCB level in the blood of 10 capacitor factory workers was 0.82 ppm (0.32-2.1 ppm) immediately after the cessation of PCB usage, and 0.31 ppm 3 months later, when almost all of the subject were observed to have skin signs. It seems significant that the blood PCB concentrations observed in this study were several fold higher than those seen by Hasegawa et al., (1973). Kitamura et al., (1973) attributed the skin effects to PCB's accumulated in the workers' bodies during the period of PCB usage. No other abnormalities were reported.

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Sagami et al., (1973) reported the case of a housewife in whom they observed skin effects several years after she had left 6 years of employment in a capacitor factory. She was found to have PCB concentrations of up to 0.13 ppm in her blood and of 42 ppm in samples her subcutaneous adipose tissue; this contrasted sharply with the findings of Hara et al (1974) that the blood PCB levels of 3 workers who remained at the same factory had decreased to 0.05 ppm and below, one year after the cessation of PCB usage (from levels of 0.05-0.3 ppm during the time of PCB usage (Hasegawa et al., 1973).

N.B. Some capacitor manufacturers in the U.S. use epoxide-type alkylating agents as additives to prolong the service life of PCBs. EPA sec. 308 responses from the General Electric Co., probably contain identifying data.

VI. Air and Water Exposure to PCBs

As indicated previously, nominal human exposure to PCB's in the U.S. population may occur from air and water. Samples of ambient air were collected in suburban areas of Miami, Florida; Jackson, Mississippi; and Fort Collins, Colorado. Preliminary results (Kutz and Yang, 1975) for samples taken in April, May and June of 1975 show that PCBs were present at all locations. Although the data varied, the average concentrations at each of the three locations was approximately 100 nanograms per cubic meter. Initial

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identification of the PCBs: indicated that they were most comparable to the Aroclor 1254 standard.

Dennis (1975) has reported that data gathered from monitoring activities of surface waters and bottom sediments of the major drainage basins of the United States indicate the widespread occurrence of PCBs in both surface water and bottom deposits. A preliminary assessment of PCB levels shows mean residue levels in water ranged from 0.01 to 0.05 mcg/liter. The 0.05 mcg/liter were found in the South Atlantic Slope and Eastern Gulf of Mexico drainage basin. In general, the lowest PCB residue levels were found in drainage basins west of the Mississippi.

Kleinert (1975) has summarized the work completed by the Wisconsin Department of Natural Resources to identify some PCB sources in the environment in Wisconsin. Effluents from cooling water in aluminum foundries contained PCBs ranging from 11.5 to 335 ppb. Investigations revealed the common source to be leaking hydraulic fluids containing PCBs which were used in die cast machines. Effluents from paper mills that recycle wastepapers has measureable discharges ranging from 0.01 to 25 ppb.

Snow samples (Kleinert, 1975) were collected early in 1975. Analysis of the snow melt water from Racine, Kenosha, Madison, and Milwaukee revealed concentrations from 0.17 to 0.24 ppb. The author concludes that these values suggest that fallout of PCBs from the air may be a principal source of PCBs entering the waters

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of the State.

Hesse (1975) indicates that similar to the studies in Wisconsin, not all industrial effluents tested in Michigan contain measureable PCB levels. In testing over 900 industrial samples, approximately 40 percent contained PCBs above the 0.1 mcg/liter laboratory sensitivity limit. Twenty-three percent of the industries tested had greater than 0.5 mcg/liter, 18 percent greater than 1 mcg/liter, 6 percent greater than 10 mcg/liter and 2 percent greater than 100 mcg/liter.

Although much of the PCBs entering municipal waste treatment facilities are removed and become incorporated into the waste sludge, a sampling of 58 municipal wastewater treatment plant effluents throughout Michigan in 1973 showed an average concentration of 0.52 mcg/liter. Concentrations of PCBs are much higher in the sludges. The average for all plants was 15.6 mg/kg with individual values as high as 350 mg/kg. Since sewage sludges are commonly disposed of by incineration, spreading on agricultural land, or placing in landfills, the addition of PCBs to the environment is obvious.

VII. Residues of PCB's in Human Tissue and Milk

Yobs (1972) has reported that 31.1 percent of 637 samples of human adipose tissue collected from the general population as part of the Human Monitoring Survey during 1971 were positive for PCBs in measureable amounts. These samples were collected in 18 states

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and the District of Columbia and positive samples were obtained from each of the sampling states and District. The percentage of PCB levels ranged from 34.2 percent non-detected, 33.3 percent less than 1 ppm, 27.3 percent 1-2 ppm and 5.2 percent greater than 5.2 ppm.

Kutz and Strassman (1975) have described the results of PCB monitoring during fiscal years 1973 and 1974 in which 35.1 percent and 40.3 percent, respectively, of the tissues collected contained levels of 1 ppm or more of PCBs on a net-weight basis. Analysis of the tissue revealed that the compounds found in adipose tissue were most comparable to those prevalent in Aroclor 1254 and Aroclor 1260. Additional analysis indicated that the most frequently encountered PCB residues were penta-, hexa-, and heptachlorobiphenyl compounds.

Residues of PCBs have also been detected in a study of human milk collected in Colorado where 8 or 40 samples contained residues ranging from 40 to 100 ppb (Savage et al., 1973).

A study of adipose tissue samples collected at autopsy from Canadians (Grant et al., 1975) indicates that the majority of Canadians have adipose tissue residues of 1 to 2 mg/kg of PCB. All adipose tissues had detectable levels of PCBs and 30 percent of the samples had PCB residues greater than 1 mg/kg with a range

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of 0.11 to 6.60 mg/kg. PCB residues in human milk from Ontario residents were found to be approximately 1 mg/kg on a fat basis.

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HUMAN EXPOSURE TO THE POLYBROMINATED BIPHENYLS

I. Introduction and Background

The polybrominated biphenyls (PBBs) in this report refers to either Firemaster BP-6 or hexabromobiphenyl manufactured by Michigan Chemical Corporation for use as a flame retardant for thermoplastics. This product is a mixture of brominated biphenyls with an average bromine content equivalent to about six bromine atoms per biphenyl molecule. Firemaster BP-6 is a mixture of the following brominated biphenyls(1):

Tetrabromobiphenyl 2.0%

Pentabromobiphenyl 10.6%

Hexabromobiphenyl 62.8%

Heptabromobiphenyl 13.8%

Other bromobiphenyls 11.4%

The Michigan Chemical Corporation has stated that to their knowledge Firemaster BP-6 is the only polybrominated biphenyl produced in commercial quantity in the U.S. Their production estimates are:

Year	Pounds
1970	20,000
1971	200,000
1972	2,300,000
1973	3,900,000
1974 (Projected)	4,800,000

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Firemaster BP-6 has been used as a flame retardant in the manufacture of typewriter, calculator and microfilm reader housings, radio and TV parts, miscellaneous small automotive parts and small parts for electrical applications. The use of Firemaster BP-6 has been restricted to those applications where the end-use product is not exposed to either animal feed or food and there is no known use in flame retarding fabrics where human exposure would occur (1).

The ultimate disposition of Firemaster BP-6 upon burial is uncertain. The Michigan Chemical Corporation has stated that in their opinion this material will eventually undergo oxidative/biological degradation forming carbon dioxide, water and bromide ion (1).

II. Human Exposure

In October of 1973, adverse health effects were observed in cattle in several dairy herds in the State of Michigan. At that time, the cattle refused to eat manufactured feed; milk production decreased; there was a loss in body weight and the cattle developed abnormal hoof growth with lameness; cattle and swine aborted; and farmers reported the inability to breed heifers after they consumed feed manufactured by Farm Bureau Services. A herd of some 100 head of cattle sent to slaughter during this time period. exhibited enlarged livers.

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Analysis of samples of the suspected feed by laboratories of the U.S. Department of Agriculture at Beltsville, Maryland, revealed that the feed was contaminated with a flame retardant chemical, hexabrominated biphenyl. Subsequent investigation revealed that the Michigan Chemical Corporation manufactured magnesium oxide, a dairy feed supplement sold under the tradename Nutrimaster, and a flame retardant, hexabrominated biphenyl, sold under the tradename Firemaster BP-6. Both of these products were distributed in brown paper bags with either the name Nutrimaster or Firemaster stenciled across the top of the bag. When the top of the bag was torn off and discarded, identification was essentially lost.

As the result of a mix-up in bags, Firemaster BP-6 was mixed with animal feed in place of the Nutrimaster, apparently in the same proportion of use for the Nutrimaster. It appears that three kinds of feed were initially involved in this episode with PBB levels as follows:

Feed No.	PBB (ppm)
405	2.4
410	1,790
407	4,300

Samples of milk collected from individual farms soon after the PBB was identified as the contaminant ranged from 2.8 ppm on

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a fat basis to 270.5 ppm on a fat basis. Other products seized and destroyed included:

Butter	Range 1-2 ppm
Cheese	1.4 - 15.0 ppm
Canned milk	1.15 - 1.62 ppm

It has been estimated that between the onset of contamination in the fall of 1973 and the establishment of the quarantine of affected herds and flocks in the spring of 1974 over 10,000 Michigan residents have been exposed to PBB through the consumption of contaminated milk, meat and other dairy products. A considerable amount of variation in exposure has proabably occurred in both length of exposure and levels of exposure. As a group, the farm family members have been at greatest risk followed by those individuals who purchased dairy products from contaminated farms on a regular basis.

In order to determine whether or not persons exposed to PBB-contaminated products had suffered any acute adverse health effects, the Michigan Department of Public Health undertook a series of studies in the summer and fall of 1974. Study participants for the exposed group were dairy farm residents from farms which had been quarantined by the Michigan Department of Agriculture. The exposed subjects were limited to those who had lived or worked on the quarantined dairy farms for more than six months since May

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of 1973. Non-exposed subjects were randomly selected from a list of dairy producers in the same geographical area where farms had not been quarantined.

A total of 298 persons were interviewed in the study and physical examinations and/or blood samples were obtained for 110 persons in the exposed group and 104 persons from the control group.

The Michigan Department of Public Health has reported (1975) that responses to a set of 24 specific medical conditions revealed that none of the health complaints occurred consistently in either of the study groups. Statistical analysis showed that none of the listed complaints was significantly more frequent in those persons with the highest PBB levels when compared to other study subjects. Physical examinations of adults and children showed no unusual abnormalities of the heart, liver, spleen or nervous system. Urinalyses and complete blood counts did not reveal a significant excess of unusual abnormalities related to exposure or PBB levels.

These studies showed that blood levels of PBB were significantly higher in the study subjects from quarantined farms as compared to those from the non-quarantined farms; although some subjects from the farms showed low PBB blood levels (Table 17).

Several exposed females delivered normal babies without complication. Tests showed concentrations of PBB in breast milk to be considerably higher than that found in paired blood plasma (Table 18).

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Table 17

Distribution of PBB Blood Levels, Michigan, 1974

PBB Blood Levels (ppm)	Quarantined Farms				Nonquarantined Farms			
	Adults		Children		Adults		Children	
	No.	%	No.	%	No.	%	No.	%
0	3	3.7	-	-	21	28.4	-	-
0.002 - 0.019	43	52.4	8	28.6	52	70.3	29	96.7
0.020 - 0.090	19	23.2	10	35.7	1	1.4	1	3.3
0.100 - 0.490	11	13.4	3	10.7	0	0	0	0
0.500 - 2.260	6	7.3	7	25.0	0	0	0	0
TOTAL	82	100.0	28	100.0	74	100.1	30	100.0

Table 18

Comparison of PBB Concentrations In Human Breast Milk and Blood Plasma

Date	PBB Levels (ppm) Breast Milk	Blood Plasma
12/74	10.800	.082
6/74	22.700	.252
10/74	1.800	.014
3/75	.210	.003
3/75	92.660	1.068

Paired samples of adipose tissue and blood were collected in a group of 13 individuals entering the hospital for surgical procedures. The concentration of PBB in adipose tissue ranged from 61 to 370 times the PBB value found in blood plasma with an average ratio of 175 to 1 (Table 19).

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TABLE 19

Comparison of PBB Concentrations in
Human Adipose Tissue and Blood Plasma

Date	PBB Levels (ppm) Adipose Tissue	Blood Plasma
11/4	.410	.002
6/74 - 1/75	1.400	.005
3/75	3.000	.012
3/75	174.000	1.068
3/75	.248	.002
3/75	.274	.003
4/75	.177	.003
4/75	.152	.003
4/75	1.140	.004
4/75	.808	.004
4/75	.530	.007
4/75	.210	.003
5/75	1.110	.003

Reports of health complaints such as numbness, stomach pain, headache, fatigue and anxiety continue to be reported in the various newspapers in Michigan. Reports have also appeared in the press that several physicians in Michigan have reported abnormal liver function tests in patients exposed to PBB. Attempts to verify these reports with physicians have been unsuccessful.

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THE PCB-POLLUTION PROBLEM
January 21 and 22, 1970
St. Louis Meeting With General Electric Co.

GENERAL ELECTRIC REPRESENTATIVES:

Mr. Edward L. Raab, GE Pittsfield, Mass., representing all GE locations

Mr. H. Gerade, GE toxicological consultant

Dr. K. Murphy, GE Schenectady, New York, Environmental Pollution Control

MONSANTO REPRESENTATIVES:

H. S. Bergen, D. A. Olson, E. P. Wheeler, Dr. W. R. Richard, Dr. R. H. Munch, Dr. R. Keller, Dr. S. Tucker, W. B. Papageorge, J. G. Bryant, P. G. Benignus

A. Presentation and Discussion of Published Articles About Chlorinated Aromatic Hydrocarbon Insecticides, (DDT etc.) and PCBs

Mr. Wheeler presented to Mr. Raab a booklet containing most of the pertinent publications, to date, and indicated that additional articles will appear shortly.

He mentioned that manufacturers of DDT and chlorinated aromatic hydrocarbon insecticides will tend to emphasize the finding and interference of PCBs as the Government hearings limiting or banning use of the insecticides are held.

This lead GE to seek understanding of the scope, reproducibility, reliability and validity of the analytical procedures used by various investigators who reported finding PCB in concentrations as low as parts per billion.

B. The Analytical Procedures

Drs. Keller and Tucker presented details of Monsanto's GLC - Mass Spectrometric analytical capability and apparatus, as portrayed in Table 1. The sophistication of our analytical capability was emphasized to assure that our approach is the ultimate and is not surpassed. On this basis our views of the validity of results given in various publications are indicated in the attachments to Table 1.

General Electric were impressed and completely satisfied with the scope of our analytical capability and work.



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C. Biodegradeability of PCBs

Mr. Wheeler related that while Aroclor 1254 and 1260 are being found, especially in aquatic environment, the lower chlorinated biphenyls are not being observed. It is anticipated that the lower chlorinated members may be largely biodegradeable.

Drs. Richard, Keller and Tucker discussed biodegradeability studies by Monsanto at Ruabon and elsewhere.

These studies appear preliminary and not conclusive. Much more needs to be done in this area to allow GE to draw conclusions.

Since the literature indicates that trichlorobenzene and tri-tetrachlorobenzene are not susceptible to biodegradation, GE are intrigued with the absence of reports about finding these materials in the environment. The obvious implication is that since these materials are used with the higher chlorinated PCBs found -- the source of the latter is not from dielectric fluids. However, it was reasoned that chlorobenzenes may not remain due to their relatively higher vapor pressure or may not be found to date because they have not yet been zeroed in to the analytical spectrum.

D. Status of Aroclor Studies At Industrial Bio-Test. Table 2.

In essence results reported by Mr. Wheeler on chronic animal toxicity tests and animal reproducibility studies underway are not as favorable as we had hoped or anticipated. Particularly alarming is evidence of effect on hatchability and production of thin egg shells regards white leghorn chickens. The studies involved Aroclor 1242, 1254 and 1260. Some of the studies will be repeated to arrive at better conclusions.

E. The Location of Askarel Transformers. Table 3.

Messrs. Raab and Benignus formulated Table 3 to portray the use and locations of askarel transformers throughout industry and our commercial and residential areas.

On discussing these askarel transformer applications Mr. Raab was most impelling and forceful about the non-replaceability of transformer askarel fluid and the critical or essential use and need for askarel transformers, which have safety from fire as their outstanding virtue. Without dwelling on details and instead carried to the ultimate, the concensus is that without availability of askarel transformers large cities like New York would be shut down with no power. Certain industries that rely mainly on askarel transformers would go down with no power. Without Aroclor capacitors most of the lights across our country would go out and motors in air conditioners and many industrial applications would not run.

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Frankly, no one could think of a suitable replacement for transformer askarel fluid. Fortunately, Aroclor 1242 with promise about biodegradeability is used in most all of the Aroclor type capacitors. Moreover, possible favorable isomer rearrangements are foreseen in the case of Aroclor 1242.

Need to control, accumulate and properly dispose of scrap askarels is unquestionable in light of the PCB pollution problem, and essential toward maintaining the use of askarel dielectrics. At GE alone apparatus in which askarel fluid is used represents 100 million dollars annually. About 60% is in the capacitor area and 40% represents transformers.

GE requested and we were pleased to give Dr. Murphy their Environmental Control man, a list of all GE and other locations receiving Pyranol shipments in 1969. This amounts to about 16 million pounds of askarel fluids with economic worth of near 2.5 million dollars. This listing included 244 different locations of which 115 were GE plants and service shops scattered throughout our country.

Of course in addition to dielectric use in hermetically sealed capacitors and transformers major amounts of PCBs are used as Plasticizers, Industrial Hydraulic Fluids and Heat-Transfer media.

F. Environmental Sources of PCBs From Dielectric Applications

1. Spills
2. Disposal of waste
3. Ultimate disposal of product -- for failed apparatus
4. Ventilation of operation for employe protection
5. Waste from containers
6. Field on service failures
7. Repair and return apparatus "service shops"

G. Considerations of Degradation Disposals

1. PCBs up to and including 3 chlorine atoms appear biodegradeable in preliminary laboratory work.
2. Thus far there is no evidence that higher chlorinated biphenyls will biodegrade.

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3. According to the literature TCB and TTCB biodegrade at a very slow rate.

4. Chemical, catalytic breakdown would probably require high temperatures.

5. Incineration will require 800°C. and 5 second sojourn time. HCl scrubbing would be required.

H. Estimated Annual Amounts of Contaminated and Scrap PCBs From The Electrical Industry

1. From The Transformer Industry:

a) In plant and field spills are small and controllable with adsorbents, which should be incinerated.

b) Near 2 million pounds a year of transformer askarels are sold to service and repair shops. These people do not manufacture new transformers, although on occasion they may fill new transformers sent into the field without fluid. As these service shops are devoted primarily to repairing faulty transformers, we can assume that as much as 1.0 million pounds annually of "scrap" is generated. Most of this has been dumped or disposed of in streams.

c) We estimate that probably 150,000 pounds of this is arced beyond reworking and needs to be incinerated. The remainder may be reworkable by distillation.

2. From The Capacitor Industry:

a) Collectable waste from normal capacitor impregnation operations amounts to about 850,000 pounds annually. Most of this should be reworkable via simple take-over distillation.

b) Scrap, badly contaminated with polypropylene, epoxides, solvents, oil, grease and "junk" is generated at not over 50,000 pounds a year. This material should be incinerated, along with the 150,000 pounds of scrap from transformers.

c) Power capacitors are designed to last over 30 years. Modern motor runs may last 10 years and the small lighting ballast usually last not over 10 years.

Eventually and cumulatively there is a large potential of field-failed capacitors. Fortunately Aroclor 1242 has been used almost exclusively since about 1950.

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The failed units are disposed of in industrial dumps. In case of ballasts the Aroclor capacitor along with the transformer imbedded in asphalt or encapsulated in epoxy resin, all encased in a metal box are discarded as a unit. This is emphasized to indicate that incineration of such apparatus is not applicable.

3. From Containers:

Most askarel moves in bulk, tank cars or tank wagons, which do not present a problem.

It is questionable that drum shipments may present a problem. The drums can be used for returning scrap.

I. Monsanto's Program To Handle Scrap

1. GE asked what is Monsanto's plan about reclamation of scrap PCB from GE plants, service shops, utilities, industrial users, commercial users, etc.?

2. What is our view about a "Buy-Back" arrangement?

3. What arrangements will Monsanto make for incineration? Disposal in suitable land-fills? Reclamation by distillation at Monsanto?

4. To date Monsanto's posture is:

a) We have taken "good quality" scrap from GE's capacitor plant at Hudson Falls and had it reworked by simple filtration at Findett. This Findett arrangement is not practical nor economical. We paid GE 1 ¢/lb. for this "quite good" Aroclor, plus 1.9 ¢/lb. freight. Findett charged 2.1 ¢ to filter this material, making our cost 5 ¢/lb.

b) 130,000 pounds of somewhat lower quality scrap from Westinghouse capacitor plant has accumulated at Findett for lack of distillation equipment.

c) Scrap from GE's Ft. Edward plant appears to need reprocessing by distillation.

d) About ½ million pounds of "bad scrap" from GE Hudson Falls, has been disposed to a land-fill in New Jersey. Monsanto paid half of the freight cost.

e) A car load of scrap transformer askarel from Westinghouse, South Boston, Virginia is being sent to W. G. Krummrich for reprocessing.

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f) We advised Westinghouse, Sharon to incinerate 12,000 gallons of oil contaminated askarel.

g) We talked with Sangamo, Picken, S. C. and strongly urged them to discontinue present disposal.

5. The above "take-back" arrangements have been made on an individual and experimental basis. We have no fixed "buy-back" arrangement, regards answering GE's question.

6. We have no established process for reclaiming either capacitor or transformer scrap.

7. We have no incinerator for disposal of totally unreclaimable material.

8. To date and for the foreseeable future our only effective disposal is to a land-fill. While this is not desireable, it is better than indiscriminate dumping.

J. Transformer Askarel Blends Discussed With GE. Table 4.

Table 4 lists the transformer askarel blends reviewed with GE.

1. GE Rome has discontinued use of Blend A due to combustibility of arc formed gas. For this same reason, as dictated by their legal people they will not use Blend B.

2. Today both GE, Pittsfield, Mass. and Rome, Ga. use Blend C (Pyranol A13B3B), which they mix themselves.

3. Blend D optimizes the Aroclor concentration in conformance with GE's requirements for non-combustibility of the arc formed gas and with the pour point requirements. The price is in direct conformance with our previous quotation for Aroclor 1242, when GE was using this at a concentration of 80% by weight.

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Accordingly Blend D meets GE's requirements, although containing 71.6% of the higher chlorinated Aroclor it does not conform with Monsanto's concern with the PCB pollution problem.

4. For all practical purposes Blend E (Inerteen 70-30) is identical properties with Blend D, which latter GE, Rome, Ga. proposes to use. In the interest of standardization, we seek to have GE, at Pittsfield and Rome, Ga. use Blend E, which is used by Westinghouse for low temperature applications and is used by many other askarel transformer manufacturers for general application.

5. Although Westinghouse USA uses Blend F (100% Aroclor 1242) for all applications, except for low-temperature application, GE does not accept this use of 100% Aroclor 1242 in transformers.

   GE will not accept Aroclor 1242 or any other blend with less than a 1 to 1 ratio of chlorine to Hydrogen atoms. A ratio significantly lower than 1 to 1 tends to yield combustible arc-formed gasses. GE feels strongly that this does not conform with the original definition of an askarel. Accordingly their legal people stress that this presents potential liability in case of an accident for which various precedents have already been set in court actions.

   Mr. Raab points out that this precedent for liability regards combustibility is already set, in contrast with the PCB pollution situation which thus far is void of legal actions. He reiterated that the pollution problem thus far is a source of technical publications and warnings and emphasized that in the case of electrical applications which involve only hermetically sealed apparatus, adequate control should be possible.

K. Facts As Agreed By Those In Attendance

1. Cl_5 - C_{6-8} Biphenyls -- found in aquatic eco system in populated and industrial areas.

2. DDT + Cl hydrocarbon insecticides have effect on fish-eating birds (reproduction) leading to possible extinction of some species.

3. PCBs (some) are definitely suspected along with polychlorinated hydrocarbon insecticides.

4. Research data being developed seems to confirm incrimination of PCBs subject to rechecking.

5. Public, political and government pressures stopping some uses of chlorinated hydrocarbon insecticides (PCHI).

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6. PCBs have been brought into hearings proposing restrictions or elimination of DDT, PCHI.

7. As manufacturer of PCHI's fight for their life, attention will be directed to PCBs.

8. To our knowledge PCBs are not being found in terrestrial birds or animals, but DDT and PCHI's are found.

9. PCBs are not being found in the eco system without the presence of DDT or PCHI's.

10. PCHI's residue are found without PCBs.

11. We have no evidence that anyone has found lower PCBs except that Dutch researchers found PCBs in roaches.

12. There is no evidence of natural sources of PCBs nor any source other than industrially produced and used.

13. PCBs in a single dose have a low order of acute toxicity and are no significant problem to rats, dogs, chickens, fish and humans.

14. Based on six months of chronic studies in rats and dogs some PCBs are "moderately" toxic and more so than DDT, but less toxic than some of the other chlorinated hydrocarbon insecticides.

15. Some PCBs affect rat reproduction, (10 ppm. apparent no effect levels).

16. Some PCBs affect leghorn chicken reproduction (100 ppm.). PCBs have no affect level for chickens, estimated 10 ppm.

17. Some environmentalists are claiming that the PCBs pose a threat to humans, are so "philosophizing" in publications.

18. One published page indicates that PCBs are as bad (or worse) than DDT in microsomal enzyme effect. What is significant? Since many chemical compounds react similarly!

19. Human experience in production of PCBs and their use has been favorable. Less than 20 instances of illness known to Monsanto Company since 1940-45. Proper precautions were not always followed.

20. GE Company's use of PCBs as dielectric fluids, has been extremely favorable without illness throughout 40 years.

21. Monsanto Company is convinced that analytical techniques and data from some laboratories investigating PCBs are reliable and that conclusions being formulated are valid.

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22. Monsanto Company has not run duplicate analysis on samples reported in the literature.

L. What GE Desires

1. GE seeks that Monsanto take no precipitous reaction to the PCB problem that would result in withdrawing supply of Aroclor 1254 or 1260 to GE.

2. The consensus is that no suitable replacement for transformer askarel fluid is foreseen.

3. In event of development of a suitable fire-resistant fluid replacement for askarel, Mr. Raab emphasized that a minimum of 2 years testing work would be required before commercial use could be adopted.

4. In reply to Monsanto's legal question whether with continued use of Aroclor 1254 and 1260 GE would assume sole and complete liability -- Mr. Raab answered, No! To substantiate his reply, Mr. Raab cited case examples involving GE where damages were sought and collected, even though GE was only the third party. He further stated that any arrangement seeking to delegate and confine liability to GE relative to the PCB problem would be worthless.

5. GE seeks to know the magnitude and time of Aroclor price increase that would result if Monsanto discontinues sale of Aroclor for non-electrical uses, or if pollution control expenses warrant a price increase (as anticipated).

6. GE seeks to send a letter to their plants and service shops and major users of transformer askarel, such as the utilities giving notice of the PCB problem and guidance about the most suitable controls.

7. In the case of GE service shops scattered throughout our country it is unrealistic that these people would assume any expense to return scrap to Monsanto.

   The minimum we can expect is that Monsanto pay the freight charges, and reimburse for a suitable container to avoid additional and excessive contamination.

   This emphasizes need for Monsanto to have an effective reclaiming process. Otherwise, the best we can expect from service shops and many other users is to continue to dump in a land-fill and stop discarding into the sewers.

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8. GE realizes that Monsanto is caught between the explosiveness of arc-formed gasses problem and on the other hand the PCB pollution problem. Realizing possible unfavorable outcome of the arc-formed gas problem, GE desires to withhold the PCB problem from involvement at NEMA, ASTM, IEEE, EEI and ASIA at this time, (making it an industry-wide problem) pending better in-depth understanding of the PCB problem.

9. GE strongly seeks to continue manufacture of askarel type transformers, because in many applications this apparatus cannot be replaced with mineral oil nor open dry, nor seal gas dry type units.

   Mineral oil burns. Open dry accumulates dust, lint, moisture and can then fail with explosion and burning. Sealed gas dry types are very expensive, space consuming and very difficult to maintain sealed.

   Transformer design and application is governed by National Electric Code, by local building codes, Fire Underwriters, NEMA, IEEE, ASTM, IEC, ASA, Insurance companies and others. Because of the diversity of organizations involved a directive to discontinue askarel transformer manufacture would assume highly complex proportions.

P. G. Benignus
January 26, 1970

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DEPTS. 246/259

Department Hazardous Chemical Information

name	characteristics	hazard	symptoms	first aid	handling instructions
LORINE	GREENISH-YELLOW GAS WITH PUNGENT, IRRITATING ODOR. IN EITHER LIQUID OR GASEOUS STATE, IT IS NON-FLAMMABLE AND NON-EXPLOSIVE.	SKIN IRRITANT EYE IRRITANT RESPIRATORY CONGESTION. SEVERE EXPOSURE WILL CAUSE DEATH. CONCENTRATIONS OF 1000 PPM FOR 1/2 HOUR TO 1 HOUR CAN BE FATAL.	1. INHALATION - CAUSES COUGHING, DISCOMFORT IN THE CHEST, HOARSE COUGH, NAUSEA, AND VOMITING. 2. EYE CONTACT - CAUSES SMARTING AND IRRITATION. 3. SKIN CONTACT - CAUSES LOCAL IRRITATION AND/OR MINOR BURNS.	1. INHALATION - REMOVE MAN QUICKLY FROM AREA. APPLY BREATHING AIR OR ARTIFICIAL RESPIRATION IF NOT BREATHING OR HAVING DIFFICULTY IN BREATHING. KEEP WARM AND LYING DOWN IF POSSIBLE. GIVE MAN 1-2 GLASSES OF MILK TO SETTLE STOMACH. BRONCHIAL DILATOR PILLS WILL ASSIST BREATHING. 2. EYE CONTACT - RINSE WITH WATER (LIDS OPEN) FOR 15 MINUTES. 3. SKIN CONTACT - FLUSH WITH WATER.	WHEN CHANGING CHLO TANK CARS USE GAS AND GLOVES.
BIPHENYL	WHITE FLAKES OR SOLID OFF-WHITE MASS AT ROOM TEMPERATURE; WATER-WHITE TO STRAW-COLORED LIQUID WHEN ABOVE 69°C.; MEDICINAL SWEET ODOR.	EYE IRRITANT AND RESPIRATORY IRRITANT, ESPECIALLY VAPORS FROM MOLTEN FORM. NORMAL LEVEL IN WORKING AREA SHOULD NOT BE ABOVE 1 mg./m³ AIR (ABOUT 0.2 PPM). CAN ABSORB THROUGH SKIN. WILL CAUSE THERMAL BURN WHEN MOLTEN.	1. EYE CONTACT - CAUSES SMARTING & IRRITATION. 2. INHALATION - CAUSES COUGHING, CHOKING. 3. SKIN CONTACT - CAUSES IRRITATION AND/OR BURNS.	1. EYE CONTACT - RINSE WITH WATER FOR 15 MINUTES. REPORT TO DISPENSARY. 2. REMOVE PERSON FROM AREA OF VAPORS. USUALLY THIS IS ADEQUATE. GIVE ADDITIONAL BREATHING AIR IF NEEDED. 3. SKIN - FLUSH WITH WATER.	BIPHENYL IS HANDLED MOLTEN DEPT. 246. WEAR GLOVES AND GOGGLES WHEN UNLOADING TANK AVOID BREATHING FUMES.
FERRIC CHLORIDE	BLACK, FINE GRANULAR SOLID	DUST IS EYE IRRITANT AND RESPIRATORY IRRITANT; VERY LOW PROBABILITY OF BECOMING A HAZARD.	IRRITATION, COUGHING	FLUSH EYES WITH WATER, GET OUT OF DUST.	STORE IN CLOSED CONTAINERS BECAUSE IT ABSORBS WATER AND RELEASES HEAT. WET FERRIC CHLORIDE WILL NOT CATALYZE BIPHENYL CHLORINATION.
LIME	WHITE ALKALINE POWDER. GENERATES HEAT IN CONTACT WITH WATER (SLAKING).	CHEMICAL BURNS; EYE DAMAGE; INHALATION IRRITANT.	CHEMICAL BURNS TO SKIN EITHER IN SOLID FORM OR SOLUTION. EYE DAMAGE - DUST OR SOLUTION CAN CAUSE IRRITATION OF THE EYES. INHALATION IRRITATES THE MUCOUS MEMBRANES.	SPEED IN REMOVING FROM BODY IS MOST IMPORTANT. FLUSH WITH LARGE QUANTITIES OF WATER. REMOVE CLOTHING INCLUDING SHOES IF NECESSARY. IF EYES ARE AFFECTED, FLUSH WITH WATER FOR 15 MINUTES. IF LARGE QUANTITIES ARE INHALED, DRINK LARGE QUANTITIES OF WATER. CALL DOCTOR IF IRRITATION PERSISTS OR EYES ARE AFFECTED.	WEAR RUBBER GLOVES AND GOGGL
POROCEL	LIGHT-WEIGHT, BROWN, POROUS, INERT GRANULAR SOLID.	EYE IRRITANT (PHYSICAL, NOT CHEMICAL)	EYE IRRITATION AS FROM DUST	FLUSH EYES WITH WATER.	WEAR EYE PROTECTION
ATTAPULGUS EARTH	INERT, TAN-COLORED POWDER.	EYE IRRITANT (PHYSICAL, NOT CHEMICAL)	EYE IRRITATION AS FROM DUST.	FLUSH EYES WITH WATER.	WEAR EYE PROTECTION
NITROGEN GAS (N_2)	COLORLESS GAS	NON-TOXIC, NITROGEN IS AN INERT GAS. BREATHING ONLY NITROGEN WILL CAUSE ASPHYXIATION, DEATH.	DIZZINESS, HEADACHES, LOSS OF CONSCIOUSNESS, FINALLY DEATH.	REMOVE TO FRESH AIR. ADMINISTER OXYGEN OR BREATHING AIR IF NECESSARY.	AVOID BREATHING GAS, PROVIDE GOOD VENTILATION.
TRICHLORO-BENZENE (TCB)	WATER-WHITE LIQUID; STRONG ORGANIC CHEMICAL ODOR.	SKIN IRRITANT. INHALATION IRRITANT.	SKIN IRRITATION, CAUSES LOSS OF HAIR ON EXPERIMENTAL ANIMALS. BURNING SENSATION WHEN FUMES ARE BREATHED.	WASH SKIN WITH SOAP AND WATER; CHANGE CLOTHES IF CONTAMINATED. GET OUT OF VAPORS.	WEAR GLOVES AND EYE PROTECTIC
TRI-TETRA CHLOROBENZENE (TTCB)	WATER-WHITE LIQUID; STRONG ORGANIC CHEMICAL ODOR.	SKIN IRRITANT. INHALATION IRRITANT.	SKIN IRRITATION CAUSES LOSS OF HAIR ON EXPERIMENTAL ANIMALS. BURNING SENSATION WHEN FUMES ARE BREATHED.	WASH SKIN WITH SOAP AND WATER; CHANGE CLOTHES IF CONTAMINATED. GET OUT OF VAPORS.	WEAR GLOVES AND EYE PROTECTIC
GLYCIDYL PHENYL ETHER	VISCOUS LIQUID	SKIN IRRITANT; CAN CAUSE SEVERE RASH.	REDNESS, SWELLING OF CONTACTED AREA IF NOT REMOVED FROM SKIN.	WASH THOROUGHLY WITH SOAP AND WATER, REMOVE CONTAMINATED CLOTHING. IF SYMPTOMS ARE ALREADY PRESENT, REPORT TO DISPENSARY.	WEAR RUBBER GLOVES, EYE PROTE
UNOX EPOXIDE	VISCOUS LIQUID	SKIN IRRITANT; CAN CAUSE SEVERE RASH.	REDNESS, SWELLING OF CONTACTED AREA IF NOT REMOVED FROM SKIN.	WASH THOROUGHLY WITH SOAP AND WATER, REMOVE CONTAMINATED CLOTHING. IF SYMPTOMS ARE ALREADY PRESENT, REPORT TO DISPENSARY.	WEAR RUBBER GLOVES, EYE PROTE

PLAINTIFF'S EXHIBIT 1186

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name	characteristics	hazard	symptoms	first aid	handling instructions
INTERMEDIATES & BY-PRODUCTS:					
CRUDE AROCLORS	PURPLISH TO BLACK OILY LIQUID, PETROLEUM-LIKE ODOR, USUALLY HANDLED HOT; CONTAINS LESS THAN 0.05% UNDISSOLVED FERRIC CHLORIDE.	INHALATION IRRITANT (HOT VAPORS). THERMAL BURNS.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROTEC
HYDROGEN CHLORIDE (HCL)	COLORLESS GAS; HIGHLY CORROSIVE; NON-FLAMMABLE. READILY DISSOLVES IN WATER TO FORM AN ACID.	IRRITANT TO EYES AND RESPIRATORY TRACT. CHEMICAL BURNS TO SKIN. THE ACID COMBINES WITH MANY METALS AND RELEASES EXPLOSIVE HYDROGEN GAS.	IRRITATION TO EYES, SKIN AND THROAT.	FLUSH EYES WITH WATER FOR 15 MINUTES. FLUSH CONTACTED AREA WITH WATER. REPORT TO DISPENSARY.	AVOID BREATHING HCl VAPORS OR CONTACT WITH SKIN. USE SCOTT AIR PAK WHEN IN CONTAMINATED AREA.
FINISHED GOODS:					
MCS-1109 CAPACITOR 21 AROCLOR 1232	WATER-WHITE OILY LIQUIDS; CHLORINATED BIPHENYLS AND SOME UNREACTED BIPHENYL. FLASH POINT LOWER THAN THOSE PRODUCTS THAT ARE CHLORINATED BIPHENYLS ONLY.	INHALATION IRRITANT (HOT VAPORS). THERMAL BURNS.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROTE
AROCLORS (#15) 1016 1242 1248 1254 1260 1262	WATER-WHITE OILY LIQUIDS; CHLORINATED BIPHENYLS; VISCOSITY INCREASES WITH DEGREE OF CHLORINATION.	INHALATION IRRITANT (HOT VAPORS) THERMAL BURNS.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROTE
THERMINOL FR-0 FR-LOW TEMP., INERTEEN 54201KJ (#16)	WATER-WHITE OILY LIQUID; BLENDS OF AROCLORS AND CHLOROBENZENES	INHALATION IRRITANT (HOT VAPORS) THERMAL BURNS. SOMEWHAT MORE IRRITATING THAN AROCLORS BECAUSE CHLOROBENZENES ARE PRESENT.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROTI
PYRANOL A13B3B PYRANOL A13B3B2 INERTEEN PPO INERTEEN 70/30	WATER-WHITE OILY LIQUID; BLENDS OF AROCLORS, CHLOROBENZENES, AND EITHER GLYCIDYL PHENYL ETHER OR UNOX EPOXIDE.	INHALATION IRRITANT (HOT VAPORS) THERMAL BURNS. SOMEWHAT MORE IRRITATING THAN #15 OR #16 (ABOVE) BECAUSE THE CHLORIDE SCAVENGER IS PRESENT.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROT
INERTEEN 54201 CN	WATER-WHITE OILY LIQUID; BLEND OF AROCLOR AND GLYCIDYL PHENYL ETHER.	INHALATION IRRITANT (HOT VAPORS) THERMAL BURNS. SOMEWHAT MORE IRRITATING THAN AROCLORS BECAUSE THE CHLORIDE SCAVENGER IS PRESENT.	COUGHING, IRRITATING TO BREATHE. REDNESS AS FOR ANY OTHER THERMAL BURN.	GET OUT OF VAPORS. WASH AREA TO REMOVE AROCLOR AND TREAT AS ANY OTHER BURN.	WEAR RUBBER GLOVES, EYE PROT
MONTAR	BROWN TO BLACK VISCOUS LIQUID; HANDLED AT TEMPERATURES UP TO 300°C. A SOLID AT AMBIENT TEMPERATURES.	VAPORS ARE A RESPIRATORY IRRITANT; THERMAL BURN HAZARD.	COUGHING, IRRITATION; THERMAL BURN.	GET OUT OF VAPORS; TREAT AS ANY OTHER BURN.	USE RESPIRATOR WHEN AROUND VAPORS; USE GLOVES, EYE PROT & HANDLE WITH EXTREME CARE MOLTEN.

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Springfield — X

PCB PRESENTATION

Nov 17, 1969

TO

CORPORATE DEVELOPMENT COMMITTEE

I. INTRODUCTION:

We are here today to acquaint you with the PCB (Aroclor) pollution problem and to secure your guidance and approval on a recommended plan of action.

Certain PCB's have recently been identified by various scientists along with DDT in fish, birds, and other wildlife.

From the standpoint of reproduction, the PCB's are highly toxic to birds. In a few moments, Elmer Wheeler will describe the problem in detail.

Our objective is to describe for you the basic problems, the issues involved, review alternative courses of action, and suggest an action plan program for your approval.

This is a serious matter, not only from the pollution viewpoint, but also because of the $22 M worldwide customer business involved with resultant gross profits of $10 M and a net investment of approximately $9 M. In addition, there could be possible adverse legal and public relations problems leveled against Monsanto.

Our Agenda will be as follows:



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PCB AGENDA REVIEW

I. INTRODUCTION

II. THE PROBLEM

- DEVELOPMENTS INCRIMINATING PCB's
- COMPLEXITY OF IDENTIFICATION
- NATURE OF
- SERIOUSNESS

III. LAW DEPARTMENT VIEWPOINT AND RECOMMENDATIONS

IV. EFFECT ON MONSANTO AND ALTERNATIVES

V. FUNCTIONAL FLUID BUSINESS GROUP DISCUSSION

- MARKETS, USES
- SOURCES OF POLLUTION
- CUSTOMER EFFECT

VI. PLASTICIZER BUSINESS GROUP DISCUSSION

- MARKETS, USES
- SOURCES OF POLLUTION

VII. RECOMMENDED ACTION PLAN

VIII. SUMMARY

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By way of introduction, the Organic Division and the Medical Department has been actively engaged for the last 18 months in developing facts and knowledge on this subject by personal visits to Universities and Industrial test laboratories, other worldwide producers, and other industrial collaborators, as well as keeping abreast of all literature and news sources on the subject as well as funding a toxicological and analytical test program in excess of $100 M. We established an Ad Hoc Committee of both Business Groups and Medical which recently issued a report - much of which will be discussed today. We have learned a lot, but there is much yet to learn as you will hear.

What are PCB's? They are polychlorinated biphenyls - better known to us as Aroclors. The next slide will quickly re-familiarize you with our Aroclor business.

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MONSANTO WORLDWIDE AROCLOR BUSINESS

POUNDS/YEAR	104 M	(70 M in Functional Fluids 34 M in Plasticizers)
SALES/YEAR	$22 M	($16 M in Functional Fluids $ 6 M in Plasticizers)
GROSS PROFIT/YEAR	$10.0 M	($7.5 M in Functional Fluids $2.5 M in Plasticizers)
GROSS INVESTMENT	$13 M	($8.8 M net investment)
ROI	10.5%	
WORLDWIDE M/I	62%	
MONSANTO PRODUCTION LOCATIONS:	USA (2 plants, Anniston, Alabama Sauget, Illinois)	
	UK (Newport)	
	JAPAN (Yokkaichi)	
OTHER PRODUCERS:	Bayer, Prodelec, Caffaro, Flick, Kanegahuchi, and several Eastern European producers (all ex-USA)	

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THE AROCLOR PRODUCT LINE

CHEMICAL NAME	TRADE NAME	NATURE OF MATERIAL
MONOCHLOROBIPHENYL	AROCLOR 1221	THIN LIQUID
DICHLOROBIPHENYL	AROCLOR 1232	↓
TRICHLOROBIPHENYL	AROCLOR 1242	OILY LIQUID
TETRACHLOROBIPHENYL	AROCLOR 1248	↓
PENTACHLOROBIPHENYL	AROCLOR 1254	HEAVY MOLASSES
HEXACHLOROBIPHENYL	AROCLOR 1260	THICK TAR
HEPTACHLOROBIPHENYL	AROCLOR 1262	↓
OCTACHLOROBIPHENYL	AROCLOR 1268	↓
DECACHLOROBIPHENYL	AROCLOR 1270	SOLID
TERPHENYLS	SANTOWAX	↓
CHLORINATED TERPHENYL	AROCLOR 5460	SOLID

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There are theoretically 210 different isomers of chlorinated biphenyls.

Monsanto entered the Aroclor market in 1930 by acquiring Swan Chemical Company. The first load of Aroclor went out of Anniston, Alabama to General Electric in 1931. Since then, the market has grown to one of Monsanto's most profitable franchises. This franchise is now being threatened by [illegible] recently found pollution problems which Elmer Wheeler will now discuss.

II. The Problem (Wheeler) - see attached Appendix A

III. Law Department Viewpoint and Recommendations (French)

IV. Effect on Monsanto and Our Alternative Courses of Action

As discussed, Aroclors 1254 and 1260 -- the 5 and 6 Cl ringed biphenyls are the ones most seriously involved in the pollution problem. Both Plasticizers and Fluids Groups are involved as shown:

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AROCLOR SALES

(M POUNDS)

	FLUIDS	PLASTICIZERS	TOTAL
AROCLOR 1254	1.45	5.4	6.85
AROCLOR 1260 & ABOVE	3.7	1.7	5.4
	5.15	7.1	12.25

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We considered 4 alternative courses of action:

(Slide)

Alternative 1: Do nothing was considered unacceptable from a legal, moral, and customer, public relations & company policy viewpoint. This is also the quickest route to being forced out of business.

Alternative 2: Go out of total Aroclor business was considered unacceptable from a Divisional viewpoint, but from a Corporate viewpoint may be necessary. ~~Only you can make that decision.~~ All Aroclor products are not serious pollutants - many degrade; there is too much customer/market need and selfishly too much Monsanto profit to go out. To go out would require a write off of Aroclor net investment of $7 M (10¢/share) or if biphenyl included $8.8 M (12¢/share). In addition, inventory disposition, continuing cost of utilities, and back-up capital and serious manpower & resources reallocation at Anniston.

Alternative 3: Go out of Aroclor 1254 and 1260. This was seriously considered and may eventually occur by our actions and customer actions, nevertheless, we feel that segments of this business are defensible or are so "confined" in use that specific plans of action are called for this portion. Our reasons for eliminating this alternative will become clearer as we outline our action plans.

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ALTERNATIVE COURSES OF ACTION

1. DO NOTHING - JUST REACT TO LEGISLATION AND EMOTION.

2. GO OUT OF TOTAL AROCLOR BUSINESS.

3. GO OUT OF AROCLOR 1254 AND 1260 PRODUCTION

4. DEVELOP SPECIFIC ACTION PLANS "TAILORED" TO EACH BUSINESS GROUP AND EACH CUSTOMER/MARKET SITUATION TO "CLEAN UP" THE MESS.

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Alternative 4: Develop specific action plans tailored to each Business Group and each customer/market situation, - was the alternative selected at this point of time and based on our knowledge from a Divisional viewpoint as making Monsanto act in the most positive, responsible way to society and our customers, as well as our interests.

However, because of the magnitude and seriousness of this problem and its total implications for Corporate Monsanto, the final decision on this matter must be made by the CDC.

V. Functional Fluids Business Group Discussion:

Aroclors are used widely in 3 of our 4 market areas in the Fluids Group:

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FLUIDS USE OF AROCLORS
BY MARKET AREA

AROCLOR PRODUCT	DOMESTIC MARKET AREA			TOTAL
	INDUSTRIAL	HEAT TRANSFER	ELECTRICAL	
1242	4.1	1.1	36	41.2
1248	1.2	1.0	-	2.2
1254	-	0.1	0.8	0.9
1260 & Above	0.6	-	3.5	4.1
	5.9	2.2	40.3	48.4

741955

NEV 028701

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SOURCES OF FLUIDS POLLUTION

APPLICATION	INTENSITY OF POLLUTION	
INDUSTRIAL FLUIDS	GREATEST	(DIRECT)
DIELECTRICS	↓	(INDIRECT CONTAINED)
HEAT TRANSFER	↓	(INDIRECT CONTAINED)
PRODUCING PLANTS	LEAST	(DIRECT)

741956

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FLUIDS CUSTOMER ALTERNATIVES

AREA OF APPLICATION	PRODUCT OF CHOICE	CUSTOMER OPTIONS
Industrial Fluids	Pydraul 312/F-9/ A-200/Phosphate Esters/ Water Glycol	Customer could get along without us, but Pydraul 312 favored. H_2O Glycol has some pollution problem Phosphate ester route ok at present.
Transformer	Air/Oil/Aroclor/Gas	Could drop Aroclor at sacrifice of safety, cost or size of equipment or noise level.
Capacitors	Aroclors	No immediate replacement available. Longer term - oil at expense of size and cost of efficiency and redesign of equipment.
Heat Transfer	Therminol	No option for FR liquid market. Other system possibility.
	Oil/Dowtherm/T66 T55 T77 T88	Liquid systems favored. T66 and T55 increasing rapidly in use. Oil also a pollution problem.

WATER_PCB-SD0000073365

Customer Choices & Alternatives & Penalties:

Summarizing, some of our customers have no immediate alternative, some could change only at sacrifices of safety, or cost or various technical factors. Only in the Industrial field could the customer make an immediate conversion.

PCB Threat to Functional Fluids Business and Profit:

WATER_PCB-SD0000073366

FLUIDS BUSINESS THREATENED

(1970 BUDGET)

PROBLEM	SALES	GROSS PROFIT
1. Confined to A-1254/ 1260 only.	$ 3.0 M	$1.36 M
2. Spreads to A-1242 and 1248		
First to: a) Industrial Fluids	$ 4.0 M	$1.6 M
Then to: b) Dielectric Fluids	$ 8.0 M	$3.8 M
Then to: c) Heat Transfer	$ 1.0 M	$ .6 M
	$16.0 M	$7.36 M

— Turn over to Jim Springgate

741959

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15 +1

VI

PLASTICIZERS
(WORLD-WIDE)

	ALL AROCLORS	AROCLOR 1254/1260 TYPES
1969 SALES, DOLLARS	$ 6.0 M	$1.7 M (28%)
POUNDS	34.0 M	9.5 M (28%)
1969 GROSS PROFIT	$ 2.5 M	$0.8 M (32%)

741960

NEV 028706

WATER_PCB-SD0000073368

COMMENTS: DISTINCTIONS FROM F.F.

1. Large number of direct U.S. customers - 570.
2. Customers are small: 23 direct customers - 47% A-1254/1260 sales.
3. 50% domestic A-1254/1260 sales through distributors - difficult to police.

741961

NEV 028707

WATER_PCB-SD0000073369

MARKETS	1968 SALES	MAJOR AROCLOR USED
Carbonless Carbon Paper	8.8 M lb.	Aroclor 1242
Hot Melt Adhesives	5.7 M lb.	Aroclor 5460
Swimming Pool Paints	1.7 M lb.	Aroclor 1254 ✓ Aroclor 5460)
Protective Coatings	5.3 M lb.	Aroclor 1254 ✓ Aroclor 5460)
Emulsion Adhesives	1.5 M lb.	Aroclor 1254) Aroclor 1260) ✓
Sealants	3.0 M lb.	Aroclor 1254) Aroclor 1262)
Wax Modification	2.0 M lb.	Aroclor 1254 ✓ Aroclor 5460)
Miscellaneous	5.0 M lb.	Aroclor 1248) ✓ Aroclor 1254)

Comments: 1. [illegible] major customer (85% of Aroclor 1242 sold).

2. 55% of domestic Aroclors sold through [illegible].

741962

NEV 028708

WATER_PCB-SD0000073370

POSSIBLE CONTAMINATION SOURCES

(PLASTICIZERS)

DEGREE OF CONTAMINATION	MARKET	APPLICATION	SOURCE	IS A-1254 /1260 USED?
Most	Coatings	Marine Paints) Water tank linings)	Leaching	Yes
	Coatings	Swimming Pool Paints	Leaching	Yes
	Carbonless Carbon Paper	-	Vaporization	No
	Wax Modification	-	Vaporization	Yes
	Emulsion Adhesives	-	Contact with product via packaging. Incineration.	Yes
	Hot Melt Adhesives	-	Contact with product via packaging. Incineration.	No
Least	Sealants	Automotive Construction Joint Sealants	Long-term leaching	Yes

COMMENTS: 1. Unlike fluids, Aroclor plasticizers are combined into plastics to produce the final product - therefore, far less mobile.

2. Problems such as wastes from our manufacturing plants, customers plants and leasing of drums common to both groups.

3. Paint or protective coatings are not considered a high [illegible] of PCB.

4. The [illegible] plant processing of [illegible] products. [illegible]

741963

NEV 028709

WATER_PCB-SD0000073371

PLASTICIZER BUSINESS THREATENED

PROBLEM	SALES RETAINED*	$ G.P. RETAINED (LOST)
1. Confined to A-1254/1260 type only.	$4.3 M	$1.7 M (-$0.8 M)
2. Spreads to all chlorinated biphenyls.	$2.0	$0.6 M (-$1.9 M)
3. Spreads to all PCB's and all chlorinated terphenyls	0.0	0.0 (-$2.5 M)

*Based on 1969 prospects.

NOTE: Plasticizers sell A-color 1262/4465 which are very close to A-1254/1260 and these have been included as A-1254/1260.

741964

NEV 028710

WATER_PCB-SD0000073372

RECOMMENDED ACTION PLAN

THE JOINT ACTION PLAN DEVELOPED BY THE FUNCTIONAL FLUIDS AND PLASTICIZER BUSINESS GROUPS, AND THE MEDICAL AND LAW DEPARTMENTS IS AS FOLLOWS:

1. Appoint a Project Manager - responsible for the overall management of the Aroclor pollution problem. He would be assisted by a Task Force from members of each Business Group plus Medical, Law, Engineering and Manufacturing.

2. Notify all Aroclor customers of PCB problem and relabel containers - within 60 days.

3. Clean up Monsanto plants' effluents within 12 months.

4. Develop and implement new packaging systems for Aroclor 1254/1260 - within 6 months.

5. Educate customers on need for clean-up at their plants - within 4 months.

6. Introduct to market, replacement products for Aroclor 1254/1260 - beginning 1/1/70 (Fluids), 4/1/70 (Plasticizers).

WATER_PCB-SD0000073373

RECOMMENDED ACTION PLAN

7. Continue and expand biodegratation test program with Aroclor series, particularly 1242, 1248 and 1254.

8. Continue toxicological test program.

9. Accelerate present analytical test program.

10. Determine feasibility and cost of eliminating 5/6 Cl_2 in Aroclors 1242 and 1248. (3/70)

11. Study incineration products. (3/70)

12. Develop business plan to offer:

    Monsanto Fluid Reclamation and Recovery with Enviro Chem (4/70). (Reclamation already underway at Findett.)

WATER_PCB-SD0000073374

WHAT COULD WE EXPECT FROM THIS PROGRAM?

Through this action program, Monsanto would expect to:

1. Retain or convert a good portion of our business and profits:

PROBLEMS	CONVERT OR RETAIN	$M SALES OUT OF PRESENT	ODDS OF SUCCESS
a. Confined to A-1254/ 1260.	$20.3 M	$22 M	70%
b. Spreads to A-1248 and 1242.	$10 M	$22 M	60%

2. Gain further valuable knowledge and time to:
   a. Learn more facts.
   b. Protect our position.
   c. Make further decisions regarding our program.
   d. Contribute to overall pollution knowledge.

3. Clean up the major contributing PCB pollution factors.

4. Minimize customer complaints and hardships.

741967

NEV 028713

WATER_PCB-SD0000073375

The Program Would:

1. Cost some money.

   Est. SARE - $400-500 M

   Est. Capital - $700 M

   $1.1 M - 1.2 M

2. Expose us to continued adverse publicity and possible law suits.

3. Cause some customer discontent - but much less than an abrupt termination of production.

741968

NEV 028714

WATER_PCB-SD0000073376

SUMMARY

In summary, the PCB pollution problem is a very serious one. It is a worldwide ecological problem. At present the most serious offenders are the 5 and 6 chlorine containing products (Aroclors 1254 and 1260). There are some indications other members are biodegradable to varying degrees. Currently, much scientific testing is underway and more information will be forthcoming. Monsanto must act in a positive cooperative fashion. A plan of action has been discussed which we feel indicates responsible action. Our stakes are large and because of the many possible effects on the Corporation -- your guidance and approval of the suggested action program is requested.

Thank you for your consideration. May we answer any questions?

WATER_PCB-SD0000073377

BCC: P. G. BENIGNUS
D. A. OLSON

July 6, 1970

Mr. Garlington Wilburn
Manager, Engineering
Westinghouse Electric Corporation
South Boston, Virginia

Dear Gary:

I have read your Process Specification 8914004 "Disposition of Scrap Inerteen and Inerteen Contaminated Materials" and I found it an excellent document which reflects Westinghouse's concern about the PCB problem and is a major step forward toward improved control.

I do have one concern that I would like to pass on to you. The suggestion to burn solvent or oil contaminated with Inerteen does not refer to any minimum combustion temperature. As we discussed previously, total destruction of PCB's can only occur above 800°C. Any temperature below this minimum will result in vaporization with release to the atmosphere or worse yet, it is possible to partially oxidize PCB's into materials which can be highly toxic (e.g. dioxins or furans). Your incineration should be thoroughly reviewed.

I found our discussion and plant tour last week very interesting and informative. Your plant has excellent housekeeping and with continued emphasis on controlling loss of PCB's to the air and sewer, I am confident you can succeed in achieving a "bone dry" plant in which the leakage, spills, etc. are a rarity.

I am working with our P.R. Department on a suggested press release which I will send you soon.

Sincerely,

W. B. Papageorge, Manager
Environmental Control

cc: G. R. Graham

PLAINTIFF'S EXHIBIT 1335

PLAINTIFF'S EXHIBIT

GBRN003404

906102

WATER_PCB-SD0000073378

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

May 10, 1977

Paul E. Heisler
Monsanto
Route 3
Sauget, Illinois 62201

Dear Mr. Heisler:

Enclosed is a copy of our final report of the industrial hygiene survey conducted at the W.G. Krummrich plant on July 21-22, 1976.

Copies of this report are being sent to the NIOSH Regional Office, OSHA Regional Office, Local #12, International Chemical Workers and the Illinois Department of Labor.

As previously mentioned, all investigative findings and reports are subject to mandatory disclosure, upon request, under the provisions of the Freedom of Information Act.

We appreciate the cooperation that you and your staff displayed during our visit. If you have any questions or desire clarification of this report, I can be reached by calling (513) 684-2876.

Sincerely,

Mark W. Jones

Mark W. Jones
Industrial Hygienist
Industrial Hygiene Section

enclosure
cc: J.T. Garrett
Dr. Craft
NIOSH Regional Office, Region V
OSHA Regional Office, Region V
International Chemical Workers, Local #12
Illinois Department of Labor
NIOSHTIC
B. Peterson

PLAINTIFF'S EXHIBIT 1337

INDUSTRIAL HYGIENE SURVEY OF THE

Polychlorinated Biphenyl Production Operation
Monsanto Industrial Chemicals Company
Sauget, Illinois

SURVEY DATE

July 21-22, 1976

SURVEY CONDUCTED BY

Mark Jones
Janson Becker

REPORT WRITTEN BY

Mark Jones

DATE OF REPORT

May 6, 1977

Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio

NEV 014058

743310

WATER_PCB-SD0000073380

PLACE VISITED:	Monsanto Company W.G. Krummrich Sauget, Illinois
DATE OF VISIT:	July 21-22, 1976
PEOPLE CONTACTED:	Mr. Art Leisy Manufacturing Superintendent Mr. Paul Heisler Director, Safety and Environmental Control Mr. Bruce Eley Corporate Industrial Hygienist Mr. Virgil Brawley Supervisor - PCB Production Mr. John Peduzzi Supervisor - Incineration Mr. Julio Munoz Senior Technician, Environmental Control Mr. Neil Sullivan Technician, Environmental Control Mr. Frank Basile Senior Engineer, Environmental Control Mr. Ed Heumann Technician, Environmental Control Mr. Dale Rachel - Foreman, PCBs Production Mr. Tom Carrico - Foreman, PCBs Production
PERSONS MAKING VISIT:	Mark Jones Janson Becker
PURPOSE:	To conduct an industrial hygiene survey to determine the workers' level of exposure to chemicals present in the polychlorinated biphenyls production area at the Sauget, Illinois facility.

WATER_PCB-SD0000073381

INTRODUCTION

Recent literature has linked polychlorinated biphenyls with possible carcinogenic effects. Because this literature is incomplete, the Division of Surveillance, Hazard Evaluations and Field Studies of the National Institute for Occupational Safety and Health has underway an "industrywide" study of industries using polychlorinated biphenyls. Since Monsanto is the sole producer of polychlorinated biphenyls in the United States, an industrial hygiene survey was conducted at their PCBs production area in Sauget, Illinois, on July 21-22, 1976. This survey was conducted by Janson Becker and Mark Jones.

During the visit, 18 air samples were collected for evaluation of polychlorinated biphenyls exposure. In addition, samples were collected for exposure to iron silica and chlorine.

DESCRIPTION OF THE FACILITY

The polychlorinated biphenyls production operation is one of many operations present at the Monsanto facility in Sauget, Illinois. Sulfuric acid, benzene derivatives, rubber chemicals (antioxidants, etc.), chlorine and phosphorous products are other products produced at the facility.

The facility began production of polychlorinated biphenyls around 1936. Production continued to grow until 1970 when Monsanto began restricting the sale of PCBs to use in closed systems.

The entire work force at the facility is approximately 1300 persons, with approximately 835 of these persons being hourly employees. Approximately 25 employees are involved with the production of PCBs. The union representing this group is the International Chemical Workers, Local #12.

MEDICAL, INDUSTRIAL HYGIENE AND SAFETY PROGRAMS

A dispensary is located at the plant. Nurses are present at the dispensary 24 hours a day and a physician is present during the day. All employees are required to take a pre-employment physical examination and annual physical examinations. Certain employees are required to take additional examinations and/or special tests.

Industrial hygiene matters at the facility are handled by the Environmental Control Group. The six people who are assigned to this group work in conjunction with the safety department. The only sampling that has been done for polychlorinated biphenyls is the waste water discharged from the area is sampled continuously and analyzed twice a week and the collection of a few air samples (Appendix B).

WATER_PCB-SD0000073382

Four people work in the safety department. Safety meetings are held every month and safety information is provided to the different work areas through safety committees. Personal protection programs used at the plant include safety shoes, safety glasses, hard hats, protective clothing and respirators (where needed).

Corporate industrial hygienists also give support to the industrial hygiene and safety programs.

DESCRIPTION OF PROCESS

Three products are made in the PCBs production area: Aroclor 1016, Aroclor 1242, and Aroclor 1254. Aroclor 1016 is used in capacitors and Aroclor 1242 and 1254 are used in transformers. The operation is outdoor and consists mainly of pipeline, reaction vessels, distillation columns and storage tanks. Even though the system is theoretically a closed system, samples are drawn off and leaks occur which give a potential for employee exposure.

Biphenyl is brought to the facility by tank car and pumped to storage tanks. The chlorine used for the operation comes by pipeline from another part of the plant. The chlorine and biphenyl are piped into a chlorinator in the presence of a catalyst and allowed to react. There are two separate groups of chlorinators, one group for producing Aroclor 1254 and the other for Aroclor 1242. The product from the Aroclor 1254 chlorinators goes through a purifying operation which includes a still, receiving tank and filtering system. From this operation the polychlorinated biphenyls go to the appropriate storage tank. The product from the Aroclor 1242 chlorinators goes to an intermediate storage tank and then either through a similar operation as the Aroclor 1254 or to a distillation column for producing Aroclor 1016. From here it goes to the storage tanks.

The mixing tanks are used to formulate the final product by the introduction of the appropriate additives needed to give the polychlorinated biphenyls the properties desired by the customer. Diatomaceous earth is used as an aid to filtration.

INSPECTION OF PLANT

Potential Health Hazards

Potential health hazards observed during this survey were as follows:

1. Polychlorinated biphenyls exposure
2. Chlorine exposure
3. Free silica exposure

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Ventilation

The polychlorinated biphenyls production operation is located outdoors. Local exhaust ventilation is used in two operations. The drumming operation is equipped with a hose which is placed near the opening of the 55 gallon drum while it is filled. Near the chlorinators is a work station where employees perform specific tests on samples drawn from the chlorinators. This work station has an exhaust fan and a hood over the area where the tests are performed.

Housekeeping

Housekeeping in the polychlorinated biphenyls production area was taken care of fairly well. The aisleways were kept clean and clear.

SURVEY PROCEDURES

General

Air samples were collected in the polychlorinated biphenyls production area for evaluating exposure to polychlorinated biphenyls, iron chloride, and chlorine. A bulk sample of the diatomaceous earth used was analyzed for free silica content. The following paragraphs describe the methods used to collect and analyze the air samples.

Polychlorinated Biphenyls

Both personal and area air samples were collected in the polychlorinated biphenyls production area. Sipin Spl pumps were used to collect the air samples on florosil tubes. The tubes contain a magnesium silicate absorbent called florosil and have a 100 mg primary section and a 50 mg backup section. Samples were collected for six to eight hours at a flow rate of approximately 200 cc/min. The polychlorinated biphenyls were desorbed from the florosil with hexane and analyzed by using a gas chromatograph with an electron capture detector.

Iron Chloride

Area air samples were collected for iron chloride while the employees poured the iron chloride (powder) into a vessel. MSA Model G pumps were used to collect the air samples on a 0.8 micrometer pore size mixed cellulose ester filter (37 mm in diameter). Samples were collected for the duration of the task which was approximately three minutes at a flow rate of 1.7 liters per minute. The samples were analyzed for iron by atomic absorption and are reported as such.

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Free Silica

One bulk sample of the diatomaceous earth used was collected for analysis of free silica content. The per cent free silica was determined by x-ray diffraction.

Chlorine

Detector tubes were used to evaluate concentrations of chlorine in the PCBs production area. Chlorine measurements were made using "Bendix Gastec Analyzer Tubes - Low Range (1-8 ppm)".

RESULTS AND DISCUSSION

Polychlorinated Biphenyls

The results of the area and personal air samples are given in Table 1 and the job descriptions corresponding to the job titles are in Appendix A.

Eleven personal and seven area air samples were collected for analysis for polychlorinated biphenyls. The polychlorinated biphenyls being produced at the time of the survey were for Aroclor 1016 (42% chlorine). The personal air samples ranged from a concentration of 20 $\mu g/m^3$ to 86 $\mu g/m^3$ while the area air samples ranged from 16 $\mu g/m^3$ to 55 $\mu g/m^3$. These are all well below the current Federal Standard for chlorodiphenyl (42% of chlorine) of 1 mg/m^3. The dermatological effect and systemic effect on the liver resulting from polychlorinated biphenyls is well documented in the literature; however, recent literature has linked possible carcinogenic effects to polychlorinated biphenyls.[1,2,3] Therefore this standard may not adequately protect the workers health.

Iron Chloride

The results of the air samples are given in Table II. Two samples were collected for determining worker exposure to iron chloride. No iron could be detected on one of the samples, but the other sample had an iron concentration of 8.1 mg/m^3. Since this procedure of adding the iron chloride only takes an average of 3 minutes per shift, the workers time weighted average is well below the current recommended ACGIH TLV for iron salts of 1 mg/m^3 based upon soluble iron. The big difference in sample results was probably due to the differences in operating procedures observed each time the task was performed.

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Free Silica

The bulk sample of diatomaceous earth was analyzed and determined to have a free silica content of 9.8%. Since the material is usually handled only once a week, the survey team was unable to observe this procedure.

Chlorine

No concentrations of chlorine were detected.

CONCLUSIONS AND RECOMMENDATIONS

Based on the observations made during this survey and the results of the air samples, the following conclusions are drawn and recommendations for improvements made:

1) Even though the concentration of iron chloride found while handling the material is below the ACGIH recommended TLV it would be good industrial hygiene practice to wear an approved respirator when this task is performed.

2) Since the diatomaceous earth contains 9.8% free silica, an approved dust respirator should be worn when the worker performs this task if this practice is not presently employed.

3) Because of the recent concern of the possible carcinogenic effect of polychlorinated biphenyls, engineering methods should be used to prevent employee exposure to polychlorinated biphenyls.

4) Emergency equipment (self-contained breathing apparatus) should be readily available in case of a chlorine leak.

is readily available - Scott Air

Emp wasn't on air collectors - so he missed entirely. There are 4 Sa...

1. Work...

NEV 014064

WATER_PCB-SD0000073386

Table I

CONCENTRATIONS OF POLYCHLORINATED BIPHENYL (detected as Aroclor 1016) IN A FACILITY MANUFACTURING POLYCHLORINATED BIPHENYLS

Personal Air Samples

Job Title	Date Sampled	Total Sampling Time (min.)	Volume (liters)	Concentration ($\mu g/m^3$)	TW ($\mu g/$
Premium Operator	7/21	436	91.0	47	33
"	7/22	451	97.8	20	
Second Operator	7/21	432	80.0	46	44
"	7/22	448	95.3	43	
Column Operator	7/21		74.9	64	57
"	7/22	446	85.7	51	
Still Operator	7/21	432	94.6	40	63
"	7/22	444	67.6	86	
Standard Operator	7/22	445	96.1	61	61
Distribution Operator	7/21	413	88.3	54	45
"	7/22	419	91.3	36	

Area Air Samples

Location	Date Sampled	Total Sampling Time (min.)	Volume (liters)	Concentration ($\mu g/m^3$)	Avera ($\mu g/$
Drumming	7/21	418	89.1	45	48
"	7/22	418	87.6	51	
Temperature Testing	7/21	417	201.6	25	39
"	7/22	455	105.4	52	
Chlorinators	7/21	419	89.0	55	46
"	7/22	459	70.3	36	
Incinerator Burner	7/21	409	81.6	16	16

*Arithmetic Average

NEV 014065

WATER_PCB-SD0000073387

Table II

CONCENTRATIONS OF IRON CHLORIDE
FOUND WHILE OPERATOR ADDED IT AS A CATALYST

Location	Date	Total Sampling Time (min.)	Volume (liters)	Concentration of Iron (mg/m^3)	Concentration o Iron Chloride (mg/m^3)
Near Reactor Lid	7/21	3	5.1	N.D.	--
"	7/22	3	5.1	8.1	18.4

WATER_PCB-SD0000073388

Appendix A

JOB DESCRIPTIONS

Premium Operator - Operates both the continuous and batch chlorinators. This includes keeping the chlorinators running, adding iron chloride and drawing samples.

Second Operator - Loads the tank cars for shipment and takes care of the tank farm and blend tanks.

Standard Operator - In charge of making sure area is clean and does all the filling of the 55 gallon drums.

Column Operator - Operates the distillation column used to produce Aroclor 1016.

Still Operator - Operates both stills used in producing Arolcor 1254 and 1242.

Distribution Operator - Works in a different area of the plant and is in charge of operating the incinerator.

NEV 014067

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Appendix B

CONCENTRATION IN THE ATMOSPHERE IN THE MANUFACTURING DEPARTMENT BATTERY LIMITS AS MEASURE IN OCTOBER, 1975

Date	Location	mg/m^3
10/9/75	12 ft. operating level at batch chlorinator	0.022
10/9/75	12 ft. operating level at continuous chlorinator	0.012
10/13/75	12 ft. operating level at batch chlorinator	0.057
10/13/75	12 ft. operating level at continuous chlorinator	0.058
10/14/75	Ground floor operating level	0.006
10/16/75	Ground floor, scrubber discharge area	0.338

SOURCE: Monsanto

NEV 014068

WATER_PCB-SD0000073390

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NEV 014069

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WATER_PCB-SD0000073391



CRITICAL REVIEWS™ in TOXICOLOGY

Edited by

Leon Golberg, M. B., D.Sc., D. Phil., FRC Path.
Research Professor of Pathology
Scientific Director, Institute of
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PLAINTIFF'S EXHIBIT 1342

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GENP 010205

WATER_PCB-SD0000073392

THE TOXICITY OF POLYCHLORINATED POLYCYCLIC COMPOUNDS AND RELATED CHEMICALS

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England

INTRODUCTION

Only the small group of the polychlorinated polycyclic compounds given in Figures 1 and 2 will be reviewed in this article. Several years ago when this laboratory was the Atlanta Toxicology Branch of the Food and Drug Administration, concern was voiced over the possible long-term effects of polychlorinated biphenyls, and we began to study the toxicity of Aroclor 1254 and Aroclor 1260. About this time a follow-up study was performed on a group of workers in New Jersey who were engaged in the production of 2,4,5-T.[1] These workers had very severe chloracne and had previously been shown to have porphyria.[2] During that same time, a petition was filed with the Food and Drug Administration for a residue level of hexachlorophene on certain food crops. Hexachlorophene, as well as 2,4,5-T, is made from trichlorophenol, although the chemical reactions are quite different. When we checked the available literature on the toxicity of hexachlorophene we felt that adequate toxicity data by present standards were not available, particularly not if the compound was meant to be ingested. Furthermore, Larson[3] had pointed out that hexachlorophene was more toxic than commonly acknowledged.

Hexachlorophene and similar chemicals behave differently from such polycyclic polychlorinated compounds as the chlorinated biphenyls (PCBs). Hexachlorophene in particular is acutely much more toxic than the PCBs and is fairly rapidly eliminated from the body, while the PCBs have a very low acute toxicity, but are very poorly metabolized, particularly those with more than four chlorine atoms on the phenyl rings. The long-term effects are therefore more critical for compounds such as PCBs. The chlorinated dibenzodioxins and furans, some of which are extremely toxic on an acute basis, may also show persistence and their long-term effects may be equally as important. These observations show that it would be erroneous to make predictions on long-term effects from results obtained in acute toxicity studies.

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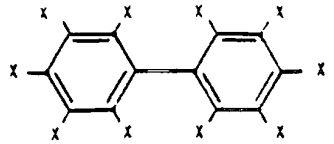
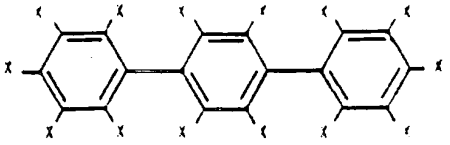
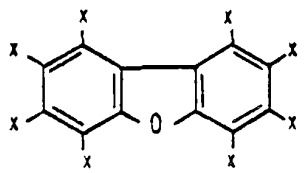


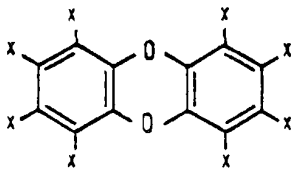
Polychlorinated Biphenyls (PCB's)



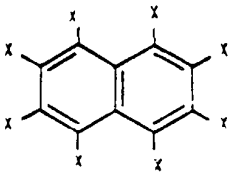
Polychlorinated Terphenyls



Chlorinated Dibenzofurans

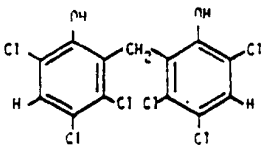


Chlorinated Dibenzodioxin

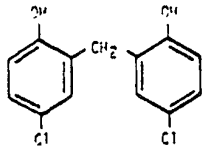


Polychlorinated Naphthalenes

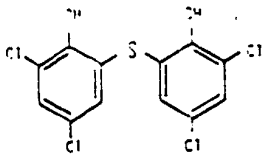
FIGURE 1. The materials shown in this figure are mixtures of compounds in which several but usually not all of the positions (-X) are chlorine and the rest are hydrogen. The properties of the materials depend on the degree of chlorination of the mixture. All are insoluble in water but soluble in varying degrees in organic solvents and in fats. The trade name for the U.S. product (Monsanto) of the chlorinated biphenyls and terphenyls is Aroclor. The trade name is followed by the number. For the biphenyls, the first 2 digits of this number are 12, and for the terphenyls, 54. In each instance the last 2 digits give the percentage of chlorine.



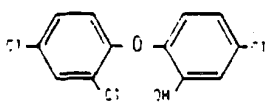
HEXACHLOROPHENE
2,2'-Methylene-bis(3,4,6-trichlorophenol)



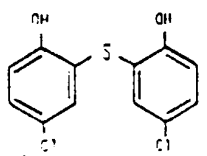
DICHLOROPHENE
2,2'-Methylene-bis(4-chlorophenol)



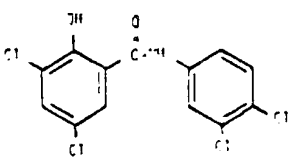
BITHIONOL
2,2'-Thio-bis(4,6-dichlorophenol)



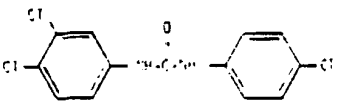
2,4,4' trichloro- 2'hydroxy-diphenyl ether
(Triclosan = Irgasan DP300)



FENTICLOR
2,2'-Thio-bis(4-chlorophenol)



3,3',4,5'-Tetrachlorosalicylanilide (TCS)



3,4,4'-Trichlorocarbanilide (TCC)

FIGURE 2. The compounds in this figure are white crystalline solids with clearly defined melting points above 160°C. They are practically insoluble in water and soluble in varying amounts in organic solvents and in fats. Those containing an -OH group, all the above excepting 3,4,4'-trichlorocarbanilide, are soluble in aqueous alkali.

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The present review is an attempt to correlate various toxic effects produced by the chemicals listed in Figures 1 and 2 in order to better understand and appreciate their behavior.

The subjects covered in this article have lately enjoyed great interest and a rapidly growing number of scientific reports are available. Since a number of the chemicals discussed produce similar or related effects, their toxicology is discussed together rather than listing each compound separately, which would have led to a great deal of repetition.

A detailed discussion of the various chemical reactions, analytical methods for the determination of the compounds, is not given. The review has been written with the toxic effects of the various compounds as the focal point and the literature cited serves to illustrate these points. No attempt has been made to present a complete review of the literature in this area.

DEVELOPMENT, USAGE, AND OCCURRENCE

A description of the synthesis of *chlorinated biphenyls* (PCBs) can be found in *Liebig's Annalen* as early as 1881.[4] Successful production of diphenyl in commercial quantities was not reported until 1930.[5] At that time the chlorination of technical biphenyl was also described.[6] Biphenyl itself is fungistatic and used as a preservative for citrus fruits.[7] Chlorinated biphenyls are very stable, and have been used for protective coatings, as plastic resins or gums for varnishes, and for waterproofing and flameproofing of wood.

The excellent dielectric properties of these compounds were noted as early as 1930. Until the advent of the PCBs, mineral oil was used as a cooling and dielectric liquid impregnant for high voltage electric apparatus such as transformers and capacitors. Since mineral oil is flammable and flammable gases could also be produced, restrictions for the use and installations of these transformers had to be set, particularly for indoor installation. When mineral oils were replaced by the Aroclors, the fire and explosion hazards were eliminated. This was recognized by the National Board of Fire Underwriters and the National Electric Code was modified.[8] Use of Aroclors also greatly reduced the physical size of the capacitors.[9]

A recent summary of the varied uses of PCBs has been provided by Broadhurst.[10] With a peak production of 42,527 short tons of PCBs in 1970, Monsanto is the sole producer of Aroclors (U.S. tradename for PCBs) in the U.S. Yearly PCB production figures for the period 1960-1971 were reported by Monsanto.[11] The production increased steadily until 1970 and dropped to 20,236 short tons in 1971 due to a voluntary restriction of the use of PCBs by the company. Trade names in other countries include Kanneclor and Santhaterm in Japan, Clophen, Flenclor, Phenoclor, and Sovol in Europe.

The polychlorinated capacitor liquids, commonly called askarels, are mixtures of chlorinated biphenyls and chlorinated benzenes. A variety of other industrial applications[10] have been found for PCBs. They have served as fluids for hydraulic, gas turbine, and vacuum pumps, as heat transfer fluids, as plasticizers, adhesives, textile coatings, surface coatings in paints and varnishes, as sealants, and as part of formulations to prepare pressure sensitive records and color copying papers. The extent of the current use of PCBs in printing processes is unknown. Other suggested uses over the years have included catalyst carrier for polymerization of olefins, conversion of water permeable soil to a nonpermeable state, and combined insecticide and bactericide formulations. Mixtures of chlorinated biphenyls and chlorinated naphthalenes have been employed to insulate electric wires and cables, particularly when they were used in the mining industry and on warships.[12]

Residues of polychlorinated biphenyls have been reported in the environment by a number of authors in different parts of the world. These reports were usually from areas where industrial pollution was responsible for the environmental contamination. Holden,[13] after finding PCBs in marine fish and mollusks from Scottish waters, noticed that they were generally highest in samples from the Firth of Clyde and he discovered that the PCB contamination probably originated from industrial sewage. The sewage sludge was transported from two Glasgow purification works by boats and dumped in deep water six miles south of Garroch Head. The disposal of sewage sludge on land could lead to the introduction of PCB residues into the terrestrial ecosystem by transfer through food chains. So far PCB residues have not been detected in fresh water fish in Scotland.

Polychlorinated biphenyls have also been found

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in wildlife samples collected along the Dutch coast and the Rhine River[13] and in fish and seal in different parts of the Baltic Sea along the Swedish coast.[15]

Risebrough et al.[16] compared the presence of PCBs with that of DDT and its metabolites in various birds. These authors found very low concentrations of PCBs in wildlife species in Baja, California, Mexico, and the Gulf of California, which are very remote areas with a high ratio of DDT to PCB of approximately 9 or 10. In sea birds from the Pacific, the ratio was between 5 and 10 and at that time, PCBs were not found in eggs of the Adelie penguin from Cape Crozier, Antarctica. Relatively high PCB concentrations were found in San Francisco Bay, Puget Sound, and San Diego Bay and the ratio of DDT to PCBs in wildlife samples from this area was between 1 and 2. This is again emphasized by the findings of Dustman et al.[17] Twelve Alaskan bald eagle eggs had median PCB residues of 1.65 ppm while 11 eggs collected in Maine, Michigan, Minnesota, and Florida showed a median concentration of 9.7 ppm.

Zitko[18] found low concentrations of PCBs in different types of fish taken from several lakes and the St. John River System, New Brunswick, Canada, and the Nova Scotia banks. Fish from the Milwaukee River and Lake Michigan in the midwest part of the U.S., where the river enters into the lake, contained varying amounts of PCBs[19] while fish taken from various small lakes in Wisconsin without industrial discharge failed to show PCBs. Large predators from Lake Michigan contained as much as 10 to 25 ppm PCBs on a fresh weight basis expressed as Aroclor 1254 and salmon eggs contained as much as 12 to 17 ppm PCBs on a fresh weight basis. Further studies by Veith[20] of the concentration of PCBs in different rivers emptying into Green Bay indicated a trend towards a decrease in PCB concentrations since the *voluntary* partial ban on PCB sales by Monsanto was implemented in September of 1970.

If PCB discharges are very high a fishkill may result such as the one in Escambia Bay, Florida in 1969.[21] In that particular episode the PCBs had entered a plant's effluent through accidental leakage of heat exchange fluid. The PCB found in this case resembled Aroclor 1254 most closely. The peak amount found in water of the Escambia River at the outfall amounted to 275 ppb and the peak concentration found in oysters from Escambia Bay was 3.0 ppm. Aroclor residues in sediment samples taken near the outfall reached 486 ppm. When the leakage from the plant was corrected, Aroclor levels gradually decreased in this area.

The wildlife portion of the U.S. National Monitoring Program analyzed starlings, mallard and black ducks, bald eagles, and fish of several species for PCBs. According to Stickel,[22] monitoring for terphenyls is also done but not for any of the other chlorinated compounds in this report. Research surveys that include fisheating birds, insectivorous birds, ospreys, woodcocks, and certain ducks also monitor only for PCBs and for pesticides. Oysters (*Crassostrea virginica*) are a good indicator of PCB and other chlorinated hydrocarbon concentrations in water and a national monitoring program in these mollusks in 15 coastal areas has been developed.[23] So far, mollusks have only very occasionally contained low levels of PCBs.

In summary, the PCB concentrations in water are low or nonexistent in remote lakes and fresh water streams and can be as high as 50 μg/l (5 ppb) or higher in polluted rivers such as the Hudson River.[24] The PCB concentration is usually higher in sediment from these polluted waters because PCBs are only very slightly soluble in water.[25] Since PCBs are stored in living matter, they are concentrated in the food chain and the usual "biomagnification" is encountered as we know it from other poorly metabolized and excreted substances. The concentration of PCBs in fish, particularly those in the upper end of the food chain from polluted rivers and lakes, is usually estimated in the ppm range and fisheating birds will have somewhat higher levels of PCBs than the fish from the same geographic location.[26] Young animals may contain less PCBs than their older counterparts of the same species in a particular location.

PCBs are also infrequently encountered in dairy products, meat, fish, and poultry in ready-to-eat human food.[27,28] Occasionally, human food and domestic animal feed have been more extensively contaminated with PCBs. In these instances, the contamination could usually be traced to local misuse of transformer fluid, leakage of PCBs from heat exchange fluid, or contamination of recycled paper with PCBs where the paper had been used for food packaging such as cereal boxes.[29] The U.S. Food and Drug Administration has recently set temporary tolerances for PCBs in certain food products (see Table 1).

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TABLE 1

Temporary Tolerances Expressed as Parts per Million (ppm) Established by U.S. Food and Drug Administration

(1) Milk (fat basis)	2.5
(2) Dairy products (fat basis)	2.5
(3) Poultry (fat basis)	5.0
(4) Eggs	0.5
(5) Complete and finished animal feeds	0.2
(6) Animal feed components	2.0
(7) Fish and shellfish (edible portion)	5.0
(8) Infant and junior food	0.2
(9) Paper food-packaging material	10.0

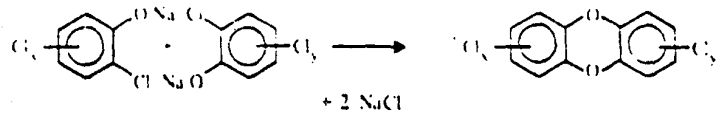
Note: The tolerance for paper food-packaging material shall not apply to such material separated from the packaged food by a functional barrier impermeable to PCB migration.
The Food and Drug Administration will provide upon request the analytical methods it will use for enforcing the temporary tolerances.

All of these aspects of PCBs in the environment have been the subject of a number of reports, reviews,[30] and conferences.[31-35]

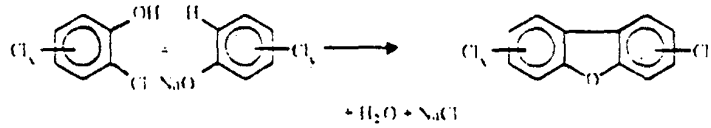
Terphenyls and chlorinated terphenyls are used as reactor coolants. The terphenyls consist of mixtures of ortho-, meta-, and paraterphenyls. Chlorinated terphenyls are produced by Monsanto and termed Aroclor, followed by numbers. The first 2 digits of these numbers are 54 and the last 2 indicate the percent of chlorine such as Aroclor 5460. Aroclor series 25 and 44 consist of mixtures of polychlorinated biphenyls and polychlorinated terphenyls.[36] According to Zitko et al.,[37] polychlorinated terphenyls have been found in environmental samples. Polychlorinated terphenyls do not elute from GLC columns under conditions used for PCBs,[38] which may explain why they have only been detected occasionally, but the way they are used probably also precludes their extensive spread in the environment.

Chlorinated dibenzodioxins and *chlorinated dibenzofurans* may occur as contaminants of cyclic chlorinated hydrocarbons.

In 1959 Tomita et al.[39] reported on the synthesis of polyhalodibenzo-p-dioxins. According to these authors, chlorophenols, when heated to about 200°C or more under alkaline conditions and pressure, will form chlorodibenzodioxins, as shown below.



Under similar conditions a chlorodibenzofuran may also be formed.



Chlorinated dibenzodioxins and chlorinated dibenzofurans are formed, or can be formed, as contaminants in the manufacture of a variety of products which use chlorophenols and chlorobenzenes as starting materials, such as 2,4,5-T, pentachlorophenol, nitrofen, hexa- and pentachlorobenzene, and tri- and tetrachlorophenol. Polychlorinated biphenyls may also be contaminated with chlorinated dibenzofurans,[40,41] and chlorinated dibenzofurans may result from polychlorinated biphenyls under UV irradiation.[42] The toxicity of these products varies depending on the position and number of chlorines attached to the phenyl rings. Products from different manufacturers may show a great deal of difference in the type and amount of contamination and different lots of the same product may vary in composition, making toxicological evaluations of these products very difficult. Rigorous production control and cleanup procedures need to be implemented so that the composition of different lots manufactured by the same company becomes more uniform.

Villanueva et al.[43] and Jensen and Renberg[44] reported the presence of chlorinated dibenzo-p-dioxin in pentachlorophenol. Hydroxynonachlorodiphenyl ether was also found and referred to as "predioxin" under the assumption that it represented a precursor of dioxin.

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According to Johnson et al.,[45] the predominant dioxin in a commercial pentachlorophenol was octachlorodibenzodioxin while trace amounts of hexachlorodibenzodioxin and no tetrachlorodibenzodioxin were found. Since the technical pentachlorophenol was in some respects more toxic in animal studies, than the pure product, the production process of pentachlorophenol was changed to minimize the dioxin concentration and a new product has now been registered under the Federal Insecticide Fungicide and Rodenticide Act with a lower dioxin content.

Technical 2,4,5-T has also been found to be contaminated with a dioxin. In this instance, unfortunately, the very toxic 2,3,7,8 tetrachlorodibenzodioxin,[46-48] was present. The contamination of the 2,4,5-T with 2,3,7,8-tetrachlorodibenzodioxin ranged from < 1 ppm to as much as 32 ppm over the years. In newly manufactured 2,4,5-T in the U.S. the content of tetrachlorodibenzo-p-dioxin has been substantially reduced and is usually kept below 0.1 ppm. Whether other dioxins or furans have ever been detected in 2,4,5-T in the U.S. has not been reported in the literature.

Chlorinated dioxins have also been found in so-called "toxic fat," which produces chick edema disease when fed to chickens. After several years of study by industry and the Food and Drug Administration, Flick et al.[49] were able to separate a purified crystalline product which produced chick edema disease. Two years later, Cantrell et al.[50] announced that 1,2,3,7,8,9-chlorodibenzo-p-dioxin was one of the toxic compounds that produced chick edema. The origin of the chlorinated dibenzodioxin in "toxic fat" was not clear. It was suspected that it arose from chlorophenols which were used to preserve hides for the manufacture of leather. Tallows and greases were obtained from these hides[51] and a more recent outbreak of chick edema disease was traced to the contamination with chlorophenols of soapstock used as feed fats. Higginbotham et al.[52] showed that chlorophenols and their salts, when heated, undergo condensation reactions and form chlorinated derivatives of dibenzo-p-dioxin; furthermore, chlorinated dioxins and predioxins were originally present in some of the chlorinated phenols. Generally no efforts have been made to determine whether *various chlorinated dioxins and furans* are present in the environment. However, Baughman and Meselson[53] recently reported the presence of dioxins in fish taken from four locations in Vietnam in Military Region III, which includes Saigon and several provinces to the north.[54] The concentrations ranged from 18 to 814 ppt.

Zitko[55] was not able to demonstrate chlorinated dibenzodioxins and dibenzofurans in aquatic animals from various locations in Canada.

Chlorinated naphthalenes may so far have remained unidentified since they interfere with other chlorinated compounds in any multiresidue analysis and are detected only when mass spectrometry is also performed.[56]

The various *germicides* given in Figure 2 have been used as antiseptics, deodorants, and particularly, as far as hexachlorophene is concerned, also as preservatives for various cosmetics, soaps, and lotions. A listing of different products that contained hexachlorophene prior to the new regulations was given by the American Pharmaceutical Association.[57] Registration of bithionol was cancelled in the U.S.[58] because it produced photosensitivity reactions in humans using soaps that contained this product. None of the polychlorinated polycyclic compounds used as germicides have been shown to accumulate in the environment. Hexachlorophene has additional uses as a fungicide on ornamental plants, on conveyor chains as a mildewstat, in laundry rinses as a mildewstat, in shoes and air filters and assorted industrial uses as a fungistat, and on leather, paper and textiles.[59] It is also registered as a pesticide for use on cucumbers, peppers, and tomatoes,[60] and for cotton.

Dichlorophene is used as a mildew preventive on cotton and is recommended as a fungicide and bactericide for the protection of textiles and materials from molds.[61]

CHEMISTRY: METHODS FOR CHEMICAL DETERMINATION AND PHOTOLYSIS

Much of the chemistry of *polychlorinated biphenyls* has recently been reviewed.[33-34] Commercial chlorinated biphenyls are mixtures of biphenyl groups with different numbers of chlorine atoms (Figure 1). When hydrogen atoms are replaced by chlorine on the biphenyl ring, a large number of substitution combinations can arise since the number of chlorine atoms on the molecules can vary and the chlorines can also be

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attached to the molecule in different positions, resulting in a variety of isomers. Even if the chlorination may be the same, different commercial batches may vary in the relative concentration of isomers. The PCBs produced in the U.S. by Monsanto fall under the trade name Aroclor. The various Aroclor mixtures have a great number of constituents, and when the biphenyl is chlorinated, 210 different chemicals are theoretically possible. Aroclor 1254, for instance, yielded 69 constituents while the fractionation of Aroclor 1242 and 1260 yielded 45 and 78 components, respectively.[34]

The chlorinated biphenyls (PCBs) are chemically very inert, resistant to corrosive chemicals, insoluble in water, and have a low vapor pressure. Aroclor 1221, for instance, has a boiling point of 278°C. The boiling point increases with increasing chlorination. The chlorinated biphenyls are determined in biological and environmental samples by a combination of electron capture gas liquid chromatography and mass spectrometry. Nuclear magnetic resonance spectroscopy is used in addition to the above two procedures in some laboratories. PCBs were first identified in environmental samples by Jensen in 1966.[62] They were detected as interfering peaks on GLC analysis of environmental samples that were analyzed for chlorinated pesticide residues.[63]

The PCBs interfered with routine pesticide analyses for chlorinated hydrocarbons. Various authors have therefore published separation methods[64] and Reynolds[38] discussed this extensively in a review.

According to Safe and Hutzinger,[65] the use of mass spectrometry for structural studies of PCBs is limited because the chlorine atoms may be randomized between the phenyl groups when the PCBs are fragmented by electrons. The only exception to this is 2,2'-dichlorobiphenyl.

The quantitation of polychlorinated biphenyl in environmental samples has met with difficulty since the PCBs represent mixtures. Several workers have compared PCB components in field samples to Aroclor 1254 because the sample chromatograms were most similar to these mixtures.[66-68] Rote and Murphy[68] quantitated individual peaks of different Aroclors by means of a response curve. The semilogarithmic relationship of detector response (total peak area/16 ng) to average chlorine content was obtained for each Aroclor by the method of least squares. From this relationship the theoretical response of the detector to each chlorinated biphenyl was calculated. When this approach was used, the levels of PCBs were lower than when the PCB levels were compared to the Aroclor 1254 standard. Because of these difficulties in quantitation, the PCB levels reported from different laboratories may vary greatly. The various problems encountered in the analytical methodology of polychlorinated biphenyls and their quantitation are also described in a U.S. FDA report which can be obtained upon request from the U.S. Food and Drug Administration in Rockville, Md. The title of the report is *Analytical Methodology for Polychlorinated Biphenyls* (Feb. 1973).

Polychlorinated terphenyls (Figure 1) are not eluted from gas chromatography columns under conditions used for polychlorinated biphenyls.[38] By altering their gas chromatograph column, Zitko et al.[37] were able to detect polychlorinated terphenyls.

Chlorinated naphthalenes (Figure 1) elute at the same time and cause interference with the determination of chlorinated biphenyls and chlorinated hydrocarbon pesticides in general, unless mass spectrometry is performed to establish the identity of the various chemicals involved.[56]

The methods presently available for the determination of *trichlorocarbanilide* and *other germicides* (Figure 2) are not very well developed. Graber et al.[69] outlined a thin layer chromatography method for the determination of these chemicals in soap and very briefly mentioned other methods that have been employed in the past.

Several methods for the determination of *chlorinated dibenzodioxins* and *chlorinated dibenzofurans* have been described. The goal of these methods is two-fold. First of all, quite a number of technical polychlorinated organic compounds may contain one or several of these compounds[70-72] as contaminants and methods have been developed to determine them in various technical products. Other methods dealt primarily with toxic fats where many attempts were made to isolate and identify the compounds responsible for chick edema disease.[73] Some of these methods were described in the papers that will be cited in connection with the description of chick edema disease in this article.

When preparing the various chlorinated dibenzodioxins and dibenzofurans for toxicity studies in

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order to obtain pure products, methods also need to be available for their separation and identification.[74]

One of the problems with tetrachlorodibenzodioxin as well as tetrachlorodibenzofuran is their severe toxicity in the microgram range which will probably not result in an accumulation within the ppm in biological tissues, for instance, for residue analysis. Baughman and Meselson[53] have recently described a method for the determination of these materials, within the ppt range.

Hexachlorophene is made from trichlorophenol. A process for its production was patented by Gump.[75] Additional methods for the production and purification for hexachlorophene have been published and are cited in *Chemical Abstracts.*

Recently several methods[76-79] have been developed for the determination of small amounts of hexachlorophene in blood and biological tissues. Some methods were based on extraction of hexachlorophene with ether or ethanol or a mixture of ether and ethanol. An acetyl or methyl derivative was formed and the hexachlorophene was determined with electron capture gas chromatography.[79] In an earlier method described by Bachmann and Shetlar,[80] simple benzene extraction was used and no derivative of hexachlorophene was made, which led to very variable results. The various advantages and disadvantages of these methods were discussed by Ulsamer.[79] In earlier work my co-workers used ether for extraction and prepared a dimethyl ether derivative of hexachlorophene.[81] Recovery with this method was only about 75% and we have recently altered our method of extraction to obtain better recovery.[82] A method developed by Kabacoff et al.[78] for the determination of hexachlorophene is, according to the authors, also suitable for determination of dichlorophene and Gutenmann and Lisk[83] have described a method for the determination of hexachlorophene in several agricultural products.

The production of hexachlorophene from trichlorophenol proceeds at low temperature and under acidic conditions which makes the production of a chlorinated dibenzodioxin as an impurity highly unlikely.

Since chemicals that are found in the environment are exposed to sunlight, the effect of *UV light* on the compounds under discussion has been given considerable attention. Hustert and Korte[84] synthetized a few PCB isomers, namely, 2,4,6,2′,4′,6′-hexachlorobiphenyl, 2,4,5,2′,4′,6′-hexachlorobiphenyl, 2,4,2′,4′-tetrachlorobiphenyl, 2,5,2′,5′-tetrachlorobiphenyl, and irradiated the various isomers with UV light. A mercury vapor lamp with quartz filters was used as a light source. The UV spectrum of the synthetized chlorinated biphenyls only shows significant absorption below 300 nm. When these compounds were irradiated in a solvent such as hexane, acetone, methanol, or a mixture of methanol and water, dechlorination and polymerization of the compounds was observed. When the PCB isomers were irradiated in perfluorinated dimethylcyclohexane, an inert medium, isomerization, and chlorination dechlorination were observed. These experiments indicate that, under environmental conditions, photolysis products may result with a lower chlorine content but small amounts of higher chlorinated biphenyls may also occur in low concentrations. Safe and Hutzinger[85] reported that the irradiation of 2,4,6,2′,4′,6′-hexachlorobiphenyl at 310 nm resulted in compounds of lower chlorine content, such as di-, tri-, tetra-, and pentachlorobiphenyls. In these investigations hexane and methanol were used as solvents. It is possible that new compounds are formed by loss of chlorine. Rearrangement and condensation may lead to chlorobiphenyls in environmental samples that are not present in commercial PCB mixtures. The 24-hr irradiation of 3,3′,4,4′-tetrachlorobiphenyl, 2,2′,6,6′-tetrachlorobiphenyl, 2,2′,5,5′-tetrachlorobiphenyl dissolved in hexane resulted in about 70% loss of the starting material, while with 2,2′,4,4′,5,5′-hexachlorobiphenyl, only 3.8% remained and less than 1% of 2,2′,3,3′,4,4′,5,5′-octachlorobiphenyl remained. The irradiation of Aroclor 1254 in hexane resulted in a change of the composition of the Aroclor mixture. The gas chromatogram obtained from the irradiated Aroclor showed shorter retention times than the standard Aroclor 1254. The irradiation of Aroclor 1254 in a dioxane water mixture also containing sodium bicarbonate did not lead to the formation of chlorodibenzofurans or hydroxychlorobiphenyls. The compounds that were observed corresponded to PCB molecules to which water was added and a more polar "carboxylic" acid fraction. Irradiation of Aroclor as a thin film with a frequent addition of water led to newly formed hydroxylated compounds and a more polar "carboxylic" fraction. The results obtained from irradiating

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isomers, namely, nyl, 2,4,5,2′,4′,6′- trachlorobiphenyl, nd irradiated the mercury vapor s a light source. hetized chlorinated absorption below re irradiated in ne, methanol, or a ter, dechlorination compounds was s were irradiated in hexane, an inert hlorination dechlor- periments indicate ditions, photolysis er chlorine content orinated biphenyls trations. Safe and the irradiation of yl at 310 nm chlorine content, tachlorobiphenyls, and methanol were at new compounds Rearrangement and hlorobiphenyls in e not present in 4-hr irradiation of 2,2′,6,6′- hlorobiphenyl about 70% loss of with 2,2′,4,4′,5,5′- remained and less tachlorobiphenyl Aroclor 1254 in he composition of is chromatogram Aroclor showed standard Aroclor oclor 1254 in a ontaining sodium the formation of ychlorobiphenyls. ved corresponded r was added and a action. Irradiation frequent addition ed hydroxylated lar "carboxylic" from irradiating

PCBs therefore depended greatly on the solvents used and the pH of the solution in addition to the light source used and may result in dechlorination, formation of polymers, hydroxylation, and carboxylic products.[86]

Exposure of various chlorinated dibenzodioxins to summer sunlight or fluorescent UV light with an intensity of roughly 100 $\mu w \cdot cm^2$ in the presence of organic solvents such as methanol led to rapid photolysis of 2,3,7,8-tetrachloro- and 2,7-dichlorodibenzodioxin, while 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin produced a series of chlorinated dioxins with uniformly decreasing chlorine content. Some evidence was also found that reactions other than reductive dechlorination occurred.[87] When 2,3,7,8-tetrachlorodibenzodioxin was spread on a glass plate in a methanol solution and the methanol was allowed to dry, quantitative recovery of the dioxin was possible even after 14 days of UV irradiation. Similar results were obtained when 2,3,7,8-tetrachlorodibenzodioxin was dissolved in methanol, put on a glass plate, covered with soil, and irradiated.[87] These results demonstrated that under favorable environmental conditions, when organic hydrogen donors are present, photolysis will take place. Bare surfaces of soil, concrete, or water are not effective inducers of photolysis. Chlorinated dibenzodioxins could at times prove to be quite persistent. Partial dechlorination may also occur with chlorinated diphenyls or the higher chlorinated dibenzodioxins and may result in less chlorinated compounds.

The possible long lasting presence of the dioxins is also emphasized by Kearney et al.,[88] who recovered 56 and 63% of originally applied tetrachlorodibenzodioxin after one year in Hagerstown and Lakeland, Md. soils.

Tetrachlorosalicylanilide and similar compounds split off chlorine atoms when exposed to sunlight. This is briefly mentioned in connection with photosensitivity reactions of the skin. Shaffer et al.[89] irradiated *hexachlorophene* in absolute ethanol with UV light and obtained a number of dechlorinated bisphenols resulting from loss of chlorine in the ortho and para positions relative to the hydroxy group.

GENERAL TOXICITY AND EFFECT ON REPRODUCTION

Diphenyl itself, without any chlorine atoms, is fungistatic agent which is used as a preservative for citrus fruits, and is usually impregnated into the wrapping paper. The protected citrus fruit contains a certain amount of biphenyl residue. In different countries the amount allowed as a residue on citrus fruit varies between 70 to 110 ppm of biphenyl. Booth et al.[90] found a reversible nephrotoxic effect of biphenyl on the rat kidney when rats were fed 0.5% or 1% (10,000 ppm biphenyl) in the diet). None of these effects was observed on diets containing 0.1% (1000 ppm biphenyl). Deichmann et al.[91] showed that prolonged exposure to air containing diphenyl in high concentrations of 5, 40, and 300 $mg \cdot m^3$ produced liver and kidney injury as well as bronchopulmonary lesions in mice and rats. In general, diphenyl has always been considered to be relatively nontoxic. In 1969, in Finland, a man who had been intensively exposed to diphenyl for 11 years became ill and died.[92] Diphenyl impregnated wrapping paper had been manufactured in Finland for about 15 years in the plant where the man was employed. The equipment used in the impregnating process was cleaned 5 to 10 times a year with tri- or tetrachloroethylene. The cause of death of the worker in this particular report was not satisfactorily explained and neither were the complaints of 31 other workers engaged in the same factory. Since chlorinated ethylene compounds were used for cleaning, it should be established whether organic solvents containing halogens could lead to the production of toxic substances when they are brought in contact with diphenyls. If this proves to be the case, then care should be taken that this situation is avoided.

The *PCBs* are also not very toxic when given as a single or a few repeated doses to birds and mammals. However, the juvenile pink shrimp is very sensitive to PCBs in water, while trout and catfish can tolerate higher doses; insects are also not very sensitive to PCBs. Pin fish are not quite as sensitive to a single dose, but will die when exposed for 14 to 45 days to 5 ppb of Aroclor 1254.[93] PCBs are of a low order of toxicity to rats and rabbits when given as a single dose. The acute oral toxicity decreases in rats with increasing chlorine content, while this is not as obvious when the dermal toxicity is tested in rabbits.[13] This may be due to poorer absorption of the higher chlorinated compounds. In studies with adult Sherman strain rats, we found that the oral LD_{50} for Aroclor 1254 and 1260 was somewhere in the

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μg/l × 10³ = μg/m³

range of 4 to 10 g. These two compounds proved to be more toxic in weanling rats. The single oral LD_{50} for weanlings was 1295 mg/kg, and 1315 mg/kg for Aroclor 1254 and 1260, respectively, and the lowest lethal doses were 1000 mg/kg for Aroclor 1254, and 1200 mg/kg for Aroclor 1260. The intravenous LD_{50} for Aroclor 1254 in adult female rats was 358 mg/kg.[94]

A number of short-term studies have been reported where the PCBs were given to animals over a period of one or two weeks. When the PCBs were given in this fashion they were somewhat more toxic than when they were given in a single dose. These studies are reviewed in great detail by Nelson et al.[32] and will not be reported here since they do not give a great deal of additional information.

Vos and Koeman[95] studied the toxicity of three PCB preparations in chickens, Phenoclor DB6, a French product, Clophen A60, a German product, and Aroclor 1260, a product from Monsanto in the U.S. The birds were fed 400 ppm of PCBs in their diets for 60 days; the Phenoclor and Clophen were much more toxic than Aroclor. The birds fed the two European samples died between 12 and 60 days after onset of exposure. The findings at autopsy consisted of hydropericardium, ascites, subcutaneous edema, and liver necrosis. Only 3 of 20 birds fed Aroclor 1260 died during this time with hydropericardium. None of the Aroclor fed birds showed liver necrosis.

With the help of mass spectrometric and microcoulometric analyses, the authors[95] determined that the two European samples were contaminated with tetra- and pentachlorodibenzofurans. As an additional contaminant, chlorinated naphthalenes were found.

Dermal toxicity studies with the three compounds, Clophen, Phenoclor, and Aroclor 1260, in rabbits[96] after two days led to reddening of the skin where the materials were applied. The skin reaction was more pronounced after one week, desquamation of the external epidermal layers of the skin was observed, the hair grew at a reduced rate, the skin became thickened, and prominent transverse wrinkles developed. The test animals showed a gradual loss of weight, and one of the rabbits given Phenoclor and three of those given Clophen died. All but one rabbit showed fluorescence of the liver under UV light, and microscopic changes were also observed in the livers and the treated skin.

Vos and Notenboom-Ram[97] compared the dermal toxicity of the isomer 2,4,5,2′,4′,5′-hexachlorobiphenyl with that of a PCB mixture (Aroclor 1260) in rabbits. Their dermal application resulted in early microscopic skin lesions in the Aroclor group. The lesions in the 2,4,5,2′,4′,5′-hexachlorobiphenyl group appeared later and were less severe. Both experimental groups showed liver changes. The liver damage was more pronounced in the animals that had been exposed to hexachlorobiphenyl than in those that had been exposed to the Aroclor.

In inhalation studies with Aroclor 1242 and 1254, rats, mice, rabbits, guinea pigs, and one cat were exposed to PCB vapors five days a week for several weeks. The concentration of Aroclor 1242 vapor was 1.90 to 8.63 μg/l and no ill effects were observed. The exposure of animals to the vapor of Aroclor 1254 in the concentration of 5.4 or 1.5 μg/l produced enlarged livers in rats. An intercurrent respiratory infection in some control as well as experimental rats made it difficult to interpret the results.[98] Since it is now known that the chronic toxicity of PCBs is a more important parameter in establishing their effects than short-term exposures, further studies with lower levels over longer periods of time would give more meaningful information. Fortunately, most of the compounds under discussion have a low vapor pressure so that exposure by inhalation probably does not present a great problem.

A number of reproduction studies in various species have been conducted with PCBs; usually, embryo toxicity was observed but there were no malformations. Heath et al.[99] were unable to demonstrate an effect on *reproduction* with dietary levels of 25 and 50 ppm of Aroclor 1254 in mallards and bobwhites. An increase in eggshell cracking or reduction in shell thickness was also not observed while DDE, which was used as a positive control, induced significant shell thinning and cracking and a reduction in hatching successes in mallards but not in bobwhite.

In field studies with brown pelican shells, it was found that thinning could be best correlated to DDE residues rather than aldrin or PCBs. This finding indicates, according to Blus et al.,[100] the PCBs are not responsible for eggshell thinning in most birds following environmental exposure.

Peakall[101] fed ringdoves 10 ppm Aroclor 1254

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for 6 months. He injected others with 160 mg/kg intraperitoneally for 4 days, and evaluated the ashed eggshell weights of these birds. He found no difference in eggshell thickness between the experimental and the control groups.

In a pheasant reproduction study with Aroclor 1254,[102,103] a significantly greater difference in the number of eggs that were pipped but not hatched was found in the group of hens that received 50 mg of PCBs weekly. Egg production and hatchability was lower in this group, the survival of chickens that did hatch at six weeks of age was reduced, and the ones that did survive were significantly lighter than the controls.

Aroclor 1242 at 10 ppm or 100 ppm and Aroclor 1254 at 100 ppm in the diets of chickens did reduce egg production and hatchability and caused thin eggshells, while Aroclor 1242 at 1 ppm, Aroclor 1254 at 10 ppm, and Aroclor 1260 at 100 ppm did not affect reproduction in chickens.[104] In a rat reproduction study, decreased survival of pups at a dietary level of 100 ppm of either Aroclor 1242 or 1254 was observed. The results obtained from the reproduction studies in birds particularly seem to indicate that the lower chlorinated biphenyls affect reproduction more than the higher chlorinated biphenyls, and it is very important to determine whether the lower chlorinated biphenyls that have been suggested as replacements for presently employed chlorinated biphenyls have an effect on reproduction.

In another rat reproduction study[94] the lowest dose of Aroclor 1254 that affected reproduction was 20 ppm (1.5 mg/kg/day) which manifested itself in a decreased number of litters and less pups per litter. Neither 1 ppm nor 5 ppm of Aroclor 1254 had an effect on reproduction in the Sherman strain rat; however, an exposure of the dams to the Aroclors at 5 ppm or higher increased the liver-to-body weight ratios in weanling rats of both sexes. At 1 ppm the increase in liver weight was observed only in Fla and Flb weanling *male* rats. The dietary levels of 100, 20, and 5 ppm of Aroclor 1260 did not affect reproduction; however, the liver-to-body weight ratio of 21-day-old pups was increased at all exposure levels.

Mink are highly susceptible to the toxic effects of PCBs. A daily dietary intake of 30 ppm resulted in death in about 6 months. Exposure to 5 ppm Aroclor 1254 in the daily diet severely affected reproduction.[105]

Unfortunately, it is often very difficult to compare the various dietary levels that affect different species, since the food consumption may vary decisively from one animal species to another and the daily food intake in g/kg body wt. is often not included in the scientific report. Some mice strains, for instance, will be exposed to as much of a given substance that is present in the diet at the concentration of 300 ppm as rats on a diet containing 600 ppm or more. With some species it is of course difficult or almost impossible to measure the food consumption, but a greater effort in establishing these very basic facts would be helpful for the interpretation of toxic effects in different species.

Not very much is known at present about the toxicity of *terphenyls* or *chlorinated terphenyls*. These materials have not been studied to any great extent. The few studies that are available only describe very specific effects such as microsomal enzyme induction in the liver and give no overall evaluation of their toxicity.

The most toxic of the various *chlorinated dibenzodioxins* and *dibenzofurans* is 2,3,7,8-tetrachlorodibenzodioxin which, in the German literature, is sometimes referred to as 2,3,6,7-tetrachlorodibenzodioxin. Single oral LD_{50} values are female rats: 44.7 μg/kg; male rats: 22.5 μg/kg; male guinea pigs, 0.72 μg/kg; rabbits: < 30 μg/kg; and dogs: between 30 and 300 μg/kg.[106] It is possible that young animals are more susceptible to the toxic effects of this compound than older animals and LD_{50} values should therefore also be determined in weanling animals. One of the characteristics of this compound was that it caused delayed death, sometimes as delayed as 40 days after a single dose. During the period of intoxication, the animals lost a great deal of weight.[106]

On the other hand, 2.0 g/kg of dichlorodibenzo-p-dioxin and 4.0 g/kg body weight octachlorodibenzo-p-dioxin were not lethal to rats. Hexa-, hepta-, and trichlorodibenzo-p-dioxin were more toxic.[106]

Schulz[107] in earlier experiments found that oral doses of 20 to 50 μg/kg/body weight of 2,3,7,8-tetrachlorodibenzodioxin resulted in fatal liver necrosis in rabbits. More recently Milnes[108] reported that 10 μg/kg was lethal to rabbits.

The 2,3,7,8-tetrachlorodibenzodioxin has a variety of specific toxic effects. Whether these effects vary in different species is presently not well defined. With the interest in this and the other related compounds, more information on

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their toxicity probably will soon become available. The problems inherent in studying these compounds are the unavailability of some of them, the fact that they may not be completely pure, particularly the hex- and hepta- preparations, and of course with respect to the tetrachlorodibenzodioxin, its extreme toxicity, which makes it difficult to handle.

In contrast to PCBs, teratogenic as well as fetotoxic effects have been reported for 2,3,7,8-tetrachlorodibenzodioxin. Sparschu et al.[109] gave 0, 0.03, 0.125, 0.5, 2.0, and 8.0 μg/kg/day of 2,3,7,8-tetrachlorodibenzo-p-dioxin to pregnant rats on days 6 to 15 of pregnancy. With the 0.03 μg/kg dosage level, an effect on the fetus was not observed, but doses from 0.125 μg/kg on up resulted in fetal mortality, early and late resorptions, and fetal intestinal hemorrhage. Khera and Ruddick[110] gave doses ranging from 16 to 0.125 μg/kg to Wistar rats on days 6 to 15 of pregnancy. These authors also observed pronounced fetotoxicity at all dosage levels except 0.125 μg/kg. The affected fetuses showed cerebral and intestinal hemorrhage as well as subcutaneous edema at autopsy. The offspring of mothers given 0.5 and 1 μg/kg of the tetrachlorodibenzo-p-dioxin gained less weight during their suckling period and their survival to weaning was reduced. This could have been caused by the intrauterine effect of the dioxin or by excretion of the dioxin in the milk of the dams given the material during pregnancy. Courtney and Moore[111] observed cleft palates in 3 strains of mice given 3 μg/kg TCDD subcutaneously from days 6 to 15 of pregnancy and an increased incidence of kidney anomalies. Hydronephrotic kidneys were also produced in mouse pups that were nursed by dams treated with TCDD during pregnancy or at time of parturition.[112]

The 2,3,7,8-tetrachlorodibenzo-p-dioxin is extremely toxic in the chick embryo assay.[52] In the rat, hexachlorodibenzodioxin caused fetotoxic effects at 1 and 10 μg/kg and teratogenic effects at doses of 100 μg/kg.[106] Harris et al.[113] gave female rats daily doses of 0.1, 1, or 10 μg/kg TCDD for 31 days. Rats given 10 μg/kg lost weight and most of them were moribund within 3 weeks. Weight gain was also less at the 1 μg/kg dietary level. The rats receiving 0.1 μg/kg were not affected. In experiments with guinea pigs, 9 of 10 animals died after a single dose of 3 μg/kg TCDD, while guinea pigs receiving a single dose of 1 μg/kg gained less weight. All guinea pigs receiving 1 μg/kg/week died within 24 to 32 days and a weekly dose of 0.2 μg/kg depressed their weight. Of the various animal species tested, the guinea pig seemed to be most susceptible to the toxic effects of TCDD.

Reduced thymus and spleen weights were observed in rats that received a single dose of 25 μg/kg TCDD. The rats that died at the various dosage levels showed massive hemorrhages into the heart, liver, brain, adrenal glands, and gastrointestinal tract. Necrosis and ulceration of the glandular part of the stomach were observed. Occasionally organized thrombi were noted and the liver revealed necrosis of parenchymal cells. Sublethal doses of TCDD produced microscopic changes in liver, kidneys, and thyroid. In the kidneys the collecting tubules were primarily affected. Doses of 0.1 μg/kg/day for 31 days, a single dose of 5 μg/kg, and multiple weekly doses of 1.0 and 0.2 μg/kg did not produce changes in rats discernible with the light microscope.

Toxicity studies were conducted in our laboratory with *dichlorophene*.[114] The oral LD_{50} for adult female rats when the material was given in peanut oil by stomach tube was 1,660 mg/kg and in males it was 1,500 mg/kg. The only signs of toxicity observed in these rats were diarrhea and some depression. When 200 mg/kg was applied daily in propylene glycol to the skin of a clipped area of the back of male adult rats as a 12.5% solution, local irritation of the skin with some ulceration resulted but there was no systemic toxicity. The acute intravenous LD_{50} in adult male rats was 16.8 mg/kg when it was given in a saline lecithin suspension. In a two generation rat reproduction study, a dietary level as high as 1,000 ppm (50 mg/kg day) had no effect. Gross and microscopic examination of the various organs including the brains of the parents as well as the offspring did not reveal any morphological changes that could be related to dichlorophene exposure. These findings indicated that dichlorophene was not very toxic to rats. The great difference between the oral and the intravenous LD_{50} suggested either poor absorption or rapid breakdown of the material in the gastrointestinal tract. Martins[61] lists the acute LD_{50} for guinea pigs as 1,250 mg/kg and for dogs, 2,000 mg/kg. Rats fed for 90 days on a diet containing 2,000 ppm showed no evidence of toxicity.

The acute toxicity of *hexachlorophene* is much greater and varies in different animal species and is

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also dependent on the route of administration and the solvent in which it is given. Gunn[115] lists the acute oral LD_{50} in mice as 108 mg/kg and cites LD_{50} values reported by other investigators ranging from 80 mg/kg to 215 mg/kg. Dogs and sheep were more susceptible to the toxic effects of hexachlorophene. The interest in the effect of hexachlorophene on sheep in particular stemmed from the fact that it is effective against liver flukes[116] and advocated for its anthelmintic properties. This even led to the treatment of children with orally administered hexachlorophene in China.[117] Intravenously administered hexachlorophene in rats resulted in an LD_{50} value of 9.1 mg/kg and in rabbits of 8.5 mg/kg.

More recently we found that the oral LD_{50} (single dose) for adult male rats was 66 mg/kg and for adult female rats 56 mg/kg, for weanlings it was 120 mg/kg when the material was given in peanut oil by stomach tube to Sherman strain rats. The acute intravenous LD_{50} was 7.5 mg/kg in adult male rats.[118] Nakaue et al.[119] reported similar oral LD_{50} values in Wistar rats. The single oral LD_{50} for sheep and cattle lies between 30 and 60 mg/kg.[120]

Single dermal LD_{50} values have not been reported in the literature. We found in rats[118] that single applications of 600 mg/kg hexachlorophene in 95% ethyl alcohol solution caused death in 1 of 10 rats. Dermal application of 24 and 48 mg/kg/day for 30 days in propylene glycol or in a detergent as a 3% solution caused ulceration of the skin and affected the white matter of the central nervous system in at least half of the rats. A dose of 12 mg/kg/day as a 1.5% solution caused only mild erythema and desquamation of the skin of rats. No effect on the central nervous system was observed. Whether a single dose given in either propylene glycol or a detergent would be more toxic than one given in ethyl alcohol was not established.

The signs of acute hexachlorophene poisoning following a single oral dose varied with the age of the rats.[118] Adult rats suffered from severe depression and diarrhea, but showed few signs of leg weakness. Weanlings, on the other hand, developed posterior leg weakness as well as depression. The leg weakness became more apparent in the adults when they were given repeated doses of hexachlorophene. Death was usually preceded by convulsions in rats dosed intravenously. In rats killed with hexachlorophene, rigor mortis developed very rapidly and was very pronounced. Body temperature elevation following hexachlorophene poisoning has also been recorded in rats. Both changes (the pronounced rigor mortis and the temperature elevation) may be related to the fact that hexachlorophene uncouples oxidative phosphorylation. Additional symptoms of hexachlorophene poisoning particularly in other species are discussed under neurotoxicity.

Nakaue et al.[119] fed 400 ppm hexachlorophene (28.9 mg/kg/day) to Wistar rats. The developed leg weakness within 5 days, diarrhea, emaciation, and they died in 7 to 10 days. No deaths occurred in the rats that were fed 200 ppm (about 13 mg/kg/day) for 16 weeks.

In a two generation rat reproduction study which we conducted in our laboratory, we found reduced survival in the offspring of the F_1 generation fed 100 ppm (11.8 to 5.5 mg/kg/day in their diet for 54 and 166 days. This was statistically significant in the second breeding of the F_1 generation. In the second generation the litters were slightly smaller, but the survival to weaning was not significantly reduced.[118] A dietary level of 20 ppm (2.3 to 1.1 mg/kg) did not influence reproduction. Thorpe[121] reported that the oral administration of hexachlorophene to male rats as well as single doses of 25 and 50 mg/kg hexachlorophene to sheep produced degeneration of spermatogenic cells, multinucleated cells were observed within the tubules of the testes. The doses given by Thorpe were higher than the ones we used in the reproduction study, and microscopic examination of the testes of the rats used in our reproduction study did not reveal any abnormalities. Toxic doses of hexachlorophene given to the dam during pregnancy may result in malformations of the offspring. Thus far, two studies have been reported in the literature; both studies were conducted in rats.[122,123] It should be determined whether malformations can also be produced in other species and with lower doses before any conclusion can be drawn from these findings.

A number of *human* poisoning cases have been reported in the literature and some of these were fatal. Most of the poisoning cases in humans have either been caused by accidental ingestion, because a hexachlorophene detergent solution was mistaken for milk of magnesia, or by the application of hexachlorophene to large areas of burned or otherwise damaged skin.[115,124] Larson[1] was

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the first to recognize that burned patients developed convulsions and other toxic symptoms after repeated exposure to hexachlorophene which was applied to burned areas of the skin. The incidence of convulsions in burned patients decreased when the use of hexachlorophene was discontinued.[125]

Eleven cases have been reported[126-127] in which a single dose of 3% hexachlorophene detergent solution had been taken orally. Gastrointestinal symptoms including nausea and vomiting were observed in ten of these cases; the eleventh case, a child who drank about 250 mg/kg hexachlorophene, became comatose and died. One additional death occurred in this group, however, this was most likely due to other causes. A 17-day-old infant was accidentally given daily oral doses of 37 mg/kg hexachlorophene for 7 days. On the third day the child started to have loose stools. On the fourth day of hexachlorophene administration the child developed spasms of the extremities with twitching of the face, sucking movements of the lips, and lateral shaking movements of the head. It was also noted in the case report that the child refused to take the medicine, there was drooling and frequent vomiting, and it is not quite clear whether the child received 37 mg/kg/day. The child survived. A week after the hexachlorophene suspension was discontinued, persistent spastic flexion of the fingers, hands, and arms was still observed. After a month the hands were slightly flexed at the wrists but were not spastic. Horizontal nystagmus was observed but cleared later. The child was discharged when it was two months and three weeks old. At this point it had shown great improvement and when checked at six months the child was healthy looking.[128] Pilapil mentioned in his discussion a number of other unpublished cases, some of which were reported to the National Clearing House for Poison Control Centers. Among these was the case of an infant who by mistake got a spoonful of PhisoHex in each feeding bottle for approximately two weeks, when it suddenly died.

Chung et al.[117] treated a total of 105 patients 5 to 15 years old with hexachlorophene for chlonorchiasis sinensis infestation. Sixty of these patients received 1 dose of 20 mg/kg, 32 received 2 doses of 20 mg/kg/day, 8 patients received 3 daily doses of 20 mg/kg, and 5 patients received 20 mg/kg body weight on the first day and 10 mg/kg on the second day. The toxicity reactions observed in these patients were mainly confined to the central nervous system and to the gastrointestinal tract. The group that received 3 doses of 20 mg/kg/day had the most severe reaction. One patient in this group became comatose on the fourth day with loss of light reflex and positive pyramidal signs. Fundus examination of the eyes revealed mild papillary edema. A low grade fever was also observed. Complete recovery occurred within three days. One half to two thirds of the patients had diarrhea within 1 to 2 hr after medication and in some cases a marked depressive effect on the central nervous system was also observed. An additional case of poisoning after oral ingestion was reported by Korlof and Winsten[129] in Scandinavia and two fairly recent cases with fatal outcome occurred in the U.S.[130]

Herter[131] was probably the first to report a human poisoning case caused by the dermal absorption of hexachlorophene. Because of a language barrier, the mother of a newborn infant applied 3% hexachlorophene as a lotion after the infant's bath without rinsing the baby. After four days, excoriations appeared on the child's face and buttocks, the infant developed convulsions, his face twitched and his extremities jerked. A roving nystagmus was present. This child recovered within 16 days after exposure to hexachlorophene had been discontinued.

In addition to the two cases already mentioned in which poisoning occurred because of oral ingestion, Mullick[130] also reported four cases – children who died following the treatment for burns in two instances and the treatment for severe ichthiosis with a 3% hexachlorophene bath.

Larson[3] reported six burned patients who developed central nervous system symptoms following the dermal exposure to hexachlorophene. All six patients recovered. Korlof and Winsten[129] reported two cases of poisoning following the dermal application of hexachlorophene. Both patients were fairly extensively burned, and developed central and peripheral nerve damage as well as some kidney impairment.

Lockhart[132] mentioned six deaths that were reported to the FDA caused by the topical application of hexachlorophene on burned patients. In all of these cases the skin was damaged, probably enhancing absorption of hexachlorophene, and although skin does represent a barrier, it is not impermeable – a fact we tend to forget at times. Damaged or abnormal skin may be

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more permeable, and the skin of prematures, newborns, and children in general may have absorption characteristics other than those of adult human beings, another factor that is often neglected. Recently[134,135] 41 deaths due to hexachlorophene poisoning have been reported in France. The deaths occurred in infants who were treated with a powder to which 6% hexachlorophene had been added by mistake. This powder was mainly applied in the diaper area where the skin became inflamed, this as well as the diaper which served as an occlusive dressing, probably enhanced absorption. These cases will not be made public until litigation problems have been settled.

Little published information is available on the toxicity of the germicides in Figure 2 aside from hexachlorophene and dichlorophene. The acute oral LD_{50} for triclosan (TCC) in mice and rats is about 4,000 mg/kg.[135] The acute subcutaneous toxicity for rats was 14,700 mg/kg and the acute dermal toxicity was about 9.3 g in rabbits. Concentrations of 1 to 5% solutions caused eye irritation in rabbits. Daily oral doses of TCC up to 1,000 mg/kg day for 4 weeks did not produce an effect in rats. When 2.5 and 5% suspensions in gum arabic were applied dermally to rats for 4 weeks, the animals did not gain as much weight. Unpublished material cited in the minutes of the OTC (Over the Counter Drugs) Panel listed a "no effect" level as 170 mg/kg/day in rats and for a 90-day feeding study in rabbits, 138 mg/kg/day. In baboons a daily oral dose of 100 mg/kg/day did not produce a toxic reaction. The minutes also mentioned some work where lower doses showed an effect on rats and dogs. Since some of these results are conflicting, further studies are indicated and should be performed with products used as ingredients in soaps; a chemical analysis of these products is necessary to determine whether impurities might be responsible for varying results. Chloroaniline as a result of heating during manufacture could be present as such an impurity. Of the anilines, according to Hamblin,[136] only p- and m-chloroaniline may cause methemoglobinemia if absorbed through the skin. The o- and m-chloroaniline may cause liver and kidney damage. Triclosan itself is also absorbed through the skin and absorption is greater when applied to damaged skin.

SPECIAL TOXIC EFFECTS

Skin Reactions

Chloracne

Thus occupational skin disease can be produced by a number of chemical compounds.[137] Polychlorinated biphenyls as well as the chlorinated naphthalenes, a few isomers of the chlorinated dibenzodioxins, and chlorinated dibenzofurans are all able to produce chloracne in a certain proportion of the human population. Oily skin and large pores seem to predispose to the disease while the opposite is true for smooth, tender skin and it is possible that young children might be less susceptible because of the nature of their skin.

Chloracne has also occurred in workers engaged in the production of 2,4,5-T[1]. During the industrial production of trichlorophenol a sudden rise in temperature within the reactor has occasionally resulted in accidents. In one instance this exothermic reaction caused an explosion.[108] When the rise in temperature occurred, 2,3,7,8-tetrachlorodibenzodioxin was formed and severe outbreaks of chloracne were observed among the workers.[137]

The term chloracne was first used by Herxheimer in 1899,[138] who thought it was caused by free chlorine generated in certain factories. Wauer in 1918[139] and Teleky in 1922[140] suggested the term "Perniakrankheit." Another term sometimes used is halogenwaxacne.

As the word chloracne implies, part of the lesion of this occupational skin disease resembles adolescent acne; however, it is generally more severe and the distribution of the lesions is not consistent with adolescent acne, although it may be superimposed on adolescent acne. Chloracne is described in the literature as consisting of the formation of comedones with or without cysts and pustules. The follicular orifices are filled with sebaceous and keratinous material. Melanosis and a secondary inflammatory reaction may also exist. In addition to this description, skin changes occur that have been discussed less frequently in the more recent literature. These skin changes are usually referred to as cable rash or cable itch. Cable rash has been observed in workers who have insulated cables with various mixtures of chlorinated naphthalenes and chlorinated biphenyls and in workers handling these cables.[141] It has been observed also in factories that make condensers.[142,143] According to Braun,[142] a few of

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the cases with manifest chloracne started with changes in the skin of the face resembling photo sensitivity and the bearers of these lesions suffered severe pruritus in the areas of the skin lesions. This lesion termed cable rash occurred predominantly on the cheeks but also on the skin of the arms. The outcome of cable rash varied: it could either disappear or it could develop into full-blown chloracne.

In addition to the pustules and comedones of typical chloracne, brownish keratinization of the skin was observed in some patients. Braun[142] pointed out that the workers, particularly those with poor hygiene, transmitted the disease to their spouses and children through direct contact.

Many of the occupational cases of chloracne that have been reported in the literature have been reviewed previously.[137,144] Jones and Alden[145] reported one of the first outbreaks of chloracne in a company that was engaged in the manufacture of chlorinated biphenyls. They described one typical case and mentioned 24 men working on the manufacture of chlorinated biphenyls; 23 had had an acneform eruption on the face and body. Particularly during the 1930s and 1940s large outbreaks of chloracne occurred in a number of factories.

Much discussion has been devoted in the literature to the problem of whether the chloracne was produced by external contact alone or whether it was caused by systemic absorption, particularly the inhalation of vapors. One question asked was whether internal administration could cause chloracne, and if so what part it played in any particular case. As we know now from outbreaks of poisoning due to the consumption of rice oil that was contaminated with polychlorinated biphenyls in Japan (see under "Yusho"), chloracne can be produced by the systemic absorption of chlorinated biphenyls. The experiments by Shelley and Kligman[146] and Plewig[147] showed that the skin lesions could also be produced by applying the chloracnegenic compound to the skin.

After occupational chloracne manifested itself, the patients also complained of systemic effects such as loss of appetite, nausea, edema of the face and hands, abdominal pain, vomiting, and burning and soreness of the eyes. Particularly with the chlorinated naphthalenes, hepatotoxic effects have also been observed. Application of chemicals to the skin can lead to their absorption and cause systemic toxicity. Whether a systemic toxic effect results will depend on the skin surface area covered, the amount of the toxic substance applied, and the ability of the skin to absorb it. If dermal absorption is poor, a single application will usually not be very toxic. However, if the compound is not easily metabolized and excreted, repeated dermal application may result in sufficient accumulation in the body to cause systemic toxicity.

Crowe[144] has pointed out that chloracne due to chlorinated naphthalenes has decreased because these compounds have been used less since the Second World War. However, Weber in 1969[148] reported an outbreak of chloracne in a company engaged in the production of electric coils that were coated with a mixture of chlorinated naphthalenes with the tradename "Nibrenwax."

Detailed examination by several German investigators indicated that the capacity of 2,4,5-trichlorophenol as well as 2,4,5-T (2,4,5-trichlorophenoxyacetic acid)[149,150] to produce chloracne was due to contamination with 2,3,7,8-tetrachlorodibenzofuran or 2,3,7,8-tetrachlorodibenzodioxin.

Schwartz et al.[151] indicated that the most potent chloracne producing agents were the chlorinated naphthalenes, chlorodiphenyls, and chlorodiphenyloxides. Persons who worked with chlorinated naphthalenes usually developed acne after a month or more of exposure.

Light microscopic observations made of the chloracne lesions of humans varied somewhat, depending primarily on the length of time the lesions had existed at the time of examination. The earliest change encountered consisted of acanthotic widening of the external root sheath of the hair follicle. Above a layer of basal cells 6 to 10 layers of large round cells were observed, followed by a layer of 2 to 3 cell rows of granular cells. In later skin biopsies, folding of the basal layer occurred and comedo formation was observed, resulting in dilatation of the follicle and atrophy of the epithelium surrounding the comedo. The contents of the follicles consisted predominantly of keratinous material rather than sebum. The sebaceous glands also underwent changes. Within the alveoli of the glands the basophil cells increased in number and basal cell hyperplasia was noted. The ducts of the sebaceous glands were filled with a solid mass of basophil epithelial cells. The sebaceous glands gradually

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disappeared and in later sections were only recognized as solid protrusions of the comedo wall. Aside from atrophy of the sebaceous glands, hyperplasia has also been described and many large sebaceous glands forming huge cysts filled primarily with keratinous material have been observed. Hyperkeratosis and acanthosis of the surrounding epidermis has usually accompanied these lesions. Foreign body granulomata which are thought to result from rupture of the follicular cysts have been found in the skin [147-151]. In the Japanese poisoning incident (Yusho), the predominant skin lesion was marked hyperkeratosis of the epidermis, cystic dilatation of the hair follicles, and an increase in the melanin pigment in the basal cells of the epidermis. Foreign body granulomata were also observed. The contents of the cysts consisted partially of keratin. In a stillborn child the hyperkeratosis was even more pronounced, accompanied by atrophy of the epidermis; cystic dilation of hair follicles was observed, especially in the skin of the head. According to earlier reports[151] some differences exist in the microscopic changes observed in the skin following exposure to the various chlorinated cyclic compounds that can produce the lesion. It is, of course, possible that these histopathologic variations are in reality only differences that exist between an early, a well-developed, and a subsiding lesion.

Many theories have been advanced to explain the development of chloracne. None is satisfactory. The concept of mechanical plugging of the hair follicles on skin exposure to polychlorinated polycyclic compounds is not supported by the fact that chloracne develops following ingestion of these compounds. It is possible that the skin lesions are caused by a toxic effect on the epithelium of the skin and its appendages which is manifested in proliferation and loss of normal function of the cell. Since the chemicals are lipid soluble they could occur in a more concentrated form in sebum and therefore affect sebaceous glands more than sweat glands or salivary glands. The reports on the Yusho outbreak suggest that proliferation of the epithelium of the mucous membranes may also occur. The increased pigmentation of the skin and mucous membranes may indicate a functional disturbance resulting in increased melanin production. Hyperpigmentation is also observed when the adrenals are damaged, as in Addison's disease, and adrenal function should be investigated in chloracne patients who manifest hyperpigmentation.

In none of the human case reports on chloracne have the mucous membranes been studied to any great extent. Vaginal smears in women and sputa, corneal, and nasal scrapings may give helpful information in this respect. Since in animals exposed to polychlorinated polycyclic compounds low vitamin A levels have been observed in the liver, it is possible that the compounds may affect vitamin A absorption and storage, and adequate utilization in the liver and elsewhere in the body. If the lesion is produced by inadequate utilization of vitamin A, then administration of vitamin A per se may not necessarily alter the course of the disease. Protein deficiency may also mimic hypovitaminosis A in that it affects transport of vitamin A. The liver stores 90% of the available vitamin A and these stores may be affected in liver disease. The microscopic appearance of the skin lesions resembles in some respects observations made in skin of patients suffering from vitamin A deficiency. In vitamin A deficiency, hyperkeratosis of the hair follicles is observed. Multiple firm papules may develop as a result of the keratin plugs in the sebaceous glands. Dryness and scaliness as well as furunculosis of the skin may also be present. In contrast, night blindness has not been reported as a symptom in patients suffering from chloracne. Unfortunately, chloracne outbreaks are often not well investigated and, because of problems with litigation, accounts are often only published many years after the outbreak has occurred if they are published at all.

Chloracne is a very persistent skin disease and in the Japanese outbreak of poisoning with chlorodiphenyls, the skin changes were still present in a number of patients three years after exposure to the chlorodiphenyls had been discontinued. What needs to be investigated is whether this persistence of the skin disease is caused only by the fact that once the lesion has developed it regresses very slowly, or whether it may be sustained by the chloracne-producing chemicals which have been absorbed and stored in the body, particularly the adipose tissue, and are only very gradually excreted. In patients with chloracne, adipose tissue biopsies should be analyzed for the presence of the offending polycyclic polychlorinated compounds. If adipose tissue is unobtainable, the sebum of the ear canal or the content of the skin lesions may represent a good substitute.

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Apparently there is no known effective treatment for chloracne and the best control measure is prevention. The manufacture of chlorinated hydrocarbons and the coating of wires and condensors with insulating materials containing them should be done in totally enclosed areas so that the fumes of the insulating substances and of the solvents if any are used do not come in contact with the workers. The workers should be provided with clean overalls and underclothes daily. These should be laundered at the plant and cleaned in such a way that no chlorinated hydrocarbons remain on them. Shower baths after work should be compulsory and supervised and there should be sufficient shower facilities provided so that the workers are not unduly delayed after work. Special synthetic wetting agents[151] seem to remove the material from the skin more effectively than ordinary soaps.

The experimental induction of chloracne in men has also been accomplished with 2 applications of 10 μg 2,3,7,8-tetrachlorodibenzo-p-dioxin[107] and with Halowax 1014, pentachloronaphthalene, and hexachloronaphthalene.[147]

Experimental work in animals has shown that most species do not develop the same type of dermatitis. The rabbit's skin,[152] particularly the inner aspect of the ear lobe, provides a good test medium for the development of acneform dermatitis. The rabbits, in addition to the development of hyperkeratosis of the ear, will also show a hepatotoxic effect.[150] Microscopic examination of the changes in the rabbit ear were described by Jones and Krizek.[153] Inagami and Koga[154] were able to produce hyperkeratosis in hairless mice that were fed rice oil contaminated with Kaneclor 400. These mice also showed hepatomegaly. Microscopic examination of the skin revealed cystic dilation and hyperkeratosis of hair follicles and sweat glands. Hairless mice may be another suitable experimental animal for testing the effect of these chemicals on the skin.

X-disease in Animals

Chloracne-type lesions do not usually occur in other species except for the rabbit and the hairless mouse, already mentioned. However, in 1947 Olafson[155] described a disease in cattle which was designated as *X-disease* or hyperkeratosis. Symptomatology included excessive lacrimation, diarrhea, polyuria, marked salivation, and discharge from the nostrils. The animals developed a chronic cough, poor appetite, numerous red maculae in the buccal mucosa, in addition, hyperkeratosis of the skin developed. The skin was hard, and fissured particularly across the withers and sides of the neck. Many wart-like proliferations on the lips, tongue, and hard palate were also observed. The abomasum was greatly inflamed, swollen, and edematous with many superficial ulcers.[156] In the cows that had X-disease, a low vitamin A plasma level was also observed, which again indicates that vitamin A may play a role in the etiology of these various disease entities.

The disease was first thought to represent a virus infection and other factors were also suspected. After numerous investigations it was finally established that X-disease could be produced in cattle by the ingestion of highly chlorinated naphthalenes, and also by petroleum products such as crankcase oil. Bell[157] tested the ability of the various compounds of the chlorinated naphthalene group to produce X-disease. He demonstrated in his studies that dichlorinated and trichlorinated naphthalenes did not result in X-disease, while tetrachloronaphthalene had an effect and the higher chlorinated naphthalenes such as pentachloronaphthalene, hexachloronaphthalene, heptachloronaphthalene, and octachloronaphthalene caused severe disease. Octachloronaphthalene was less toxic than hexa- and heptachloronaphthalene. Wagener[158] reported the occurrence of hyperkeratosis in cattle in Germany between 1946 and 1948. The cause of this outbreak was traced to a wood preservative which was used in postwar Germany. The author proved experimentally that animals housed in cabins painted with the wood preservative developed typical X-disease. The poisonous ingredient in the wood preservative appeared only in certain lots of this product and later lots did not contain it. The poisonous ingredient was never identified by chemical analysis.

Animal experiments were conducted with the toxic ingredients of rice bran oil that produced Yusho in Japan. These toxic substances consisted of a mixture of chlorinated biphenyls containing 48% chlorine, with a trace of 0.01% of naphthalenes.[159] When mice were exposed to them for 3 to 4 months, they showed eczematous changes of the skin around the eyelids, erosion, ulceration and perforation of the ear laps, loss of hair, and erosion and ulceration of the skin around the neck, forelegs, and sides of the chest. The authors

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...re conducted with the ...iran oil that produced ...xic substances consisted ...ed biphenyls containing ...e of 0.01% of naphtha-...exposed to them for 3 ...l eczematous changes of ...ids, erosion, ulceration ...r laps, loss of hair, and ...of the skin around the ...of the chest. The authors stated that at the end of the experiment, some changes in the skin similar to those in the experimental mice were seen in some of the control mice also, which makes it difficult to interpret their findings.

In 1957 a disease that will be discussed in greater detail later in this article occurred in a large number of chickens. It was termed chick edema disease and was found to be caused by certain toxic fat. Allen and Carstens[160] fed this substance to monkeys and found that, among other changes which will be discussed later, the monkeys developed a generalized alopecia and subcutaneous edema one to two months before death. Schoettle et al.[161] produced hyperkeratosis of the skin in rats by feeding them hexachloronaphthalene. Young swine[162] and sheep[163] did not develop skin lesions as a result of exposure to chlorinated naphthalenes.

Photocontact Dermatitis and Irritation of the Skin

As was pointed out earlier, the hyperpigmentation observed in patients with chloracne as well as the reaction described as cable rash could also be the result of a photosensitive reaction. This photosensitive reaction is the predominant lesion in the skin produced by a number of germicides, namely, bithionol (Figure 2), tetrachlorosalicylanilide (TCSA), and a number of other halogenated phenolic compounds including fenticlor. Patients who develop photodermatitis complain initially of a burning sensation, and this is followed by itching. A rash develops which in the beginning is erythematous and associated with varying degrees of edema. As it subsides, pigmentation is observed.[164] Wilkinson[165] was the first one to describe cases where patients developed a photo allergy which was due to the incorporation of TCSA into popular soaps. He observed that the outbreak of dermatitis was confined to the areas that usually were exposed to light. Most of the cases reported from England were transient and as soon as exposure to the compound was discontinued the reaction subsided. Jillson and Baughman[166] and Jillson,[167] on the other hand, reported that their cases were more persistent.

Willis and Kligman[168] demonstrated that the photocontact allergy of the skin with these various compounds was simply a contact sensitization. The reason that allergic reactions of the skin developed only after exposure to the sun was due to the photodecomposition of the various products to which the skin had been exposed. If various brominated and chlorinated salicylanilides were irradiated in vitro in an appropriate solvent, the resulting breakdown products caused an allergic reaction on contact, without exposure to UV light. These studies were performed because of information provided in earlier studies by Coxon et al.,[169] who had irradiated brominated and chlorinated salicylanilides and found that these compounds gave off halogens. With 3,5 substituted salicylanilides, the halogen substituted on the 3 position was lost. Tetrachlorosalicylanilide photosensitized subjects reacted to 3′, 4′, 5-trichlorosalicylanilide and to 3′, 4′-dichlorosalicylanilide. A reaction to nonhalogenated salicylanilide was not observed. Halogens on the anilide ring were unaffected by UV radiation, while the halogens on the salicyl ring were replaced stepwise by hydrogen upon irradiation.

Among the patients who developed photosensitivity to tetrachlorosalicylanilide reported by Wilkinson,[165] a group of patients in a shop of a factory was also included. This same outbreak was reported by Jones,[170] who found that among 106 employees who used the same soap very frequently, 31% were affected by a dermatitis due to contact with tetrachlorosalicylanilide present in the soap.

Additional cases of photodermatitis due to the exposure to tetrachlorosalicylanilide were reported by Calnan et al.,[171] who pointed out that pronounced edema of the eyelids was also observed when involvement was severe. Some cases were persistent or developed acute relapses on further exposure to sunlight without further exposure to the offending chemical. Frenk[172] reported an additional nine cases of acute contact dermatitis of the hands due to tetrachlorosalicylanilide. Epstein[173] described a photoallergic reaction in two patients to tribromosalicylanilide (TBS). With patch tests these patients showed a cross reaction to TCSA. A similar cross reaction pattern to a number of halogenated salicylanilides was also observed by Osmundsen[174] in patients who had developed photodermatitis following exposure to tribromosalicylanilide.

Because of the photosensitivity reactions and the cross reactions that were also found with bithionol, which is similar in structure to tetrachlorosalicylanilide (Figure 2), the U.S. Food and Drug Administration, on October 24, 1967, withdrew all new drug applications of all drugs that

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contained bithionol. In the notice of withdrawal of approval in the Federal Register, the Commissioner of the Food and Drug Administration pointed out that bithionol may in some instances cause a very persistent photosensitization and severe dermatitis may occur with exposure to sunlight without further contact with the sensitizing articles, and that bithionol may produce cross photosensitization with other commonly used chemicals such as certain halogenated salicylanilides and hexachlorophene.

Hexachlorophene preparations may also cause irritation of the skin if these preparations are used frequently. A true allergic reaction to hexachlorophene is apparently rare.[175] The more severe reactions were usually confined to the skin of the scrotum and consisted of a primary irritant contact dermatitis.[176,177] The cases reported by Baker et al.[176] also included a 33-month-old Caucasian female who developed a rash around the buttocks, vulva, and upper thighs following the use of a hexachlorophene preparation in her bath water.

We observed severe skin irritation and ulceration in rats that were exposed dermally to a 3% hexachlorophene solution in propylene glycol or a detergent. The skin reaction was not as severe when the hexachlorophene concentration was reduced to 1.5%.[118] Boutwell et al.[178] reported considerable skin irritation in mice that had 5 mg/mouse applied twice weekly for 21 weeks. Harber et al.[179] were able to induce contact photosensitivity with TCSA or TBS. These authors also found that cross contact sensitivity and photosensitivity to hexachlorophene existed in guinea pigs with primary photosensitivity to TCSA and TBS. Photosensitivity to trichlorocarbanilide (TCC) was not produced in guinea pigs.

The guinea pig may represent a suitable animal species to study contact and photosensitivity of these and related compounds. After exposure to the photosensitizing agents has been discontinued, humans may still be sensitive to sunlight, a fact that needs further study. To a certain extent this could be due to a persistence of the chemical compound on or in the skin.

Dichlorophene used as an antimicrobial preservative may also cause contact dermatitis. Cross-sensitivity to hexachlorophene was not demonstrated.[180]

Chick Edema

Simpson et al.[181] and Sanger et al.[182] described a new highly fatal disease in chickens. The first outbreak occurred in 1957 in Georgia. Large numbers of birds from approximately three weeks of age to adult laying hens were affected. Clinical signs consisted of dyspnea, reduced body weight gain, stunting, subcutaneous edema, paleness, and sudden death. In young chickens, gasping was the first noticeable sign. This was followed by a waddling, unsteady gait. Gross inspection of the birds revealed a pale heart, fluid was noticed in the pericardial sac, and the livers were pale, mottled, and had an irregular granular surface. In advanced stages of the disease the chickens had large distended abdomens that were filled with fluid. Ecchymotic hemorrhages were present in the skin beneath the wings, on the legs, and over the Q bone in a few chickens. The kidneys were pale and swollen. Following the first outbreak, no additional cases were reported until late summer and early fall of 1957, when extensive losses of chickens and turkeys occurred throughout the southeastern part of the U.S. Suspicion soon developed that losses were caused by the consumption of rations containing certain lots of animal fat.[181] The animal fats contained tallows and greases obtained as by-products from hides preserved with chlorophenols prior to leather manufacture.[51]

This material was excluded from commercial poultry rations and no additional cases occurred where animal fats were responsible. Simpson et al.[181] came to the conclusion that the edema in the chickens was the result of vascular changes that seemed to be the primary lesion. The vascular lesion, or endotheliosis, consisted of proliferation and hypertrophy of the endothelial cells of arterioles and small arteries in most tissues. Pronounced proliferative changes in endothelium of the glomerular capillaries were observed, but no significant changes were noticed in the tubular epithelium of the kidney. Necrosis of the parenchymal cells of the liver was also noted.

In some reports it was pointed out that exposure to toxic fat resulted in a decrease of the total serum protein and a shift on the albumin to globulin ratio with a decrease in the albumin fraction. This could, of course, lead to edema formation, particularly when combined with malfunctioning glomerular capillaries. It has also been suggested that increased permeability of the cardiovascular bed contributed to the edema forma-

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tion[183,184] In other studies the serum protein concentration did not differ from that of the controls[184,185] and increased permeability of the cardiovascular bed was advanced as the sole cause of the fluid accumulation In addition, pulmonary edema was observed in diseased chickens and perivascular lymphocytic infiltration as well as edema of the cardiac muscle with interstitial lymphocytic infiltration has been noted.[186] Electron microscopic examination of the cardiac muscle revealed degeneration and loss of mitochondria.[184] It is possible that the heart may play a primary role in the development of chick edema, but a hepatorenal syndrome could be the underlying cause as well Studies that investigate the development of the lesion more closely are needed to elucidate these problems The type of diet also influenced the development of the disease. It could be brought on more rapidly with a semi-purified diet than with a natural grain ration; sodium chloride in the diet was a prerequisite for the development of the syndrome.[187]

If low rations of the toxic fat were fed to chickens they did not develop chick edema but reproduction and hatchability were drastically reduced.

Toxic fat was not the only product that caused the chick edema syndrome. Chlorinated biphenyls caused the disease in chickens[188] and in Bengalese finches.[26] A mixture of pentachloronaphthalene and hexachloronaphthalene fed to chickens also resulted in chick edema disease.[189] Cantrell et al.[190] announced in 1967 that one of the toxic compounds capable of producing chick edema found in toxic fat was 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin. Then Huggenbotham et al.[52] showed that the chick edema factor was produced by two principal compounds isolated from toxic fats: 2,3,7-trichlorodibenzo-p-dioxin, and 2,3,7,8-tetrachlorodibenzo-p-dioxin. They also suggested fats and fatty acids that contain commercial chlorophenols as possible sources of contamination. When crude fats and tallows are heated to produce fatty acids, chlorophenol residues may be converted to a chick edema factor. Whether these last three compounds mentioned are the only ones that produce chick edema disease is questionable unless the chlorinated naphthalenes as well as chlorinated biphenyls that produced chick edema were also contaminated with them. Another outbreak of chick edema disease occurred in 1969.[51] In this incident millions of birds in North Carolina were involved. The outbreak was traced to a vegetable oil refinery where feed fat became contaminated with "chlorophenols." The company formulated the chlorophenols as antimicrobial water treatment products An underground pipeline from the "pesticide" plant led to trays used to collect by-product fatty acids held as feed fats.

Flick et al.[185] have recently shown that pyrolytic products of 2,3,4,6-tetrachlorophenol were toxic to chicks and produced chick edema if 50 ppb were fed for 21 days. The product fed consisted of 53% hexa-, 45% hepta-, and 2% octachloro-p-dibenzodioxin. The pyrolytic product of pentachlorophenol consisted of a mixture of 5% hexa-, 62% hepta-, and 33% octachlorodibenzo-p-dioxin that produced mild edema and increased mortality when fed a diet containing 1 ppm (200 μg total ingestion) of the material for 21 days. When a mixture of tri- and tetrachlorodibenzo-p-dioxin was fed to the animals at a dietary concentration of 0.01 ppm (a calculated intake level of 1.9 μg), the birds developed edema and 83% of them died. Further studies with pure compounds are necessary to confirm these findings.

The effect of PCBs on the chicken was again demonstrated when PCBs that were used in the U.S. as heat transfer fluids in food processing plants contaminated large quantities of fish meal that was processed for animal feed in a plant in Wilmington, North Carolina.[191] From about April 1971 until July 1971, PCBs leaked into the fish meal and 16 thousand tons of contaminated fish meal were distributed to more than 60 companies in 10 states. One of the purchasers of the fish meal, The Holly Farms, the nation's largest poultry producer, had to slaughter 77,000 fowls after discovering contamination of the chickens with PCBs. Some of the levels found in the adipose tissue of the animals were as high as 40 ppm. The Holly Farms first discovered that the chicken meal was contaminated because the hatchability of their eggs was drastically reduced to 18% of normal.

In February and March of 1968 an outbreak of chick edema also occurred in Japan, where more than 400,000 chickens reportedly died. The disease was traced to the contamination of animal feed with Kanechlor 400, a Japanese PCB. The chick edema disease occurred simultaneously with an outbreak of polychlorinated biphenyl poisoning in people that was due to the contamination of

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rice bran oil, also contaminated with Kanechlor 400 and produced by the same company.[192]

Metcalfe[193] suggested that chick edema factor could be minimized if fleshings grease from hides preserved with technical pentachlorophenols containing chlorinated dibenzodioxins were no longer used for food products. It was also pointed out that the use of glue emulsions containing chlorophenols in rendering operations is another possible source of the toxic factor. Whether elimination of these sources from animal food products will prevent chick edema epidemics remains to be seen, since polychlorinated biphenyls that may be contaminated with chlorinated dibenzofurans have also produced chick edema disease.

Yusho

During the summer of 1968, 13 cases of chloracne were observed in the western part of Japan, centering around Fukuoka prefecture. The incidence of the disease seemed to be familial and it became apparent that all patients had used the same brand of cooking oil (canned Kanemi rice oil). These findings were picked up by the newspapers and a strong demand was voiced to elucidate the cause. Therefore, a Yusho study group was established by Kyushu University.[192] The term Yusho stands for rice oil disease. After extensive investigations it was found that several illnesses occurred in a number of households that had used common cans of rice bran oil.

When a total number of 89 males and 100 females that suffered from Yusho were examined, a variety of symptoms were found in these patients. The incidence of the different symptoms that varied a great deal is given in Table 2. The epidemic outbreak was finally, after very extensive investigation, pinpointed to Kanemi oil, manufactured on February 5, 1968. Chemical analysis of this oil established that it was contaminated with 2,000 ppm of Kanechlor 400, a chlorobiphenyl that contains 48% chlorine. It was also demonstrated that most of the components of the chlorobiphenyls were stored in adipose tissue of the patients for quite a long time and passed through the placenta into the fetus of a few women who happened to be pregnant.[194]

The amount of oil necessary to produce disease was found to be at least 2.5 l. The younger the patient, the higher the morbidity rate with a smaller total amount of ingested oil. The average amount of chlorobiphenyl consumed by individual patients was calculated to be a total of 2 g.[195] (Various reports written on this subject give different accounts of what actually was consumed and the amount can at best only be estimated.)

When the rice bran oil was heated under reduced pressure, Kanechlor leaked from the old pipes in which holes were subsequently discovered.

The Yusho outbreak spread not only over Fukuoka, Japan, but also over 20 other prefectures in the western part of Japan. A total of 1,057 poisoning cases resulted according to the latest tabulation (August 1971, Ministry of Welfare).[196] The most common initial symptom experienced by 136 patients with Yusho was increased eye discharge and swelling of the upper eyelids (38.3%) followed by acneform eruption, follicular accentuation (33.1%), and pigmentation of the skin (9.6%). Itching of the skin and "stiffening" of the soles of the feet and the palms of the hands were also observed. Pigmented mucus membranes were noticed in many of the patients; a small percentage of them developed jaundice, many complained of a feeling of weakness and headaches; occasionally vomiting, diarrhea, and fever also occurred. Various neurological symptoms manifested themselves such as transient visual disturbances, numbness and spasms in the limbs, and hearing difficulties. Most patients showed acnelike skin eruptions that resembled the chloracne observed after occupational exposure to chlorinated naphthalenes or chlorinated biphenyls. When the age and sex specific incidence rates were analyzed it was found that a significant sex difference was not present, but a lower risk for both males and females in the age groups over 60 years was noted. The proportion of severe cases among those age 15 to 29 was significantly larger than that of other age groups.

During the Yusho epidemic, 11 women with Yusho and 2 wives whose husbands had Yusho, but who themselves did not show the disease, delivered 10 liveborn and 2 stillborn babies. Nine of these babies had unusually greyish, dark brown stained skin, and dark pigmentation of the gingiva and nails was noted in five of them. Most infants also had heavy eye discharge. Histological examination of a stillborn fetus showed a marked hyperkeratosis and atrophy of the epidermis and cystic dilation of hair follicles, especially of those of the head. A marked increase of melanin pigment in the basal cells of the epidermis was also noted. Most fetuses that were born were smaller

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TABLE 2

Symptoms (complaints) of Patients 189 males, 100 Females, as of October 31, 1968)*

Symptoms	Males	Females
Blackening of nails	83.1	75.0
Black spots in all pores	64.0	56.0
Excessive sweating in palms	50.6	55.0
Acnelike skin eruptions	87.6	82.0
Red spots on limbs	20.2	16.0
Itching	42.7	52.0
Change in skin color	75.3	72.0
Swelling of hands and feet	20.2	41.0
Hardening of backs and hands	24.7	29.0
Pigmentation of mucous membranes	56.2	47.0
Sebum (gum secretion in eyes)	88.8	85.0
Hyperemia of mucous membranes in eyes	70.8	71.0
Temporary failing of eyesight	56.2	55.0
Jaundice	11.2	11.0
Swelling of upper eyelids	71.9	74.0
Sense of weakness	58.4	52.0
Numbness of hands and feet	32.6	39.0
Fever	16.9	19.0
Hearing difficulty	18.0	19.0
Spasms of hands and feet	7.9	8.0
Headaches	30.3	39.0
Vomiting	23.6	28.0
Diarrhea	19.1	17.0

*Reprinted with permission from Kuratsune et al.[1,3]

than the national standards and four of them were small for gestational age babies. As they grew older their skin gradually became lighter over a period of three months.

Okumura and Katsuki[1,7] studied a group of 24 patients whose main complaint had been aceneform skin eruptions and who had been diagnosed as definitely having Yusho. Eighteen of these were adults and six were children. Irrespective of the seriousness of the disease in all patients, the initial symptoms were eye discharge associated with edema of the eyelids, defects in vision, generalized fatigue, anorexia followed by comedo and aceneform eruptions of the face, and pigmentation and flattening of the nails. The principal subjective symptoms were fatigue, numbness of the lower limbs, and intolerance for *sake*, which is a Japanese alcoholic beverage made from fermented rice. Three of twelve females had an irregular menstrual cycle. Seven of nine patients with serious disease showed a low grade fever. Most laboratory tests conducted on these patients were normal, including serum enzyme values. A slight elevation in alkaline phosphatase was observed in over half of the seriously ill groups. An increase in the α_2 globulin fraction of the serum protein was noted with a concomitant reduction of the albumin fraction, but the total serum proteins were within the normal range. These same 24 patients had abnormally elevated serum triglycerides ranging from 200 to 600 mg %. In 12 of 24 cases, while the total serum cholesterol remained unchanged, phospholipids tended to be somewhat lower.[1,8] Preliminary animal experiments in rabbits conducted by the same authors showed that lipemia was consistently induced within several days. The levels returned to their previously normal values several weeks after exposure had been discontinued.

The serum concentration of triglyceride is usually elevated in humans in glycogen storage disease (Von Gierke's disease). An increase in plasma triglyceride concentration is also observed in *essential hypertriglyceridemia*, an apparent con-

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genital anomaly. Essential hyperglyceridemia has been observed in siblings of a number of families, but the mode of transmission is not known. The course of this disease is generally benign and is consistent with a normal life span.[199] Observation of the familial cases shows that the mere elevation of triglyceride does not in itself increase the risk of arteriosclerosis.

Another interesting fact in this poisoning epidemic was that out of 23 cases with obvious Yusho, 10 showed symptoms or signs of a sensory neuropathy that included numbness, pain and hypoesthesia, and, in addition, 1 case also showed areflexia.[200,201] This effect on the sensory nerves would not be immediately obvious in animal experiments and probably should be investigated further.

Samples of sputa and adipose tissue collected from patients who suffered from Yusho contained chlorinated biphenyls on chemical analysis.[194] The concentration in adipose tissue was much higher than in sputa. Recently Kuratsune et al.[196] reported on the present status of the patients who suffered from Yusho. Many of the patients were still suffering from the illness. When the findings made in 159 patients in 1970 were compared with those observed in 1969, it was found that half of the patients had improved clinically, while the remaining half showed no such improvement and more than 10% of the patients had become worse.

Immunosuppression

Several reports have indicated that PCBs and possibly some of the chlorinated dibenzodioxins and furans may alter the immune response in animals. Atrophy of the thymus and reduced total white count were observed in rabbits following the dermal exposure to PCB fractions containing tetra- and pentachlorodibenzofuran.[36] In fish, exposure to Aroclor 1254 for 14 to 45 days led to emaciation and funguslike skin lesions.[93] However, no attempt was made to isolate organisms from these lesions. When 10-day-old mallard ducklings were fed diets containing PCBs (Aroclor 1254) and were subsequently injected interperitoneally with a duck hepatitis virus, significantly more ducklings died than when they received the virus alone.[202] In guinea pigs, sublethal dosage levels of 2,3,7,8-tetrachlorodibenzodioxin produced severe atrophy of the thymus with destruction of lymphocytes, lymphoid depletion in spleen and lymph nodes, as well as extensive hemorrhages into various organs including the adrenals. Reduced thymus and spleen weights were also observed in rats that received a single dose of 25 μg/kg TCDD and in mice the cell mediated immunity was found to be suppressed.[203] The various findings listed here do not conclusively prove that the immune response is specifically altered by these compounds as we encounter it following radiation exposure or therapy with alkylating agents. In most studies relatively high doses of the chemical compounds were given, resulting in general toxicity accompanied by weight loss. Weight loss in itself may lead to atrophy of the spleen. In humans maintained on a low caloric intake with negative nitrogen balance, a general reduction of lymphoid tissue results which is not specifically related to the immune response and vitamin A deficiency is also accompanied by a reduction in lymphatic tissue. In this respect it is also of interest that when monkeys were fed "toxic fat" containing polycyclic polychlorinated hydrocarbons, The germinal centers in the lymph nodes and spleen as well as islands of hematopoietic cells in bone marrow were extremely sparse.[160] This is more extensively discussed in connection with chick edema. The fact that a combination of duck hepatitis virus and PCBs is more toxic to 10-day-old ducklings than the virus alone suggests a reduced immune response but could also merely represent an additive damaging effect on the liver, made more susceptible to infection by the toxic effects of PCBs. So far no convincing evidence of "wasting disease" as a result of exposure to chlorinated polycyclic compounds has been reported in rodents or any other species in the literature.

Atrophy of the thymus in newborn rodents reduces the capacity of these animals to produce serum antibodies, resulting in wasting disease, also referred to as runt disease or homologous disease. Such animals are then incapable of rejecting foreign skin grafts,[204] which probably represents the most convincing evidence for homologous disease. A shift in the immune response could influence the development and growth of cancer and alter the defense mechanism in infections. In order to prove that PCBs as well as chlorinated dibenzodioxins and furans do indeed influence the immune response, the effect of these substances on newborn animals of several species should be tested with adequate parameters such as skin

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and the measurement of the development of antibodies. Whether the other chlorinated polycyclic compounds in this article also affect the immune response has not been suggested or reported.

Biochemical Effects and Chemical Toxicology

Porphyria

Porphyria cutanea tarda in humans is an acquired defect in hepatic porphyrin metabolism, characterized by uroporphyrinuria, photosensitivity as manifested by blisters, and mechanical fragility of the skin. The hepatic porphyria (Porphyria cutania tarda) which is responsible for the increase in porphyrins and the skin photosensitivity can be produced experimentally by a number of drugs; all of these have the ability to stimulate the activity of the initial enzyme in the heme synthesis δ-aminolevulinic acid synthetase (ALA). In addition to this acquired porphyria, an acute intermittent porphyria erthropoietica and an acute intermittent porphyria hepatica, which are both hereditary, exist together with a number of subgroups which will not be considered here.

In 1964, Bleiberg et al.[2] reported studies of 29 workers in a 2,4-D (2,4-dichlorophenoxyacetic acid) and a 2,4,5-T (trichlorophenoxyacetic acid) factory. Many of the workers had chloracne and 11 had abnormal excretion of urinary uroporphyrins. Many of the workers with uroporphyrinuria had hirsutism, hyperpigmentation, and increased skin fragility. Liver dysfunction was noted in two hospitalized patients. Poland et al.[3] reinvestigated the workers of the same plant studied by Bleiberg et al.[2] They studied a total of 73 male employees; chloracne was found in 80% of the workers. In this study six years after the first report, clinical porphyria was not observed and only one worker had persistent uroporphyrinuria. In the Japanese poisoning epidemic (Yusho), increased uroporphyrin excretion was not reported.

Apparently polychlorinated biphenyls, as well as tetrachlorodibenzodioxins, produce hepatic porphyria in animals. Experimental hepatic porphyria was observed in Sherman strain rats when the rats were exposed to Aroclor 1254 in the diet. The porphyria resembled hexachlorobenzene poisoning and human porphyria cutanea tarda.[2,6] When female rats were fed 100 ppm Aroclor 1254 in the diet (approximately 7.9 mg/kg/day) they became porphyric after a delay of about 2 to 4 months. At this time the urinary porphyrin excretion increased rapidly. Uroporphyrin excretion was elevated to a maximum of 550-fold, prophobilinogen 27-fold, and δ-aminolevulinic acid 18-fold. The major porphyrins found in urine from Aroclor treated rats were 8-carboxyporphyrin (73%) and 7-carboxyporphyrin (16%). Substantial increases in amounts of 5 and 6 carboxcylic porphyrins were also observed. A 10-fold increase in the excretion of coproporphyrins was observed, but the increase in uroporphyrin excretion was 1,400-fold. In control rat urines, coproporphyrin (81%) represented the major porphyrin fraction. A good correlation between urinary porphyrins and liver porphyrins was also observed. Only a trace of porphyrin was found in liver samples in control rats.

When feeding rats 100 ppm Aroclor 1254, δ-aminolevulinic acid synthetase was not increased in the first month of exposure. After this time δ-aminolevulinic acid synthetase was elevated 3- to 6-fold in porphyric rats but was normal in nonporphyric Aroclor treated rats. Cytochrome P-450 and microsomal heme were also increased throughout the study but the increase was maximal in one week despite the absence of an increase of the rate limiting enzyme in heme synthesis δ-aminolevulinic acid synthetase. When a large single dose of Aroclor 1254 (500 mg/kg) was given, a 4-fold induction of δ-aminolevulinic acid synthetase could be demonstrated in the liver 5 hr after dosing the animals. These results suggested that δ-aminolevulinic acid synthetase induction occurred when porphyria had developed if lower levels of Aroclor 1254 were fed over a period of time, but when high doses of Aroclor were given it was induced immediately.

Vos and Koeman[2,5] reported that chemical porphyria was produced by the two European PCB products, Phenoclor DP6 and Clophen A60, as well as the American product, Aroclor 1260. The porphyrogenic action was observed in chickens, quail, and rats. It has not been established so far whether only certain isomers of the polychlorinated biphenyls or contamination with a chlorinated dibenzofuran is responsible for the production of hepatic porphyria cutanea tarda.

Poland and Glover[2,6] used fertile chicken eggs at a developmental stage of 15 to 20 days and injected them with 25 μl of the *halogenated dibenzo-p-dioxins*. They found that 2,3,7,8-tetrachlorodibenzo-p-dioxin produced a dose-related

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increase in ALA synthetase activity. The lowest dose tested, 4.66×10^{-12} mol/egg (1.5 ng) doubled the enzyme activity. These results were statistically significant.

Studies with other halogenated dibenzo-p-dioxins gave the following results: the 2,3,7-trichloro and 2,3,6-tribromo isomers are potent inducers of ALA synthetase while 2,3-dichloro and 2,7-dichloro, 2,8-dichloro, 1,3,6,8-tetrachloro, and 1,2,3,4-tetrachloro isomers all failed to induce ALA synthetase at doses up to 2.5 mg/egg. Of the limited number of halogenated dibenzo-p-dioxins that have been tested for fetal toxicity and the ability to produce chloracne, those that are toxic at low doses also induce ALA synthetase. Whether some of the polyneuritic symptoms reported in Yusho and also in severe exposure to technical 2,4,5-T or technical trichlorophenol that were heavily contaminated with tetrachlorodibenzodioxin are caused by an effect on the porphyrin metabolism merits investigation since neurotoxic effects have been reported in acute intermittent porphyria.[207]

The dioxins that induce ALA synthetase in the liver of the chick embryo may also induce it in the mammalian system. Woods[208] was not able to induce 5-aminolevulinic acid synthetase (ALA synthetase) in the liver of male rats up to 30 days after oral doses of 2,3,7,8-tetrachlorodibenzodioxin. Guinea pigs and mice also did not show an increase of ALA synthetase following the administration of 2,3,7,8-tetrachlorodibenzodioxin. However, it was possible to demonstate an increase in ALA synthetase and uroporphyrins in the liver in C_{57} black male mice given 25 μg/kg/week for 4 weeks.[209] It is possible that ALA synthetase induction varies in time with age and sex and may show species variation. Induction in mammals may require longer dosing, since, for instance, porphyria and induction of ALA synthetase with moderate doses of Aroclor 1254 did not develop until 2 to 4 months after dosing was started.[205] Female animals and the embryo may be more susceptible than adult male animals.

Effect on Other Enzymes and on Vitamin A

A number of investigators have shown that the *polychlorinated biphenyls* induce liver microsomal enzymes.[210-211] Norback and Allen[211] correlated an increase of hepatic microsomal enzyme activity with smooth endoplasmic reticulum proliferation. Litterst et al.[212] studied the effect of four PCB mixtures, namely, Aroclor 1242, 1248, 1254, and 1260. The animals were fed the material for 4 weeks and dietary levels employed were 500, 50, 5 and 0.5 ppm. At higher dietary levels an increase in liver weights was observed. Elevation of triglycerides in the liver was seen at 500 ppm with a maximum effect occurring at approximately 50% chlorine content. An increase in cytochrome P-450 was observed at the 50 and 500 ppm dietary levels of all PCB mixtures. An induction of the pentobarbital hydroxylation and an increase in methylase activity were observed at the higher dietary levels. Induction of pentobarbital hydroxylation increased with increasing chlorine content of the PCBs. Nitroreductase activity was markedly stimulated with increasing doses of PCB and the induction was seen at levels as low as 0.5 ppm for all mixtures. It is difficult to evaluate the enzyme induction at these low dietary levels since the control animal food can be contaminated at times with PCBs.

Two types of inducers of drug-metabolizing enzymes of the liver have been reported, one group to which phenobarbital belongs resulted in increased P-450 content of the liver and induction of a variety of pathways including benzpyrene hydroxylase and demethylation of ethylmorphine. The polycylic hydrocarbons such as 3,4-benzpyrene belong to the second group, which resulted in the formation of an abnormal cytochrome, P-448, and increased benzpyrene hydroxylation, but not ethylmorphine demethylation. Alvares et al.[213] reported that PCB treatment produced an increase in cytochrome P-448, an increase in benzpyrene hydroxylation, and N-demethylation. Since the PCBs represent mixtures, it is possible that the type of induction may depend upon the isomers present. The various effects of PCBs on liver microsomal enzymes can be blocked by the prior administration of actinomycin D. When the effect of a number of PCBs on the beef heart mitochrondrial enzyme system was studied, it was found that they inhibited NADH-oxidase, succinoxidase, and cytochrome oxidase activity. It has not been established whether these same effects will occur in vivo. Benthe et al.[214] induced liver microsomal enzymes by intraperitoneal injection of a single dose of Aroclor 1248 or 1232.

Most of the microsomal enzymes have been studied in the rat, but they are affected in other species as well. Allen et al.[215] reported liver

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hypertrophy after feeding polychlorinated biphenyls (Aroclor 1248) or a polychlorinated triphenyl (Aroclor 5460) for three months to primates. The increase in liver size was attributed to the increase in smooth endoplasmic reticulum and induction of microsomal enzymes was observed. Proof of the induction of microsomal enzymes in birds is the finding made by Lincer and Peakall[210] that livers obtained from American kestrels exposed to either Aroclor 1254 or Aroclor 1262 showed an increase in the in vitro breakdown of oestradiol to a more polar metabolite. This effect on sex hormones is also emphasized by Platonow et al.[217] Aroclor 1254 given to Yorkshire boars reduced the urinary excretion of gonadal steroids.

Both the *polychlorinated biphenyls* as well as the *chlorinated naphthalenes* affect the vitamin A content of the liver. This was particularly studied with the chlorinated naphthalenes since hyperkeratosis and other abnormal keratin formation of the skin is often accompanied by vitamin A deficiency. Low vitamin A plasma levels were observed in cattle with X-disease and young swine.[155,162] A decrease in vitamin A storage in the liver of Japanese quail and rats that were fed Aroclor 1242 was also demonstrated.[218] Since vitamin A deficiency affects reproduction, this aspect should be further investigated to determine whether the effect of PCBs on reproduction is secondary to vitamin A deficiency.[219]

Ecobichon and Johnstone[220] studied the effect of various PCB isomers on the hepatic enzyme system. Biphenyl itself did not cause induction of hepatic drug metabolizing enzymes and neither did monochlorobiphenyl (4-Cl). Substitution of chloro groups at the three and four positions of the di- and tetrachlorobiphenyls caused induction of microsomal monooxygenases. Induction of microsomal monooxygenases occurred also when hexa- and octachlorobiphenyls were given to the rats. Nitroreductase and carboxylesterase activities were not affected while all compounds produced a marked induction of the sulfobromophthalein conjugating system. *Terphenyls* as well as chlorinated terphenyls increased the pentobarbital metabolism in the rat with corresponding increase in smooth endoplasmic reticulum which suggested microsomal enzyme induction.[221,222]

Lucier et al.[223] reported that a single oral dose of 5 or 25 μg/kg body weight of *tetrachlorodibenzodioxin* induced cytochrome P-450 significantly in male rats for a period of up to 28 days. Cytochrome b-5 content was also increased. Hydroxylation of aniline was induced and aminopyrine demethylation rates were decreased. Microsomal proline was increased by approximately 15%. The induction of UDP glucuronyltransferase was most striking. Oxidative phosphorylation rates in rat liver mitochondria using succinate as a substrate were unchanged. The enzyme induction was observed as early as one day - the peak induction was reached between three and ten days after treatment. The enzyme induction was accompanied by an increase in smooth endoplasmic reticulum and a mild increase in rough endoplasmic reticulum.[224] These changes were first observed three days after the injection of the tetrachlorodibenzodioxin. Thus, enlargement of the liver during exposure to various chlorinated compounds is accompanied by an increase in smooth endoplasmic reticulum.

Furthermore, if "inclusions" or "hyaline bodies" are seen within the cytoplasm with the light microscope, concentrically arranged membranes that often surround lipid vacuoles can be seen with the electron microscope (Figure 6).

Hexachlorophene, on the other hand, does not increase the size of the liver.[118] The livers show no ultrastructural changes and probably microsomal enzymes are not induced. Whether other compounds listed in Figure 2 affect liver microsomal enzymes is not known. Hexachlorophene has an effect on a variety of other enzyme systems than those mentioned thus far. Cammer and Moore[225] and Caldwell et al.[226] have shown that hexachlorophene uncoupled oxidative phorphorylation, increased adenosine triphosphatase activity, but did not affect the activities of electron transport enzymes when compared to controls. Gould et al.[227] demonstrated that hexachlorophene inhibited succinoxidase activity of rat heart, liver, and kidney preparations. According to unpublished material cited by Gluck,[228] hexachlorophene is conjugated to the glucuronide conjugate which is excreted in bile. The proportion of conjugated hexachlorophene to unconjugated hexachlorophene in blood may be more significant in determining the toxicity of hexachlorophene than the hexachlorophene blood levels as they are presently determined.

Methemoglobinemia

In the early 1960s outbreaks of methemoglob-

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inemias were reported from hospital nurseries.[229,230] One outbreak involved a total of 18 infants with a level of methemoglobin from 4.9 to 30% of the total hemoglobin. An epidemiological investigation traced the outbreak to *3,4,4'-trichlorocarbanilide (TCC)* that was used as a 2% solution in a rinse in the laundering process, after which the laundry was neutralized with an acid and then dried in an autoclave. Twelve of the eighteen cases in this report were prematures who were probably longer exposed to the offending chemical than term infants since their hospital stay is usually longer. It is also possible that chemicals penetrate more easily through the skin of prematures.

In another outbreak, methemoglobinemia occurred among a group of custodial patients in an institution. These patients were given soap suds enemas with boiled soap that contained 2% TCC.[231]

It is possible that by heating TCC a breakdown product occurred which produced the methemoglobinemia. P-chloroaniline and 3,4-dichloroaniline have been suggested as breakdown products. None of the other compounds discussed in this article have thus far been shown to produce methemoglobinemia.

Storage, Distribution, Metabolism, and Excretion

As we progress further in our study on the distribution, metabolism, excretion, and absorption of compounds such as chlorinated biphenyls, chlorinated terphenyls, the chlorinated dibenzodioxins, and chlorinated naphthalenes, we will probably find that since they are lipid soluble they are stored in quite the same way as the more studied persistent pesticides such as DDT and dieldrin. From the evidence presently available on the chlorinated biphenyls it can be assumed that the turnover of these compounds in the body, particularly of those that have a high chlorine content, may be slower than some of the persistent pesticides. The turnover rate will vary with the degree of chlorination. Hexachlorophene, on the other hand, is fairly rapidly excreted and presently no information is available on bithionol and related compounds that have a germicidal effect. All of these compounds are not very well absorbed by the gastrointestinal tract or the skin.

Analysis of various tissues of rats given a single dose of the PCB Aroclor 1254[232] showed the highest concentration of PCBs in adipose tissue and the least in plasma. Brain, liver, and kidney had levels of the same order of magnitude but were lower. If, for instance, 1,000 mg/kg body weight of Aroclor 1254 were given by stomach tube, 24 hr later the mean concentration in adipose tissue was 1,146 ppm. The concentrations observed in individual animals varied greatly. Similar levels were found in adipose tissue when 3,200 mg/kg of Aroclor 1260 were given by stomach tube to adult female rats. The levels of Aroclor 1254 found in the brain showed a mean of 138 ppm and the values observed for Aroclor 1260 were 145 ppm. All of the values were calculated on a wet weight basis. The same concentrations in ppm were found with both compounds even though only half of the amount of Aroclor 1254 was given. This is probably due to the fact that only a certain amount of Aroclor is absorbed at a given time.

When 100 ppm of Aroclor 1254 was fed to male weanling rats for 58 days the mean concentration of Aroclor derived materials found in the feces varied roughly between 11 and 35 ppm. After the animals had been removed from the experimental diet for a week, the excretion in the feces was 8 ppm and after 16 days' recovery an average of 2.5 ppm was found in the feces. PCBs at the concentration of about 2 ppm were still observed in the feces 24 days after the animals were removed from the experimental diets. During the entire study the amount of PCB derived material recovered from the urine remained below 1 ppm. While PCBs were fed to the rats, the gas chromatogram obtained from the feces was superimposable on the one obtained from the standard Aroclor 1254 that was fed to the rats. Once the animals were no longer fed Aroclor 1254 the number of peaks observed in the gas chromatograms that resulted from the analysis of the fecal material decreased. Fewer peaks were also observed in the gas chromatograms obtained for the tissues and from urine. During the 58-day feeding period, a gradual increase in the concentration of the PCB derivatives was observed in tissues. The highest concentration was found in adipose tissue; after 58 days it reached mean values of about 500 ppm. The concentration in the liver only amounted to a mean of 12 ppm at that time. Following a recovery period of 71 days when the animals were fed plain chow, the concentration of the PCB derived material in adipose tissue had not decreased appreciably and

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still showed values in the neighborhood of about 400 ppm and 4.7 ppm was found in the liver. The concentration in the brain never reached very high proportions; it ranged from about 2 to 4 ppm. Following a 71-day recovery period the amount in the brain was still about 2 ppm. When Aroclor 1254 was fed for 240 days at the dietary level of 100 ppm, the concentration of the PCB derived material observed in adipose tissue had reached values of about 1,000 ppm. If, on the other hand, 100 ppm of DDT is fed to male rats for 2 years, the concentration in adipose tissue is about 95 ppm.[233] In a separate study where 500 ppm of Aroclor 1254 was fed to male rats for 6 months and the exposure to PCB containing diets was subsequently discontinued for an additional 10 months, the concentration of the PCBs ranged from 924 to 1,688 ppm in adipose tissue with an arithmetic mean of 1,192 ppm. The concentrations in the liver ranged from 17.3 ppm to 26.24 ppm with an arithmetic mean of 22.65 ppm.[234]

Further studies are necessary to determine whether PCBs are stored in tissues to a certain point when a steady state is reached and the concentration does not increase further. The given concentration at which this equilibrium is reached in adipose tissue would vary with the amount fed to the animals and the type of compound. The effect of starvation or illness when the amount of adipose tissue in the mammalian body is suddenly reduced also needs to be investigated further. Would this lead to increased excretion of the material or to redistribution or both? Dahlgren et al.[235] who determined PCB tissue levels in pheasants, found that a concentration of 300 to 400 ppm of the PCB derived material was usually found in the brains of birds that had died, while live birds that were fed the same amount of PCBs had much lower concentrations in their brain tissue.

Studies in bobwhite quail showed that relative peak heights and chromatograms for the tissue extracts were similar to the Aroclor standard after partitioning with acetonitrile-hexane when the birds were given a single capsule of Aroclor and their carcasses were analyzed soon after exposure. This suggests absorption of all components of Aroclor. The gastrointestinal tract, liver, skin, wings, and feet had been removed prior to analysis. When bobwhite quail were fed Aroclor 1254 for 14 days and then allowed to recover, the gas chromatograms showed a gradual reduction in the number of peaks and after 42 days on control diet only 4 major PCB component remain, which suggested selective excretion and/or metabolism of some of the components of the Aroclor tested.[236] In a reproduction study, Heath et al.[77] analyzed 2 second-year eggs of mallard fed 25 ppm Aroclor 1254 in their diet for 2 years and found 56 and 33 ppm PCB by wet weight. The gas chromatogram showed a pronounced diminution of the early peaks when it was compared to the standard, suggesting again a selective reduction of the components with lower chlorine concentrations. This is also evident in environmental samples. Lower organisms such as mussels and fish contained a higher concentration of PCBs with lower chlorination than birds.[15]

In mammals, excretion of PCBs in milk and transplacental passage is also observed. Feeding cows 200 mg/day of Aroclor 1254 for 60 days[238] resulted in higher PCB levels in milk fat than in body fat. At 30 days' exposure, 45.6 ppm was found in milk fat and 21.9 ppm in body fat; at 60 days' exposure, 66.7 ppm was found in milk fat and 44 ppm in body fat. However, once exposure to PCBs was discontinued, the concentration in milk fat sank below that of body fat.

Transplacental passage of PCBs also occurred.[237,238] Sherman strain rats were given Aroclor 1254 in peanut oil by stomach tube during days 7 to 15 of gestation. A mean of 20.60 ppm PCB derived material was found in their milk when 10 mg/kg/day was given to the dams during pregnancy, while those given 50 mg/kg/day excreted a mean of 66.34 ppm in their milk on a wet weight basis. Fetuses taken by Caesarean section on day 20 of pregnancy contained a mean of 0.63 ppm and 1.38 ppm of PCBs, respectively. With a fivefold difference in dosage, the concentration in fetuses showed a twofold difference and in milk a threefold difference.[238]

The hyperpigmented babies observed in the Yusho incidents in Japan represent additional circumstantial evidence of transplacental passage of PCBs.

Polychlorinated biphenyls have also been detected in human adipose tissue. Biros et al.[239] analyzed two human adipose tissue samples which contained 200 and 600 ppm PCBs ranging from pentachlorobiphenyl to decachlorobiphenyl and Price and Welch[240] found 100 ppm PCBs in another human adipose tissue sample. According

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to Price and Welch,[240] 41 to 45% of the general population in the U.S. contain 1 ppm or more PCBs in their adipose tissue. Among PCB sources they discussed the food chain and house dust which, from residences in southwestern Michigan, contained up to 180 ppm PCBs. Polychlorinated biphenyls were found in 31% of 637 samples of human adipose tissue that were collected from the general population of the U.S., as part of the Human Monitoring Survey. Of the samples analyzed, 5% contained more than 2 ppm.[241] PCBs have also been found in human adipose tissues of the general population of Scandinavia[242] and Japan,[244,245] and in human milk and human adipose tissue of the general population of Germany.[243] In general, low concentrations of PCBs were stored in adipose tissue in a certain proportion of the general population. This is probably more prevalent in the highly industrialized countries and almost nonexistent in underdeveloped countries unless most of the food was imported from polluted areas. These low levels of PCBs are harmless, as far as we know at the moment; however, the occasional levels found in the 100 to 1,000 ppm range give rise to concern. It would be of interest to establish whether average adipose tissue levels increase with age and whether those in certain professions such as painters, printers, textile workers, workers in plastic factories, and those engaged in the manufacture of transformers and capacitors had higher PCB levels than the general population.

Reports on the absorption, storage, and metabolism of chlorinated naphthalenes, terphenyls, dichlorophene, bithionols, fenticlor, triclosan, and tetrachlorosalicylanilide are almost nonexistent in the literature. Some unpublished results on some of the compounds used as *germicides* are mentioned in the summary minutes of the Over the Counter Drug Panel on antimicrobials. Copies can be obtained by writing to Dr. Mary Bruch, Bureau of Drugs, Rockville, Md.

Approximately 9% of *triclosan*, also called Irgasan DP300 and CH 3565 (2,4,4'-trichloro-2'-hydroxydiphenyl ether), is absorbed when it is applied dermally in a soap solution. The halflife of the chemical was 20 hr when applied dermally and 10 hr when given intravenously. Humans excrete 65% in urine and 20% in feces after intravenous injection. It is excreted either as a free compound or as a glucuronide.

In dogs nearly 100% of the injected material is recovered as the glucuronide or sulfate in urine and feces over a 5-day period. It has been shown that TCC is absorbed through the skin.

Tissue levels of the *chlorinated terphenyl* Aroclor 5460 were determined in codfish.[246] In this study it was found that Aroclor 5460 was apparently poorly absorbed from the gastrointestinal tract; it was stored in all tissues that were analyzed. The highest concentration was found in the liver and following a single dose of 1 g some of it was still present in the codfish after 70 days, an indication of slow excretion. The authors pointed out that with the method used to determine the chlorinated terphenyls, it would be difficult to distinguish chlorinated biphenyls from chlorinated terphenyls. A comparison of the chromatograms of the standard with those obtained from chlorinated terphenyls extracted from tissues revealed more of the earlier peaks in material obtained from tissues and fewer of the later peaks. A variation in the intensity of the peaks was also observed. There seems to be a change in the chlorinated terphenyls within the living organism; however, part of this could also have been introduced as an artefact by the analytical methods or by differential absorption from the gastrointestinal tract.

Calves born to cows with X-disease developed hyperkeratosis and it was found that highly *chlorinated naphthalenes* were excreted in milk.[156] This suggests that chlorinated naphthalenes may well follow similar storage and excretion patterns as PCBs.

Chlorinated dibenzodioxins and *furans* are probably also stored in tissues of animals and men who are exposed to them, but again not much information is presently available. Firestone et al.[247] fed the unsaponifiable fraction isolated from "toxic fat" or 3% "toxic fat" itself to young cockerels. The "toxic fat" contained chlorodibenzodioxins with 2 to 8 chlorine atoms. When the excreta were analyzed it was found that a certain percentage of the hexachlorodibenzodioxins had been absorbed from the gastrointestinal tract, while all of the octachlorodibenzodioxins remained in the gastrointestinal tract, and only very little of the heptachlorodibenzodioxin was absorbed. Because of the presence of interfering components, the chick tissues and excreta could not be examined for the lower chlorinated dioxins. In the organs, the highest concentration was found in the liver and an appreciable amount

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was also found in the bone and skin, while the other organs contained very few dioxins. Some evidence for a possible metabolism of hexa- and heptachlorodibenzodioxin by the chick was also observed. Zitko and Wildish[245] fed di-, tri-, tetra-, and octachlorodibenzofuran to fish and detected only octachlorodibenzofuran in muscle and gut of dead fish. One problem with metabolism, storage, and distribution studies of chlorinated dibenzodioxins and furans is that not all of the compounds are readily available and, if they are available, any long-term feeding studies in large animals are expensive. The very toxic dioxin compounds can be given only at such low levels that they escape detection easily. In our laboratory we detected a chlorinated dibenzofuran in the urine of rats fed Aroclor 1254. We found this same chlorinated dibenzofuran in the Aroclor itself[40] as a contaminant.

Williams et al.[249] fed rats a total of 22.7 and 120.7 μg of octachlorodibenzodioxin. They recovered a great deal of the compound in the feces. Very small amounts were recovered in the liver at both dosage levels and in adipose tissue at the higher dosage level. Further studies are needed to establish the absorption, excretion, and storage of these compounds, and their persistence. Studies with labeled material may eventually give us some information on their metabolism. Piper et al.[250] gave a single oral dose of C^{14} labeled 2,3,7,8-tetrachlorodibenzo-p-dioxin to rats and found that about half of the radioactive material was recovered within 21 days in the feces and only 1.3% in urine and 3% in expired air. Most of the remaining radioactive material was found in the liver.

In another study[251] 100 μg of Cl^{36}-octachlorodibenzodioxin was given daily to rats by stomach tube for 21 days. Less than 0.3% of the material was absorbed. Subsequently the rats received a control diet for 7 weeks and still showed 20% of the absorbed material found at 21 days in their tissues.

The in vivo metabolites of the various compounds under discussion have in most instances not been identified. Block and Cornish[252] studied the urinary excretion of biphenyl and 4-chlorobiphenyl in rabbits. Biphenylglucosiduronic acid and 4-hydroxybiphenyl were isolated from urine of rabbits fed biphenyls. The rabbits fed the 4-chlorobiphenyl excreted 4-(p-chlorophenyl)-phenol and 4-chlorobiphenyl glucosiduronic acid. Twice as much 4-chlorobiphenyl as biphenyl was excreted as the glucosiduronic acid derivative. It is possible that other low chlorinated biphenyls and naphthalenes are excreted in urine in a similar manner; whether they would be detected by present gas chromatographic methods would have to be checked by comparing the identification of radio labeled material with gas chromatography.

Hutzinger et al.[253] found evidence that some chlorinated biphenyls are hydroxylated by some species. Apparently trout is not able to hydroxylate 4-chlorobiphenyl, 4,4'-dichlorobiphenyl, and 2,2',5,5'-tetrachlorobiphenyl, while the rat and the pigeon both formed monohydroxychlorobiphenyl from 4-chlorobiphenyl. In addition, the rat also produced dihydrochlorobiphenyl. Large quantities of unchanged material were excreted by the rat when 4,4'-dichlorobiphenyl and 2,2',5,5'-tetrachlorobiphenyl were given to them and only a monohydroxyderivative was identified in their urine. Pigeons followed a similar pattern but no dihydrochlorobiphenyl was observed in the bird excreta fed 4-chlorobiphenyl. No hydroxy metabolites could be identified in the excreta of the three species when they were given 2,2',4,4',5,5'-hexachlorobiphenyl. No evidence of reductive dechlorination was observed in any species.

Only very few studies have been conducted with radiolabeled *hexachlorophene* to study its absorption, distribution, and metabolism. Wit and Van Genderen[254] gave rats and rabbits hexachlorophene-C^{14} (2,2'-methylene-C^{14} bis(3,4,6-trichlorophenol). Complete recovery of radioactivity in excreta after a single dose of 50 or 15 mg/kg of radioactive hexachlorophene was observed in rabbits within 5 days. Roughly one third was excreted in urine and feces, respectively, as unchanged hexachlorophene and the remainder was excreted in the feces as unidentified metabolites. The metabolites could not be extracted from the feces with ethanol. The biological halflife calculated from the experimental results was found to be approximately 17.8 hr. In rats, about two thirds of the radioactivity was recovered in feces within seven days and only very little in urine. A complete recovery of radioactivity was not obtained in these studies within seven days. Five cows given a single dose of 15 mg/kg body weight of hexachlorophene excreted about half to two thirds in their feces within five days. Very little was excreted in urine and none in milk.

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Metabolites were not identified and tissue levels were not determined in this study. The authors cited a study by Kok,[255] who did determine hexachlorophene in various organs of rats.

Carroll et al.[256] studied the absorption of C-14 labeled hexachlorophene on the tail skin of the rat. Hexachlorophene in a detergent solution was absorbed by the intact skin of the tail at the average rate of 1.7 $\mu g/cm^2$ of exposed surface area/hr. Immediately after the infliction of second degree burns, the absorption rate increased 2.5 times that of the normal skin surface. After 24 hr the absorption rate dropped to normal or subnormal levels. Immediately after traumatizing the tail, the absorption rate of hexachlorophene was even greater than following the infliction of a burn wound.

Manowitz and Johnston[257] found that hexachlorophene was deposited on the skin when used in various formulations and could be extracted from the skin by soaking the exposed areas (hands and forearms) in alcohol. The amount recovered increased in proportion to the amount applied. These authors were unable to confirm earlier investigations which suggested that the quantity of hexachlorophene retained by the skin reached a plateau level after a number of washings and remained relatively constant thereafter. Arms were washed and rinsed every 20 min. When extractions with alcohol were made on different arms after different numbers of washings, it was found that the amount of hexachlorophene recovered increased with the number of washings and no plateau was reached. A greater amount of hexachlorophene was also deposited on the skin with increasing length of time of a single washing. Since we now know that hexachlorophene is also absorbed from the intact skin and some of it is probably also lost from the surface of the skin, the time interval between the washings plays a role in the amount of hexachlorophene found to accumulate on the skin. Also of interest is that bathing water containing 4 mg/l of hexachlorophene deposited approximately the same amount of the chemical on the skin as a single washing with a 2% hexachlorophene soap.

Since hexachlorophene was used very extensively and often unknowingly by the general population, we investigated whether it was present in the blood of a few random samples of the general population. We found that the arithmetic mean concentration of hexachlorophene in adults was 0.028 ppm (μg g) of whole blood of a total of 14 samples. In infants who were washed with hexachlorophene in the nursery the amount of hexachlorophene found in whole blood after the infants had anywhere from 2 to 14 washes averaged 0.109 ppm (μg g whole blood). Blood obtained from the cord at the time of birth contained an arithmetic mean of 0.022 ppm hexachlorophene.[258,259]

In the rats that were used in a reproduction study and were fed 100 ppm hexachlorophene in the diet for 258 days, the hexachlorophene blood levels averaged 1.21 ppm, while the blood levels of rats fed 500 ppm of hexachlorophene for 55 days who had severe symptoms of poisoning amounted to 8.5 ppm.[259,260] At the time we reported these blood levels, our recovery rate was only about 75%. All blood levels reported at that time were determined in whole blood. (It is assumed at the moment that blood levels are equivalent to half the amount of that found when plasma is analyzed.) A study undertaken at the request of Sterling Laboratories[132] illustrated that newborn rhesus monkeys following total body bathing with a 3% detergent solution for 1 week had blood levels of about 1.5μg ml (ppm). In subsequent months a plateau effect was observed and at 90 days the blood level was equivalent to 1.1 μg/ml. These monkeys showed status spongiosus of the white matter of the brain, this indicates that at least in the monkey, blood levels of about 1.5 μg/ml whole blood were consistent with fluid accumulation in the myelin sheath of the central nervous system.

Lockhart[132] cited unpublished studies by Gluck, who found that hexachlorophene blood levels in term infants after washing with a 3% hexachlorophene detergent solution were somewhat higher than those reported by us with a mean concentration of 0.345 ppm (μg/g whole blood). This difference could have been due to a difference in washing procedure and a better recovery rate in the analytical method in Gluck's study, or both.

Premature infants apparently absorbed hexachlorophene more readily. In 15 premature infants that were washed with a 3% hexachlorophene detergent solution, the average blood concentration amounted to 0.475 ppm (μg/g).[261] Abbott et al.[262] using a different washing regimen found a mean hexachlorophene blood concentration 12 to 18 hr after the initial wash of 0.154 ppm (μg/g

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whole blood and on the 7th-10th day of life, 24 to 48 hr after the second or third application of hexachlorophene, the mean blood level amounted to 0.287 ppm (μg/g). The amount found in cord blood of 16 infants was 0.013 ppm (μg/g). When hexachlorophene was applied only on the day of delivery, the hexachlorophene blood levels gradually decreased from a mean of 0.145 ppm on the first day to a mean of 0.057 ppm on the ninth day, following an increase to 0.194 ppm on the fourth day. The authors suggested that premature infants may absorb more hexachlorophene through their skin since in one infant 29 weeks of gestation and weighing 1.42 kg the blood level was 1.17 ppm 24 hr after the initial wash and 0.655 ppm at 48 hours. Alder et al.[263] reported mean hexachlorophene blood levels of 0.18 ppm in infants who were dusted with a powder containing 0.33% hexachlorophene.

Adults using hexachlorophene preparations also absorbed it via the skin.[132] The blood levels obtained in adults that exposed their total body surface to a 3% hexachlorophene preparation twice daily for 60 days, 5 min each time, showed blood levels of approximately 0.68 ppm (μg/ml whole blood) with a range of 0.25 to 1.08 ppm (μg/ml whole blood). If only hand washing was employed for a period of 28 days, 4 times daily, a mean blood level of 0.07 ppm was reached and in a face hand washing study the mean blood level after 28 days was 0.196 μg/ml.

Blood levels obtained in a patient with burns who died between 24 and 48 hr after the last hexachlorophene application were 2.2 ppm (μg/g whole blood). The blood levels that have been reported all indicate that following dermal hexachlorophene exposure the chemical can be found in blood, and from information through animal studies as well as some human experience, levels of approximately 1.5 to 2 ppm (μg/g) in whole blood in humans are presently considered to represent toxic levels if the analysis for blood was performed with the methods mentioned elsewhere in this article.

Probably a better way of assessing a toxic dose would be to measure the amount of hexachlorophene in the brain, but for obvious reasons that is not possible. Female rats fed hexachlorophene at the rate of 500 ppm (25 mg/kg body weight/day) for 55 days with very definite lesions had about 4 ppm hexachlorophene in their brain and 3.91 ppm in the liver. Squirrel monkeys given 5 mg/kg body weight/day of hexachlorophene for 56 days showed a mean hexachlorophene concentration in the brain of 0.38 ppm and in adipose tissue the hexachlorophene concentration was 0.94 ppm.[264] The recovery rate in this study was only 75%. These squirrel monkeys had no overt clinical signs of toxicity, but showed mild status spongiosis of the white matter of the brain. Electroencephalographic changes had also been observed in these primates. Ulsamer et al.[265] found hexachlorophene brain levels of about 1 ppm in newborn rats with signs of central nervous system toxicity. In 1 suspected case of human hexachlorophene poisoning in a child, the hexachlorophene brain level was about 2.2 ppm.[261] Adult rats dying after the administration of a single dose of hexachlorophene showed concentrations of 6 to 9 ppm of hexachlorophene in the brain.[266] Some variation of the concentration of hexachlorophene in the brain which can be related to neurotoxic symptoms must be expected in different species and perhaps also with age and sex. Whether the fund accumulation which may occur in the myelin sheaths after repeated exposure to hexachlorophene would alter hexachlorophene brain levels has thus far not been reported.

With present methods, we are probably only determining free hexachlorophene while the conjugated portion remains undetected. The toxicity of hexachlorophene will vary with the ability of the organism to conjugate, metabolize, and excrete this material.

We found in rats that hexachlorophene is excreted in milk of dams fed hexachlorophene at the rate of 20 and 100 ppm in the diet (2.3-11 mg/kg-day and 11.8-55 mg/kg day, respectively, for 241 days). Electron capture, gas-liquid chromatographic determinations revealed levels of 0.07 and 0.33 ppm in the milk. Since hexachlorophene did not seem to accumulate to a great extent similar values would probably have been obtained, had the levels in milk in these animals been measured earlier. Although we now have some information on the absorption and distribution as well as excretion of hexachlorophene, the possible storage of the material as well as its metabolism needs further investigation. Since hexachlorophene was found in cord blood of infants, it can be assumed that transplacental passage also occurred.

Morphologic Effect on the Liver

Some of the chlorinated naphthalenes, chlori-

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nated dibenzodioxins, chlorinated dibenzofurans, the chlorinated biphenyls, as well as the chlorinated terphenyls have an effect on the liver in various species, including humans. Bennett et al.[267] compared the toxicity of differently chlorinated naphthalenes and a biphenyl that contained 65% chlorine. Tri-chloronaphthalene apparently was less hepatotoxic than the higher chlorinated compounds and the chlorinated diphenyl was the most toxic of all. The studies were done in rats and the exposure was by feeding as well as inhalation. The findings described in the liver consisted of liver necrosis, fat accumulation, and the presence of hyaline bodies in the cytoplasm of the liver cells. A marked deposit of finely divided granular yellow or yellow-brown pigment was observed in Kupffer cells, particularly in those animals that had been exposed to the chlorinated biphenyls. This pigment apparently did not stain characteristically for either hemosiderin or hemofuchsin. Of course, all livers were enlarged macroscopically; in addition, these authors described proliferative changes in occasional bile ducts, particularly after feeding mixtures of chlorinated naphthalenes and chlorinated biphenyls. The number of bile ducts was increased in certain areas and the epithelial cells lining the bile ducts showed mitotic figures.

In inhalation studies with low concentrations of PCBs which consisted of either a 16-hr daily exposure to average concentrations of 0.57 mg/m^3, or to 8 hr daily with an average concentration of 0.93 mg/m^3, neither group of rats appeared ill. The periods of exposure varied from 37 to 143 days. When the animals were sacrificed the livers were pale or slightly yellow and somewhat mottled. Microscopic examination of the livers revealed similar changes as had been observed after feeding the material, and an increased vacuolation of the liver cells. Microscopic evidence of recovery was not observed in the livers of rats that had been exposed to the chlorinated diphenyl for a total of 105 days and were removed from exposure for 2 months.

Similar findings were made by Miller[268] who studied the effect of a PCB which contained approximately 42% chlorine. This author observed varying degrees of liver damage after subcutaneous injection as well as oral ingestion of the toxic substance in guinea pigs, rats, and rabbits. The liver damage consisted of fatty degeneration and atrophy of the central lobular cells. In the rat, hyaline bodies within the cytoplasm of the liver cells were also noted. Most of the liver damage was found in the guinea pig, less in the rabbit, and least in the rat.

Nishizumi,[269] who studied the effects of a Japanese biphenyl Kaneclor 400 with 40% chlorine in monkeys and mice, described enlargement of liver, fatty changes, granular cytoplasm of the hepatocytes, increases in the size of Kupffer cells and hepatocytes, and a brown pigment in some of these cells. He also studied the livers under the electron microscope and found an increase in smooth endoplasmic reticulum, variation in the appearance of mitochondria, and an increase in the number of microbodies. In addition, "myelin figures" were observed in the cytoplasm of hepatocytes.

Vos and Koeman[75] observed liver necrosis in chickens that were dosed with European PCBs, while a Monsanto product with 60% chlorine did not produce this effect. Increased amounts of iron were demonstrated with Perl's iron stain in the livers of all chickens exposed to the European as well as the American PCB sample. Vos and Beems[96] studied the PCB-induced lesions in the liver of rabbits, following dermal exposure to Aroclor 1260, Phenoclor, and Clophen. The microscopic changes observed in the liver included fatty degeneration, focal necrosis, centrolobular liver cell atrophy, ceroid pigment in Kupffer cells, periportal fibrosis, and cytoplasmic hyaline degeneration.

The feeding of Aroclor 5460, a chlorinated terphenyl, Aroclor 1254, or a chlorinated dibenzo-p-dioxin, not further specified in the article, led to liver hypertrophy of Sprague-Dawley rats within eight days to three weeks. Ultrastructural alterations were similar in the three groups and consisted of numerous multilayered, concentric membrane arrays and proliferated smooth endoplasmic reticulum. In many instances these membrane arrays surrounded lipid droplets.[270] Rabbits given 300 mg of Aroclor 1242 and 1254 once a week for 14 weeks developed enlarged livers and the ones given Aroclor 1254 showed midzonal necrosis of the hepatic lobules. The livers of rabbits fed Aroclor 1221 in a similar fashion did not show any histologic changes.[271]

We conducted studies to compare the toxicity of Aroclor 1254 and Aroclor 1260 in Sherman strain rats. The acute effect of these two mixtures on the liver was negligible. If rats were given a

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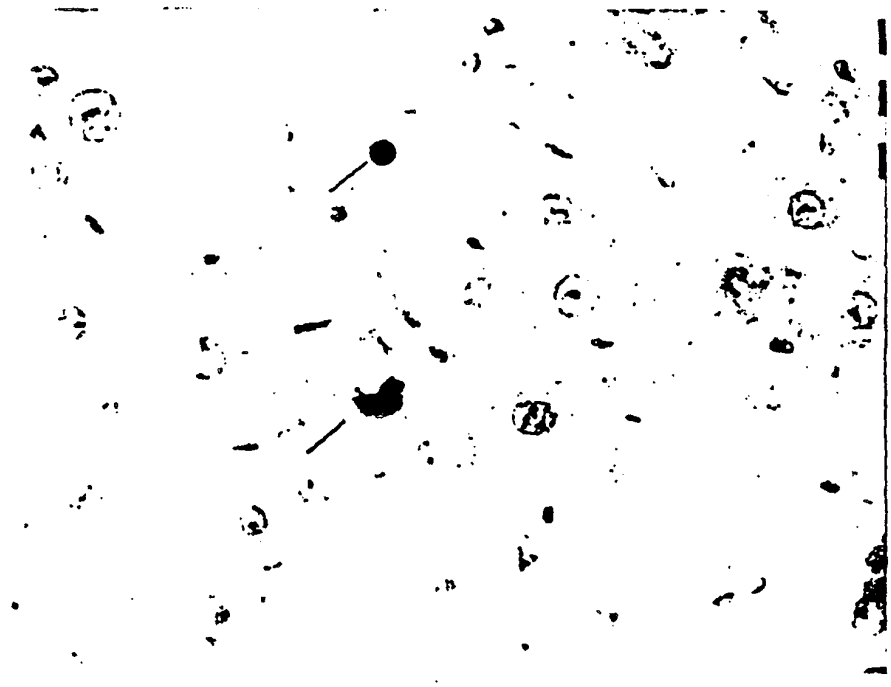

FIGURE 3. Section of liver of a rat fed Aroclor 1260 for 90 days. This figure illustrates a mitotic figure and a hyperchromatic nucleus (arrows) H & E X 500

single dose of 10,000 mg/kg in peanut oil by stomach tube, and were sacrificed the next day, the liver was essentially normal microscopically. Doses of 1,000 ppm (72 mg/kg) of Aroclor 1260 for 3 months produced only an increase in mitotic figures (Figure 3) and enlarged hepatocytes. When groups of rats were fed dietary levels of 20, 100, 500, and 1,000 ppm of Aroclor 1260 and 20, 100, and 500 ppm Aroclor 1254 for 8 months, the liver changes were pronounced.[272] The hepatocytes were enlarged in many of the rats of the experimental groups and lipid accumulation, foamy cytoplasm, and a brown pigment which stained partially positive for hemosiderin were observed in the livers. The pigment was primarily observed in macrophages and Kupffer cells. Inclusions (Figure 4) that stained slightly more eosinophilic than the surrounding cytoplasm were present in the cells. These inclusions within the cytoplasm have been described for many compounds such as mirex[273] (dodecachloro-octahydro-1,3,4-metheno-2H-cyclobuta[cd]pentalene), DDT[274], 1,1,1-trichloro-2,2-bis(p-chlorophenyl) ethane dieldrin[275], 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a-5,6,7,7,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene, and piperonyl butoxide[276] (α-[2(-butoxyethoxy)ethoxy]-4,5-methylenedioxy-2-propyltoluene). They are identical to the so-called hyaline bodies that were described in the earlier literature by Bennett et al.[267] and Miller.[268]

Aside from these general changes, extensive, grayish-white, firm, glistening areas were noticed in the livers of a number of the experimental animals, particularly at the high dietary levels. Microscopic examination of these grayish-white areas showed that the hepatic parenchyma had been replaced by glandular pale staining epithilial cells that formed ducts and were surrounded by proliferating fibrous tissue (Figure 5). Larger lesions often had extensive fibrosis and also contained collagen and the ducts that were formed by epithilial pale staining cells were markedly dilated and contained necrotic debris or mucus. The lesion has been classified as adenofibrosis for the time being. It has been described in detail by Edwards and White[270] who observed it in rats that were fed butter yellow (p-dimethylamino-azobenzene). These lesions enlarge peripherally by the formation of new glandular structures. Hepatic

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FIGURE 4. Section of liver from rat fed Aroclor 1254. A cluster of inclusions is present in the cytoplasm of one hepatocyte (arrow). Usually individual cells contain only one of these formations at a time. Toluidine blue stain of maraglass embedded material X 300.

tissue may be trapped between the glands of the peripheral area of adenofibrosis. The older central parts of the lesions sometimes contain pigmented avascular collagenized stroma with atrophic epithelial cells lining dilated ducts that appear atrophic and dead. The glands of actively growing adenofibrosis show atypical epithelium with large pleomorphic nuclei. The epithelium can occasionally become stratified. Parts of the lesion may be quite extensive, while in addition, in many areas of the same liver small foci of adenofibrosis exist simultaneously in close relationship to portal areas. It has therefore been assumed that these lesions arise from bile ducts, but they can also be primarily confined to the region of the hepatic veins. The absence of bile ducts around hepatic veins led to the conclusion[277] that a precursor, other than bile ducts, existed from which adenofibrosis developed. However some investigators of the lesions have assumed that it represented an atypical bile duct proliferation, also referred to as cholangiofibrosis.[278] In addition to this lesion we also observed small clusters of glandular cells within areas of adenofibrosis as well as adjacent to blood vessels that were surrounded by relatively normal appearing hepatic parenchyma with staining characteristics of salivary gland tissue. These clusters of cells very closely resembled pancreatic tissue.[279] The distinction between adenofibrosis and adenocarcinoma is difficult. The glands are quite atypical in adenofibrosis but it may be helpful to remember that in adenofibrosis, in contrast to adenocarcinoma, the irregularity observed is limited and duplicated with considerable exactness from lesion to lesion. Mucus is always present in adenofibrosis, but not always in adenocarcinoma. The stroma of adenofibrosis is concentrically arranged, young and cellular at the periphery and old and hyalinized towards the center of the lesion.[277] Of course a liver showing adenofibrosis may also contain carcinomatous lesions. So far conclusive evidence is lacking in the literature that adenofibrosis gives rise to carcinomas. However, it has been found to coexist with carcinoma of the liver in rats and some investigators feel that the lesion is in fact a precursor of cancer.[280] Choline deficient rats apparently, in addition to other changes in the liver, also develop

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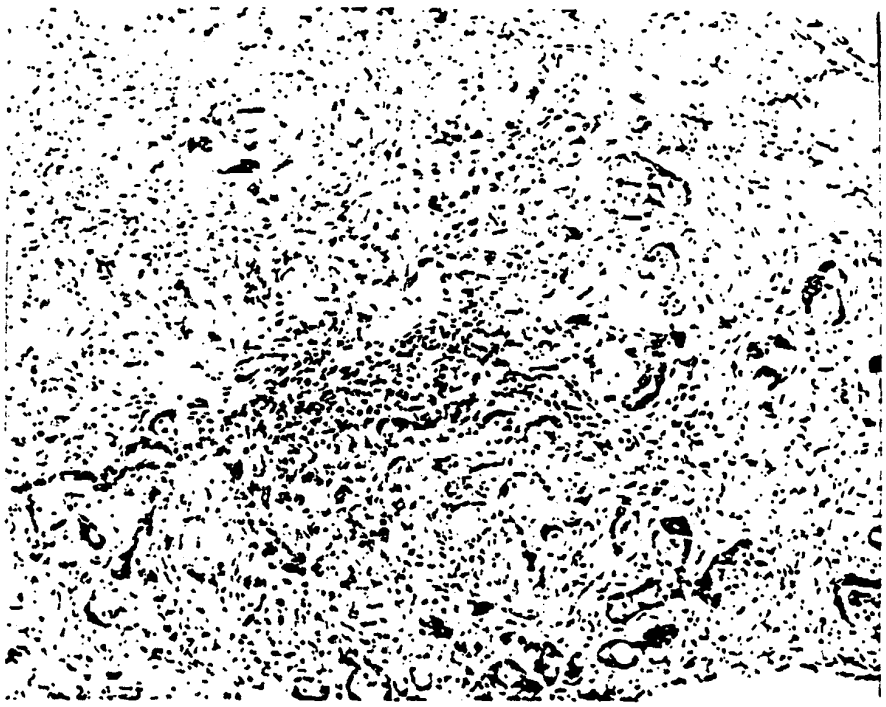

FIGURE 5. Section illustrates an area of adenofibrosis of the liver of a rat fed Aroclor 1254. Note the epithelial cells forming small ducts. The ducts contain cellular debris and are surrounded by fibrosis which can be more quite pronounced. H & E. X 125

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adenofibrosis.[28] However, these rats were fed peanut meal and soymeal and therefore the possibility exists that the experimental diet was contaminated with a mycotoxin. Bennet et al.[26] also described the lesion (adenofibrosis) in rats when a mixture of chlorinated naphthalenes and chlorodiphenyls was fed to them. A critical review of the histopathogenesis of this lesion was made by Stewart and Snell.[27]

Ultrastructural changes of the livers of animals exposed to the Aroclor consisted of an increase in smooth endoplasmic reticulum and atypical mitochondria. Many lipid vacuoles were observed, particularly at the higher dietary levels. They were at times surrounded by concentrically arranged membranes. The "inclusions" or "hyaline" bodies observed in the cytoplasm with the light microscope correspond to these formations when they are examined under the electron microscope. Their ultrastructural appearance has led to their being referred to as "finger prints" (Figure 6). The epithelial component of the adenofibrosis outlined consisted of cuboidal or columnar cells with the free surface lined by microvilli, granular cytoplasm with many ribosomes, and a few endoplasmic membranes. Some of the cells contained a great deal of mucus and resembled goblet cells. Tonofilaments and terminal bars were also observed. These various observations suggested that the epithelial component of adenofibrosis had all the morphological characteristics of bile duct epithelium.

Chickens with chick edema disease and cattle with the X-disease, already mentioned, usually showed changes in the liver which consisted predominantly of liver cell necrosis and fat accumulation. The hepatotoxic effect of chlorinated naphthalenes has also been described in rats.[26]

In a number of reports on the occupational occurrence of chloracne in workers that were exposed to chlorinated naphthalenes, chlorinated diphenyls, or 2,4,5-T, and technical trichlorophenol, reference is made to the hepatotoxic effect of these compounds. This hepatotoxic effect can manifest itself only in a decreased tolerance for alcohol; it may also develop into hepatic deficiency with acute yellow atrophy and jaundice. Apparently the effect on the liver was

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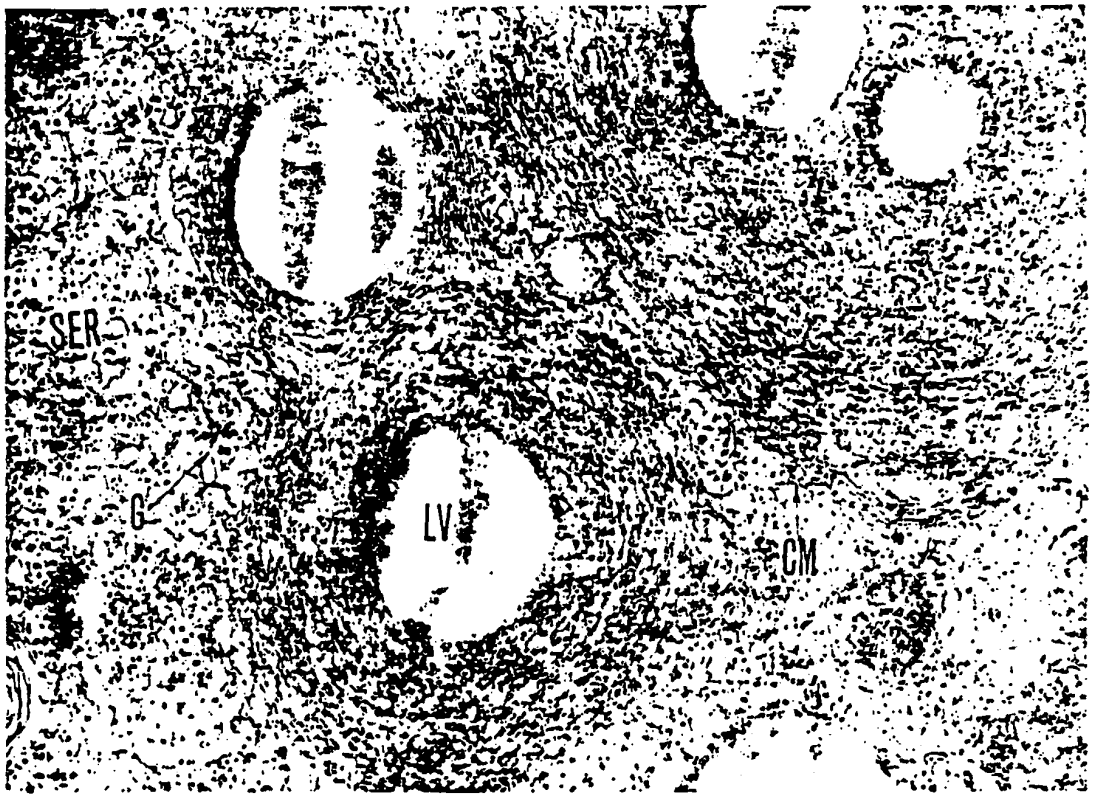

FIGURE 6. Electron micrograph of a portion of the cytoplasm of a hepatocyte. The section shows concentrically arranged arrays of membranes which surround vacuoles containing lipid. Lead citrate, uranyl acetate X 34,200.

particularly bad following exposure to halo-waxes, which are chlorinated naphthalenes.[282]

Cotter[283] reported seven cases of pentachlorinated naphthalene poisoning in workers who were engaged in manufacturing wire cable during World War II for the navy. Four of the workers developed jaundice and two died. Microscopic examination of the liver of the two workers that died showed complete loss of liver cells in some areas, the centrolobular areas were hemorrhagic, and prominent bile duct proliferation was seen in the periphery.

Another group of compounds that have at least some representatives that cause a hepatotoxic effect are the chlorinated dibenzodioxins and chlorinated dibenzofurans.

Single oral doses of 1 to 10 μg/kg *2,3,7,8-tetrachlorodibenzodioxin* given to rabbits produced a hepatotoxic effect. At the higher dosage level the animals died and the lower doses caused serious liver damage.[108] Schulz[107] had reported earlier that single oral doses of 20-50 μg/kg body weight resulted in fatal liver necrosis in rabbits.

Weanling rabbits were treated with 2,3,7,8-tetrachlorodibenzo-p-dioxin by applying a dose of 1.67 μg daily to the inner aspect of both ears for three days. The total dose given was 7.05 μg/kg body weight. When these rabbits were sacrificed 18 days following the last application of the dioxin, their livers were significantly larger than those of the controls. Microscopic examination of the livers showed enlarged hepatocytes. Some of the hepatocytes were multinucleated. The cytoplasm was foamy or vacuolated. A light brown pigment in some liver cells as well as Kupffer cells was also observed. Inclusions were seen in the cytoplasm in some liver cells, slight interstitial fibrosis was present, and two of three rabbit livers examined showed foci of necrosis that were surrounded by fibrosis.[284]

Studies with "toxic fat," the cause of chick edema disease, showed that it had a necrotizing

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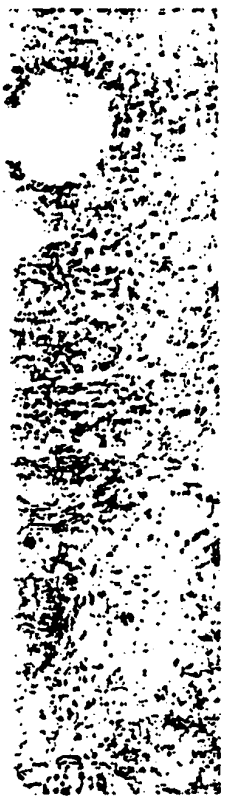

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effect on the liver in chickens. As we now know the toxic agents responsible for chick edema disease are chlorinated dibenzo-p-dioxins. Toxic fats also altered liver morphology in Macaeca mulatta monkeys.[285] Hepatocytes were enlarged, multinucleated and focal necrosis in the centrolobular zone was observed. Many liver cells were vacuolated and stained positive for neutral fat.

In our studies of rats given *hexachlorophene*, we did not observe any liver pathology with the light microscope and no change with the electron microscope at the dosage levels that we employed.[118] Thorpe[121] on the other hand, observed periportal fatty changes in livers of sheep given three or four doses of 50 mg/kg hexachlorophene and histochemical changes were also observed in the hepatocytes. Pugh and Crowley[286] also observed hepatotoxicity in sheep after giving them hexachlorophene.

Of the other germicides discussed in this article, only triclosan (Irgasan DP-300) (2,4,4-trichloro-2′-hydroxydiphenyl ether) has been reported to have a toxic effect on the liver at a dose of 125 mg/kg and enlarged the liver of rats at a dose of 25 mg/kg, according to the summary minutes of the OTC Panel, U.S. Food and Drug Administration. It was not stated whether these were single or repeated doses. Oral administration of triclosan to beagle dogs produced jaundice and severe liver damage was observed. The effect that these compounds have on the liver will have to be studied further.

The accumulation of fat in the liver indicates that either fat transport or fat metabolism is impaired; if the insult to the liver is removed, the liver gradually recovers unless the lesion has become irreversible. The increase in smooth endoplasmic reticulum as well as the "inclusions" will also disappear after a certain amount of time if exposure to the material is discontinued.[287] The significance of the increase in smooth endoplasmic reticulum and the hyaline bodies with a concomitant rise in liver microsomal enzyme activity is presently not understood. These changes are considered adaptive and beneficial, but in addition to metabolizing unwanted chemicals at a higher rate, the stimulated liver also metabolizes some medications more rapidly,[288] as well as substances produced by the body such as steroids. Whether the inclusions within the cytoplasm represent the so-called inactive smooth endoplasmic reticulum which is deposited in the form of arrays of membranes within the cell is not known. The fact that smooth endoplasmic reticulum may become hypoactive was first postulated by Hutterer et al.[289]

Fibrosis of the liver as well as necrosis and the adenofibrosis observed after PCB exposure in rats should definitely be considered a very serious lesion. Usually adenofibrosis occurs concomitantly with hepatomas or hepatocarcinomas in rodent livers. A recent publication by Kimura and Baba[289a] showed that hepatomas can be induced in rats with Kanechlor 400. Chronic feeding studies may show that other PCBs will also induce hepatomas in rodents.

Neurotoxicity

In some of the reports on chloracne and also in the Yusho incident, peripheral neuropathy is mentioned as well as psychic alterations[1,290] as part of the symptomatology of poisoning, but in most reports not much emphasis was put on it. In the Yusho epidemic Murai and Kuroiwa[290] performed more detailed examinations in 21 cases admitted consecutively to Kyushu University Hospital in the northern part of Japan. Seven of the patients complained of numbness or pain in the peripheral portion of their extremities and in five cases, hypoesthesia, hypalgesia, and thermohypesthesia were noted. Slowing as well as reduction of the sensory nerve conduction velocity in the radial and sural nerve was observed in a number of these patients. Headache and peripheral nervous system symptoms were also reported in a poisoning episode which occurred in a Finnish company where paper was impregnated with biphenyl.[92]

The only chemical of the group of polychlorinated, polycyclic compounds discussed in this report that has a predominant central neurotoxic effect in animals as well as humans is hexachlorophene. Adult female rats that were fed 500 ppm hexachlorophene in the diet for 14 weeks (about 30 to 18 mg/kg body weight-day) developed leg weakness after 12 to 19 days of exposure. This leg weakness which was only evident in the hindlegs progressed to paralysis within 3 to 5 weeks.[291] At autopsy the brains of the exposed rats were enlarged; they weighed an average of 2.6 g while the control brains weighed an average of 1.99 g. Microscopic examination of the brains revealed normal gray matter throughout the brain and the spinal cord in the few instances that the spinal

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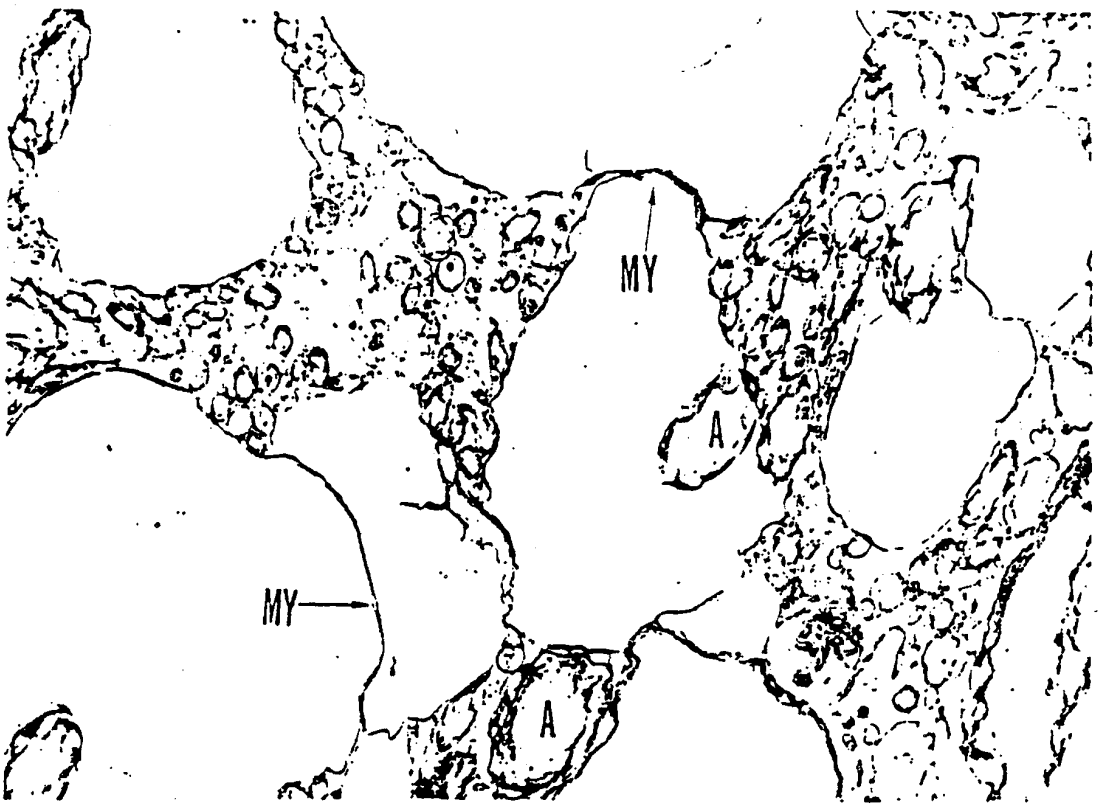

FIGURE 7 Electron micrograph from the white matter of the brain of a rat, illustrating status spongiosus. Note the large empty appearing vacuoles lined by myelin (MY = myelin, A = axon). Lead citrate, uranyl acetate X 34,200.

cord was examined. The white matter on the contrary seemed widened and showed many cystic spaces that appeared empty and were lined with strands of material that stained positive for myelin. The vacuoles were very numerous and varied greatly in size giving the tissue a spongy appearance. The brains in these studies were usually fixed in either Bouin's solution or buffered formalin for light microscopic study.

Brain tissue, particularly that of rodents, may normally show small vacuoles that are considered to represent an artefact.[292] These vacuoles are smaller, usually very uniform, and at times contain a homogeneous pink staining material. They are usually separated by a wider area of normal appearing white matter than the vacuoles in status spongiosus. Brains that show this artefact do not weigh significantly more than those that do not show it.

Electron microscopic examination of brains of rats given hexachlorophene showed that the vacuolation in the white matter of the brain revealed large vacuoles lined by myelin. The axons that were present appeared usually to be quite normal; occasionally strands of myelin had separated and traversed the vacuoles. The vacuoles were otherwise empty except for some electron dense granular material (Figure 7). No other alterations were observed in the white matter. This lesion is not unique for hexachlorophene, other chemicals that have produced status spongiosus as we have called the lesion include triethyltin,[293] isoniazid,[294] the halogenated benzanilide, 2-acetoxy-4-chloro-3,5-diiodobenzanilide,[295] and tatoxanide,[296] which is the 3,5-diiodo-3′-chloro-4′(4-chlorophenoxy) salicylanilide. Triethyltin seemed to produce the lesion at a much lower dietary level and more rapidly than the other chemicals mentioned, particularly hexachlorophene.

In an additional study, after feeding rats 500 ppm hexachlorophene in the diet for 10 weeks and then discontinuing the exposure to hexachlorophene, function began to return in the hindquarters of paralyzed rats after 2 weeks and within

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6 weeks the rats had almost completely recovered clinically. However, microscopic examination of the brains of these rats showed that a few cystic spaces were still present 12 weeks after the exposure to hexachlorophene had been discontinued. In weanling rats, but not in adult rats, the brain lesion and symptoms of paralysis could be produced with a single oral dose of 100 mg/kg of body weight given by stomach tube in peanut oil.[115] Part of the reason for being able to produce the brain lesion in the weanling rats with a single dose may be related to the fact that the weanling was able to survive a higher single dose than the adult rat.

Other species that have also shown paralysis and other neurological deficits after exposure to hexachlorophene are rabbits,[207] pigs,[208] and cats.[209] Sheep become blind according to Udall and Malone.[120] Haag et al.[209] recorded the neurological deficits produced in cats in more detail. Early symptoms consisted of lassitude, weakness and ataxia of the hindlegs, impaired righting reflex, patellar hyperreflexia which later developed into hyporeflexia, urinary retention, and eventually complete flaccid paralysis. The cranial nerve functions remained intact except preterminally. In these cats an increase in cysternal cerebralspinal fluid pressure was observed.

In our first studies we continued exposure to hexachlorophene for a period of 14 weeks because we had designed the experiment to conduct an approximate 90-day feeding study. It is not necessary to feed rats for this length of time. As we determined later, microscopic changes can be observed in rats after a feeding period of two weeks when the animals were exposed to levels high enough to produce the lesion. Some vacuolation can already be observed 3 to 4 days after onset of exposure to hexachlorophene in some rats. When lower dietary levels were fed in a reproduction study,[118] the dietary level of 20 ppm (2.4–0.9 mg/kg body weight/day) had no effect on the brain. At the dietary level of 100 ppm (11.8–4.6 mg/kg body weight/day) focal areas of vacuolation of the white matter of the brain were observed in some of the rats, but they were never extensive. The rats in these lower dietary levels did not show any clinical neurological symptoms.

The brain lesion observed in rats was also described in monkeys following the exposure to hexachlorophene. Newborn monkeys washed with 3% hexachlorophene detergent solution [illegible] a diffuse status spongiosis of the white matter of the brain.[300] Santodonato et al.[301] was able to produce the vacuolation of the white matter, the so-called status spongiosus, by injecting squirrel monkeys daily subcutaneously with 5 mg hexachlorophene/kg of body weight for 37 days. When monkeys were *fed* hexachlorophene they did not develop the brain lesion but showed electroencephalographic changes which need further investigation. The monkeys that showed the vacuolation also demonstrated electroencephalographic changes. Sheep have apparently also shown status spongiosus of the white matter according to Hale and Reid.[302] Lampert et al.[303] were able to produce the lesion in mice as well as rats. These authors reported that the morphological changes were also observed in frozen sections of brains quenched in liquid nitrogen. Trypan blue injected intraperitoneally did not stain the brain, an indication that the blood brain barrier was intact as far as trypan blue was concerned.

The brain changes consistent with status spongiosus due to hexachlorophene exposure have also been described in humans particularly children. Mullick[130] examined the brains of six human cases that died from hexachlorophene poisoning. The two adults in this group did not show vacuolation of the white matter of the brain. They had died less than 48 hr after exposure to hexachlorophene. The four children (two with congenital ichthyosis, two with burns) had at least three or more days of exposure to hexachlorophene baths in which a 3% hexachlorophene preparation was used. The final concentration of hexachlorophene in the bath water was not known. All four children showed status spongiosus of the white matter. The brain weight given in one of the cases, a 12-day-old child, was 425 g. The normal brain weight for a child that age is 382 g. Shuman et al.[304] in a retrospective blind study were able to demonstrate that the incidence of status spongiosus in the brain stem reticular formation in infants who had died from a variety of causes could be correlated to hexachlorophene exposure. The authors found 21 cases in a series of 250 autopsies of children. Of these cases, 18 were premature infants weighing less than 1,400 g and were of less than 30 weeks' gestation. All but 2 of the cases had 3 or more total washes with 3% hexachlorophene. In the group of cases that were studied were a number of stillborns who did not

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show the lesion and of course had not had dermal hexachlorophene exposure. Shuman et al.[304] mentioned earlier cases of Letterer Siwe's disease in which they had observed status spongiosus of the white matter. Each of the children with Letterer Siwe's disease had had pronounced exposure to hexachlorophene because of the skin lesions which had been vigorously scrubbed with a detergent containing the chemical. The various observations show that, in patients with abnormal skin as well as the skin of the premature, hexachlorophene may be absorbed in sufficient amounts to cause status spongiosus. The fact that blood levels in premature infants washed with hexachlorophene tend to be higher than in mature infants also substantiates these findings.

Almost identical observations were made by Powell et al.[305] In premature infants weighing less than 1,400 g, 7 of 13 that had 4 or more exposures to hexachlorophene washes showed status spongiosus of the myelinated tracts of the brain stem. If this group was further subdivided according to the number of exposures, 6 of 9 infants that had 9 or more exposures to hexachlorophene washes showed the lesion, and 1 of 4 that was washed 4 to 8 times. Four stillborns and 13 infants washed 0 to 3 times with hexachlorophene and weighing less than 1,400 g did not show the spongy change. Electron microscopic examination showed that the spongy change observed in the premature infants was due to a split in the myelin sheaths.

In August of 1972 the press reported a number of deaths of infants in France that occurred because a baby powder to which hexachlorophene had accidentally been added at a concentration of 6% was used on the infants. The final death toll amounted to 41 infants and young children[306] (New York News, Dec. 13, 1972). Detailed accounts have not been published of this incident because of litigation problems. As we pointed out earlier, under acute toxicity, the higher the concentration of hexachlorophene is in a preparation applied to the skin, the more likely it is that skin damage will result. Skin damage also occurred in the French incident. In addition to this, the powder was probably used in many instances where some diaper rash already existed and was then well covered with a diaper, which may have contributed to increased absorption in this area. The brains and spinal cord of a few infants from the French poisoning outbreak that were examined microscopically showed status spongiosus of the white matter.[306]

These various accounts show that status spongiosus can also be produced in humans and probably represents a nonspecific reaction which can be elicited by a number of chemicals.

The lesion status spongiosus of the white matter as far as we now know seems to represent a specific or restricted type of brain edema where the fluid accumulation is confined to the inside of the myelin sheath and myelin is not actually damaged or at least breakdown products of myelin have not been observed. The term status spongiosus or spongy change has been used as a descriptive term and a spongy change of the gray matter may also occur in certain diseases. Status spongiosus together with other morphological changes can be observed in the brain in a variety of many etiologically different diseases and the reader is referred to Klatzo.[307] Ardonato and Lampert,[308] and a recent editorial in the British Medical Journal.[309] From clinically observed poisoning cases as well as animal experiments it is evident that the brain lesion is to a great extent reversible. However, in our own studies as well as those by Lampert et al.,[303] macroscopic changes in rodents did not completely regress and the fact that sheep do not recover their eyesight after hexachlorophene poisoning[120] indicates that repair may not always be complete. No reasonable explanation exists at the moment to indicate why certain chemicals produce this very specific edema confined to certain structures of the central nervous system.

Gastrointestinal Lesions

Only two types of compounds under discussion have produced lesions in the gastrointestinal tract. We observed in our study with Sherman strain rats that high single oral doses of 3,000 mg/kg Aroclor 1254 and 1260 or more caused ulceration of the gastric and duodenal mucosa (Figure 8). Ulcers in the GI tract were not observed in the long-term feeding studies with 500 ppm or less. No other changes in the gastrointestinal tract were observed. Ringer et al.,[105] in their reproduction study with mink, observed that Aroclor 1254 produced hemorrhage in the gastrointestinal tract of the offspring.

Allen and Norback[310] observed hyperplasia and dysplasia of the gastric mucosa in rhesus monkeys. Six of these rhesus monkeys were fed

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FIGURE 8. Section of the glandular portion of the stomach of a rat given a single dose of 3,000 mg/kg of Aroclor 1254. *This figure illustrates the focal loss of mucosa and the infiltration* by inflammatory round cells. H & E X 50.

300 ppm Aroclor 1248 and six were given 5,000 ppm Aroclor 5460, a polychlorinated triphenyl. The glandular formations in this lesion were highly atypical; penetration of the muscularis mucosae and invasion of the submucosa by the mucosal epithelium were observed. Allen and Carstens[285] reported an effect of toxic fat on the gastric mucosa in 18 of 27 monkeys, *Macaca mulatta*, which consisted of hypertrophy of the gastric mucosa and small gastric ulcers within the mucosa. The toxic fat used in these studies, as we now know, contained chlorinated dibenzodioxins.

It has also been observed that hemorrhaging occurred into the gastrointestinal tract of rat fetuses who were exposed to 2,3,7,8-tetrachlorodibenzo-o-dioxin in utero. It was not stated in the reports whether the gastrointestinal hemorrhages were caused by ulceration of the mucosa.[110,111] Ulceration of the glandular portion of the adult rat stomach was also observed.[113]

Patients with chloracne frequently complained of loss of appetite, nausea, vomiting, and abdominal pain, and Goldmann[111] described a worker with a follicular dermatitis who died six months after exposure to 2,3,7,8-tetrachlorodibenzo-dioxin. At autopsy a ruptured duodenal ulcer and a gastric ulcer were found. Whether any relationship existed between the ulcers and the exposure to the poisonous chemical was not mentioned in the paper.

It should be established if these gastric lesions also occur at lower dietary levels and whether the contamination of the chemicals with various chlorinated dibenzodioxins and furans is responsible for them. Valuable information might be obtained from retrospective studies of workers following occupational exposure. Whether the ulcers are caused by a direct effect of the chemical on the mucosa of the gastrointestinal tract or whether stress plays a primary role in their etiology similar to ulcers that may occur in burned patients for instance (Curling's ulcer) is not clear.

COMMENTS

The acute toxicity of compounds such as the chlorinated biphenyls, the chlorinated naphthalenes, and the chlorinated terphenyls is very low.

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On the other hand, they are poorly broken down in the environment and the metabolism of the biphenyls with more than four chlorine atoms seems to be negligible. Because of these characteristics, the use, wherever possible, of chlorinated biphenyls that consist of mixtures of compounds with one to four chlorines has been proposed. Neither the chlorinated napithalenes nor the chlorinated terphenyls have so far been shown to present a pollution problem.

Whether the various disease entities reviewed in this article are produced by all the different products mentioned in connection with them is not established with certainty. For instance, some of the compounds that produce chloracne or chick edema have been shown to be contaminated with various chlorinated dibenzodioxins and chlorinated dibenzofurans. The possibility remains that the compounds illustrated in Figure 1 are contaminated with these chemicals and the products themselves are not really responsible for the observed symptoms. On the other hand, a number of structurally unrelated compounds may produce the same disease entity.

Some of the chlorinated dibenzodioxins and the chlorinated dibenzofurans are highly toxic. The most toxic is 2,3,7,8-tetrachlorodibenzodioxins, while the dibenzodioxins without any chlorine and those with eight chlorines are much less toxic. The difference in toxicity of these compounds may be partly caused by the fact that they are very poorly dissolved and absorbed. Intravenous toxicity data are thus far not available on most of these compounds.

We also do not know at present if the porphyria which develops after prolonged exposure to a number of technical compounds such as hexachlorobenzene, chlorinated biphenyls, chlorinated dibenzodioxin, and 2,4,5-T is in many instances due to the contamination of these products with chlorinated dibenzodioxins; of course it may be possible that one or more chlorinated dibenzofurans also produce porphyria. It has also not been established whether all compounds that produce porphyria in animals will do so in humans as well.

In general, the exposure of the various population groups to chlorinated biphenyls and other cyclic chlorinated hydrocarbons is at too low a range to induce porphyria. Whether this can also be said for occupational exposure is not known. When production conditions and general hygiene of the workers are poor, porphyria cutanea tarda can apparently occur.[3] It is also not known if the combined effect of different porphyria inducing agents is cumulative. Whether the photosensitivity observed in humans with some of the germicides discussed in this paper is related to an effect on the porphyrin metabolism was not evident from the published literature.

So far the mechanism that causes chick edema, chloracne, X-disease, and liver disease has not been satisfactorily demonstrated. Chick edema disease has been thought to be caused by proliferation of the vascular endothelium. This might explain the fluid accumulation observed in diseased animals, but so far the sequence of events that led to this disease is not really clear and factors other than the embarrassment of the vascular system may play a role in its etiology such as a toxic myocarditis, decrease in serum proteins, and renal failure. More detailed study of the pathology of the various disease entities is needed for a better understanding of the development of the various lesions mentioned.

The chlorinated polycyclic hydrocarbons seem to alter the immune response of certain animal species and perhaps also of people. These very important findings need to be pursued further. Thus far it has not been established beyond doubt whether this is caused by a general debilitating effect on the animal of which atrophy of the lymphoendothelial system may be one manifestation, or whether this is a specific alteration, as we know it from the effects of radiation and exposure to certain alkylating agents. In this respect not enough attention has been paid to the function of the adrenal, and several of the observed symptoms in humans such as the hyperpigmentation suggest hypofunction of the adrenal cortex. Depending on the information obtained from these studies, a tolerance level of 5 ppm in some food products as set by the U.S. Food and Drug Administration may have to be revised particularly since no long-term low level feeding study has been reported in animals.

Many questions have recently been raised about the use of germicides in various toiletries, common soaps, etc. The objection to their use in the specific case of hexachlorophene is its neurotoxic effect, that can also occur in humans, particularly if the skin is defective in some way. Of course, limited localized exposure, such as handwashing or treatment of a small wound, will not produce neurotoxicity.

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In infant nurseries in [illegible] the greatest problems is the constant threat of staphylococcus infection of epidemic proportions. In order to prevent outbreaks of staphylococcus infections, a routine was developed in many hospitals in the U.S. and elsewhere in the early 1960's where infants were washed once daily with a 3% hexachlorophene detergent solution, and in addition the diaper area was washed several times a day. The detergent was subsequently rinsed off more or less vigorously, depending upon the philosophy of the different nurses. In some hospitals the detergent was directly applied to the infant, in others it was first diluted in water. Since the neurotoxic effect of hexachlorophene has become known, many hospitals have changed their policies on the use of hexachlorophene. Another drawback to this routine, in addition to a possible neurotoxic effect, is that hexachlorophene keeps not only the staphylococcus of certain phage types from growing on the skin, but reduces all Gram-positive bacteria,[11,12] which is highly undesirable and may lead to disease. Recently Evans et al.[13,14] have pointed out that a marked annual variation exists in the prevalence of several bacteria in the nares as well as the umbilical cord of newborns. A decline of staphylococcus aureus was observed in the fall; the prevalence of *Escherichia coli* and streptococcus also varied. Staphylococcus epidermis and Enterobacter organisms did not show this fluctuation. Any studies of efficacy undertaken in a clinical setting should take these normal fluctuations into account and it is possible that good general housekeeping practices are ultimately more effective in preventing bacterial disease in newborns than various germicides. Unfortunately, breaks in technic do occur which in many hospitals makes the use of germicides on infants desirable.

The information reviewed in this article shows that the toxic effects of the polycyclic polychlorinated compounds are complex. The mere knowledge of an LD_{50} value in an animal species does not give us a great deal of information about the toxicity of a compound. Toxicity or "toxic effects" are a relative concept and such household items as table salt, vitamins, pepper, and allyl propyl disulfide volatilizing from onions to name a few are also toxic. Nevertheless, we have to learn not to use chemicals indiscriminately, without knowing a great deal about them, particularly their long-range effects, when they are persistent and poorly metabolized. The indiscriminate use of these products and discharge into the environment invariably lead to their restriction or ban, which is accompanied by a great deal of emotionalism, distorted facts, and often great economic loss. Prudence, better judgment, and a critical approach to the usage of chemicals and drugs, particularly an evaluation of whether in specific situations they are necessary or not, may help us avoid these situations in the future. Particular attention should be paid to avoiding unnecessary exposure of children to chemicals that we know little about. Children may react differently from adults and as far as long-term exposure is concerned, they would be the most vulnerable.

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WATER_PCB-SD0000073446

MATERIAL SAFETY DATA SHEET

CORPORATE RESEARCH & DEVELOPMENT

SCHENECTADY, N. Y. 12305

MATERIALS INFORMATION SERVICES

No. 1200

AROCLOR 1254

Date May 1980

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: AROCLOR 1254
DESCRIPTION: Distillation cut of polychlorinated biphenyl (or diphenyl), containing 54%
OTHER DESIGNATIONS: PCB, an Askarel, PYRANOL, GE Material A13B1, CAS # 027 323 188
MANUFACTURER: Material was a product of Monsanto Co., but dropped in 1977. Except for uses specifically exempted and regulated by EPA (for example power transformers), legal manufacture, distribution in commerce, and use of PCB's in USA ended in 1979 under TSCA.

SECTION II. INGREDIENTS AND HAZARDS	%	HAZARD DATA
Mixture of Chlorinated Biphenyls, $C_{12}H_{10-x}Cl_x$:	ca 100	EPA exemption or authorization needed for any measurable exposure*
x: 2 — Approx. %: 0.5 3 — 1 4 — 21 5 — 48 6 — 23 7 — 6 Includes 69 or more compounds with average of 4.98 Cl atom/molecule. Mixture may contain 0-2 ppm chlorinated dibenzofurans.		Rat, Oral LD_{50} Adult 4-10 g/kg Weaning 1.2 g/kg
		Rat, Intravenous LD_{50} 358 mg/kg
		Rat, Oral, TDLo 1220 mg/kg/35 wk (neoplastic effect)

*Current ACGIH 8-hr TWA is 0.5 mg/m^3. NIOSH has proposed a 10-hr TWA of 1.0 µg/m^3. Materials with over 50 ppm PCB content are regulated for handling, storage, records, and waste disposal. EPA criterion in navigable waters is 0.001 µg/L. PCB's.

SECTION III. PHYSICAL DATA

Boiling range at 1 atm, deg C	ca 360-390	Specific gravity (65/15.5 C)	1.5
Vapor pressure at 150 C, mm Hg	<1	Pour point, deg C	10
Water solubility at 25 C, ppm	ca 0.01	Molecular weight (Av)	327
Viscosity at 100 F, cstk	ca 460	Partition Coef. (octanol/water)	>10^4

Appearance & Odor: A light yellow, viscous fluid.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPE
None to boiling point				

Extinguishing Media: Use media appropriate to the surrounding fire conditions. This material has very low combustibility, but it can undergo thermal-oxidative degradation in a fire situation.

Firefighters should use full protective clothing and self-contained breathing equipment when fighting fire where any PCB's are involved

PLAINTIFF'S EXHIBIT 1366

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SECTION V. REACTIVITY DATA

AROCLOR 1254 and other PCB's are nearly inert materials with very high chemical stability; the higher chlorine levels usually give the greater stability. At about 300 to 600 C some PCB's can oxidize to produce chlorinated dibenzofurans which are much greater in toxicity than the PCB's. For complete incineration of PCB's a 2-second dwell time above 2000 F (1090 C) with 3% excess oxygen in the stack is suitable (see Sect. VII).

AROCLOR 1254 shows very little degradation after 3 weeks exposure to direct sunlight.

PCB's are strongly absorbed on particulates or sediments in aquatic systems (streams, lakes, ocean, etc.).

Mixed in activated sludge, biodegradation occurs slowly, but only very slowly or almost not at all with compounds above Cl_4.

GENP 00306/

NO. 1200

SECTION VI. HEALTH HAZARD INFORMATION

TLV (See Sect. II)

PCBs show high levels of bioaccumulation in fatty tissue and very slow metabolism, especially for C_{15} compounds and above. They have become widely dispersed in world-wide environment and in the food chain (much like DDT) since their introduction in 1929. Effective control of PCB discharge into the environment began after 1970.

AROCLOR 1254 has a low vapor pressure, but it can be irritating to the eyes, nose, and throat if misted or heated to produce vapors. Excessive acute and chronic exposures may cause liver damage. Chronic exposure to or ingestion of PCB's (especially when thermally oxidized) can result in chloracne after 1-6 months. There is some evidence of possible carcinogenic risk and adverse reproductive effects with this material. PCBs may appear in the breast milk of an exposed mother.

FIRST AID:

Skin Contact: Clean exposed skin with waterless cleaner, wipe with a disposable towel, then wash with soap and water. Promply remove contaminated clothing. (Control separate disposal of PCB-contaminated materials.)

Eye Contact: Flush promptly & thoroughly with lots of running water for 15 minutes.

Inhalation: Remove to fresh air. Get medical help if symptoms continue.

Ingestion: Get medical help. NIOSH has recommended that vomiting be induced.

Get medical help in all cases of severe exposure, repeated exposures, or persistent symptoms.

SECTION VII. SPILL, LEAK, AND DISPOSAL PROCEDURES

Notify safety personnel of all PCB spills or leaks. Promptly contain spilled material! Prevent its release into the environment! Restrict PCB spill area to trained clean-up personnel; use proper protective gear; follow an established emergency plan.

Stop leakage if possible. Pick up spill. Absorb small spills and residues using a powdered, dry clay. Place leaking containers, picked-up PCBs, and PCB-contaminated materials and refuse into approved, properly labeled, closed containers for storage under controlled, EPA regulated conditions prior to disposal. EPA allows approved storage to 1/1/84.(See Sect.IX.) Storage: 40CFR761.42; Annual report: 40CFR761.45

DISPOSAL: Destroy PCB-containing material by burning in an EPA approved facility. Liquid 50-500 ppm PCB material can be burned as above or landfilled if not ignitable. Non-flowing, PCB-contaminated debris can be disposed of in an EPA approved landfill. (See 40CFR 761; Federal Register, Vol. 44, 31551-4, 66989; Vol.45, 20473.)

SECTION VIII. SPECIAL PROTECTION INFORMATION

Provide highly effective local exhaust ventilation (trap for exhaust vapors) especially if this material is heated or misted. Unless authorized by EPA an isolated system must be used for PCBs.

For nonroutine and emergency conditions of exposure use an approved canister respirator or self-contained breathing equipment.

Prevent skin contact for those who work with PCBs. Use neoprene or polyethylene gloves and apron, safety glasses and/or face shield, and other protective clothing as determined by use conditions. An eyewash station and washing facilities should be available to the work area.

Provide for special handling and disposal of PCB-contaminated materials, including paper towels and clothing (see Sect. VII). Provide locker and shower facilities. Workers must be trained for PCB work, and they must follow good hygienic practice.

Provide pre-placement medical exams for workers with emphasis on liver function, skin condition, and reproductive history. Provide annual medical exams for exposed workers.

SECTION IX. SPECIAL PRECAUTIONS AND COMMENTS

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PCB materials in containers and in equipment must have proper labeling including the date of storage. Short term (up to 30 days) storage of non-leaking PCBs can be done. Long term storage requires an EPA approved facility, including such criteria as roof and walls to shield from rain, impervious base and diking which will contain 25% of stored volume or twice the volume of the largest container, no drains or openings to allow flow loss, and the base must be located above the 100-year flood water elevation. Prevent physical damage to containers. Inspect storage frequently.

Prevent skin contact with PCBs, or with solid products contaminated with PCBs. Prevent inhalation of airborne PCBs. Properly contain PCBs until legally disposed of; do not allow them to escape into the environment!

PCBs, and especially used PCBs, can contain higher toxicity contaminants.

DATA SOURCE(S) CODE: 1-6,20,26,31,36

Judgments as to the suitability of information herein for purchaser's purposes are necessarily purchaser's responsibility. Therefore, although reasonable care has been taken in the preparation of such information, General Electric Company extends no warranties, makes no representations and assumes no responsibility as to the accuracy or suitability of such information for application to purchaser's intended purposes or for consequences of its use.

APPROVALS: MIS CRD J.M. Gilen

Industrial Hygiene and Safety 5-29-80

MEDICAL REVIEW: June 1980

GENP 003068

WATER_PCB-SD0000073448

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION

MANUFACTURER'S NAME: GENERAL ELECTRIC CO.	REGULAR TELEPHONE NO. / EMERGENCY TELEPHONE NO.
ADDRESS: 100 Woodlawn Avenue, Pittsfield, Mass. 01201	
TRADE NAME: PYRANOL	
SYNONYMS: AROCLOR, CHLORINATED BIPHENYL, CHLORINATED BENZENE BLENDS	
SHIPPING NAME[1]: DOT. / IATA	

II HAZARDOUS INGREDIENTS[2]

MATERIAL OR COMPONENT	CAS NO.	%	HAZARD DATA
Askarel/Chlorinated Aromatics			
Trichlorobenzene, MO39-2968			

III PHYSICAL DATA

BOILING POINT, 760 MM HG	410-780°F	MELTING POINT	
SPECIFIC GRAVITY (H_2O = 1)	1.53 g ml^{-1} @ 25°C	VAPOR PRESSURE	Approx. ~ 1MM @ 104°F
VAPOR DENSITY (AIR = 1)	Approx. ~ 6.5	SOLUBILITY IN H_2O % BY WT	
% VOLATILES BY VOL.		EVAPORATION RATE (BUTYL ACETATE = 1)	
APPEARANCE AND ODOR	Clear Liquid with Yellow Tint, Slight Acrid Odor	Ph (AS IS, Ph (1% SOLN.)	

IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)	Cleveland Open Cup - None to Boiling Point	AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL.	None	LOWER	UPPER
EXTINGUISHING MEDIA	None Required		
SPECIAL FIRE FIGHTING PROCEDURES	Material is non-flammable		
UNUSUAL FIRE AND EXPLOSION HAZARD	Gases produced by electric arcing contain high percentage of HCl; the unpleasantness and irritation caused by HCl give ample warning of its presence.		

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GENP 003069

WATER_PCB-SD0000073449

V HEALTH HAZARD INFORMATION

HEALTH HAZARD DATA	HAZARD CLASSIFICATION	BASIS FOR CLASSIFICATION	SOURCE
ROUTES OF EXPOSURE INHALATION	PCBs Vapor 0.5 - 1.0 mgm/cu. meter/8 Hr. Day Trichlorobenzene - 5ppm		TVLs - Threshol Limit Values fo Chemical Substa and Physical Ag in the Workroom Environment wit Intended Changes for 1977
SKIN CONTACT	Dermatitus		
SKIN ABSORPTION			
EYE CONTACT	Eye Irritation		
INGESTION			

EFFECTS OF OVEREXPOSURE

ACUTE OVEREXPOSURE Chloroacne

CHRONIC OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

EYES. Remove from exposure. Wash irrigate eyes.

SKIN Remove from exposure. Wash skin.

INHALATION Remove from exposure. Consult physician.

INGESTION:

NOTES TO PHYSICIAN

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GENP 003070

WATER_PCB-SD0000073450

VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

MPATIBILITY

IAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

VII DISPOSAL, SPILL OR LEAK PROCEDURES

AQUATIC TOXICITY (E.G. 96 HR. TLM):

WASTE DISPOSAL METHOD

Comply with appropriate EPA and State regulations for PCB materials. See ANSI C107.1-1974 "Guidelines for handling and disposal of capacitor - and transforme grade askarels containing polychlorinated biphenyls".

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

Use Fuller's earth to avoid spread of liquid. Immediate sweeping of the area is required with disposal into drum container designated for Pyranol contaminated Fuller's earth - see ANSI C-107 1-1974.

NEUTRALIZING CHEMICALS

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

Good general ventilation - local exhaust ventilation may be necessary in confined areas.

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

NIOSH

RESPIRATORY (SPECIFY IN DETAIL) Gas mask of organic cannister type or self-contained breathing apparatus to be used in emergency if exposed to high concentration of askarel or its arced products.

EYE

Safety glasses or eye shields

GLOVES

Gloves of neoprene, polyethylene or Vitron

OTHER CLOTHING AND EQUIPMENT

Use aprons of neoprene, polyethylene or Viton

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GENP 003071

WATER_PCB-SD0000073451

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44R1387

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME	EMERGENCY TELEPHONE NO.
General Electric Company	Rome, Ga. 404-234-0211 ~~Pittsfield, Ma. 413-494-1110~~
ADDRESS (Number, Street, City, State, and ZIP Code)	
Redmond Circle, Rome, Ga 30161 or 100 Woodlawn Ave., Pittsfield, Mass. 01201	
CHEMICAL NAME AND SYNONYMS: Chlorinated Biphenyl/Chlorinated Benzene Blend	TRADE NAME AND SYNONYMS: Pyranol, Aroclor
CHEMICAL FAMILY: Askarel/Chlorinated Aromatics	FORMULA

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	410-780°F	SPECIFIC GRAVITY (H_2O=1)	1.56-1.57
VAPOR PRESSURE (mm Hg.)	Approx. 1MM @ 104°F	PERCENT, VOLATILE BY VOLUME (%)	Rome, Ga. 60 Pittsfield, Mass 40
VAPOR DENSITY (AIR=1)	Approximately 6.5	EVAPORATION RATE (_____ =1)	6 Hrs. @ 212°F 30 - 37%
SOLUBILITY IN WATER	Nil		
APPEARANCE AND ODOR	Clear Liquid with Yellow Tint, Slight acrid odor		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used): Cleveland Open Cup None to Boiling Point	FLAMMABLE LIMITS: None	Lel	Uel
EXTINGUISHING MEDIA: None Required			
SPECIAL FIRE FIGHTING PROCEDURES: Material is nonflammable	737820		
UNUSUAL FIRE AND EXPLOSION HAZARDS: Gases produced by electric arcing contain high percentage of HCl; the unpleasantness and irritation caused by HCl give ample warning of its presence.			

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(Continued on reverse side)

WATER_PCB-SD0000073452

SECTION V - HEALTH HAZARD DATA

Vapor 0.5 - 1.0 mgm/cu. meter/8 Hr. Day

Dermatitus; Possible Cloracne - Eye Irritation

See ANSI C107.1 - 1974

EMERGENCY AND FIRST AID PROCEDURES

1. Remove from exposure.
2. Wash skin; irrigate eyes.
3. Consult physician.

SECTION VI - REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		
	STABLE	X	

INCOMPATABILITY (Materials to avoid)

HAZARDOUS DECOMPOSITION PRODUCTS: HCl when arced electrically

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	X	

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Use Fuller's earth to avoid spread of liquid. Immediate sweeping of the area is required with disposal into drum container designated for Pyranol contaminated Fuller's earth - see ANSI C-107.1-1974.

WASTE DISPOSAL METHOD

Incineration

See ANSI C107.1-1974 "Guidelines for handling and disposal of capacitor - and transformer-grade askarels containing polychlorinated biphenyls".

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify type) Gas mask of organic cannister type or self-contained breathing apparatus to be used in emergency if exposed to high concentration of askarel or its arced products

VENTILATION	LOCAL EXHAUST	SPECIAL
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES: Use gloves of neoprene, polyethylene or Viton

EYE PROTECTION: Safety glasses or eye shields

OTHER PROTECTIVE EQUIPMENT: Use aprons of neoprene, polyethylene or Viton.

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid open exposure of hot askarels (> 130°F). Be alert for possible allergic reactions. Normally shipped in metal containers. After handling, wash hands with warm water and soap before eating, drinking, smoking or use of toilet facilities.

OTHER PRECAUTIONS

GENP 003077

WATER_PCB-SD0000073453

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

Form Approved
OMB No. 44R1387

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917

SECTION I

MANUFACTURER'S NAME	EMERGENCY TELEPHONE NO.
General Electric Company	Rome, Ga. 404-234-0211 ~~Pittsfield, Ma. 413 494-1110~~
ADDRESS (Number, Street, City, State, and ZIP Code)	
Redmond Circle, Rome, Ga. 30161 or 100 Woodlawn Ave., Pittsfield, Mass. 01201	
CHEMICAL NAME AND SYNONYMS: Chlorinated Biphenyl/Chlorinated Benzene Blend	TRADE NAME AND SYNONYMS: Pyranol, Aroclor
CHEMICAL FAMILY: Askarel/Chlorinated Aromatics	FORMULA

SECTION II - HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES, & SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)

SECTION III - PHYSICAL DATA

BOILING POINT (°F.)	410-780°F	SPECIFIC GRAVITY (H_2O=1)	1.56-1.57
VAPOR PRESSURE (mm Hg.)	Approx. 1MM @ 104°F	PERCENT, VOLATILE BY VOLUME (%) Rome, Ga. / Pittsfield, Mass	60 / 40
VAPOR DENSITY (AIR=1)	Approximately 6.5	EVAPORATION RATE (_____=1) 6 Hrs. @ 212°F	30 - 37%
SOLUBILITY IN WATER	Nil		
APPEARANCE AND ODOR	Clear Liquid with Yellow Tint, Slight acrid odor		

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
Cleveland Open Cup None to Boiling Point	None		

EXTINGUISHING MEDIA: None Required

SPECIAL FIRE FIGHTING PROCEDURES: Material is nonflammable

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UNUSUAL FIRE AND EXPLOSION HAZARDS
Gases produced by electric arcing contain high percentage of HCl; the unpleasantness and irritation caused by HCl give ample warning of its presence.

GENP 003044

(Continued on reverse side)

WATER_PCB-SD0000073454

SECTION V - HEALTH HAZARD DATA

Vapor 0.5 - 1.0 mgm/cu. meter/8 Hr. Day

Dermatitus; Possible Cloracne - Eye Irritation

See ANSI C107.1 - 1974

EMERGENCY AND FIRST AID PROCEDURES

1. Remove from exposure.
2. Wash skin; irrigate eyes.
3. Consult physician.

SECTION VI - REACTIVITY DATA

STABILITY	UNSTABLE		CONDITIONS TO AVOID
	STABLE	X	

INCOMPATABILITY *(Materials to avoid)*

HAZARDOUS DECOMPOSITION PRODUCTS HCl when arced electrically

HAZARDOUS POLYMERIZATION	MAY OCCUR		CONDITIONS TO AVOID
	WILL NOT OCCUR	X	

SECTION VII - SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Use Fuller's earth to avoid spread of liquid. Immediate sweeping of the area is required with disposal into drum container designated for Pyranol contaminated Fuller's earth - see ANSI C-107.1-1974.

WASTE DISPOSAL METHOD

Incineration

See ANSI C107.1-1974 "Guidelines for handling and disposal of capacitor - and transformer-grade askarels containing polychlorinated biphenyls".

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION *(Specify type)* Gas mask of organic cannister type or self-contained breathing apparatus to be used in emergency if exposed to high concentration of askarel or its arced products

VENTILATION	LOCAL EXHAUST	SPECIAL
	MECHANICAL *(General)*	OTHER

PROTECTIVE GLOVES Use gloves of neoprene, polyethylene or Viton

EYE PROTECTION Safety glasses or eye shields

OTHER PROTECTIVE EQUIPMENT

Use aprons of neoprene, polyethylene or Viton.

SECTION IX - SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING

Avoid open exposure of hot askarels (> 130°F). Be alert for possible allergic reactions. Normally shipped in metal containers. After handling, wash hands with warm water and soap before eating, drinking, smoking or use of toilet facilities.

OTHER PRECAUTIONS

GENP 003075

WATER_PCB-SD0000073455

Monsanto

FROM (NAME & LOCATION) W. B. Papageorge - St. Louis

May 20, 1971

cc H. S. Bergen
C. J. Smith

SUBJECT PCB ENVIRONMENTAL PROBLEM
APRIL STATUS REPORT

TO :
P.J.A. Marsh - Brussels
W. S. Clark
J. R. Durland - Tokyo
E. V. John
R. E. Keller - 2nd Street
R. M. Kountz
T. L. Gossage
P. S. Park
W. R. Richard
J. R. Savage
E. P. Wheeler

MARKETING:

The plasticizer Aroclor replacement program is proceeding very well, being about twenty percent over forecast for April based on pounds sold. Several major accounts, including W. R. Grace, Chrysler, Nashua, and DuPont are now purchasing the replacement products.

E. G. Wright from Anniston Plant will visit Westinghouse, S. Boston, Virginia, on May 4, 1971 to assist in resolving PCB containment, collection and disposal so as to avoid environmental pollution.

Jeno's, Inc., Duluth, Minnesota, and Interstate Brands, Chicago, Illinois, converted small FR systems to Therminol 66. Both are food cooking applications.

Jiffy Fry, Inc. (Div. Foremost-McKesson), Crookston, Minnesota, had FR leakage through cooling gland in pump, resulting in french-fried potatoes contaminated with FR-1. Will be able to convert system to Therminol 66 in July. Approximately 5,000 gallons of fluid involved.

ENGINEERING:

CEA-2415 Waste Incinerator

Construction is complete and water bridging scheduled to start May 16. Curing of the oxidizer refractory scheduled to start May 18 and chemical feed will be started later in the week.

PLAINTIFF'S EXHIBIT 1452

CEA-2417 MCS 1016 Distillation

Construction on all elements was continued; however, a further restriction of plant manpower has caused a further slippage in the estimated mechanical completion to August 1, 1971. Design is continuing on the necessary additions required to produce orthomonochlorobiphenyl.

CEA-2451 NC-Phosphates

Basic design is complete and detailed mechanical design has been started. A few items needed for the June run are currently being installed. Limited plant construction manpower has caused slippage in total project mechanical completion to mid-1972.

JAPAN:

In advance of any action by the government, the manufacturers of pressure-sensitive copy paper, including NCR Japan, have all discontinued the use of chlorinated biphenyl. Thus, NCR Japan has stopped using both MMK's Aroclor and the competitive product, Kaneclor, and has returned stocks to the manufacturer. So, as of this moment, no new encapsulated PCB's are being processed. It will take some while for the inventory of copy paper to be replaced. In spite of some deficiencies, a by-product, KA Oil, is being used as a replacement; this is a refined hi-boiler bottoms from a petroleum cracking operation in which Kaneka cracks naphtha to mixed ethylene and acetylene--the bottoms are a great mixture of all kinds of aromatics. Odor is a problem, but the price is right and apparently some kerosene can be utilized as diluent.

EUROPE:

1. UK press comment arising from "New Scientist" article on Monsanto's response to the PCB problem has generally been very favorable. Publication of this article coincided with the release of the NERC report on the Irish Sea Bird Wreck and press comment has generally linked both items. We have also agreed to an interview for Independent Television's "News at Ten", one of the major UK television news programs.

2. Contract proposals for the Purle Waste agreement are to be reviewed in St. Louis at month end.

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3. The Swedish National Environment Protection Board has recommended the Government to control the use of PCB's and ban its use for some applications. It is expected that legislation will come into force next January. We expect to meet the Director of Research for the Board next month. It is reported that similar action may follow in Finland.

MEDICAL:

Through arrangements made by Sam Pickard, Messrs. Papageorge, Wheeler and Pickard visited Dr. William M. Upholt who at the time was Staff Director of the Pesticides Advisory Committee of the Environmental Protection Agency (the following week Mr. Ruckelshaus reorganized EPA and appointed Dr. Upholt Deputy Assistant Administrator and Director of the Office of Pesticide Programs in EPA). Monsanto's involvement in the PCB problem was discussed in detail in a chronological fashion including the efforts to define the problem, the development of a business plan to prevent escape to the environment and the development of the chronic and other toxicity data.

The visit was timely in that a meeting of a "blue ribbon" Pesticides Advisory Committee to EPA chaired by Dr. Emil Mrak was scheduled for the following two days during which the overall environmental aspects of PCB's was to be discussed. Subsequent to that meeting, Dr. Upholt requested that we provide copies of all of the material we had left with him to be sent to Dr. Mrak, Chancellor Emeritus of the University of California, Dr. Gordon Guyer, Chairman of the Dept. of Entomology of Michigan State University and Mr. James Terrill, Jr. of Westinghouse Electric Corporation. These gentlemen plus Dr. Norton Nelson of NYU, who is a personal friend of Mr. Wheeler, and two other scientists whom we know through our association with the Food Protection Committee make up the Pesticides Advisory Committee.

Dr. Upholt indicated to Sam Pickard following the committee meeting that he did not expect any recommendations for precipitous action (such as banning PCB's) to develop from the committee.

PUBLIC RELATIONS: 738371 NEV 025116

A two-page article appeared in Chemical Week on Monsanto's PCB environmental program. This feature, plus the New Scientist and Science Journal article from the U.K., will

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be sent to science editors and other writers who have done PCB stories in the past.

A correspondent for the National Observer, doing a story on PCB, requested information on our program. Material was furnished by phone and follow-up letter. Background information was also sent to the Seattle Times following their first PCB article.

RESEARCH:

Bio-Test Tissue Analysis

An inventory of all Bio-Test tissues held by Monsanto for PCB analysis has been prepared as well as an estimate of those retained by Bio-Test Laboratories. Analysis of all tissues (muscle, fat, liver and kidney) from the first sacrifice (3 month exposure) of the two year chronic rat toxicity study have been completed.

Customer and Plant Support Analysis

No. of Samples	Sample Source	Sample Description	Status of Analysis
1	NCR (Dayton)	Plant effluent composite	Completed
3	Ameripol	Plant effluent composite	Completed
2	J. F. Queeny	Plant effluent composite (Feb. & Mar.)	Completed
1	Rogansky Feed Co.	R-83	Completed
1	C. F. Mueller Co.	Vermicelli	Completed
14	R. A. Kimerle/ CRD	Coagulated Anniston plant effluents	Completed
2	Goodyear Point Pleasant, West Virginia	Plant effluents	Completed
1	Kimberly Clark (Moraine Mill)	Plant effluent	Completed
25	Central Soya	Products associated with commercial chicken raising	8/25 Completed
8	Westinghouse Aquatechnics	Treated Plant effluents	Scheduled for Completion

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NEV 025117

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Polychlorinated Terphenyls (PCT)

Hexane extraction of effluent water spiked with Aroclor 5460 demonstrated that it is not a suitable solvent for quantitative extract of PCTs from plant effluent samples. The recovery (50±1%) on duplicate samples was reproducible but much too low to be used for isolation of PCTs from water. Quantitative extractions of PCTs were obtained with either benzene or dichloromethane. The extraction recoveries using dichloromethane (99.0%) were calculated from UV absorption data. For benzene, total organic chlorine was determined using a sodium biphenyl-silver nitrate titration procedure.

MCS 1043, MCS 1016, Aroclor 1221, Aroclor 1242, Aroclor 1254, and Arobromochlor 1232

The present SCAS tests on MCS 1043, MCS 1016, Aroclor 1221, Aroclo 1242, and Aroclor 1254, and Arobromochlor 1232 have been halted an the total residues from each unit isolated for detailed GC analysi

Two new test units were started on MCS 1016 and the Aroclor 1142 distillation residue, at a 5 mg feed level and a 5 day time cycle, in hopes of demonstrating differences between these materia In the 1st cycle, 58% of the MCS 1016 was lost and 53% of the distillation residue. EC/GC analysis of samples from both units did not show any isomeric alteration indicating that the initial losses are due to a physical phenomenon, i.e., adsorption on the glass, etc.

Aroclor 5460, Aroclor 5432, ARobrom 5465, and Hexabromobiphenyl

Current scheduling should allow sampling and analysis of these four SCAS units to start in the first or second week of May.

Environmental Studies-Ruabon

An informal meeting of the Pesticide Chemicals Group was attended at Unilever, Welwyn, Hertfordshire. At this meeting we obtained very useful information on the identification of GLC peaks using capillary columns with Apiezon L as stationary phase. Results of feeding trials on pigeons and quail using Aroclors 1242 and 1254 and some pure isomers were reported by Ministry of Agriculture workers, with particular reference to degradation residues.

Koeman and Vos from Utrecht reported on the distribution of PCBs in the Rhine Estuary and on relative toxicities of commercial PCB products.

Other papers included one from the Fisheries Laboratory on the distribution of PCBs in fish in U.K. coastal waters. This was interesting in that it showed very low levels in fish taken from the Bristol Channel (Newport Plant!), but very high levels in the Clyde Estuary. Explanations for this distribution do not seem very conclusive.

WATER_PCB-SD0000073460

Biodegradation-Ruabon

Improvement in analytical techniques using capillary column GLC has yielded further results on degradation residues which suggest that MCS 1016 may be a bigger improvement over Aroclor 1242 than we had previously estimated. We have also had access to other workers' results which have enabled better identification of chromatogram peaks to be made. We also have some results of feeding trials which show that degradation of many isomers in animal organs is different from that induced by micro-organism of the types we have so far studied. On the basis of these results we conclude that residues from MCS 1016 would be very small and our present view is that MCS 1016 does provide a very significant improvement over Aroclor 1242 from the environmental viewpoint. Further work is planned to substantiate these views during the next few weeks.

Aroclor Pollution Study-Anniston

Carbon Adsorption Study

PR&D Report No. 2 covering the evaluation of Aroclor removal from waste streams by carbon adsorption was issued under Job #446-514.

Pilot Clarification Study

The pilot clarification unit has been operating since March 15 with minimum mechanical difficulties. Initial test runs were made with optimum coagulant concentrations -- 15 ppm of bentonite clay and 1.5 Betz polyelectrolyte 1170 (determined in lab by jar test) -- at a 5 gpm flow to the clarifier. Results (Table I) indicate that the floc is not consistent in reducing the Aroclor level to 10 ppb although the expected solids level is realized. Of interest here is the fact that solids in the plant effluent averaged approximate 50 ppm during the test period. These levels are considerably lowe than the 100 to 1000 ppm values recorded when this study was initiated. As a result, more bentonite clay is being added to provide more surface area for Aroclor to be adsorbed.

Table II contains the results of the study in which the clay concentration in the feed was increased to 30 ppm without a significar reduction in the Aroclor levels.

At this point it was felt that a close approximation of the optimum clay concentration could be realized in a less time-consuming, batch type adsorption operation in the premix tanks (i.e., whose walls were believed to be saturated with Aroclor from continuous exposure). This effort proved fruitless except there were some indications that clay would reduce the Aroclor level to the desired value.

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Table III shows the results of increasing the clay concentration to 120 ppm after resorting again to the original treatment approach. The last few samples show promise; however, more data is being collected at this point to verify previous results.

Upon the completion of this phase of the work, a revised work plan will be issued.

NEV 025120

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TABLE I

AROCLOR REMOVAL BY FLOCCULATION CLARIFICATION

Test Conditions:

Clay conc. in feed - 15 ppm
Polymer conc. in feed - 1.5 ppm
Flow through clarifier - 5 gpm

	Avg. Influent Concentration				Avg. Effluent Concentratio			
Volume Treated (gal.)	Sus-pended Solids	A-1221	A-1242	A-1260 or A-1254	Sus-pended Solids (ppm)	A-1221	A-1242	A-125
9,600		446	240	70		31	11	6
16,800		22	16	--		15	23	--
25,800		210	60	--		NDA	1	--
		--	--					
		--	--					
41,600	29	100	14	--	18	72	8	--
48,800		196	38	--		100	10	--
52,400	52	146	30	--	2	110	12	--
57,600	40	560	.7	--	11	66	6	--
64,800	14	105	28	--	2	58	9	--

NEV 025121

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TABLE II

AROCLOR REMOVAL BY ADSORPTION-FLOCCULATION

Test Conditions:

Avg. flow - 5 gpm
Bentonite clay concentration in feed - 30 ppm
Betz polymer 1170 in feed - 1.5 ppm

	Avg. Influent Concentration				Avg. Effluent Concentrati			
Volume Treated (gal.)	Suspended Solids (ppm)	A-1221	A-1242	A-1254	Suspended Solids (ppm)	A-1221	A-1242	A-12
1,500	24	86	18	--	50	41	7	-
13,200	46	320	40	--	7	64	5	-
20,400	314	236	117	--	8	19	15	-
27,600	65	146	54	--	10	63	7	-
34,800	13	290	160	--	3	88	7	-
42,000	9	154	10	--	5	17	4	-
49,200	38	73	25	--	22	25	4	-

NEV 025122

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TABLE III

AROCLOR REMOVAL BY ADSORPTION-FLOCCULATION

Test Conditions:

Clay concentration in feed - 120 ppm
Polymer concentration in feed - 1.5 ppm

	Avg. Influent Concentration				Avg. Effluent Concentrati			
Volume Treated (gal.)	Suspended Solids (ppm)	A-1221	A-1242	A-1254	Suspended Solids (ppm)	A-1221	A-1242	A-12
1,650		480	380	--		80	30	--
8,850		210	13	--		6	2	--
16,050		52	42	--		11	9	--

NEV 025123

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MANUFACTURING:

W. G. Krummrich Plant

I. PCB Level In Sewer

Aroclor losses for April averaged 1#/day and waste treatment plant effluent averaged 24#/day. Losses from Dept. 246 appear higher than previously reported due to rerouting of several department flows including some that contain Therminol units. The Pollution Group will try to find a new sample location which will isolate the Aroclor Department losses.

II. Program To Eliminate Sewered PCB's From Using Departments

A. Therminol Unit Change-Outs

Dept.	Status
255	Complete
222 - ONA	Complete
222 - PNA	Drained in April
244	Complete
243 (4 units)	3 units complete. 4th unit will be changed out by 5/7.
270	Completed in April.
275	Completed in April
258	Completed in April
275	Department down and unit drained. Will complete project work for operation with T-66 by end of May.
245	Scheduled to be changd out by 5/15.
239	Scheduled for mechanical completion by May 15.

B. All units using Pydraul A-200 in Dept. 251 changed out to Pydraul A-200B.

C. Continuing to drum liquid caught at catch tank at Dept. 218. Drumming of liquid caught at catch tanks at Dept. 217 started about mid-April. Program begun to determine PCB sewer losses resulting from Aroclor carried out as vapor in the HCl off-gas from the Aroclor Department. Drowning jet at Dept. 218 and CS acid scrubbers at Dept. 217 are potential points of entry to the sewer.

NEV 025124

WATER_PCB-SD0000073466

Anniston Plant

PCB Levels In Sewer

Current level Aroclor losses during April 1971 averaged 0.65#/day (71 ppb).

Project Evaluations

1. #1 HCl pit will not be used until PR&D solids removal work is completed.

   #2 HCl pit is performing well enough to permit this delay

2. Samples from 36 storm sewers recently repaired to avoid infiltration show definite decrease in PCB. Further analytical work required to determine magnitude.

3. Engineering work resumed on collection and disposal of spent carbon from HCl Department. Premise target is 6/1.

Spills

There were no known spills of Aroclor during the month.

W. B. PAPAGEORGE

ms

NEV 025125

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WATER_PCB-SD0000073467

To: Corporate Management Committee April 20, 1970

Minckler, Mason, Bragen, Papageorge

PRESENTATION OF THE PCB MANAGEMENT PLAN

On November 17, 1969 we discussed with you the PCB problem and outlined a program for coping with it.

* (Show transparency on pounds-dollars-return)

On this chart we have summarized the total worldwide business. Our concern is great because of the $21 M worldwide business involved with gross profits of $10 M on a net investment of approximately $9 M.

* (Show transparency on non-degradable Aroclors)

The next chart summarizes the business which now depends on the non-degradable (persistent) Aroclors. Solid Aroclors, which are not an environmental problem and Aroclor 1221 which has been demonstrated in our laboratories to respond to degradation, have been excluded.

NEV 022748

In November, the decision was made to develop a plan to phase out the manufacture of Aroclor 1254 and 1260. Since then, as you well know, the pollution hysteria continues to grow and specifically in the area of PCB's the number of laboratories,

PLAINTIFF'S EXHIBIT 14/55

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both governmental and university, involved continues to increase as we predicted.

At this meeting, I wish to bring you up-to-date on the latest developments, the progress we have made, the need for modifying our strategy, and our new strategy.

Since November, the press has been relatively quiet except for the recent flurry following Congressman Ryan's Press Conference. Two publications have appeared which implicate PCB. The January-February, 1970 issue of Environment published in St. Louis carried an article by Dr. Robert Risebrough and Virginia Brodine. The presence of PCB in samples of human milk is first publicly reported in this article. An article by Dr. David Peakall of Cornell University appeared in the April issue of Scientific American. In this article, the effect of DDT and PCB on egg shell formation and reproduction is described, and emphasizes that the problem has been apparent since the introduction of

NEV 022749

WATER_PCB-SD0000073469

DDT to the environment. Three newspaper articles were noted, one in the Miami Herald, another in the Tampa Tribune, and the third in the Ann Arbor News, again describing the effects of DDT and PCB on the environment. The Florida papers referred to the effect on shrimp of hydraulic fluid which was traced to our Pensacola plant.

In March, we held discussions with Dr's. Risebrough and Olcutt at Berkeley, California. They are personally convinced PCB's are harmful and were pleased that Monsanto was concerned and cooperative.

Also in March, we participated with about 50 technical representatives representing State, Federal and Canadian Water, Fish, Wildlife regulatory agencies in a very objective discussion in Duluth, Minnesota. Analytical techniques, monitoring of the environment and toxicity of PCB were discussed. Absolute identification of PCB and its effect on the environment were identified

NEV 022750

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as requiring considerable research. Concern was expressed by many present that some agency such as the FDA would take precipitous action before adequate information could be gathered; which was believed by many to require at least one year. Monsanto's presence and offer to cooperate was appreciated.

About two weeks ago, we received word from a Dr. Hill, Ohio State Health Department, that his laboratory had found PCB's in milk from an area around Columbus, Ohio. They believed they traced the source of PCB to deteriorating coating applied to silos in 1967. This coating was formulated using Aroclor 1254. We requested samples which our laboratory could analyze and our analytical work has confirmed that chlorinated compounds similar to our Aroclor 1254 are present.

During our discussions with Dr. Hill, we were told that the FDA was considering establishing a PCB limit of 0.2 ppm in food. In pursuing this further, Dr. Kelly was subsequently told by

WATER_PCB-SD0000073471

the FDA personnel that the FDA will, in a few weeks, advise their offices that PCB contents exceeding 0.5 ppm in milk and 5 ppm in food would subject the milk or food to confiscation.

In the U.K. we are, of course, also experiencing considerable concern. The Ministry of Agriculture, Fisheries and Food has repeatedly requested Monsanto to divulge the names of our major customers. From the U.S. point of view, we were reluctant to divulge this information because of possible adverse consequences worldwide. From the U.K. point of view, divulging the customer's name with assurances that it would be kept in confidence is considered the wiser approach in the long run. We are receiving permission from NCR to divulge their name and will approach the Ministry on a confidential basis.

NEV 022752

In Europe, we have assumed worldwide leadership and contacted the representatives of the European producers. Initially, their response was indifferent. Subsequently, Bayer, Germany

WATER_PCB-SD0000073472

and Prodelac, France have become more concerned, have initiated programs of their own, and are cooperating with information exchange. The Italian producer does not believe he has a problem. MMK, Japan, has been fully informed of our progress.

During our meeting with General Electric representatives in late January, we discussed our decision to discontinue the manufacture of Aroclor 1254 and 1260. GE immediately challenged the decision on the basis that information available was not adequate to incriminate these Aroclors for electrical use, since other non-degradable ingredients used in dielectric fluids have not been identified in the environment, and that the adverse consequences of fires and explosions far exceed the potential threat to the environment. They also indicated that at the proper time they would be willing to have an officer of their company go on record as stating that the unavailability of these materials would result in serious power blackouts. Without Aroclors the maintenance of existing equipment would be impossible. Replacement of this equipment would be extremely costly, primarily

NEV 022753

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because of the increased space required by the replacement. The power companies could not provide the uninterrupted service expected.

As you can see, we are still very much on the defensive, however, considerable progress has been made. In our plants, control of emissions is progressing extremely well. After initial audits, all plants instituted programs for control of spillage, leaks and disposal. Our Newport plant installed and placed in service this month an interceptor pit to hold major spills. Anniston and the Krummrich plant are proceeding with similar installations. These should be in service by the end of the third quarter. Reduction in PCB contents of our plant streams below the solubility level in water (50-200 ppb) will be achieved only after research work now underway is completed and plant units are designed and installed. Completion of this work is expected to occur in late 1971.

(Show transparency on plant effluent)

WATER_PCB-SD0000073474

A major development has been achieved by our research department in refining our analytical procedures to the level that we now possess capabilities far exceeding many laboratories and unsurpassed by any. We are actively communicating our methodology to other laboratories to improve the type of information being generated and published. Our objective is to be considered experts with relaible results.

Toxicity studies are now in the tenth month. Data to date indicate that Aroclors are mildly toxic to mammals, however, it is highly unlikely that this will be a significant factor in any decision regarding the banning or restricting of the use of Aroclors.

Biodegradation studies have, thus far, confirmed our initial beliefs that the lower chlorinated biphenyls would degrade easily. We were disappointed in the resistance to degradation of some of the isomers in Aroclor 1242. This would tend to

NEV 022755

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confirm the belief that some of the 5 and 6 chlorinated biphenyls being found in the environment could be residue from degraded Aroclor 1242. We are actively pursuing the possible use of distilled Aroclor 1242 with degradable components as a possible substitute with minimum loss of other favorable characteristics; e.g. fire resistance.

* (Show transparency on Aroclor Applications)

This chart is a summary of the major uses of the Aroclors which have shown resistance to degradation. Solid Aroclors are not included.

A critical review of these uses was completed. We have classified these uses into three categories. Business we discontinue, business we retain and business we retain with product substitution.

Uses in which control to prevent environmental contamination is virtually impossible are being immediately discontinued as shown on this chart.

NEV 022756

* (Show transparency)

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The use of Aroclors to extend pesticide persistence, a use developed by the U.S. Department of Agriculture, is not one we have been recommending, however. We still have some extremely minor sales through distributors which we are discontinuing.

We have recommended to the U. S. Department of Agriculture to reject Aroclors as an approved inert material when pesticide reregistrations occur this year.

We are taking immediate steps to terminate the use of Aroclors for cutting oil, medicinal, dental and cosmetic applications.

We don't know where our distributors are selling Aroclors. To obtain better control of the end uses of Aroclors, we will immediately take steps to terminate distributor selling arrangements as soon as possible.

There are many applications which are extremely difficult to control which we will discontinue, but we will retain the business with acceptable product substitutes.

WATER_PCB-SD0000073477

(Show transparency)

This chart is a summary of those applications for which we either have or will have substitutes. The formulations for sealants, coatings and Industrial Fluids consist of biodegradable Aroclors, chlorinated terphenyls (Aroclor 5000 Series) or phosphate esters.

In the NCR paper application, we are applying considerable pressure on NCR to accelerate the conversion to products we manufacture or propose to manufacture. At present, HB-40 appears promising in the U.K. after one month of plant trials. Alkylated biphenyl appears promising for the U.S. application. We can at present satisfy the HB-40 needs for U.K. by sacrificing some low profit plasticizer business. However, capital funding will be required to expand our production capabilities. We do not at present manufacture alkylated biphenyls, but we have the technology. Facilities must be designed and installed to provide for this application.

NEV 022758

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WATER_PCB-SD0000073478

Successful control to prevent contamination is possible in systems in which Aroclors are sealed. We are working very closely with our customers to educate and motivate them and have offered technical assistance on their disposal and effluent problems.

Aroclor business which we will retain is shown on this chart. (Show transparency)

In summary, we have assumed worldwide leadership in facing the PCB problem. We have educated and pressured our customers and co-producers to fully appreciate the problem. We are leaders in analytical methodology. Our plants are effectively reducing the PCB content of their effluent. We have without waiting for any orders from any agency, selectively and voluntarily discontinued the sale of Aroclors for some uses. We are aggressively developing and introducing product substitutes for uses difficult to control. Where control is possible, we are working hard at making it effective and keeping the business.

NEV 022759

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WATER_PCB-SD0000073479

We are doing this and at the same time, maintaining the image of Monsanto as a responsible member of the business world genuinely concerned with the welfare of our environment.

NEV 022760

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MONSANTO WORLDWIDE AROCLOR BUSINESS

POUNDS/YEAR	104 M	(70 M in Functional Fluids 34 M in Plasticizers)
SALES/YEAR	$21 M	($15 M in Functional Fluids $ 6 M in Plasticizers
GROSS PROFIT/YEAR	$10.0 M	($7.5 M in Functional Fluids $2.5 M in Plasticizers)
GROSS INVESTMENT	$13 M	($8.8 M net investment)
ROI	10.5%	
WORLDWIDE M/I	62%	
MONSANTO PRODUCTION LOCATIONS:	USA (2 plants, Anniston, Alabama Sauget, Illinois)	
	U.K. (Newport)	
	JAPAN (Yokkaichi)	
OTHER PRODUCERS:	Bayer, Prodelec, Caffaro, Flick, Kanegahuchi, and several Eastern European producers (all ex-USA)	

NEV 022761

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WATER_PCB-SD0000073481

WORLDWIDE AROCLOR BUSINESS

PRODUCTS CONTAINING NON-DEGRADABLE AROCLORS

POUNDS/YEAR	92 M	(70 M in Functional Fluids 22 M in Plasticizers)
SALES/YEAR	$18 M	($15 M in Functional Fluids 3 M in Plasticizers

NEV 022762

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NR

PCB CONTENT

PLANT EFFLUENT

Anniston

June, 1969	50 pounds per day	(5,000 ppb)
Present	5 pounds per day	(500 ppb)
October, 1970	2 pounds per day	(200 ppb)
January, 1971	.5 pounds per day	(50 ppb)
September, 1971	.1 pounds per day	(10 ppb)

Sauget

April, 1969	700 pounds per day	(3,500 ppb)
March, 1970	200 pounds per day	(1,000 ppb)
Present	65 pounds per day	(325 ppb)
September, 1970	55 pounds per day	(275 ppb)
October, 1970	10 pounds per day	(50 ppb)
September, 1971	2 pounds per day	(10 ppb)

Newport

Present	30 pounds per day	(3,000 ppb)

NEV 022763

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AROCLOR APPLICATIONS

APPLICATION	M DOLLARS/YEAR
Industrial Fluids	5,000
Transformers	6,000
Capacitors	3,000
Heat Transfer	1,300
NCR Paper	2,000
Coatings	200
Emulsion Adhesives	200
Sealants	200
Wax Modification	200
Miscellaneous Plasticizers	200

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AROCLOR BUSINESS TO BE DISCONTINUED IMMEDIATELY

APPLICATION	SALES M DOLLARS/YEAR	COMPLETION DATE
Pesticide Extender	$10	Completed
Medicinal, Dental, Cosmetic	90	June, 1970
Cutting Oils	50	June, 1970
Distributor Sales - Plasticizers		September, 1970

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AROCLOR BUSINESS TO BE RETAINED WITH PRODUCT SUBSTITUTES

APPLICATION	SALES M DOLLARS/YEAR	COMPLETION DATE
Sealants	$ 200	December, 1970
Coatings	200	December, 1970
Adhesives	200	December, 1970
Wax Modification	200	December, 1970
Miscellaneous Plasticizer	200	December, 1970
NCR Paper	2,000	April, 1971
	$3,000	
Industrial Fluids		
Pydraul AC	$ 300	September, 1970
Pydraul AC-WG	5	September, 1970
Pydraul 625	300	September, 1970
Pydraul F-9	700	December, 1970
Pydraul A-200	800	December, 1970
Pydraul 540	50	December, 1970
Pydraul 280	150	December, 1970
Pydraul 135	500	June, 1971
Pydraul 150	500	June, 1971
Pydraul 230	50	June, 1971
Pydraul 312	1,600	June, 1971
Santosafe 100, 150, 300	50	June, 1971
	$5,005	

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AROCLOR BUSINESS TO BE RETAINED

APPLICATION	SALES M DOLLARS/YEAR	REMARKS
Transformers	$3,000	In sealed systems. Can exercise tight control at customer plants and repair shops. Contaminated material to be reclaimed or safely destroyed.
Capacitors	$6,000	In sealed units. Can exercise tight control at customer plants and repair facilities. Contaminated material to be reclaimed or safely destroyed. Disposal of old capacitors presents problems. Development of degradable Aroclors is underway.
Heat Transfer	$1,300	Used in closed systems. Control can be exercised. We will discontinue the sale of Aroclors for heating systems used in food preparation.

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STANDARD MANUFACTURING PROCESS

AROCLORS (TAKE-OVER DISTILLED)

DEPARTMENT 246

NEV 024922



738177

WATER_PCB-SD0000073488

Dept. 246 - Standard Manufacturing Process

AROCLOR

APPENDIX J

SAFETY AND TOXICITY DATA

I. SAFETY EQUIPMENT

A. Fire Extinguishers

1. Carbon dioxide - 1st floor, NE of lean-to
2. Dry chemical - 1st floor, SE of lean-to
3. Dry chemical - 2nd floor, west wall
4. Dry chemical - 2nd floor, west wall

B. Gas Masks

1. 1st floor, outside west wall of repair room
2. 2nd floor, on west wall
3. Control room, east wall
4. 3rd floor, on handrail by #1 chlorinator
5. 4th platform, Aroclor column (4)

C. Scott Air Pak

1. Outside west wall of lean-to

D. Emergency Clothing

1. Box on 2nd floor, west wall.

E. Safety Showers With Eye Wash

1. Batch department, 1st floor
2. Batch department, 2nd floor
3. Batch department, 3rd floor
4. Continuous department, 1st floor
5. Continuous department, 2nd floor
6. Continuous department, 3rd floor
7. West side of tank farm (alarm in control room)
8. Control room (eye bath only).
9. Mezzanine level between #1 and #2 Still furnaces

F. Personal Safety Equipment

1. Hard hat
2. Safety glasses
3. Safety shoes
4. Goggles
5. Rubber or canvas gloves
6. Rubber overshoes

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SAFETY AND TOXICITY DATA (Cont'd)

II. DEPARTMENT SAFETY RECORD (246/259)

A. Lost time accidents - Last occurred on January 28, 1948.

B. Serious injuries - The last two serious injuries were:

1. 4/12/73 - Fractured finger when tank car lid dropped on it.
2. 2/15/72 - Lacerated finger on tank car clamp dome.

C. Minor injuries

Year	Injuries	No. of Men
1973	2	20
1974	6	20
1975	7	20

III. TOXICITY

The following toxic rating code will be used in describing the toxicity of these materials:

0 - none
1 - slight
2 - moderate
3 - high
U - unknown

A. Biphenyl (Code 82601)

1. Synonyms: Diphenyl
2. Description: White flakes or solid off white mass; somewhat pleasant odor.
3. Constants: Mol. Wt. 154.2; M.P. 69°C.; B.P. 255°C.; Density .9910 @ 75°/4°C.
4. Flash Point: 235° F. (C.C.)
5. Auto Ignition Temperature: 1004°F
6. Toxic Hazard Rating:
   Acute Local: U
   Acute Systematic: Ingestion 3, Inhalation 3
   Chromic Local: U
7. Fire Hazard: Definitely when exposed to heat or flame; can react with oxidizing materials.
8. Fire Fighting: CO_2 or dry chemical.
9. Formula: $C_6H_5C_6H_5$

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SAFETY AND TOXICITY DATA (Cont'd)

III. (Cont'd)

A. (Cont'd)

10. Biphenyl vapors are irritating to the upper respiratory tract. Workers should not be exposed to vapor levels throughout their shift in excess of the threshold limit value of 1 milligram per cubic meter of air (or about 0.2 ppm). The compound, or organic solutions of the compound can absorbe through the intact skin; therefore, repeated skin contact should be avoided.

11. See Hygienic Guide Series on "Diphenyl".

B. Chlorine (Code 81059)

1. Description: Greenish yellow gas.
2. Formula: Cl_2
3. Constants: Mol. Wt. 70.914; M.P.=101°C.;B.P. - 34.5°C.; Density 1.47 @ 0°C.
4. Toxic Hazard Rating:
   Acute local: Irritant 3; Inhalation 3
   Acute systemic: 0
   Chronic local: U
   Chronic systemic: U
   M.A.C. - 1 PPM in air per 8 hour day

5. Toxicology: Chlorine is extremely irritating to the mucous membraines of the eyes and respiratory tract. It combines with moisture to liberate nascent oxygen and from hydrochloric acid.

   Both of these substances, if present in quantity, cause inflammation of the tissues with which they come in contact. If the lung tissues are attacked, pulmonary edema may result. A concentration of 3.5 ppm produces a detectable odor; 15 PPM causes immediate irritation of the throat. Concentrations of 50 PPM are dangerous for even short exposures. 1000 PPM may be fatal even when the exposure is brief.

   Because of its intensely irritating properties, severe industrial exposure seldom occurs, as the workman is forced to leave the area before he can be seriously affected. In cases where this is impossible, the in

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APPENDIX J (Cont'd)

III. (Cont'd)

B. 5. (Cont'd)

irritation of the eyes and mucous membranes of the nose and throat is followed by cough, a feeling of suffocation and later pain and a feeling constriction in the chest. If exposure has been severe, pulmonary edema may follow with rales being heard over the chest.

6. Fire Hazard: Moderate - can react to cause fire or explosion upon contact with turpentine, ether, ammonia gas, illuminating gas, hydrocarbons, hydrogen and powdered metals.

7. Explosion Hazard: Present by reaction with reducing agents.

8. Disaster Control: Dangerous; emits highly toxic fumes; will react with water to form toxic and corrosive fumes of HCl; is heavier than air - gas will hug the ground. People without adequate protection should go across wind until out of the affected area.

C. HCl Off-Gas (Code 828.51)

1. Synonyms: Muriatic acid, Chlorohydric Acid, Hydrogen Chloride
2. Description: Colorless gas
3. Formula: HCl
4. Toxic Hazard Rating:
   Acute local: Irritant 3, Ingestion 3, Inhalation 3
   Acute Systemic: U
   Chronic local: Irritant 2
   Chronic Systemic: U
5. M.A.C.: 5 ppm in air for 8 hr. day
6. Toxicology: Hydrogen chloride is an irritant to the mucous membranes of the eyes and respiratory tract. Concentration of 35 ppm causes irritation of the throat after short exposure. Concentrations of 50 to 100 ppm are tolerable for 1 hour. More serious exposures result in pulmonary edema and often laryngeal spasm. Concentrations of 1000 to 2000 ppm are dangerous even for brief exposures. Mists of HCl are considered less harmful than they anhydrous form since the droplets have no dehydrating effect.
7. See Hygienic Guide Series on "Hydrogen Chloride".

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SAFETY AND TOXICITY DATA (Cont'd)

III. (Cont'd)

D. Ferric Chloride (Code 33500)

1. Description: Granular solid
2. Formula: $FeCl_3$ (Anhydrous)
3. Constants: Mol. wgt. = 166.22, Melting Pt.= sublimes, solubility in H_2O = very soluble with heat rise.
4. Toxic Hazard Rating:
   Acute Local: Irritant 1; Ingestion 1
   Acute Systemic: U
   Chronic Systemic: U
   Chronic Local: Irritant 1
5. Fire Hazard: There is no fire hazard under normal conditions, but it will emit toxic fumes at high temperatures.
6. Handling: Protect the skin with approved protective clothing, avoid the breathing of $FeCl_3$ dust, wear approved respirator with adequate cartridge, and protect the eyes with approved goggles. There are no storage regulations; however, it should be stored in a dry place as heat is released upon solution in water and wet ferric chloride will not catalyze the chlorination reaction.

E. Lime (Code 38800) (Calcium Oxide)

1. Description: Fine white or slightly gray powder, Rhomeric Trigonal crystals.
2. Formula: CaO.
3. Toxic Hazard Rating:
   Acute local: Irritant 3; Ingestion 1; Inhalation 3
   Acute Systemic: Ingestion 2; Inhalation 3; skin absorption 0.
   Chronic local: Irritant 3; Inhalation 2
   Chronic Systemic: Ingestion 2; Inhalation 3: Skin absorption 0.
4. Toxicology:
   Has a caustic reaction and, therefore, is irritating to the skin. As a dust it can cause dermatitis and irritation of the eyes and mucous membranes. It is a general nuisance type of dust.
5. Fire Hazard: None
6. Explosion Hazard: Virtually none

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SAFETY AND TOXICITY DATA (Cont'd)

E. (Cont'd)

7. Handling: Dust respirator, adequate protective clothing, including rubber coated gloves, optional rubber full cover apron and full cover plastic goggles should be used when handling lime (dust). Adequate ventilation and dust removal equipment should be used in the handling area.

Lime is added to the stills to neutrilize any liberated HCl and prevent sublimation of the $FeCl_3$ catalyst. It is handled in 50# bags.

F. Nitrogen (Code 43099)

1. Description: Colorless gas
2. Formula: N_2
3. Constants: Mol. Wt. 28.02; M.P. - 210°C; B.P. - 195.8°C.; Density 1.2506 gr/liter at 0°C.
4. Toxicity: None. In high concentrations it is an asphyxiant.

G. Aroclors

1. Recommended maximal atmospheric concentrations (MAC for eight hours):
   a. Aroclor 1242 - 1.0 mg per cubic meter of air
   b. Aroclor 1254 - 0.5 mg per cubic meter of air

2. Hazards and Control

   a. Inhalation: Absorption is chiefly by inhalation. Concentrations in the workroom atmosphere should be maintained below the recommended levels. Where the chlorinated diphenyls are used at room temperatures, the hazard of inhalation is considered slight or absent. When these materials are subjected to elevated temperatures, the process either should be completely enclosed or other adequate mechanical exhaust ventilation must be provided to reduce concentrations to safe levels.

   b. Skin contact: Operations and handling procedures should be such as to avoid the possibility of prolonged or repeated skin contact. Contaminated clothing must be laundered before reuse.

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SAFETY AND TOXICITY DATA (Cont'd)

G. 2. (Cont'd)

c. Eye contact: Goggles or face shield should be used where there is a possibility of liquid splashes.

3. Emergency Treatment: Skin surfaces exposed to chlorodiphenyls should be thoroughly washed with soap and water at once. If clothing has been contaminated it should be removed promptly.

If exposure to a high vapor concentration occurs, as in the case of spills at elevated temperatures, the patient should be moved from exposure and kept at rest until seen by a physician. Oxygen should be administered if breathing is difficult.

Eyes contaminated with chlorodiphenyl should be irrigated with water for at least 15 minutes and the patient should be seen by a physician.

Special procedures: Persons who are regularly or repeatedly exposed to chlorodiphenyls should be examined periodically to detect early evidence of skin irritation and/or liver damage. Persons with known liver disease should not be exposed to repeated contact with the chlorodiphenyls.

WATER_PCB-SD0000073495

Monsanto INDUSTRIAL CHEMICALS CO.

FROM (NAME & LOCATION) E. S. Tucker - T2F

DATE November 20, 1973

cc H. S. Bergen - B2SL
R. E. Keller - T1B
R. H. Munch - T1B
W. R. Richard - T3A

SUBJECT PCBs

REFERENCE

TO : W. B. Papageorge
B2NA

While attending a NAS workshop on marine pollutants held at the Marine Biological Laboratories, Woods Hole, Mass., I talked at length with Bob Risebrough (Canadian Wildlife Service/University of California) and George Harvey (Woods Hole Oceanographic Institute) regarding PCBs. The following is a summary of our conversations.

Bob Risebrough reported (1) that the levels of PCBs in sewage outfalls (unspecified locations - probably California) have begun to drop significantly; (2) that they had qualitatively observed low levels of chlorinated furans in some Aroclors via GC/mass and that they were in the process of attempting to quantitate their findings. He would not even guess the level, indicating that, if they have not mistaken chlorinated methyl biphenyls (same m/e) for the furans, the levels are probably sub-ppm. I reiterated that we had not detected furans in any of our Aroclor products to date; and (3) he expressed special interest in the possible presence of furans in used PCB heat transfer fluids. I reminded him that PCBs were no longer used as heat transfer fluids, having been replaced with non-halogen containing fluids and that the used PCB fluids were recovered and incinerated.

George Harvey reported that the PCB levels found in marine samples which he obtained during their most recent cruise had decreased by a factor of 10. He was puzzled by this rapid drop and did not have an explanation for it. My own feeling is that he is being much more careful about how he collects and analyzes marine samples for PCBs and that the ships they use to collect the samples are now relatively PCB free.

It will be interesting to see how he eventually rationalizes this dramatic decline in ambient PCB levels. George also gave me a pre-publication copy of a paper to be published in Atmospheric Environment (copy attached).

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Generally speaking, I would say that Harvey's and Risebrough's attitude toward Monsanto and the environmental impact of PCBs have undergone a remarkable improvement.

Scott

E. S. Tucker

js

NEV 022027

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WATER_PCB-SD0000073497

November 10, 1975

SUMMARY OF TOXICOLOGICAL STUDIES ON COMMERCIAL PCB'S

J. C. Calandra

The need for additional toxicological data became apparent in 1966 when the refinement of analytical techniques made possible the identification of PCBs in the environment.

To assess the hazards of these materials, classical feeding studies with Aroclors 1242, 1254 and 1260 in rats and dogs were conducted according to accepted traditional procedures. In addition, three-generation, two litter reproduction studies and teratology studies in albino rats and a dominant lethal mutagenic study in mice were considered to be necessary for this purpose.

Effects such as decrease in eggshell thickness described in certain avian species suggested that toxicity and reproduction studies in chickens would be helpful in evaluating possible untoward effects in birds.

The findings included the following:

1. No evidence of teratogenic or mutagenic changes were noted with any of the PCBs at maximally tolerated dose levels in rats and mice.

2. In the rat reproduction study, there were low mating indices at 100 ppm Aroclor 1242 and decreased pup survival at 100 ppm of Aroclor 1242 and 1254.

3. Egg production in hens fed 100 ppm Aroclor 1242 or 1254 was decreased with hatchability reduced severely. Poor hatchability of eggs



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from hens fed 8 ppm Aroclor 1242 was found. The specific gravity of the eggs obtained from the test group was not affected; however, Aroclor 1242 at 10 and 100 ppm levels and Aroclor 1254 at 100 ppm level were associated with reduced eggshell thickness.

4. In the dog studies the only findings were in dogs fed Aroclor 1260 at 100 ppm and these showed increased serum alkaline phosphatase activity and liver weights without concomitant histopathologic changes.

5. In the chronic rat studies a weight depression was observed at the 24 month point in females fed 100 ppm of Aroclor 1254.

Food consumption, mortality and hematologic, urine and blood chemistry studies did not differ among treatment and control groups.

Liver weight increases were noted in males and females fed 100 ppm Aroclor 1254 or Aroclor 1260, and in females only in the 100 ppm group fed Aroclor 1242.

As expected, the important histopathologic changes were present in the livers of the 24 month sacrifice animals and consisted of hepatocellular alterations such as focal hypertrophy, cytoplasmic lipid changes and in some animals at 100 ppm, hepatomas or cholangiohepatomas. No evidence of hepatocellular carcinogenicity of the Aroclors was found in this study.

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November 19, 1975

SUMMARY OF TOXICOLOGICAL STUDIES ON COMMERCIAL PCB's

J. C. Calandra*

The urgent need for additional toxicological data became apparent when the refinement of analytical techniques made possible the identification of PCBs in many portions of the ecosystem.

To assess the biological hazards of these materials, chronic feeding studies in rats and dogs were conducted according to accepted traditional procedures with Aroclors 1242, 1254 and 1260. It should be pointed out that Aroclor 1260 is no longer produced in this country since it does not meet the physical specifications for its restricted uses (ref. 1).

In addition, three generation two litter reproduction and teratology studies in albino rats as well as a dominant lethal mutagenic study in albino mice were considered to be necessary for the broad spectrum safety evaluation of these materials.

Effects such as decreases in eggshell thickness described in certain avian species suggested that toxicity and reproduction studies in chickens would be helpful in evaluating possible untoward effects in birds.

A list of the studies conducted are presented in figure 1.

The experimental design of the chronic rat and dog studies is given in figures 2 and 3. It should be noted that these studies were of typical Food and Drug Administration design for the evaluation of the safety of direct and indirect food additives.

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* Industrial BIO-TEST Laboratories, Inc., 1810 Frontage Road, Northbrook, Illinois 60062.

PLAINTIFF'S EXHIBIT 1527

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The important results in the chronic rat studies which were conducted on Charles River rats are summarized briefly in figures 4, 5 and 6.

Food consumption, mortality and hematologic, urine and blood chemistry studies did not differ among treatment and control groups. The only weight depression observed was at the 24 month point in females fed 100 ppm of Aroclor 1254.

Liver weight increases were noted in males and females fed 100 ppm Aroclor 1254 or Aroclor 1260, and in females only in the 100 ppm group fed Aroclor 1242.

As expected, the important histopathologic changes in the rat study were present in the livers of the 24 month sacrifice animals and consisted of hepatocellular alterations such as focal hypertrophy, cytoplasmic lipid changes and in some animals at 100 ppm, hepatomas or cholangiohepatomas. No evidence of hepatocellular carcinogenicity of the Aroclors was found in this study.

The conclusion that "no evidence of hepatocellular carcinogenicity of the Aroclors was found in this study" was reached only after extensive re-evaluation of the original liver slides as well as additional liver sections from all of the animals after the Kimbrough results on Aroclor 1260 became known to us (ref. 2).

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The slides were read independently and separately by Dr. Donovan Gordon (ref. 3), Professor Ward Richter (ref. 4), and by Professor P. Pour (ref. 5) of Industrial BIO-TEST Laboratories, the University of Chicago, and the Eppley Institute for Cancer Research, respectively.

The interpretation of pathologic changes that occur in the liver as a result of absorption of chlorinated hydrocarbons is a key issue that needs resolution by the community of pathologists (refs. 6-7).

The problem is highlighted in the context of PCBs since there appears to be disagreement as to whether Aroclor 1260 is or is not a hepatocellular carcinogen (ref. 8). Pour re-evaluated the Kimbrough slides and does not agree with the reported findings.

The findings in the chronic dog study are summarized in figure 7. The feeding of Aroclor 1260 at 100 ppm showed an increase in serum alkaline phosphatase activity and liver weights. A slight decrease in body weight gain was noted at the 100 ppm dose level in males and at 10 and 100 ppm in females. No remarkable histopathologic changes were found. However, evidence of gastrointestinal inflammatory lesions and ulcerations was noted which appear to be similar to those found by Allen in the rhesus monkey by feeding Aroclor 1248 (ref. 9). (This material is no longer a product of commerce (ref. 1).)

The design of the dominant lethal mutagenic study is presented in figure 8.

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No effects related to Aroclor treatment were seen in the parameters listed in figure 9 - mortality, mating index, number of implantation and resorption sites, number of viable embryos, pre-implantation loss or mutation rates. This finding is in agreement with that of Green et al. (ref. 10).

The standard design for a three generation two litter reproduction study in albino rats is given in figure 10 and the teratology study in figure 11.

A brief summary of the results (figure 12) indicates that none of the Aroclors studied produced adverse effects in the two litters of the first generation.

All progeny delivered by female rats in each of 3 generations exposed to dietary levels of up to 100 ppm of either Aroclor 1242, 1254 or 1260 were structurally normal. A reduction in the mating index was observed in the 2nd and 3rd generations of animals fed either 10 or 100 ppm. The ability of females to conceive, carry the delivery process to parturition, and to successfully nourish the young was not affected by the 3 Aroclors. It should be stressed that no changes in the reproductive tract of either male or female rats were produced by any of the 3 Aroclors. Findings in the 3rd generation were similar to those in the 1st with no suggestion of any alterations in response as a function of succeeding generations.

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Teratologic studies in which albino rats were exposed to either Aroclor 1242, 1254 or 1260 at doses of up to 30 mg/kg during rapid organogenesis - gestation days 6 through 15 - were conducted in our laboratories. No evidence of embryotoxicity as reflected by an increase of fetal resorption or teratogenicity as measured by complete external, skeletal, and internal evaluation of fetuses obtained from the Aroclor-treated females, was obtained. Other experimental data pertaining to the potential teratogenicity of polychlorinated biphenyls supports the lack of adverse effects. Mizunuya (ref. 11) and his colleagues found no evidence of teratogenicity in the rat when fed at dietary levels of up to 250 ppm. In the mouse, Toeruek (ref. 12) found that doses of up to 500 mg/kg was non-teratogenic although when given on gestation days 1 through 6, a decrease in implantation sites and fetal weights was observed. These doses given on gestation days 7 through 11 failed to produce any changes with respect to either reproductive parameters or teratogenicity. Further, no evidence of malformation was obtained in infant monkeys delivered to females fed either 2, 5, 5 or 25 ppm Aroclor 1248 although the birth weights were reported to be reduced (ref. 9).

The last study in this series was a toxicity/reproduction study in white Leghorn chickens (figures 13, 14 and 15).

Aroclor 1260 at all test levels did not produce adverse effects on the various parameters investigated. Egg production in hens fed

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100 ppm Aroclor 1242 or 1254 was decreased as was egg hatchability. In fact, poor hatchability of eggs from hens fed 8 ppm Aroclor 1242 was found (figure 15).

In addition, Aroclor 1242 at 10 and 100 ppm and Aroclor 1254 at 100 ppm were associated with reduced eggshell thickness. Chick viability was affected by both substances at the 10 ppm dose level.

Conclusions

1. The no-effect level for the Aroclors in the chronic rat and dog studies is about 10 ppm.
2. No teratogenic or mutagenic effects were found.
3. No hepatocellular carcinomas were present.
4. The no-effect level in the rat reproduction study is between 1 and 10 ppm and is the result of low mating indices.
5. In the chicken reproduction and teratology studies, effects were more severe with Aroclor 1242 with the no-effect level being 2 - 4 ppm.

WATER_PCB-SD0000073505

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4 Report on Histopathological Evaluation of Aroclor 1242, 1254 and 1260, March 24, 1975, by Ward R. Richter.

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9 Response of the Nonhuman Primate to Polychlorinated Biphenyl Exposure. Allen, J. R. Fed. Proc. 34:1675 July (1975).

10 Lack of Dominant Lethality in Rats Treated with Polychlorinated Biphenyls (Aroclors 1242 and 1254). Green, S. et al. Fd. Cosmet. Toxicol. 13:507 (1975).

11 Effects of PCBs on Fetuses and Offspring in Rats. Mizunuya, Y. et al. Shakuhim Eiseigaku Zassh: 15:252 (1975).

12 Effects of PCB on the Developing Mouse. Toeruek, P. Chemosphere 2:173 (1973).

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Figure 1

TOXICITY STUDIES CONDUCTED WITH AROCLORS 1242, 1254 AND 1260

Two-Year Chronic Oral	Albino Rats
Two-Year Chronic Oral	Beagle Dogs
Three-Generation Reproduction	Albino Rats
Teratology	Albino Rats
Dominant Lethal Mutagenic	Albino Mice
Toxicity / Reproduction	White Leghorn Chickens

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Figure 2

TWO-YEAR CHRONIC ORAL TOXICITY STUDY
ALBINO RATS AND BEAGLE DOGS

Test Material	Dietary Levels (ppm)	Number of Animals per Dietary Level			
		Rats		Dogs	
		M	F	M	F
None	— — —	50	50	4	4
Aroclor 1242	1, 10, 100	50	50	4	4
Aroclor 1254	1, 10, 100	50	50	4	4
Aroclor 1260	1, 10, 100	50	50	4	4

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Figure 3

TWO-YEAR CHRONIC ORAL TOXICITY STUDY
ALBINO RATS AND BEAGLE DOGS

Parameters Investigated:

- Body Weight
- Food Consumption
- Hematology
- Clinical Blood Chemistry (BUN, SAP, SGPT, fasting blood glucose, SGOT — dogs only)
- Urinalyses
- Pathology (gross, organ weights, microscopic)

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Figure 4

INGESTION OF AROCLOR 1242—ALBINO RATS
LIVER EFFECTS

Increase in Liver Weights — 100 ppm — Females

Primary Liver Lesions

None at 3, 6, 12 month sacrifice

24 month sacrifice—100 ppm—Increased incidence of:

Nodular Hyperplasia	(8 / 20)
Hepatoma	(2 / 20)
Cholangiohepatoma	(1 / 20)
Hepatocellular Carcinoma	(0 / 20)

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Figure 5

INGESTION OF AROCLOR 1254—ALBINO RATS
LIVER EFFECTS

Increase in Liver Weights — 100 ppm

Primary Liver Lesions

None at 3, 6, 12 month sacrifice

24 month sacrifice — 100 ppm — Increased Incidence of:

Nodular Hyperplasia	(13/27)
Hepatoma	(4/27)
Cholangiohepatoma	(2/27)
Hepatocellular Carcinoma	(0/27)

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Figure 6

INGESTION OF AROCLOR 1260 – ALBINO RATS
LIVER EFFECTS

Increase in Liver Weights — 100 ppm

Primary Liver Lesions

None at 3, 6, 12 month sacrifice

24 month sacrifice – 100 ppm – Increased incidence of:

Nodular Hyperplasia	(7 / 27)
Hepatoma	(5 / 27)
Cholangiohepatoma	(2 / 27)
Hepatocellular Carcinoma	(0 / 27)

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NEV 008581

WATER_PCB-SD0000073512

Figure 7

EFFECTS OF INGESTION OF AROCLORS — BEAGLE DOGS

Aroclor 1242 — no effects

Aroclor 1254 — slight decrease in body weight gain
- 100 ppm

Aroclor 1260 — slight decrease in body weight gain
- 100 ppm males
- 10 and 100 ppm females

— increase in SAP - 100 ppm

— increase in liver weights - 100 ppm

707834

NEV 008582

WATER_PCB-SD0000073513

Figure 8

DOMINANT LETHAL MUTAGENIC STUDY — ALBINO MICE

Test Material	Dose*
Corn Oil	0.9 ml / kg
Methyl methane sulfonate (MMS)	100 mg / kg
Aroclor 1242	500 or 1000 mg / kg
Aroclor 1254	500 or 1000 mg / kg
Aroclor 1260	500 or 1000 mg / kg

*single dose given i.p. to 12 males / group

NEV 008583

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WATER_PCB-SD0000073514

Figure 9

DOMINANT LETHAL MUTAGENIC STUDY — ALBINO MICE

No effects related to Aroclor treatment seen in:

- Mortality
- Mating index
- Number of implantation sites
- Number of resorption sites
- Number of viable embryos
- Pre-implantation loss
- Mutation rates

7078396

NEV 008584

WATER_PCB-SD0000073515

Figure 10

THREE-GENERATION REPRODUCTION STUDY* — ALBINO RATS

Test Material	Dietary Levels (ppm)	Number of Animals per Dietary Level	
		M	F
None	— — —	8	16
Aroclor 1242	1, 10, 100	8	16
Aroclor 1254	1, 10, 100	8	16
Aroclor 1260	1, 10, 100	8	16

*Two litters per generation

NEV 008585

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WATER_PCB-SD0000073516

Figure 11

TERATOLOGY STUDY — ALBINO RATS

Test Material	Dose* (mg/kg/day)	Number of Gravid Rats
Corn Oil	—	26
Aroclor 1242	10 or 30	26
Aroclor 1254	10 or 30	26
Aroclor 1260	10 or 30	26

*administered on gestation days 6 through 15 (10 doses)

NEV 008586

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WATER_PCB-SD0000073517

Figure 12

EFFECT OF AROCLORS ON REPRODUCTION / TERATOLOGY -ALBINO RATS

1. Reproduction Study

   First generation — no effects

   Second and Third generations — 10 and 100 ppm

   — decrease in mating index

   — decrease in incidence of pregnancy

   (Aroclor 1242 - no third generation with 100 ppm)

2. Teratology Study — no effects

707839

NEV 008587

WATER_PCB-SD0000073518

Figure 13

TOXICITY / REPRODUCTION STUDY — WHITE LEGHORN CHICKENS

Test Material	Dietary Levels (ppm)	Number of Animals per Dietary Level	
		M	F
None	—	8	40
Aroclor 1242	1, 2, 4, 8, 10, 100	4	20
Aroclor 1254	1, 10, 100	4	20
Aroclor 1260	1, 10, 100	4	20

707840

NEV 008588

WATER_PCB-SD0000073519

Figure 14

TOXICITY / REPRODUCTION STUDY — WHITE LEGHORN CHICKENS

Parameters investigated :

- body weight
- food consumption
- egg production
- egg quality
- egg hatchability
- eggshell thickness
- chick body weight
- chick viability
- pathology

707841

NEV 008589

WATER_PCB-SD0000073520

Figure 15

EFFECTS OF AROCLORS ON CHICKEN REPRODUCTION

Parameter	Dietary Level Causing Effect	
	1242	1254
Egg Production	100	100
Egg Hatchability	8	100
Shell Thickness	100	100
Chick Viability	10	10

Aroclor 1260 — no effects at any dose level

707842

NEV 008590

WATER_PCB-SD0000073521

Monsanto

FROM (NAME & LOCATION): W. B. PAPAGEORGE - ST. LOUIS

DATE: November 10, 1970

cc: H. S. Bergen
J. Mason
J. E. Springgate

SUBJECT: PCB ENVIRONMENTAL PROBLEM
OCTOBER STATUS REPORT

MEMO NO.:

TO :
P.J.A. Marsh - BRUSSELS
W. S. Clark
J. R. Durland - TOKYO
M. W. Farrar - 2nd Street
E. V. John
R. E. Keller - 2nd Street
R. M. Kountz
T. L. Gossage
P. S. Park
W. R. Richard
J. R. Savage
E. P. Wheeler

GENERAL:

The test to evaluate the disposal of solid waste contaminated with Aroclors in Enviro-Chem Systems' pilot unit in St. Charles, Missouri has been postponed to the middle of December.

Negotiations are underway with a drum reconditioning firm to develop a procedure for recovering contaminated drums.

MARKETING:

Marketing has reached agreement with management to continue offering Aroclor 1248 and 1254 to the vacuum industry. The product name will be Santovac I and Santovac II. Vacuum pumps are small users - from one pint to five gallons initial fill. The typical pump will use the same charge for one to two years. The pumps are under a negative pressure so there is no leakage. Customers and equipment manufacturers will be advised that the material cannot be dumped.

Westinghouse has communicated some concern with MCS 1016 as a capacitor fluid. They have noticed a greater effect on polypropylene film. The higher percentage of monochloro compounds may be the cause.

We visited a number of dielectric customers in October (both large and small). This will continue through the first two weeks of November. So far, we can report without exception, our customers are being very responsive to the "clean-up and close the system" program. They express an earnest management commitment

PLAINTIFF'S EXHIBIT 1547

NEV 025857

WATER_PCB-SD0000073522

and a clear interest in keeping communication open with St. Louis.

ENGINEERING:

Aroclor Liquid Incineration - CEA 2415

Process design is complete. John Zink's preliminary drawings for the incinerator package have been reviewed and they are in the latter stages of being approved. Zink has indicated shipment by February 15, which is a slight improvement.

Drafting and mechanical design are in progress on other elements of the project.

MCS 1016 Distillation - CEA 2417

Process design is complete, the distillation column at the Bayou is being dismantled, and mechanical design and drafting are proceeding. Preliminary information from our customers indicates that a project scope change may be in order to remove a percentage of the low boilers as well as the high boilers. The apparent marketing problem will be reviewed with Research and Marketing.

Tributyl Phosphate - CEA 2371

A pilot plant run revealed a much lower yield on phosphorous oxychloride and butanol. This is being studied. Additional laboratory runs are being made, and another pilot run will be made to establish and resolve the problem.

Nonyl-Cumyl Phenyl Diphenyl Phosphate

The tentative process report is currently being issued, and Engineering is initiating development of a scope report.

JAPAN:

No new developments.

NEV 025858

EUROPE:

Board of Trade in U.K. is considering classifying polychlorinated biphenyls as hazardous materials.

WATER_PCB-SD0000073523

MEDICAL:

Toxicity studies underway at Industrial Bio-Test Laboratories on the PCB's continue uneventfully. The beginning of the 90-day studies on rats on HB-40 and MIPB were delayed because of the receipt of a shipment of unacceptable rats. Currently these studies are scheduled to start November 2, 1970. We should have the final report in hand by February 15, 1971.

PUBLIC RELATIONS:

Two press queries were handled during the month. Science News, following an interview with Dr. Risebrough, called us to ask why we had not released production and sales figures. The reporter also asked about toxicity studies now under way. The Dayton Journal Herald wrote a lengthy article on the fate of local farmers in the area. Milk had been removed from the market due to higher than acceptable levels of PCB, calves died and some members of one family became ill. The farmers have related their bad luck to the presence of PCB in the area and charged "foot dragging" by Monsanto, the State of Ohio and the FDA in alerting them to the problem. Although the story prominently mentioned Monsanto, it did refer to PCB as a "new problem" and one in which Monsanto is playing a major role to solve.

RESEARCH:

PCB Analysis - U.S.

Fish from Anniston streams and shrimp from Escambia Bay were collected for analysis. Results will be available December 1. Plant effluent streams from two hydraulic fluid customers had 0.01 - 0.09% chlorinated biphenyl.

Impurities in Aroclor

Researchers at the University of Utrecht, The Netherlands, have reported finding low levels of polychlorinated dibenzofurans in competitive polychlorinated biphenyls. They also analyzed Aroclor 1260, Lot AK-3, and did not

WATER_PCB-SD0000073524

detect any oxygenated impurities. Because of the reported high toxicity of polychlorinated dibenzofurans, a study was undertaken to determine if these, or related compounds exist as impurities in our products.

Low levels (about 25 ppm) of polychlorinated dibenzofurans were confirmed in Phenoclor D.P. 6, a competitor to Aroclor 1260 from Prodelec (France). Aroclor 5442 appears to contain about 2 ppm polychlorinated dibenzofurans; none were detected in any other Aroclor studied. However, each of the Aroclor 1200 series contains polychlorinated naphthalenes at varying levels. The Aroclor 5442 contains polychlorinated anthracene or phenanthrene. The Aroclor 1242, 1254, and 1260 samples are the same lots tested for toxicity by Industrial Bio-Test Laboratories.

Adsorption of Aroclor from Plant Water Effluent

A series of four 5-inch diameter columns (each packed to a bed depth of 5.5 feet with Calgon's Filtrasorb 300 carbon) was placed on stream 10/2 at the Aroclor Sump. To-date the unit has been operating with minimum difficulties at an average flow rate of 2 gpm/ft^2 ($\approx$1000 cc/min.). The available test results indicate an Aroclor reduction in the range (600-2,000 ppb) in the influent to (NDA[1] 10 ppb) in the effluent of the first columns. Since there has been no indication of a breakthrough in the first column, plans are now to increase the flow to 4 gpm/ft^2.

In a 4 day pilot run, initial concentrations of 40-150 ppb in the effluent of the new limestone pit were reduced to an essentially NDA upon passing through a filter (4 inch diameter tube packed to 5.5 inch depth with carbon) at a flow of 100 cc/min. Tests are now being run under the same conditions utilizing sand as the filtering media.

1. NDA - no detectable amount

Contact was made with a Monsanto Biodize on 10/5. Biodize has agreed to provide a 2300 gallon clarifier to be used both in a flocculation and a batch adsorption study. A sludge sample and a sample of the new limestone pit effluent have been sent to Denver Equipment Company for an evaluation of solids removal by froth floatation. Pit effluent samples have also been sent to Betz's Waste Water Lab for an evaluation of their different coagulants.

Photodegradation of Aroclor

Preliminary experiments with Aroclor 1242 indicate that it is easily decomposed by ultraviolet light. A 0.1% solution of Aroclor 1242 in iso-octane shows no significant EC active material after exposure to a 450 watt Hanovia Xenon arc at a distance 4" for 50 minutes. Upon completion of the

WATER_PCB-SD0000073525

analysis of all samples taken during the study, a report will be issued. The exposure of the Aroclor to ultraviolet light was carried out by Dr. Bloomfield in Monsanto Central Research.

Biodegradation Testing - St. Louis

A three-day sampling of the HB-40 and mono-isopropyl biphenyl (MIPB) semi-continuous activated sludge units nine weeks after the previous sampling period has shown significant changes in the biodegradation rates. For MIPB, disappearance rates for the three days by UV analyses were 75, 70 and 77 percent compared with the mean of 67 percent in the previous sampling period. GC analyses indicate that the predominant monoisopropyl biphenyl components are almost completely degraded during the cycle, leaving as the undegraded portion the dialkylated components. For HB-40, the previous sampling period had shown essentially a zero disappearance rate with a high degree of scatter. During the three-day period, disappearance rates of 54, 52 and 58 percent were found. From GC analyses, it appears that the one-ring hydrogenated components are more readily degradable than the two-ring hydrogenated components.

Feeding of the MIPB and HB-40 is continuing. An additional sampling period is planned to determine if any further significant changes will occur.

Five additional units are now being added to our setup to permit simultaneous testing of a greater number of products. Testing of Aroclor 1221 will be started in one of the new units.

Biodegradation rate studies on chlorinated biphenyl have not been reproducible. Semi-continuous activated sludge units for Aroclor 1242, Aroclor 1254, MCS 1016 and MCS 1043 were modified to permit use of magnetic stirring. The addition of stirring to the units appears to reduce the degree of scatter to some extent. The method of sampling is now being investigated to determine its contribution to the scatter. No conclusions can be drawn at this time concerning differences in biodegradation rates. Some changes in component ratios will be noted for MCS 1016 and MCS 1043. Testing of trichlorobenzene, Arobromchlor 1232, Gulf 200 Bright Stock, Aroclor 5432 and Aroclor 5442 are now started in magnetically-stirred units.

Aroclor 5460

NEV 025861

Eleven lots of current Anniston Plant production were analyzed for polychlorinated biphenyls (PCB) by carbon skeleton GC. The results ranged from 0.32 to 1.29% PCB. The latter is probably too high to satisfy the FDA for use as a hot melt adhesive in food packaging.

WATER_PCB-SD0000073526

PCB - Environmental Studies - Europe

Environmental Studies - At an informal meeting on 24th Sept. with high level representatives of the British Nature Conservancy and British Ornithological societies, we gave a presentation of the PCB problem and Monsanto's efforts to deal with it. This was well received and comments approving of Monsanto's cooperative approach were made. Dr. Martin Holdgate, of the British Cabinet Office, who has wide responsibility for environmental problems in the U.K., thought that the Monsanto response to the problem was very generous. Among other things he has responsibility for the issue of the NERC report on the deaths of sea-birds in the Irish Sea. He undertook to ensure that Monsanto would see this report in draft before publication and that relevant comment from us would be included. We are still awaiting this draft, but understand that it is being revised at present and we will receive a copy on completion of this revision. We have been told, however, that the report accepts that high levels of PCB's were found in the dead sea-birds and thus although the deaths could not be attributed directly to the presence of PCB's this could have been a contributory factor.

The meeting at Stockholm, organized by the Swedish National Environmental Protection Board, was attended. Not very much new information was provided and, generally the meeting discussion was limited and rather an anticlimax. Reference to the Monsanto contribution at CIGRE was made in complimentary terms. A modified print of this paper was available to the delegates of the Stockholm meeting, but was not read. We presented a summary of the 9 month chronic toxicity trials on rats and dogs (Bio-Test) to counter some alarmist speculation on toxicity to humans.

A meeting on analytical problems of PCB's organized by the British Ministry of Agriculture was attended. A preliminary report from the Fisheries Laboratory of the Ministry suggested that no significant levels of PCB's were found in fish from the Severn Estuary. This is perhaps, surprising in view of the location of the Newport Plant.

Biodegradation - The Monsanto sponsored project at University College, Bangor has now started. A meeting with Professor Evans and his student was held to discuss the initial program and it was agreed that the elective technique would be used in an attempt to prepare soil cultures capable of degrading Aroclors 1242 and 1254 and specific isomers. Evans claims to have isolated a biphenyl degrading organism which operates through a different ring-splitting mechanism from the previous culture (C_2). This is being made available to Ruabon for study and is of interest since it opens up the possibility

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of degrading structures which are stable towards C_2.

Analytical results are awaited on the degradation tests on HB-40, MCS 717 (repeat), MCS 762, MCS 1016 (repeat), and on the 2:3 - 2':3': 4':5' hexachlorinated biphenyl (repeat).

MANUFACTURING:

Anniston Plant

PCB Level In Sewer

Aroclor losses during October averaged 3#/day (405 ppb). Four high daily values (1000-4000 ppb) account for 1.8 lb/day - neglecting those, October average is 1.3 lb/day. Actions now being taken to reduce upsets.

Alabama Water Improvement Commission Contacts

A meeting was held with the AWIC technical staff. They were satisfied with the progress made at Anniston on the PCB problem. Plant effluent levels will be reported monthly.

Spills

Cleaning out a plugged Montar drumout line caused some to spill on the floor which was absorbed in sand and cleaned up.

A leak in a chlorinator pump caused some Aroclor to enter the sump where it was contained without leaving the department into the plant waste sewer.

Projects & Evaluations

1. Input data to define magnitude of solid waste disposal problem was published in October. Later work has indicated that Montar 5 (Aroclor 5460 bottoms) contains very little PCB. If confirmed, this reduces PCB-containing bulk solids by 10 M pounds per year/

2. Promise approved for spent carbon (containing PCB) collection and burial. Ultimate disposal by incineration is present plan.

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Projects & Evaluations

3. Removal of PCB-laden sludge from limestone pit by pumping was successfully demonstrated. This opens the way to longer pit life by removal of solids during operation of the pit.

4. Premise for rehabilitation of No. 1 limestone pit by 1/1/70 was approved in plant. Project preliminary estimate is $12M Capital, $2M Dismantling, and $26M Mechanical Expense. This estimate will be reviewed and an AFE prepared in November. Cleanout work is presently underway by pumping (see 3 above) so that the usual PCB discharge to Snow's Creek from pit cleanout will be minimized. Precautions are being taken to minimize PCB escape during limestone removal.

5. Flow sheet developed for pilot clarifier intended to demonstrate removal of solids (with adsorb Aroclor) from limestone pit effluent. Premise and estimate will be developed by mid-November.

6. Approximately 500 gallons of liquid PCB was removed from department sump after 2½ months of operation.

"Skimmer" was successfully demonstrated with collected scum being very high in PCB content (200M ppb). Approval was received to purchase.

W. G. Krummrich Plant

PCB Levels In Sewer

A. For the period 9/22 - 10/15 losses to the river from the treatment plant ranged from 457 to 2416 ppb with an average loss of 597 ppb for 8 samples. This is equivalent to 85 lbs/day.

B. WGK Laboratory's chromatograph for measuring PCB's has been repaired and current schedule of 6 samples/week will be maintained.

Projects To Reduce Sewered PCB's From Aroclor Department

A. Blow tank demister (Est. 2031) project completed and started up on 10/22. No mist downstream from the demister was detected using a Brink mist sampler. Scrubber jet samples have been sent to the laboratory for analysis to verify loss reduction.

B. Design package for the project to provide paving, curbs, trenches and catch basin in the tank car and truck loading areas will be completed in November.

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Program To Eliminate Severed PCB's From Using Departments

A. Summary report covering losses from using departments in October will be issued by November 9. Only reported loss for September was 1 quart from Dept. 251. Facts concerning major loss on 10/23 at the Rip Track will be published separately by the investigation committee.

B. Project (Est. 2457 for $2490 Expense) to provide 150,000 gallons of interim storage for scrap Aroclor was completed in October.

PCB Levels In Atmosphere

A. Vapor samples taken to date are inconclusive. Some sampling problems are indicated. Sampling program to identify air losses will be completed in November.

PCB Rework Project (Est. 2095)

Design package completed and safety review held for Phase III (installation of storage facilities for rework material).

Newport Plant (September)

PCB Levels In Sewer

PCB's in the Newport Plant effluent between 1st September and 5th October ranged from 20 to 932 ppb. There were 3 high results of 2,998 ppb, 81,039 and 3,095 ppb. The highest of these coincides with leaks from the Santotherm pumps on 4-NDPA Plant. Excluding the 3 high results, the average figure is 246 ppb.

246 ppb of PCB is equivalent to approximately 2.46 lbs/day.

Information has been requested from Anniston on trials using carbon treatment for removal of Aroclors from waste effluent.

Installation of sump level alarms now complete.

Spills

A bunded area draining into a closed drum has been installed around the Santotherm pumps on the 4-NDPA plant. Modifications are in hand to improve the drainage from this area.

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PCB Levels In Atmosphere

TSD Progress Report No. 2 on Job No. 27/7139/2392 was issued on 15th October giving results obtained to date on sampling of plant atmosphere for PCB contamination. Results are:

	Area	PCB mg/m³ air	Comments
1.	Drumming	0.38	Indoors. 2 roller doors
2.	Chlorination (ground floor)	0.59 0.13	Enclosed area, large rol door open
3.	Santolube 900	0.23	Indoors, Normal process
4.	4. NDPA (Expansion tank)	0.94 Pract. Nil	Outdoors Outdoors
5.	Aroclor control room	0.28	Indoors
6.	Chlorination (1st floor)	0.12	Chlorinators shutdown
		0.19	Chlorinators operating
		0.12	" "
7.	Airblowing room	0.39	Indoors. Normall process conditions

Used Drum Disposal

Blagdens drum reconditioning plant at Barking in Essex visited to see a trial to recondition used Aroclor drums.

W. B. PAPAGEORGE

ms

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MINUTES OF MEETING

ON

PROPOSED PCB EFFLUENT STANDARDS

February 28, 1974

Monsanto Company
St. Louis, Mo.



NEV 025264

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WATER_PCB-SD0000073532

Chairman: Mr. W. B. Papageorge
Manager, Product Acceptability
Monsanto Industrial Chemicals Co.

Objective:

The purpose of the meeting was to share information, experiences and impressions to help each of the participating companies in taking appropriate actions which are mutually supportive and effective in persuading the Administration of EPA to modify the proposed PCB Effluent Standard.

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PARTICIPANTS

PCB STANDARDS MEETING

February 28, 1974

CERTIFIED BALLAST MANUFACTURERS

Mr. N. R. Clark	Universal Manufacturing Co.

E.I.A.

Mr. Arnold S. Doty	P. R. Mallory & Co., Inc.
Dr. E. M. Moore	Electrical Utilities Co.
Mr. Rudy Carlson	Electrical Utilities Co.

GENERAL ELECTRIC COMPANY

Mr. James S. Nelson
Mr. Stuart Richel
Dr. Edward L. Simons

JARD COMPANY, INC.

Mr. Richard Rollins

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

Mr. A. M. Salazar

WESTINGHOUSE CORPORATION

Mr. H. Sheppard
Mr. N. H. Smith

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MONSANTO COMPANY

P. G. Benignus	Market Manager
H. S. Bergen	Business Director
D. B. Hosmer	Utilities and Environmental Protection Director
R. H. Munch	Senior Science Fellow
W. B. Papageorge	Manager, Product Acceptability
W. W. Withers	Attorney
C. Paton	Product Manager
W. R. Richard	Manager, Research and Development
J. R. Savage	Manager, Manufacturing
E. S. Tucker	Research Group Leader
P. L. Wright	Manager, Toxicology

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AGENDA

PCB EFFLUENT STANDARDS MEETING

February 28, 1974

9:00 AM	1. Welcome - H. S. Bergen
9:10 AM	2. Introductory Remarks - W. B. Papageorge
	a. Brief Review of Proposed Standard
	b. Critical Action Dates
	c. Objectives of Meeting
	3. Discussion Topics
9:15 AM	a. PCB Characteristics - Realistic Definition chemical, physical, biodegradation
9:45 AM	b. Sampling and Analytical Methodology
10:15 AM	Break
10:30 AM	c. Toxicity Acute Chronic
11:30 AM	d. Bioaccumulation - Biomagnification
12:00 Noon	e. Dilution - Stream Size
12:30 PM	Lunch
1:15 PM	f. Proposed Effluent Standard
2:00 PM	g. Control at Manufacturing and Use Sites Current losses Background
2:45 PM	Break
3:00 PM	h. Economic Considerations
3:30 PM	i. Action Plans
4:00 PM	Adjourn

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MINUTES OF PCB EFFLUENT STANDARDS MEETING

1. Mr. Howard S. Bergen, Jr., Director, Specialty Products Business Group of Monsanto Industrial Chemicals Company, welcomed the participants.

2. Introduction - W. B. Papageorge

Mr. Papageorge summarized the timetable past and future on toxic pollutants:

July 6, 1973 - Toxic Pollutants list published

September 7, 1973 - Final toxic pollutants list published including PCBs and 8 other chemical classes (e.g. cyanide, mercury, DDT, cadmium, etc.)

December 27, 1973 - Proposed Effluent Standards published

January 18, 1974 - Filing date for status as participant at proposed EPA Hearing on Standards

January 25, 1974 -

(i) Prehearing Conference with EPA

(ii) NEMA, Monsanto, G.E. and Westinghouse recognized as participants.

(iii) A total of 38 objectors expressed an interest. They represented industry or trade associations with the exception of the Michigan Water Research Commission and two powerful environmental groups (Environmental Defense Fund and National Resources Defense Council).

(iv) Presiding officer made it clear that Hearings will be strictly for cross-examination of participants' testimonies in affidavit form only.

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March 15, 1974 - Written testimony by 38 objectors to be submitted in affidavit form.

April 8, 1974 - Hearings open for cross-examination and rebuttal evidence. CN^-/Cd/Hg - first three. PCBs are 7th (third from last).

Mid-May, 1974 - Hearings completed. (Evenings/week-ends may be used.)

June 25, 1974 - Final standards published - effective in one year.

It should be noted that others who are affected by these standards can still comment by March 25 to:

Dr. C. Hugh Thompson,
Chairman-Hazardous and Toxic Substances
Regulation Task Force
Office of Water Protection Agency,
Environmental Protection Agency
Washington D. C. 20460

Industry representatives still wishing to comment and who need more background information can contact any of the industry participants (see attached list) or Mr. W. B. Papageorge of Monsanto (314-694-4051).

Mr. Richel (G.E.):

(i) Made a plea for greater industry participation. Comments can still be made up to March 25 with sound excuse for tardiness.

(ii) EPA at January 25 prehearing Conference were reluctant to expose themselves to cross-examination. Dr. Hugh Thompson to be available for cross-examination at Hearings.

(iii) Many objectors had common interest (e.g. environmentalists). EPA suggested a common counsel for this group.

(iv) On each of first 3 pollutants, EPA would offer 2 witnesses.

Mr. Doty (P.R. Mallory) asked about bearing of economic factors on standards.

Mr. Richel (G.E.) stated:

(i) Law is clear-economic factors are not relevant in establishing standards.

(ii) EPA is somewhat of a split personality on this. The

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Presiding Officer at the Prehearing Conference ruled that economics are relevant. NRDC (National Resources Defense Council) objected and was over-ruled.

(iii) Industry can and should therefore introduce relevant economic data. EPA would be wise not to expressly refer to such data in the published standard otherwise NRDC could go to court and EPA over-ruled.

Department of Commerce

It was pointed out that Sidney R. Gallier, Deputy Assistant Secretary for Environmental Affairs at the Department of Commerce wrote Monsanto on January 15 asking their views on the proposed effluent standards. Copies of Dr. Gallier's letter and Monsanto's response were circulated at the meeting. Industry should contact the Dept. of Commerce. Their legal counsel (Mr. Morland) has been active on the side of industry in other environmental hearings.

Mr. Salazar (NEMA) pointed out that the PCB Task Force had recommended a standard for PCBs of 0.01 ppb in the main body of water. (EPA was a member of that task force). ANSI C-119 proposes to use this Task Force recommendation and print this as a standard of 0.01 ppb in main body of water.

Mr. Sheppard (Westinghouse) queried if plant effluent standards could be set to meet 0.01 ppb.

Dr. Simons (G.E.) said this implied an acceptance of ANSI C-119 by industry.

There seemed to be some doubt on this.

PCB Characteristics

Dr. Tucker (Monsanto) presented hand-outs on:

(a) Monsanto's proposed definition of PCBs

(b) Comments on EPA's proposed analytical methodology

(c) Monsanto's pre-publication paper on biodegradation of PCBs.

(a) Definition of PCBs

1-4 chlorobiphenyls do not have long residence time. PCBs up to tetrachlorobiphenyl are not of concern on environmental persistence or biomagnification. Dr. Tucker proposed the following definition:

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"Polychlorinated biphenyls (PCBs) means materials containing the biphenyl group which is chlorinated and which have been shown to persist and rapidly bioaccumulate in the aquatic environment. These chlorinated biphenyls are identified as those components having gas chromatographic retention times greater than 54, relative to p, p-DDE = 100, under the standard conditions recommended in the EPA PCB test method."

Mr. Sheppard (Westinghouse) said Monsanto's proposed definition was relevant to persistence but was it relevant for standards directed toward toxic materials? Are persistent materials non-toxic?

Mr. Wright (Monsanto) stated the proposed effluent standard had two parts:

(i) acute limits directed to toxicity of materials and specifically limits PCB concentrations on that basis.

(ii) daily load in effluent - based solely on biomagnification (relevant to persistence).

Dr. Simons (G.E.) pointed out that section 307-A of the proposed standard refers to persistence as being a critical factor to be considered.

Dr. Tucker (Monsanto) stated we were badly hurt if all PCBs are regarded as persistent and if biomagnification factors of 200,000 are used. Researchers other than Monsanto have found bacterial degradation of PCBs and that PCBs have been found to undergo metabolism in both aviarian and mammalian animals.

Mr. Nelson (G.E.) asked if proposed PCB definition would exclude Aroclor 1016.

Dr. Tucker (Monsanto) Aroclor 1016 would be excluded for the most part (98.9% is lower than pentachlorobiphenyl). Aroclor 1242 would be excluded to 65% or better. Aroclor 1254 however would not be excluded.

Mr. Papageorge (Monsanto) pointed out that of the factors listed as being critical in determining which pollutants made the EPA list of 9/7/73 only biomagnification appeared relevant to PCBs.

Dr. Simons (G.E.) agreed.

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Mr. Wright (Monsanto) stated that an acute toxicological level is defined in the EPA Basis & Purpose document as ≤ 10 ppm (96 hour LC-50). He also believes that differences in toxicity among PCBs are minor until chlorinated as high as Aroclor 1260.

Mr. Nelson (G.E.) stated that words should be used in a discourse on definition to properly screen us on acute toxicity.

In reference to a comment that Aroclor 1254 would not be excluded by the proposed definition, Dr. Tucker (Monsanto) offered the opinion that transformer fluids were easier to recover than capacitors.

(b) Analytical Methodology

Dr. Tucker (Monsanto) stated the EPA's proposed method for PCB analysis was being submitted to ASTM. He thought the method was well written and capable of detection to ppt (parts per trillion) but it was untried and the quantitative accuracy is in question. The method was not submitted for round-robin testing before EPA adopted it. Monsanto has found that by spiking distilled water with 500,000 ppt or 500 ppb of PCBs we get values for PCB that vary by ± 55%. The EPA, however, claims a capability of detecting absolute values at 50 ppt. The EPA method ignores interfering substances.

Mr. Clark (Universal Manufacturing) said that with a proposed upper limit for PCB discharge of 0.0648 lb./day the sensitivity of the analytical method would vary "all over the lot" depending on the size of the water "reservoir" into which the PCBs discharge.

Mr. Sheppard (Westinghouse) commented that if the analytical techniques on determining PCB levels are so difficult, how valid are the determination of toxic values for PCBs.

Mr. Clark (Universal Manufacturing) asked if analytical techniques differentiate between different chlorine levels. Dr. Tucker (Monsanto) said it would depend on the PCB mixture. Aroclor 1242 could probably be identified quantitatively in a mixture with Aroclor 1260 but addition of Aroclor 1254 to the mixture would prevent identification because Aroclor 1254 contains PCB homologs that overlap both Aroclor 1242 and 1260.

Dr. Munch (Monsanto) said that the proposed EPA method does not use high resolution and hence handicaps identification of individual peaks.

Dr. Simons (G.E.) mentioned that after EPA set automotive emission standards (NIOX) the analytical methodology was found faulty and the standards were delayed. In this case, EPA is not setting the effluent standard on analytical methodology but

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on factors such as toxicity and persistence. The methodology is relevant in enforcement and monitoring. This then leads to the possible argument that the effluent standard is correct and justified on the basis of toxicology et al, but is not enforceable due to lack of an accurate method for absolute value determination of PCB discharge.

Mr. Richel (G.E.) pointed out that EPA won't buy an answer to that argument which seeks to raise the effluent standard to a level that can be accurately measured. Mr. Savage (Monsanto) felt strongly, however, that this dilemma needed to be in the record. Others agreed.

Dr. Tucker (Monsanto) said ASTM would hold a round-robin on the EPA method and that Monsanto would participate. He will send the name of the ASTM contact to the participants so that they can decide if they want to join the round-robin test.

Mr. Sheppard (Westinghouse) said he was not prepared to accept that the proposed EPA method for determining quantities and types of PCB in samples and animals was accurate enough so that toxic limits could be defined on the basis of PCB levels of questionable accuracy.

Toxicity

Mr. Hosmer (Monsanto) stated that the original EPA publication on Water Quality Criteria came from a publication by McKee and Wolfe for the State of California. The McKee/Wolfe volume was well done and EPA did not change much of it. There is now a new 2-volume EPA edition extracted from the work of 10 committees of the National Academy of Sciences.

The toxicity of PCBs is related to salmon egg studies and Monsanto doubts the validity of this. Monsanto has made their feelings known to Dr. Thompson of EPA but he thought the criteria were sound. Since then Russell Train has been sued by NRDC and other groups on the grounds that the toxic pollutants list is not long enough and the proposed standards are too lenient.

Mr. Wright (Monsanto) went through the rationale used by EPA in arriving at a PCB discharge maximum of 0.0648 lb./day. He also showed how the standard could be changed and yet be consistent with published data on PCBs. Details follow.

(a) FDA set arbritary proposed tolerances:

5 ppm in fish for human consumption
5 ppm in components for animal feed
0.5 ppm in complete animal feed

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(b) Monsanto would not disagree with these tolerances.

(c) FDA has presented - acute toxicity limits (point sources)
- chronic toxicity limits (daily load)

Acute toxicity limits:

96 hour LC-50 studies for PCBs show:

~280 ppb in fresh water (bluegill)
~10 ppb in coastal or seawater (pink shrimp/oysters)

Published data based on materials leaving an outlet and going into a body of water. Acute limits have no direct relation to chronic limits.

Chronic toxicity limits:

The EPA equation is:

Chronic limit X water flow rate X safety factor = gm/day discharge

In Marine organisms the chronic limit is set as

$$\frac{0.5 \text{ ppm}}{30{,}000} = 0.0167 \text{ ppb}$$

In fresh water the chronic limit has been determined by using 0.5 ppm as toxic limit for salmon eggs and a 200,000 biomagnification factor. This gives a chronic limit of

$$\frac{0.5}{200{,}000} = \underline{0.0025 \text{ ppb}}$$

The biomagnification level of 200,000 is based on unpublished data from Stalling & Meyer (Fish Pesticide Lab, U. S. Dept. of Interior, Colombia, Mo.). Dr. Simons said that in response to repeated requests by G.E. to the Columbia Lab the only reference they have been given is a Stalling & Meyer paper presented in Carolina in 1971 and which contains no mention of a 200,000 factor. Mr. Wright (Monsanto) stated he has seen only one literature reference to an accumulation factor of ~200,000 and that was in the hepato pancreas of a pink shrimp. If the PCB level was calculated on the basis of the total shrimp then the accumulation factor was only 22,000. Other references give accumulation factors of 1000-75,000 for whole tissues of various fresh water organisms. Accordingly, Mr. Wright proposes that a biomagnification factor of 30,000 and not 200,000 be used. He also proposes that we retain the chronic limit of 0.5 ppm without debating the salmon egg issue.

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This would lead to a discharge level for PCBs:

$$\frac{0.5}{30{,}000} \times (\text{flow rate})\ 10{,}000 \times (\text{safety factor})\ 0.5 \times (\text{conversion into lb./day})\ 5.4 = 0.459 \text{ lb./day}$$

0.5 × 189 m³ × — × 5.4 = 243 #/day.

This compares to the proposed standard of 0.0648 lb./day.

The safety factor comes from the EPA's Basis and Purpose document supporting the proposed effluent standards. It is supposed to take account of non-point sources of PCBs and is the same as 6 of the 9 toxic pollutants proposed for EPA standards. Monsanto's Medical Department feels this safety factor is arbitrary and confers no real toxicological benefit. If deleted, the revised Wright PCB discharge level would be 0.918 lb./day.

One of the most critical parts of the discharge equation is the water flow rate. A significant number of dielectric PCB manufacturers have plants on rivers where the flow rate is under 100 cfs or 1% of the EPA cut-off flow of 10,000 cfs. Several plants discharge into sewage plants which in turn have treated liquid flowing into rivers or streams with very low flow rates. For a river with 100 cfs flow the EPA maximum discharge would drop to 0.000648 lb./day or 0.162 lb. in a 250 work-day year. Even a revised standard of 0.918 lb./day at 10,000 cfs would only be 0.00918 lb./day at 100 cfs or ~2.3 lb. per 250 work-day year. Clearly this is a staggering target to have to meet.

Mr. Doty (Mallory) pointed out that in the present language of the EPA standards municipal sewage systems are not considered point sources.

Mr. Richel (G.E.) was of the opinion that where a plant discharged into a sewage system without treatment and hence into navigable waters the plant could have to comply with effluent standards on toxic pollutants. Mr. Papageorge (Monsanto) felt we should not be complacent and regard discharge to sewage plants being the answer to problems. Mr. Hosmer (Monsanto) stated that 10,000 cfs represents the largest flow the EPA will consider on the grounds that all industry would move to the largest river. The opposite of that argument is that it encourages small plants on every stream in the country.

Mr. Sheppard (Westinghouse) raised the issue of sedimentation. Since it appears that all the experiments to establish toxic values were run without sediment effects being considered, the real-life values were questioned. PCBs attach themselves to sediment. Furthermore the sediment moves down river and so PCB would be dispersed from the point source. It was pointed out by Dr. Richard (Monsanto) that Aroclor 1254 is soluble in water up to 50 ppb and that in time partitioning between sediment and

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water could take place. Mr. Wright (Monsanto) agreed that the discharge limits were extreme cases in the absence of sediment considerations and this was worth study and incorporation into arguments against the proposed levels.

Dr. Simons (G.E.) queried whether we were correct in concentrating our attacks on the criterion of toxic effects of mammals eating fish and ignoring the possible argument that fish per se must be protected. Mr. Wright (Monsanto) said the proposed standard says both. In salt water, standards are proposed that would protect the species that eat organisms containing PCB. In fresh water, if 0.5 ppm in salmon eggs correlates with <5 ppm in salmon then we are protecting salmon. He also said that the chronic limits and biomagnification limits he was proposing would protect the species themselves. We should, however, beware of arguing for higher levels in fish because we could draw EPA and FDA into conflict. The FDA levels in food, fish etc., are temporary tolerances and any arguments against their validity could lead to a reduction in these tolerances.

Mr. Savage (Monsanto) queried whether raising the level in organisms could cause possible danger to predators.

Dr. Simons (G.E.) quoted from page 39 of the Basis & Purposes document which states that the body burdens of birds and mammals should not increase over present levels. Page 51 of the same document cites a Nat. Acad. Sci. report which gives 2.0 ppm PCB as tolerable level in flesh of whole fish. $\frac{2.0}{200,000} = 0.1$ ppm PCB is given as tolerable level in water divided by a safety factor of 5 to give a maximum PCB concentration in water of 0.002 ppm. Thus EPA accepted 2 ppm PCB level in fish but got to water concentration of 0.002 ppm by using a high level of 200,000 for biomagnification and an arbitrary factor of 5.

If we were to revise the proposed EPA standard by:

(i) using 2.0 ppm as chronic limit in fresh water species instead of 0.5 ppm;

(ii) substituting 30,000 instead of 200,000 for biomagnification factor;

and

(iii) ignoring safety factor of 0.5

then the maximum permissible discharge in lb. PCB per day would be:

$$\frac{2.0}{30,000} \times 10,000 \times 5.4 \simeq 3.6 \text{ lb.}$$

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For the plant situation on a river with a flow of only 100 cfs the discharge would be 0.036 lb/day or 9.0 lb. per 250 work-day year. These levels are still far below the 5 lb./day given in ANSI C-107.

It is therefore apparent that other aspects of PCBs must be highlighted in order to get away from PCB discharge levels as low as even our "revised" proposals.

Aspects to concentrate on are:

(1) Definition of PCBs that excludes biodegradable homologs.

This could exclude 90% or better of Aroclor 1016 and 65% or better of Aroclor 1242. On that basis, discharge levels would be as follows:

PCB Type	Stream Flow (cfs)	Discharge (lb.PCB equivalent/day)		
		EPA	Wright	Simons/Wright
Any PCB	10,000	0.0648	0.918	3.6
Any PCB	100	0.000648	0.00918	0.036
Aroclor 1016	10,000	0.648	9.18	36.0
Aroclor 1016	100	0.00648	0.0918	0.36
Aroclor 1242	10,000	0.194	2.75	10.8
Aroclor 1242	100	0.0019	0.027	0.10

(2) Try to change stream flows from the present value of the flow rate in cubic feet per second (cfs) expressed as the probable low rate occurring during a 7 consecutive day period once in 10 years at the effluent point.

If the average flow rate over a period of time (to be agreed on) was used, the lowest flow rate in the equation could conceivably be raised by a factor of 10 from 100 to 1000. In the Simons/Wright version for a standard the Aroclor 1016 discharge could be raised to 3.6 lb./day at 1000 cfs flow and Aroclor 1242 to 1.0 lb./day at 1000 cfs flow.

(3) Magnitude of PCB Point-Sources

It is possible that EPA and environmentalists are totally misinformed on the number of plants still using PCBs. In the U.S. today there are:

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1 PCB manufacturing plant

~18 capacitor plants using PCB

~27 transformer manufacturing plants using PCB

In the past there were probably 1500-2500* plants using PCBs. Only 2-3% of these plants continue to use PCB today.

* (Subject to closer checking if necessary)

In the past ~97% of plants using PCBs purchased ~40 million pounds of PCB per year. Monsanto's PCB sales policy has therefore

- reduced number of using plants to ~2-3% of previous total.
- eliminated ~40M lbs. PCB sales per year.

The EPA standard would limit PCB discharge per plant to 0.0648 lb./day or ~3.2 lb./day across the U.S. (~50 plants). This equates to ~800 pounds in a 250 work-day year. Since fish have survived throughout the 40+ years that PCBs have been produced and widely used, the standard proposed by EPA seems far too drastic.

Turning again to the Simons/Wright proposal we can estimate the effect in terms of annual PCB discharge into water across the U.S. at 1000 cfs:

			US Total per	As Persistent PCBs		
Discharge As	Discharge (lb./day)	No. Plants	250 days (pounds)	Discharge (lb./day)	No. Plants	US Total
Any PCB	3.6	*1	900	1.2	1	300
Aroclor 1016	3.6	18	16200	0.36	18	1620
Aroclor 1242	1.08	4	1080	0.36	4	360
Aroclor 1254	0.36	23	2070	0.36	23	2070
			20,250			4350

* Plant is on river in excess of 10,000 cfs.

Using this technique an argument can be made in favor of the ANSI C-107 proposal of 5.0 lb./day.

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Proposed Effluent Standards

Dr. Simons (G.E.) summarized the points he felt had to be dealt with in trying to change the proposed standard:

1. Higher persistence of higher PCBs versus alleged lower acute toxicity

2. Background levels of PCBs

3. Written testimony of participants and correlation

Toxicity

EPA Basis & Purpose document (page 50) states that 96 hour LC-50 to fish cannot adequately measure toxicity of PCB. Where is time demarcation between acute and chronic. Chronic effects can be either lethal or non-lethal.

Why are PCBs on the list on toxic grounds?

LD-50 for PCB is such that it is not considered toxic to humans.

For protection of aquatic life the Nat. Aca. Sci. set a 96 hour LC-50 of 10 ppm or less.

In proposing a definition for PCBs, Dr. Simons (G.E.) felt we should stress:

(a) lack of persistence of homologs below tetrachlorobiphenyl.

(b) chronic toxicity does not arise for the lower homologs because they are non-persistent.

(c) ignore acute toxicity - no real differences between Aroclor 1016, 1242 and 1254.

Participants need to consider: Do we have the best definition?

In the tentative EPA analytical method we should take note that in the table on p.3-22, the percentage of PCB was not controlled.

Mr. Carlson (E.U.C.) pointed out that in its present form the standard could saddle present PCB users with all other discontinued uses. Dr. Richard (Monsanto) pointed out that FDA and Boxboard Manufacturer's Association had agreed on a protocol that protected recycle paper users from just such a situation. Mr. Bergen (Monsanto) asked that copies be circulated to participants.

We need to word our definitions to exclude residuals. Participants should exchange proposed drafts on wording regarding residuals by March 7.

G. E. stated we should not approach the hearing on the basis that things can't be done. Rather take the proposed standard and point out what it means in real life. In G.E.'s case they use X M lb./year and yet can't lost 0.5 drops per day. Stream flow rates make the matter worse. This is a point on which Dr. Thompson should be cross-examined.

Of the participants present, 5 plants discharge into sewers with outlets into rivers (very small except in 2 cases). Three plants discharge into small rivers.

No one at the meeting could cope with the EPA standard as it is proposed. Only Jard expressed an opinion on what level they could live with. (Jard stated 27 lb. Aroclor 1016 per day. This would be 2.7 lb. PCB by our proposed definition.)

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Participation at EPA Hearing

Definite participation:	Monsanto G. E. Westinghouse
Undecided:	Electrical Utilities Jard NEMA
No participation:	Electronic Components Mallory

Objectors of record could adopt non-responding company as witness.

G.E.'s testimony will fall into the following areas:

- Explanation of why PCBs are used
- Consequences of ban on customers
- Inadequacy of EPA/Nat. Acad. Sci. statements
- How standards would apply to G.E.
- Inadequacies of the Standard
    - definition
    - methodology
    - logic behind the standard

Other contributory actions:

- Involve Federal Energy Office (e.g. Aerovox letter on motor-run capacitor contribution to ease energy crisis.)
- Involve F.E.O./other agencies along lines of petrochemical producers' PEG report.
- Power Systems Group of IEEE will circulate a position paper on PCBs (technical aspects) in the dielectric industry to Congress, EPA, FEO and Dept. of Commerce (target date: April).

Action Plans

1.	(W. B. Papageorge)	Circulate to participants copies of FDA/Boxboard Manufacturers protocol on PCBs in recycle paper.
2.	(Participants)	Exchange drafts on testimony regarding PCB residuals/background levels with each other by March 7. (Monsanto contact should be W. B. Papageorge.)
3.	(Participants)	Submit to W. B. Papageorge their thoughts on proposed PCB definition (to exclude 1-4 chlorine homologs).
4.	(Participants)	Communicate with each other on how best to handle sedimentation phenomenon (as raised by Mr. Sheppard of Westinghouse).
5.	(E. S. Tucker)	Send out name of ASTM contact for participation in round-robin on proposed EPA analytical method.
6.	(Participants)	Write to Dr. Galler of Commerce Dept. opposing EPA standards. (See Galler letter to Monsanto and Monsanto response.)
7.	(Participants)	Those who have not responded to EPA can still write Dr. Thompson by March 25.
8.	(A. Salazar, NEMA)	(a) Get feedback from Sangamo/McGraw Edison on the proposed standards.
		(b) Determine role NEMA will take on affidavits/testimony at EPA hearing.
9.	(W. B. Papageorge)	Obtain PEG report and send to Mr. Nelson (G.E.).
10.	(Participants)	Involve F.E.O. in EPA Hearing along lines of Aerovox letter to Secretary Simon.

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COMPANY CONFIDENTIAL

POSSIBLE CUSTOMER QUESTIONS ON PCBs

PUBLICITY

Question 1

What articles have appeared on the PCB problem?
Will you send me copies?

Answer:

In the U.S., newspaper articles have appeared in the San Francisco Chronicle on Feb. 24, 1969, the San Francisco Examiner on Feb. 25, 1969, and the Hartford Times on Aug. 3, 1969. Numerous articles were generated by the Wisconsin "DDT Hearings" in May, 1969. At the hearings, witnesses discussed the problem of PCBs as "interfering substances" in their search for DDT in the environment. PCBs, they said, produced peaks on a gas chromatograph similar to the peaks produced by DDT. In no case was PCB indicted at the Wisconsin hearings.

Copies of the articles will be made available on request. Regional managers should contact E. V. John, Public Relations Manager Organic Chemicals Division, in St. Louis and copies will be forwarded to the customer through the regional manager's office.

In addition to the newspaper articles mentioned above, there have been radio broadcasts. At the time of the San Francisco Chronicle and Examiner articles, radios in the San Francisco area also carried the story. In August, the sports editor of the Hartford Times syndicated a radio broadcast on the subject of PCBs, and in Dec., 1969, the Canadian Broadcasting Co. (radio) carried an interview they taped with a member of our medical department.

Question 2

Were Monsnato's Aroclors specifically mentioned in these articles?
If so, which ones?

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Answer

Monsanto's Aroclors were mentioned in some of the articles but only in the San Francisco Chronicle story in Feb., 1969, was Aroclor 1262 specifically mentioned by number. In several of the articles, Monsanto was also identified as the sole U.S. producer of polychlorinated biphenyls, marketed under the tradename of Aroclor.

Question 3

What did the articles on the PCB problem say?

Answer

Since the outset of the "PCB problem", when the first article appeared in the U.S. press in Feb., 1969, the whole question has been closely interwoven with the question of DDT as a possible environmental contaminant.

The San Francisco Chronicle article carried a headline, "A Menacing New Pollutant." In rather sensational style, it identified PCB as a threat to birds and humans, highly toxic in a gaseous state and related to known cancer-causers. PCB presence in the environment is rising swiftly, the article stated.

The Examiner article called PCB a "plastic pollutant in the Bay and Mothers' Milk." This article called PCB an "alarming" new chemical pollutant that is playing a role in the declining peregrine falcon population, has been found in mothers' milk, and is the "latest addition to a growing list of chemicals in the ocean---- the newest symptom of man's chemical invasion of the ocean."

These two articles quoted Dr. Robert Risebrough, a researcher at the Institute of Marine Resources in the University of California's Department of Nutritional Scientists, on the detrimental effects of PCBs. Later Dr. Risebrough said he had been misquoted in some newspaper stories.

The Hartford Times story called PCB pollution a "new puzzle." Less sensational than the San Francisco articles, the Times gave an account of PCBs being found in the environment and the studies under way to determine their biological effects. This article, says Dr. Risebrough, tends to clear PCB of blame.

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Articles generated by the Wisconsin DDT hearings generally discussed PCB as an interfering substance discovered in scientists' search for DDT in the environment. Dr. Risebrough said at the hearings that there was no proof at the moment that PCB alone can cause thin eggshells, one of the phenomenon that he had discovered in studying the declining population of the peregrine falcon.

LEGISLATION

Question 1

Are there any Federal/State/local laws under which the use or discharge of Aroclors could be prohibited?

Answer:

No existing Federal, State, or local laws prohibit the discharge of Aroclors. However, in a number of states the basic water pollution control legislation is so broad that state agencies can prohibit chemicals, deemed necessary, from being discharged.

Question 2

Is the DDT and the PCB problem related?

Answer:

We are not a manufacturer of DDT or other chlorinated hydrocarbon pesticide and, therefore, have no knowledge of the seriousness of the charges against DDT other than what has been so widely publicized on TV, in the press and in technical journals. To the extent that both DDT and PCB are chlorinated hydrocarbons, then there is a similarity. They are sufficiently different in their chemical structures, however, that it would be entirely wrong to assume that both behave in the same way in the environment. There is another and more obvious difference. DDT and other chlorinated hydrocarbon pesticides were specifically designed for a job that obviously leads to their being scattered in wide spread fashion across the countryside. Rain, birds, wind, insects further scatter these pesticides in an uncontrollable manner. PCBs are not used in this fashion and

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Monsanto has never sought to promote this. This, we believe, is an important distinction that should not be overlooked if DDT and PCB are linked as a common pollutant of the environment. To our knowledge PCBs have never been identified in the absence of DET or other chlorinated hydrocarbon pesticides.

Question 3

Could it be PCB that's causing the environmental problems and not DDT?

Answer:

We believe that present-day GLC and mass spectrometric techniques are sufficiently accurate to be able to differentiate between DDT, related pesticides, their metabolites and PCB.

Question 4

What authority do State and local governments have in banning/ controlling the use of PCBs.

Answer:

They do have authority to ban or control use of any substances they consider harmful.

EFFLUENT AND ITS CONTROL

Question 1

How do I dispose of Aroclor 1254/1260, etc. effluent from my plant?

Answer:

We would suggest collecting all process effluent, equipment washings, tank or drum washings and then regularly taking to the nearest toxic materials dump. You may also be able to use a sanitary land-fill if permits are issued for this in your locality. We don't recommend feeding this material to local sewage treatment plants or taking out to sea in drums for dumping. These methods do not

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solve the problem of contamination. We are working on the disposal of these materials by incineration and biodegradation. Our work in these areas has not yet reached the stage where we can offer practical suggestions. It is of interest to note, however, that research is underway fo find catalysts to make DDT self-destructive. The possibility exists that we could find catalysts that would destroy PCBs in settling tanks constructed to catch all your effluents.

Question 2

Can I test my effluent to see if my effluent has no Aroclor 1254, etc.?

Answer:

Yes. Analytical equipment is available that can do this if the proper technique is used. The basis of the method is GLC or gas liquid chromatography. Are you or anyone in your company familiar with this? Do you have GLC equipment? If you do, we can send you a description of a method that could identify PCB. If not, there may be a good analytical testing laboratory in the vicinity where you could send samples and rely on the results if you want to test your effluent.

Question 3

What is a "safe" PCB level for effluent leaving my plant?

Answer:

As our letter points out, parts per million (ppm) and parts per billion (ppb) have been mentioned in the published articles. There is still a lot of doubt as to how absolute any quoted values are. To bring this into the realms of reality, this definition of ppm and ppb may help clarify things.

To give you a practical example, the escape of one-two gallons per day could lead to samples in a stream beside the plant showing 10-50 ppb on analysis.

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Question 4

You must have quite a control problem at your plants--I would think Monsanto's Aroclor plants are the major polluters--how are you handling control?

Answer:

The Aroclor products we make to sell at a profit, so economics dictate maximum housekeeping, minimum loses. The Aroclor process is a "dry process" or closed system.

Question 5

How does Monsanto think Aroclors can get into the environment and cause so much pollution?

Answer:

Disposal, leakage from systems using it, spills, etc.

Question 6

If I analyze my effluent stream and find ppb there, how do I know it didn't come from air-borne contamination or was present in the process water that I pump from the XYZ river into my plant?

Answer:

Analyze water entering your plant and compare. There is a method available for sampling air.

Question 7

You seem to think from the tone of your letter that the source of pollution is from effluent disposal into streams. In my process, Aroclor 1254, 1260, etc. vapors escape. What precautions can I take to prevent (a) employee problems and (b) escape of vapors into the atmosphere?

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Answer (7):

Articles on PCB interference with pesticides analysis have mentioned the possibility of loss to the atmosphere from vaporization when Aroclors are heated. We find this hard to believe and it warrants considerable investigation.

TOXICITY

Question 1

If PCB is a danger to fish and birds, how about humans?

Answer:

The amounts being found in the environment are not considered a danger to humans or fish. The ~~whole~~ question on chlorinated pesticides relates to birds.

Question 2

Are Aroclor 1254/1260, etc. more toxic than other Aroclors? Why?

Answer:

There is a difference in toxicity depending on degree of chlorination. This is not to say that higher chlorination is more toxic than lower chlorination. The alleged PCB problem is not really related to degree of toxicity.

DIFFERENCES BETWEEN AROCLORS

Question 1*

In your letter, you state that Aroclor® 5060," 5442 and 5460 are not PCBs. What are they?

Answer:

They are chlorinated terphenyls.

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Question 2*

What's the difference between a chlorinated biphenyl and a terphenyl?

Answer:

A terphenyl has three benzenes linked together and biphenyl only two. They are, therefore, similar but different, just as naphthalene is different from benzene.

Question 3*

Why should PCB be an environmental contaminant and chlorinated terphenyls not?

Answer:

I don't think there is any positive answer on this and I can't give you any theories. However, I would emphasize that not all PCBs appear to be contaminants. Those such as Aroclor 1221, 1232, and 1242 haven't been identified in marine, aquatic and wildlife environments. Chlorinated terphenyls - at least those made by Monsanto - have not been identified in the environment either.

Question 4

Since you sell other PCBs beside Aroclor 1254 and 1260, why are they not found in the environment?

Answer:

One reason could be that they biodegrade and hence never build up to a level where they can be labelled persistent contaminants. Therefore, although you would find it in an effluent stream if you analyzed it just after you poured PCB into it, its absence when a river, for example, is analyzed downstream at a later date would indicate degradation by bacterial organisms.

We are actively working on this aspect of biodegradability in our laboratories at this time. Results of this type of work won't come to hand quickly but our preliminary work on PCBs of less than 54% chlorine looks promising.

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Question 5

In your letter, you make no mention of Aroclor 1262 and 1268. What is their status?

Answer:

It could be that their semi-solid/solid water insoluble nature means they are far, far less likely to become "mobile" contaminants. It could be that their structural differences from Aroclor 1254 and 1260 are responsible for the apparent lack of a problem. In any event, they have not been identified by scientists in the environment and--believe me-- a lot of scientists seem to be looking for PCBs.

Question 6*

Both Aroclor 5460 and 1260 contain 60% chlorine. Why is one a problem (1260) and apparently not the other (5460)?

Answer:

A terphenyl has three benzenes linked together and biphenyl only two. They are, therefore, similar but different, just as naphthalene is different from benzene.

I would emphasize that not all PCBs appear to be contaminants. Those such as Aroclor 1221, 1232, and 1342 haven't been identified in marine, aquatic and wildlife environments. Chlorinated terphenyls--at least those made by Monsanto--have not been identified in the environment either.

Question 7*

Does this PCB problem mean that you have discontinued efforts to get Aroclor 5460 approved by FDA?

Answer:

No.

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Question 8*

Is the reason for not resubmitting your petition to the FDA for approval of Aroclor 5460 due to this PCB publicity?

Answer:

No.

Question 9

What's the problem then?

Answer:

We are bringing a new solid Aroclor plant on-stream in the next two-three months. We want to make sure it produces the same quality Aroclor 5460 we used in our feeding studies for the FDA. Once we're sure that's O.K. -- and we feel it will be--then we'll get the petition moving again but FDA clearances do take time.

Question 10

Does this PCB publicity mean that FDA approval of Aroclor 5460 is not going to be obtained?

Answer:

We have no reason to think the two things are related. Aroclor 5460 is not chemically a PCB. The delay resulted from the need to set up certain analytical methods to satisfy FDA. This involved analytical instrumentation and is being completed now. It is my understanding we plan to resubmit our petition although I personally don't know the exact date.

CONTAINERS

Question 1

Joe Doe buys all my used Aroclor drums without me having to wash them. I get $5.00 a piece. I can't afford to wash them out. Even if I did, what would I do with the washings?

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(Question 1 con't)

What should I do? Should I tell Joe Doe? Will Monsanto take them back or pay me $3.00 plus my costs to take them to a dump?

Answer:

Don't have an answer at this time. We just don't know.

APPLICATIONS

Question 1*

Could Aroclor 1254/1260 escape from my sealant/adhesive/coating whatever into the environment?

Answer:

This will depend entirely on the final use to which your product is used--its ultimate disposition.

Question 2*

My product X contains Aroclor 1254/1260. What should I tell my customers?

Answer:

Tell your customer--We want to advise you of a possible environmental problem. Without knowing what your customer does with product X, this is hard to answer. (We would say that it would not seem wise to use Aroclor 1254 or 1260 for keeping dust down on the roads, for use in dental sealing compounds or as carriers for pesticides.)*

*Only if you suspect or are told this is what the application is.

Question 3

Does Monsanto intend to continue manufacture of Aroclor 1254/1260, etc.?

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Answer (3):

I have been given no indication otherwise.

Question 4*

Should I look for replacement for Aroclor 1254/1260, etc. ?

Answer:

I think only you can decide this. How easy would this be for you? Do you have any other replacement product in mind?

Question 5*

Does Monsanto have replacement products for Aroclor 1254 and 1260?

Answer:

As you know, we have over eighty plasticizers in our line and there's quite a bit of product interplay so it is possible that there is another product in our line that might replace them. What resin do you use? Perhaps we could look at these resin/plasticizer Selector Charts in the back of the Blue Book. I've got it with me.

Question 6*

Is Monsanto working on replacements for Aroclor 1254 and 1260?

Answer:

These research fellows are always busy on things like that. To some people Aroclor 1254 and 1260 have draw-backs.-- quite apart from present publicity on PCB. Aroclor 1254 is fairly volatile. Aroclor 1260 is very viscous and difficult to handle. For polysulfide sealants, for example, the technical people in St. Louis have just sent us data on products that will behave better than Aroclor 1254 in polysulfide sealants. Maybe there's something here for you to look at. Let's go over it.

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Monsanto

PCB file

FROM (NAME & LOCATION) W. B. PAPAGEORGE - ST. LOUIS

DATE FEBRUARY 8, 1971

cc H. S. BERGEN
~~A. J. JASON~~

cc Paul Hodges

SUBJECT PCB ENVIRONMENTAL PROBLEM
JANUARY STATUS REPORT

REFERENCE

TO :
P.J.A. MARSH - BRUSSELS
W. S. CLARK
J. R. DURLAND- TOKYO
E. V. JOHN
R. E. KELLER - 2ND STREET
R. M. KOUNTZ
T. L. GOSSAGE
P. S. PARK
W. R. RICHARD
J. R. SAVAGE
E. P. WHEELER

GENERAL:

PCB's as high as 40 ppm in fatty tissue have been detected in chickens in New York State. FDA and USDA agreed to permit 180,000 pounds to be released for food use if PCB content does not exceed 5 ppm in salvaged edible parts. Source of PCB has not been determined.

The State of Florida informed Monsanto's Pensacola Textile plant it must take emergency measures to prevent PCB's from entering the Escambia River estuary and bay and within 30 days have an approved permanent solution or face a penalty of $5,000 per day. No PCB's are present in the plant effluent. The 2.5 ppb PCB's which were detected are being extracted from sediment contaminated prior to the summer of 1969.

Dr. K. Diane Courtney, National Environmental Health Sciences Institute, Durham, N.C. who conducted terotology studies on 2,4,5-T and NTA-mercury-cadmium informed us that she found no teratogenic effects on rats with Aroclor 1254 and Aroclor 1260. She plans to repeat her studies using laboratory mice.

Legislation has been proposed in the Massachusetts House of Representatives banning the discharge of PCB's to the environment. A public hearing is scheduled for February 8, 1971.

PLAINTIFF'S EXHIBIT 1582

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MARKETING:

Pydraul Reformulations - will be completed by our March 1 deadline. Most of the Pydrauls have already been reformulated, and assuming on February 15 our reformulated Pydrauls 135A, 230A, 312A, 540A, and 150A pass the Factory Mutual Fire Test, our work will be done.

General Motors, Phosgene Issue - seems to be under control. Elmer Wheeler and Raleigh Garcia will visit G.M. Tonawanda the week of February 8 to try and get them to issue a memo which will specify the Pydrauls as non-hazardous. Based on some telephone conversations Raleigh has already had, he thinks there is a fair possibility of accomplishing that goal.

U. S. Steel, Christy Park - converted to Vital 29. Though this competitive fluid is lower in price, Raleigh Garcia is convinced the move was primarily based on environmental considerations. To our knowledge, this is our first major loss of business for ecological reasons.

Pydraul A200-B - is now fully accepted by Johnson Motors and Chevrolet-Massena as a complete replacement for Pydraul A-200.

5-drum dielectric spillage on common carrier cleaned up so future contamination of anything not possible.

Tankcar of fluid from G.E. at Rome, Georgia coming into WGK for incineration.

More heat transfer FR food users switched to Therminol 66. Mrs. Pauls Kitchens was a big one this month - 60 drs. at various locations.

ENGINEERING:

CEA 2415 - Incineration - WGK

Design is nearing completion and field work was started by the plant maintenance force. Foundation work is well along and considerable pipe has been fabricated.

CEA 2417 - MCS-1016 - WGK

The project scope was modified to incorporate facilities for producing all liquid Aroclors at W. G. Krummrich plant. The concept here is that the Anniston facilities would be held in standby position. The revised scope was approved and the revised appropriation request data transmittal was issued.

Definitive design was continued and field work was started by the plant maintenance forces. Construction was a little slow in the start because outside labor forces would not support the plant's effort. At this time, approximately one-half of the drilled piers for foundations are completed and foundation work has started. This work needs to progress rapidly to permit shipping the fractionation column which is being assembled in St. Louis.

CEA 7817 - Disposal of PCB's on Solids

Quotations were received from selected vendors for various combinations of facilities. Simultaneously, Marketing was surveying Monsanto customers to better define what and how much solids would be returned. Engineering has been temporarily stopped until a forward program is established.

CEA 2451 - N-C Phosphate - JFQ

Research, Manufacturing and Engineering continued to study the process and resolve problem areas. The process is now fixed and Engineering is revising the preliminary scope and getting the capital estimate. An appropriation request data transmittal is scheduled for late this month.

JAPAN:

No new developments reported.

EUROPE:

Customer letter sent to all non-controllable PCB users in the U.K. advising of decision to cease sales on March 1st 1971.

All European D.S.O. Managers have been advised of this decision and background.

We are investigating press statements that restrictions or a complete ban will be put on the use of PCB's in Sweden.

At a meeting with the Marine Safety Department of the Board of Trade in London, we were informed that Aroclor 1242 had been classified under Class 9, Miscellaneous Hazardous Goods, primarily on the grounds that ecological damage could be caused in inshore waters. It was agreed that the hazard from acute toxicological effects was very slight and that classification in any higher category would not be warranted. The question of the suitability of the present Monsanto tote bins was raised. This will be investigated by our Distribution Department.

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MEDICAL:

Reports on the acute vapor inhalation studies with MCS -1016 and Aroclor 1221 were received from Industrial Bio-Test Laboratories.

The data obtained in these brief studies indicate that four hour exposures to a vapor concentration of 0.64 milligrams per liter of air of Aroclor 1221 and 3.7 milligrams per liter of MCS 1016 had no effect on the test animals. The above concentrations represent approximate saturation with the air of the vapor under ambient conditions.

Dr. Keplinger of Industrial Bio-Test was queried by Dr. Garth Fitzhugh of the U. S. Food and Drug Administration as to the current results on the on-going rat reproduction studies. He was reassured that 10 ppm of 1242 show no effect and the continued indication that 100 ppm of 1254 and 1260 show no effect on reproduction.

PUBLIC RELATIONS:

Following inquiries from the Pensacola Plant and Business Week magazine, background information on Monsanto's program to control PCB was furnished. Pensacola had been receiving calls and letters following a TV show "Death of the Gulf" which partially implicated the plant and PCB. Business Week was working on a general pollution control story.

News articles and editorials from Wales have told a positive story of Monsanto's efforts to restrict sales to closed systems and to convince other manufacturers to do the same.

RESEARCH:

Biodegradation Studies - Ruabon

To investigate and define the extent to which biodegradation of polychlorinated biphenyls is likely.

A biphenyl-degrading culture (C_2) has been found to degrade many isomers of PCB. A theoretical hypothesis has been formulated, from the known degradation pathway for biphenyl, to predict which chlorinated isomers might be expected to degrade. Experimental work has largely confirmed this hypothesis although a few loose ends still remain.

The extent of degradation of a number of Monsanto products has been studied experimentally. Analytical procedures have been developed to analyze the degradation residues and technique for quantifying these residues is at an advanced stage of development. It has been demonstrated that the

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order of degradability for Monsanto products is as follows:

MCS 1016 > MCS 717 > MCS 762 > Aroclor 1242, MCS 1016 being the most degradable.

Experimental work has also demonstrated that HB40 can be degraded by C_2, but as with the PCB products, quantifacation of the extent of degradation has still to be determined.

We are supporting a project at University College, Bangor, in which it is hoped to select and study cultures specifically for degrading chlorinated biphenyls. Claims to have isolated cultures capable of growing on Aroclor 1242 and 1254 have not so far been substantiated, but a new culture, C_3, which appears to degrade biphenyl through a different pathway from C_2 has been isolated. This culture is being grown at Ruabon for experimental studies.

Aroclor - Environmental Contamination - Ruabon

1. Prevention of Indiscriminate Pollution by PCB

Technical service to customers has included advice on how to avoid pollution and instruction on disposal of waste material. Analytical service has been provided in many cases to assist customers in defining their pollution problems.

We have established that the incinerator operated by Purle Waste Disposal Ltd., at Rainham is satisfactory for the disposal of liquor PCB wastes. We have had discussion with incinerator manufacturers and operators to find a suitable unit for the incineration of solid wastes, but have not yet completed this.

Advice and assistance has been given to the Newport Plant on monitoring and control of pollution. Improvements in the interception of Aroclor contaminated drain-water and in pollution-control generally, coupled with routine monitoring of the plant effluent, have resulted in a steady decrease in the average level of PCB's., but occasional high levels indicate the need for constant vigilance.

2. Technical Cooperation with National Authorities

During the year we have maintained close relationships with a number of national authorities in the U.K.; these have included the Nature Conservancy, the Ministry of Agriculture Fisheries and Food and the Government Chemist. In the Netherlands, the University of Utrecht

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and the TNO organization have been visited; in Sweden we have liaised with the National Environment Protection Board. Through meetings, discussions and correspondence with numerous societies and organizations interested in various aspects of the environment we have presented Monsanto's technical contribution to the PCB problem and have, in general, received complimentary comment regarding Monsanto's attitude.

The discovery, by analysts at the Ministry of Agriculture's Infestation Control Laboratory of relatively high levels of PCB's (40% chlorine) in small cardboard drums was one of the first reported findings of the lower chlorinated PCB's in the environment. This report was a major factor in influencing NCR/Wiggins Teape to change from Aroclor 1242 to HB40.

Although spasmodic press reports have appeared relating PCB's to the sea-bird incident of late 1969, the NERC report on the incident has not yet been published. The final draft, of which we have been promised a copy, has not yet been agreed amongst all the contribution.

We made technical presentations to the other European manufacturers of PCB products as part of a plan for unified action in Europe.

The paper on "Askarels-Environmental Pollution" was presented at the August CIGRE meeting in Paris and a modified version made available to the Conference on PCB's at Stockholm in September. This paper was well received.

Environmental Studies - Ruabon

During a visit to B.I.C.C. at Helsby we introduced MCS-1016 as a potential replacement product for Aroclor 1242. In a general discussion on pollution problems, with the Technical Manager, it was clear that BICC are anxious to cooperate. They will also look for any technical improvements which MCS-1016 might provide and report on to the results of the trials.

There has been some U.K. press reaction to the publication in "Nature" of the report by A. V. Holden, at Pitlochry, that PCB's are present in sewage sludge which is being dumped in the Clude and Thames estuaries. This is the report on the work which Holden described to us last May. The "Guardian" report links this with the bird-kill in the Irish Sea in late 1969. We are still awaiting the draft of the NERC report on that incident. The PCB story has now been superseded, at least temporarily, in the U.K. press by the "mercury in tuna fish" scare.

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Biodegradation - Ruabon

We have still failed to degrade the 2,3,3',4,5-pentachlor biphenyl using the C_2 organism, using a technique similar to that used successfully with the 2,2'3,3',4',5'-hexachlor biphenyl. Work is still continuing with this and with 4,4'-dichlor biphenyl.

A new soil culture (C_3), claimed by workers at University College, Bangor, to degrade biphenyl by a different mechanism from C_2, has been used to degrade Aroclor 1242 and MCS-1016. Preliminary results confirm that degradation occurs, but we do not yet have information on the pattern of degradation.

Work is progressing on the analytical procedures for quantification and identification of residues. We are now able to identify a number of peaks and by a process of elimination suggest probable identification of other components. We hope to give figures for quantifying total residues in degraded Aroclor 1242 and MCS-1016 during the next few weeks. This information will be extremely useful in "selling" MCS-1016 against competitive products.

Environment & Applied Sciences Analytical Chemistry Group

G.E. Samples

The analysis of milk samples, submitted by G. E. Pittsfield, Mass., for PCB's have been completed. The electron capture (EC) chromatograms of the extracts, although appreciably altered, were most similar to our production Aroclor 1254-Aroclor 1260 type materials. The levels found ranged from 24.0 - 29.3 ppb apparent PCB's calculated as Aroclor 1254. A second set of samples was requested to verify these results. They are in hand and will be analyzed as soon as possible.

Bisphenol A - JFQ

Three samples taken from a current lot (QM-852) of Bisphenol A were analyzed for PCB's. The material contained 26 ppb PCB's calculated as Aroclor 1242. Aroclor 1242 was used as the standard, although lighter chlorinated biphenyls were also present. The EC chromatograms were not identical with either Aroclor 1232 or Aroclor 1242.

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Anniston Plant Fish Survey

The analyses of all fish collected in the last survey of the streams associated with our Anniston plant for chlorinated hydrocarbons (Aroclor 1242, Aroclor 1254 and DDE) are greater than 50% completed (55 samples). The levels found in the completed samples have been forwarded to the Anniston Plant personnel. They, in turn, have identified 6 "target" species on which we will focus future analytical efforts in order to decrease the required man hours needed to complete the analysis of this set of samples.

Agway Company

A research representative of Agway Company was instructed on the techniques Monsanto uses to analyze biological samples for PCB's. During his visit several samples of commercial chicken chow, chicken muscle and eggs were analyzed for PCB's. EC gas chromatography indicated that PCB's were present in all samples analyzed including an egg composite extracted in Agway's research laboratories. The presence of tri, tetra and penta chloro biphenyls in the Agway extract was confirmed by GCL mass as well as EC/GC. The estimated levels of PCB's (as Aroclor 1248) found in the feed ranged from 0.10 - 0.17 ppm and in the muscle from 0.29 - 1.55 ppm. The EC/GC and GC/mass analysis of an egg composite sample remains to be completed.

Biodegradation Testing

SCAS Statistical Study

The statistical study of the semi-continuous activated sludge (SCAS) variables has now been in progress for three weeks of the required eight weeks. Monitoring of the SCAS units will continue until the complete set of data has been accumulated.

HB-40 - MIPB

Three weeks of the final four week sampling period have been completed. Ultraviolet analysis confirms that HB-40 and MIPB continue to degrade at the previously observed rates.

TCB, Aroclor 1221 & 2,2'-Dichlorodiphenyl Ether

Analysis of daily samples from these units continues. One more week of sampling is scheduled to determine if the SCAS tests with these materials can be wrapped up or if they should be continued.

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Aroclor 1254, Aroclor 1242, MCS-1016 & MCS-1043

Theoretically, the environmental residence time of the above materials should decrease significantly from left to right because of the decreasing levels of refractory PCB isomers in each. To date the SCAS testing of these materials has not shown consistently different bacteriodegradation rates. However, statistical analysis of the last set of SCAS data points did show significant evidence of biodegradability for MCS-1043, some evidence of biodegradation of MCS-1016 and Aroclor 1242, and no evidence of biodegradation of Aroclor 1254. This coupled with the MCL C_2 data which also indicates that MCS-1016 is more degradable than Aroclor 1242 leads us to believe that if the SCAS test continues our optimizing degradation differences will be measurable. In February, after the completion of testing of current compounds, the units being fed the four PCB test materials will be monitored again. It is hoped that the longer acclimation period in conjunction with a switch to a longer feeding cycle (48 hours versus 24 hours) will produce measurable degradation rates this time. These tests will require 4 to 5 weeks to complete.

In the meantime, J. Mainprize of MCL has been contacted and has agreed to calculate relative degradation rates for the materials they studied by comparison of the EC traces before and after exposure to the C_2 culture.

Aroclor Pollution Study - Anniston

Aroclor was removed from the plant effluent by filtration of the neutralization pit solids on which Aroclor was adsorbed and by adsorption on the filtration media. Aroclor concentrations (100-8,000 ppb) in the plant effluent were consistently reduced to 10 ppb upon passing through a four (4) inch diameter tube (packed to a bed depth of 5.5 inch with activated carbon) at flow rates up to 350 cc/min. In the sand filtration study conducted under similar operating conditions, the Aroclor levels in the effluent were not consistently reduced to the target level ($<$ 10 ppb). The present of 200-1000 ppm of solid particles (size range 1.5 - 250 μ) tended to blind the filter, thus setting a maximum limit on the pressure and flow at which the unit had to be operated.

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Conclusion

1. Aroclor is removed from the plant effluent by the filtration of the solids on which Aroclor was adsorbed.

2. Aroclor is adsorbed on activated carbon within a very short adsorption zone.

3. The effectiveness of sand in removing Aroclor is not sufficient at the experimental bed depth.

4. Solids removal is a primary concern in any final clean-up method.

Future Work

1. A pilot adsorption study has been conducted in a series of 5 inch diameter columns. These results are being compiled for an evaluation and recommendation. A report will be issued by 1/28/71.

2. A pilot clarification (flocculation) unit is scheduled to be put in operation by 1/29/71. This unit will also be used to carry out semi-continuous adsorption studies with other finely divided solids.

Dielectrics

Capacitor Fluids

Research reported on a series of dielectric fluids with dielectric constants from 3.5 to greater than 20 which could be replacements for Aroclor 1242. We are seeking an optimum combination of the following variables: dielectric constant, biodegradability, fire resistance, suitable physical properties and manufacturing cost. We prepared electrical grade 2,2'-dichlorodiphenyl ether, overcoming problems of high power factor with new clean-up procedures.

Three new diphenyl sulfones were prepared for evaluation: p-cyclohexyl-p'-methyl diphenyl sulfone, p-ethyldiphenyl sulfone, and 4-methyldiphenyl sulfone. We are seeking suitable solvents to blend with these sulfones.

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Pydraul Reformulations

We issued a Tentative Process for Pydraul 312A, an oil, Santicizer 711, CDP, Aroclor 5432 blend. We are seeing increasing competition from Vital 29 and Dasco FR-300 for the Pydraul 312A-type market. Vital 29 contains 56% hydrocarbon oil, 39% Reofos type phosphate ester, 5% fatty acid solubilizer plus stabilizers. Fire resistance is close to Pydraul 312 and the fatty acid has a positive effect on fire resistance.

Pydraul 540B has accumulated 700 hours on the oil gear pump with no signs of wear.

We are adjusting the spray fire resistance of Pydraul 135A and Pydraul 230A to meet FM requirements.

Pydraul 150A was formulated with improved fire resistance over Pydraul 150.

MANUFACTURING:

Anniston Plant

Current Level

Aroclor losses during January averaged 1.8 lbs/day (307 ppb). This was up from December. Lbs/day up - ppb down due to 300 gpm water flow from start-up of Niran.

28 day average	138 ppb	.8#/day
Amount from Niran		(.4)
Increase due to work on sewer to stop contamination of current water flow	169	1#
	307	1.8#

Aroclor Removal From Waste Water

Issued Progress Report R&D 446-514, Report No. 1, sent to all Aroclor producing locations.

Projects & Evaluations

No. 1 HCl pit 90% complete - 2 more weeks work to do.

Revised scope of carbon collection & disposal. Will be published by end of February.

Solids removal Pilot Plant construction is complete. PR&D work is underway.

Had no spills of Aroclor in January.

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W. G. Krummrich Plant

PCB Levels In Sewer

A. Aroclor losses from the Aroclor Department averaged about 0.6 lbs/day with a high of about 1.1 lbs/day.

Losses from the treatment plant for the period 12/17 - 1/15 averaged 22 lbs/day (114 ppb). Range for 6 samples was 2 to 53 lbs/day (9-278 ppb). - Sewer

Data gathering on Aroclor in the various plant sewers is in progress. Samples are being composited twice weekly for analysis.

Projects to Reduce Sewered PCB's from Aroclor Department

Design package for Estimate 2422 to pave and trench loading and storage areas was completed and issued in January.

Programs to Eliminate Sewered PCB's From Using Departments

Therminol system in ONA (Dept. 222) was changed to Therminol 66 during the month.

Completion of design package for 13 additional units is scheduled for 2/15/71. Changeout of all units is targeted for completion by 6/1/71.

Several alternates including use of a eutectic salt are being evaluated for the Dept. 245 (P_2S_5) Therminol unit. Evaluation is scheduled to be completed by 4/1/71.

Decision on chemical compatibility of the new Pydrauls in Dept. 251 will be made by 3/1/71.

In order to reduce the risk of PCB's being sewered from washing Aroclor trailers at Rogers Terminal, all Rogers trailers containing PCB's will be washed at WGK's Rip Track.

Reach 10 ppb in the Treatment Plant Effluent

At this time, it appears probable that PCB losses to the sewer can be controlled at less than 2 lbs/day (equivalent to 10 ppb at the treatment plant) by 9/1/71. This will be accomplished by:

1. Continuing current control of losses from Dept. 246.

2. Changeout of all Therminol units to non-PCB fluids.

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3. Installation of pads and catch basins at the loading and storage areas in the Aroclor Department.

4. Installation of a catch basin at the Rip Track.

Losses at the treatment plant are expected to remain above 10 ppb by 9/1/71 due to past sewer contamination. Projects to clean sewers could run several hundred thousand dollars. A preliminary estimate to clean the sewer from the Chlorine Department to the plant fence was $70,000 and another $70,000 would be required to clean from the fence to the treatment plant.

Both main plant sewers appear contaminated with PCB's (30W and 24W). Our plan is to continue monitoring the main sewers to determine extent of losses and loss dissipation rate. By 6/1/71, when essentially all Therminol units have been changed out, we should be able to extrapolate to when the PCB level should reach 10 ppb at the treatment plant without sewer cleaning. Based on this information, we should decide promptly on whether or not sewer cleaning is justified.

PCB Levels in the Atmosphere

Estimate 2675 for $6,000 expense was approved to replace the nitrogenpurge with a nitrogen blanket at the mix tanks. Project package is scheduled for completion by 3/15/71.

PCB Rework Project (Est. 2095)

Project package was issued in January.

W. B. Papageorge

W. B. PAPAGEORGE

ms

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Monsanto

FROM (name & location): W. B. PAPAGEORGE - ST. LOUIS

AUGUST 18, 1970

cc H. S. BERGEN
J. MASON
J. E. SPRINGGATE

SUBJECT: PCB ENVIRONMENTAL PROBLEM
JULY STATUS REPORT

REFERENCE:

TO :
D. S. CAMERON - BRUSSELS
W. S. CLARK
J. R. DURLAND - TOKYO
M. W. FARRAR - 2ND STREET
E. V. JOHN
R. E. KELLER - 2ND STREET
R. M. KOUNTZ
D. A. OLSON
P. S. PARK
W. R. RICHARD
J. R. SAVAGE
E. P. WHEELER

MARKETING:

Market withdrawal programs continue on schedule. Therminol food users are converting to Therminol 66 or Therminol 55, with little loss of business.

Customer letters for notification of Pydraul F9A are prepared and will be issued when manufacture is complete (estimate 2 weeks).

The withdrawal/replacement program for Aroclor plasticizers appears to be going well. Several customers have reported success in reformulating in such applications as epoxy coating/potting systems and inks. Production orders for the products being withdrawn have been very heavy, however, the producing plants and production planning have done an excellent job of keeping shipments moving in an orderly fashion.

ENGINEERING:

Aroclor Incineration

A preliminary project scope for a 10 M pound/year liquid incineration system was developed and issued for review. A safety review was held. The project scope is being modified to reflect comments received. The appropriation request data transmittal will be issued in early August.

PLAINTIFF'S EXHIBIT 1590

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ENGINEERING: (Continued)

MCS-1016 Distillation

Economic analyses to establish method and location for distilling 55 M pounds/year of MCS-1016 were completed and issued. The preliminary project scope was prepared and issued for comments. A safety review has just been held. The appropriation request data transmittal will be issued in early August.

EUROPE

There has been little new activity during July. Neither of the NERC reports has yet been published, although the new journal "Environmental Pollution" carried the paper written by the Monkswood people on the avian toxicity of PCB's. This provoked one or two reports in the popular press.

A NATO committee is sponsoring an investigation into marine pollution along the coast from Calais to the north of Holland, with special reference to PCB's. They were advised to get in touch with Bayer and Prodelec for information on the usage of PCB's in Belgium and within the whole of the EEC.

Implementation of the PCB plan for Europe is held up pending further meetings with the other PCB producers, firstly to determine their attitude towards a voluntary withdrawal from uncontrollable applications, and secondly to determine their reaction in the event of a unilateral withdrawal by Monsanto.

JAPAN

No new public developments in Japan. MMK writing revised policy for marketing of Aroclors. U.S.A. customers (3M, Thiokol) investigating Japanese sources.

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MEDICAL

Two year feeding studies continue. Twelve month status report is expected in August. Fish toxicity studies are being repeated as well as some of the chicken reproduction studies. FDA has issued guidelines establishing upper limits on PCB contents in milk at 0.2 ppm and other food at 5.0 ppm.

PUBLIC RELATIONS

A news release on Monsanto's recent actions to curb the use of PCB was distributed on July 16. It was primarily a rebuttal to recent stories that PCB caused birth defects, but included a complete background of voluntary actions taken to solve the PCB problem. Copies went to all news media who have carried PCB stories in the past two years.

Use of our story by the press has been light.

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RESEARCH

Aroclor 1242 Replacement for NCR

The two major problems with monoisopropyl biphenyl (MIPB) are now defined as odor and eye irritation. Both problems could be solved by changing from propylene to a higher olefin for alkylation of biphenyl. Major interest is now centered on $C_{6,8,10}$ alkyl biphenyl (ABP-11) from Ethyl Corp. α-olefin, our oxo process feedstock. Early testing by NCR was highly encouraging, however, print fade looms as a major problem. Back-up candidates include butyl, amyl, and hexyl biphenyl.

A series of six odor masks were provided NCR in an effort to improve the odor of MIPB without interfering with solvent performance.

Samples of extender and cosolvents were supplied to NCR to improve dye solubility and to give more rapid color development than NCR's current cosolvent. These materials are (1) heads fraction from alkyl benzene manufacture at Chocolate Bayou, (2) alkyl benzene (Alkylate 215), and (3) alkyl benzene high boiler (Alkylate H-230).

Plasticizer Replacements

Blends of Aroclors 5460, 5442 and 1221 were developed to approximately match the viscosities of Aroclors 1254, 1248 and 1242. Replacement recommendations were made to customers to whom viscosity is important. Specifications are being developed in cooperation with the Anniston Laboratory.

MCS-1016

Sixteen drums of the MCS-1016 have been prepared by fractionating Aroclor 1142 in a packed column equivalent to 25 trays in the Dayton Pilot Plant. The distillate was brought here and analyzed. Then the fractions were recombined to give the desired composition and treated with a Porocel column to give the desired electrical properties. The product is now ready for shipment to customers for testing in capacitors. Since all the electrical properties of MCS are indistinguishable from those of Aroclor 1242 and there are only minor differences in other properties, this fluid should be a direct substitute for Aroclor 1242 in the capacitor industry with no capacitor design change or processing changes needed.

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RESEARCH: (Continued)

Industrial Fluids

Pydraul F-9A

Pydraul F-9 was reformulated as Pydraul F-9A to avoid the use of chlorinated biphenyl. The new formulation is compatible with F-9. The lubricity in V105E pump tests is superior to any fluid we have ever run.

NC Phosphate Ester

Manufacturing costs are directly proportional to reaction times in the Step I reactor. We demonstrated that foaming in the Step I lab reactor and reaction time could be reduced by concurrent addition of $POCl_3$ and nonylphenol/cumylphenol. This should bring the reactor cycle to <6 hours. The process pay-load might be further increased by employing the Schotten-Baumann Step II and III reactors.

The pilot plant is reworking 1000 pounds of plant material by acid hydrolysis and washing to reduce acidity and hydrolyzable material.

Aroclor Substitutes

Bromoaroclor 1233 (13% Br) was scaled-up in a 35 gallon run in the Pilot Plant. This fluid is being tested in hydraulic fluid applications as a more biodegradable replacement of chlorinated biphenyl.

Isomerization of chlorinated terphenyl 5032 results in a fluid with a 100°F viscosity of 2800 cs and a 210°F viscosity of 11.7. We are seeking the lowest viscosity, all liquid terphenyl for use in hydraulic fluids.

a-Methylstyrene dimer was mono and dichlorinated for evaluation as a plasticizer in place of chlorinated biphenyl.

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RESEARCH: (Continued)

Biodegradation - Ruabon

Priority has been given to the development of more refined GLC analytical techniques so that more selectivity will be available for degradation studies of multicomponent PCB's such as Aroclor 1242. This has caused some delay, but work in progress includes biodegradation studies of Pyralene 1500 (a competitive product), two of the key isomers for assessing the viability of the theoretical mechanism for degradation and HB-40. We are also studying the soil culture which Professor Evans, at Bangor University, has said will grow on Aroclors 1242 or 1254 as sole carbon source.

Biodegradation Testing - St. Louis

Testing of Aroclor 1242, Aroclor 1254, MCS-1016 (Aroclor 1242B), and Aroclor 1230B in our semi-continuous activated sludge units will be started as soon as sample background problems have been resolved. Identical conditions will be employed to permit a comparison between our present Aroclor product and the proposed substitutes.

MANUFACTURING

Anniston

Current Level

Aroclor losses during July averaged 3280 ppb in the plant effluent. This is equal to 36 pounds/day of Aroclor.

Plant Effluent Suspended Aroclor Control

Aroclor sump construction continues. Revision requesting an additional $4500 has been prepared. This was necessitated by unforeseen ground water problems. Completion by 9/1/70 still appears possible.

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MANUFACTURING: (Continued)

Bulk Waste Disposal

Data defining magnitude of solid material quantities will be completely collected by week of August 31. Quantities and the basic estimates from which they are derived will be discussed with Production and TSD representatives August 6.

Laboratory testing of mixtures of Montar 1 and Montar 5 were not dramatically successful in reducing pumping temperatures required - 200°C range still necessary.

Experiments with hydrocarbon dilution of chlorinated and unchlorinated Montars appear to indicate this as an extremely attractive route to effectively reduce pumping temperatures, in some cases to near ambient. Economic evaluations will be made in the next two months. If successful, this will reduce handling costs and also provide auxiliary fuel for incineration.

Sauget

PCB Levels in Sewer

Current losses are about 45 pounds/day to the river which is a concentration of 200-250 ppb.

Memo being published by M. Pierle covering the sampling program for the plant. The Aroclor Department and total plant effluent will be monitored daily. Current effort is to improve the sampling technique.

Aroclor analyzer received and laboratory is ready for routine analysis. Sampling will begin on a routine basis this week.

PCB Levels in Atmosphere

Points of loss have been determined. Report being published. Most severe losses are from Therminol units in Departments 239, 245, 248 and 255. Work begun to correct these areas.

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MANUFACTURING: (Continued)

Equipment has been purchased to take vapor samples. Where vapor is flowing, losses can be measured quantitatively. Where vapor flows cannot be measured such as in breather vents, qualitative results will be obtained. Will complete this as per schedule by September 1, 1970.

Projects To Reduce Sewered PCB's From Aroclor Department

Absorber rupture disk repiping (Est. 1512) complete.

Basin for trenches (Est. 1795) complete.

Blow tank demister (Est. 2031) project approved, long delivery items on order and project package will be issued by August 7, 1970.

Provide paving curbs and catch basin in Aroclor department to prevent losses from spills, especially in the tank car loading area. Guesstimate cost is $60,000 to $80,000. Estimate will be submitted by mid-August.

PCB Rework Project (Est. 2095)

Estimate completed, $32,000 capital, $3,000 expense. Appropriation request being typed.

Incineration Liaison

Phenol department fusion reactor area firmed up as location for Aroclor incineration. Tony Rasmussen named Manufacturing Representative.

W. B. PAPAGEORGE

ms

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EPA 560/6-76-005

PCBs IN THE UNITED STATES INDUSTRIAL USE AND ENVIRONMENTAL DISTRIBUTION

TASK I

FEBRUARY 25, 1976

FINAL REPORT

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF TOXIC SUBSTANCES
WASHINGTON, D.C. 20460

PLAINTIFF'S EXHIBIT 1057

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EPA 560/6-76-005

PCBs IN THE UNITED STATES INDUSTRIAL USE AND ENVIRONMENTAL DISTRIBUTION

Task I

EPA Contract No. 68-01-3259

EPA Project Officer: Thomas Kopp

For

Environmental Protection Agency

Office of Toxic Substances
4th and M Streets, S.W.
Washington, D. C. 20460

February 25, 1976

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REVIEW NOTICE

This report has been reviewed by the Office of Toxic Substances, EPA and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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ABSTRACT

This document presents the current state of knowledge about the production, usage, and distribution of polychlorinated biphenyls (PCBs) in the United States. The information presented is derived from detailed studies on the production and first tier user industries, the past and present generation and disposition of PCB-containing wastes, environmental transport and cumulative loads, potential alternatives to PCBs usage, inadvertent losses to and potential formation in the environment, and current regulatory authorities for PCBs control. These results indicated that, although PCBs content of industrial wastes can be reduced through various approaches (treatment, substitution, etc.), there exists a potentially severe future hazard in the form of large amounts of PCBs currently contained in land disposal sites. Further definition of this and other aspects of the PCBs problem, and determination of ways to minimize the hazard, are recommended.

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SECTION I

INTRODUCTION

1.0 OVERVIEW OF THE PCBs PROBLEM

The term polychlorinated biphenyls (PCBs) refers to a family of organic chemicals which have been produced and marketed in this country for 45 years as a series of relatively complex mixtures under the trade name Aroclor. Each of these mixtures contains a number of chlorinated biphenyl isomers out of an overall range of chlorine content from one chlorine to ten chlorines per molecule. In general, higher chlorine content corresponds to greater resistance to chemical (and biochemical) degradation.

PCBs are among the stable organic compounds known, and, in addition, they exhibit other properties which render them extremely advantageous for use as dielectric and heat transfer fluids. These properties include low solubility in water, low vapor pressure, low flammability, high heat capacity, low electrical conductivity, favorable dielectric constant, and suitable viscosity-temperature relationships. Because of these properties, and also because PCBs exhibit little acute toxicity (toxic effects from high level, short term exposure), this family of materials has been extensively used in many industrial applications, primarily in "closed" or "semi-closed" systems such as electrical transformers and capacitors, heat transfer systems, and hydraulic systems. Most of the PCBs marketed to U.S. industry are still in service, primarily in electrical equipment. The remainder has entered the general environment; a significant fraction of this amount is present in air, water, soil, and sediment, but most of the PCBs in the environment are believed to be in landfills and dumps across the country.

In the late 1960's it became apparent that, although PCBs exhibit little acute toxicity, they are accumulated in the tissues of many biological species and do exhibit chronic (long-term) toxicity to many species even when the exposure is to very low concentrations. The effects of chronic PCB exposure may be considered as roughly comparable to those of DDT.

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The recognition of this problem resulted in a major program designed to lessen the environmental stress arising from widespread use and dissemination of PCBs; by mid-1971, the Monsanto Industrial Chemicals Co., the sole U.S. producer, had voluntarily terminated sales of Aroclors (PCBs and polychlorinated triphenyls, or PCTs) for all but closed electrical systems uses. Monsanto also, in the same time frame, offered incineration services for waste liquid PCBs and terminated production of the most highly chlorinated Aroclors.

During 1972 and 1973, the Food and Drug Administration developed limitations on PCBs concentrations, designed to eliminate interstate transport of PCB contaminated foodstuffs, for a number of important dietary items and packaging materials used for foods. These limitations also reinforced the elimination of PCBs usage in the U.S. except for closed electrical systems.

After approximately five years of the voluntary industrial restrictions, and about three years following the FDA limitations, a National Conference on PCBs was held in Chicago during November, 1975, under the joint sponsorship of EPA and other Government agencies. By that time it had become apparent that, although dietary intake of PCBs had declined (apparently as a result of the FDA actions plus cooperation of the food and food packaging industries), improved analytical techniques plus more extensive monitoring efforts had revealed PCBs contamination at environmentally significant levels to be more widespread than originally thought.

Results presented at the Chicago meeting indicated PCB levels in the environment, on an overall basis, to have been more or less constant since 1971, although there were local instances of both increases and decreases in PCB levels. It thus appears that, unlike DDT, elimination of PCBs from dissipative uses has not resulted in a significant reduction in environmental load.

2.0 OBJECTIVE AND SCOPE OF THE REPORT

It was against the above background that the work upon which this report is based was performed. The objective of this report is to present the current state of knowledge about PCBs production, distribution, usage, and losses to

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the environment in the United States. Many, but not all, of the facets of the PCBs problem are addressed; many of the estimates presented are based on engineering and scientific judgement instead of hard data, simply because hard data in these areas are not available. We hope that all assumptions and judgements in the report are clearly identified as such, and that sufficient supporting information, where available, is presented to justify the choices made.

While this report attempts to shed some light on the possible reasons why PCB levels in the environment are not decreasing as rapidly as had been hoped, its scope also includes a detailed presentation of past and present production and usage of PCBs in the United States, an analysis of PCB distribution and environmental transport as applied to Lake Michigan, a treatment in detail of potential substitutes and use alternatives, a discussion of the technical aspects of substitution, and discussions of various other aspects of the overall problem. Toxicological and human health aspects are not addressed; nor are the various current activities of EPA, other Government agencies, and individual states toward reducing entry of PCBs into the environment.

The information and data contained in the report were collected from personal interviews and telephone conversations with representatives of many of the firms handling or using PCBs, from trade associations, from the open literature, and from local, state, and Federal Government personnel, researchers, and other parties having interest in and information concerning the PCBs problem. Ten visits to plants were made; these covered the categories of PCBs production, small and large capacitor manufacturing, transformer manufacturing, investment casting, and waste disposal contracting (waste PCBs). The degree of cooperation, and therefore the accuracy of the data obtained, varied widely from industry to industry. Electric utilities provided key information, as did also other users or distributors of products containing PCBs.

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SECTION II

SUMMARY

1.0 PRODUCTION, USAGE, AND DISTRIBUTION OF PCBs

1.1 Overview of PCBs Industrial Usage in the United States

Over the past four years the domestic production and use of polychlorinated biphenyls (PCBs) have been approximately constant with averages of 40 million pounds per year for production and 33 million pounds per year for domestic sales. During this period Monsanto Industrial Chemicals Corp., the sole domestic producer, has supplied approximately 99 per cent of the domestic market. Monsanto sells several PCB mixtures under the generic trade name Aroclor, and purchase has been limited to intended use in nominally closed electrical systems (transformers and capacitors) since 1971 under voluntary restrictions imposed by Monsanto.

The remainder of the domestic usage depends on imported PCBs, most of which originate in Italy and the remainder in France. Decachlorobiphenyl is imported from Italy for use in investment casting wax, and the material imported from France is used in cooling systems of mining machinery.

Of the domestic sales of PCBs, 65 to 70 per cent are to manufacturers of capacitors, and the remainder to manufacturers of transformers. Transformers, which contain 2,000 to 2,500 pounds of PCBs on the average (present as a 60 to 70 per cent component of mixtures with trichlorobenzene called Askarels) are used primarily to change voltages during the transmission and distribution of electrical power. Approximately five per cent of the transformers in service in this country contain PCBs; most transformers contain mineral oil instead of PCBs. Capacitors containing PCBs are of two general types; small capacitors which are built into electrical appliances such as fluorescent lights, TV sets and small motors, and large capacitors which are used as separate units in electrical power distribution systems and with large industrial machinery such as electric motors and welding machines. PCBs are used in about 95 per cent of U.S.-produced liquid impregnated capacitors (most small capacitors in radios and other electronic equipment are solid-state units).

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PCBs are typically used in transformers where protection against fire is of paramount importance. Use of PCBs in capacitors is based on a number of factors, but fire protection and service life appear to be the most important. Industry codes, such as the National Electrical Code, specify the use of PCB-filled transformers and capacitors under a number of conditions. These codes will serve as institutional barriers to rapid reductions in PCBs usage, but at present there are also technical barriers to substitution of other materials for PCBs in electrical equipment.

The above overview of current PCBs usage in the U.S. is summarized by Figure 1.0-1, which traces domestic PCBs production and importation through first tier usage and distribution of PCBs - containing products.

1.2 Cumulative PCBs Production and Usage in the United States

Estimates developed for total PCBs production and utilization in the U.S. since their introduction to industry in 1929-30 are presented in Table 1.2-1. These data define the estimated proportions of PCBs used in various applications, and an accounting, based on available data plus estimates, of the current distribution of this material. Of the roughly 1.25 billion pounds purchased by U.S. industry, it is estimated that only 55 million pounds, or 4.4 per cent, have been destroyed by incineration or by degradation in the environment. About 60 per cent of the total domestic sales is still in service, almost all in capacitors and transformers. The remainder, about 44 million pounds, are in the environment; it is estimated that 290 million pounds are in landfills or dumps and 150 million pounds are "free" in the general environment (air, water, soil, sediments) and presumably available to the biota.

Some of the values in Table 1.2-1 are relatively well-established, while others are gross estimates resulting from a lack of data in the area. The estimated reliability for each value presented is shown on the table. For instance, the PCBs usage in carbonless copy paper is a firm value obtained from the only producer (NCR), where as the amount of PCBs environmentally degraded could conceivably range from a low value to the total of mono-, di-, and trichlorobiphenyl utilized but not still in service. The value for U.S. production could not be

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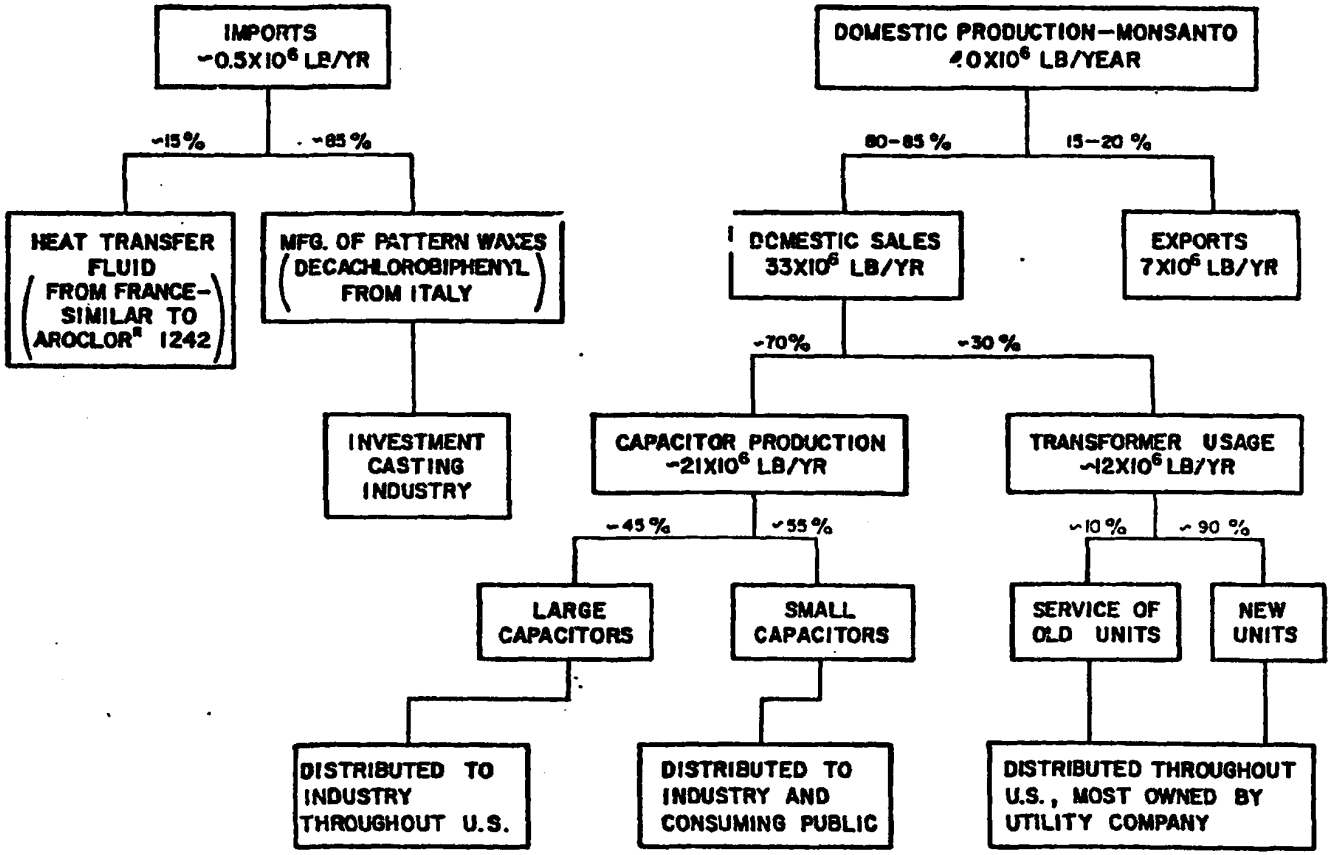

FIGURE 1.0-1. U.S. PRODUCTION AND USAGE OF PCBs SUMMARY OVER 1972-75

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Table 1.2-1

Estimates of Cumulative PCBs Production, Usage, and Gross Environmental Distribution in the United States Over the Period 1930-1975 in Millions of Pounds

	Commercial Production	Commercial Sales	Industrial Purchases of PCB	PCBs Currently in Service	PCBs Currently in Environment	PCBs Destroyed	Estimated Reliability of Values
U.S. PCB Production	1,400						+ 5% - 20%
Total U.S. PCB Imports	3						± 30%
U.S. PCB Domestic Usage		1,253					+ 5% - 20%
Total U.S. PCB Exports		150					± 20%
PCB by Use Category:							
Petroleum Additives			1				± 50%
Heat Transfer			20				± 10%
Misc. Industrial			27				± 15%
Carbonless Copy Paper			45				± 5%
Hydraulics and Lubricants			80				± 10%
Other Plasticizer Uses			115				± 15%
Capacitors			630	450			± 20%
Transformers			335	300			± 20%
Uses Other than Electrical				8			± 60%
PCB Degraded or Incinerated:							
Environmentally Degraded						30	± 70%
Incinerated						25	± 10%
Landfills and PCBs in Dumps:							
Cap. and Trans. Production Wastes					110		± 20%
Obsolete Ele. Equipment					80		± 40%
Other (paper, plastic, etc.)					100		± 40%
Free PCBs in the Environment (soil, water, air, sediment)					150		± 30%
Total	1,403	1,403	1,253	758	440	55	

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much over 1.45 billion pounds nor less than 1.1 billion pounds, based on analysis of other available or estimated data; hence, the estimated confidence interval for this value on Table 1.2-1 of +5 per cent and -20 per cent.

One of the more important conclusions from this work is the estimation of about two times the amount of PCBs in landfills and dumps as compared to the amount of PCBs already free in the environment. The material in land disposal sites may be considered a threat to become widely dispersed over a long period of time. The length of time required can only be guessed at, but is probably short in comparison to the time required for degradation of the PCBs by natural processes. Thus, release of the land disposal material through slow vaporization and leaching could very well worsen an already severe environmental problem.

1.3 Current Distribution of PCBs Usage and Associated Wastes

A material balance for PCBs production, sales, distribution, and wastes in 1974 is presented in Table 1.3-1. Reliability of the values were estimated as for the previous table. The amounts estimated to be land disposed, totaling 1.18 million pounds, do not include land disposal of previously used PCBs. However, the amounts listed under scrap PCBs incinerated account for all PCBs incineration in the U.S. during 1974 at the recommended temperature-time conditions (> 2000°F; > 1.5 seconds residence time). Of the total of 2.61 million pounds incinerated, the Monsanto facility accounted for over half. Other companies currently providing incineration services include General Electric, Rollins Environmental Services, and Chem-Trol Pollution Services, but the total number of such facilities known to be available in the U.S. is six.

1.4 Land Disposal and Environmental Load

The 1.18 million pounds per year of land-destined wastes estimated above is only a small portion of the total PCBs entering landfills and dumps yearly; the current estimated yearly rate of PCBs entering land disposal sites is about 12 million pounds. The largest source of this material is capacitors which have failed or become obsolete, or which are contained in obsolete equipment. Other important sources are industrial solid wastes from PCBs production and first-tier usage, and the total of other (non-electrical) municipal and industrial solid wastes.

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Table 1.3-1

Estimated Production, Usage, and Losses of PCBs in the United States during 1974 in Millions of Pounds

	Production or Imports	Commercial Sales	Industrial Purchases by Category	Amount Disposed or Lost	Estimated Reliability of Values
Domestic Production	40.466*				± 10%
Total Imports	0.45				± 50%
Monsanto Domestic Sales		34.406*			± 10%
Exports		5.395*			± 10%
Import Sales		0.45			± 50%
From Mfg. Inventory, etc.		0.665*			± 10%
PCBs Usage by Product Category					
Capacitors			22.0		± 20%
Transformers			12.0		± 20%
Investment Casting Wax			0.4		± 20%
Other			0.05		± 70%
PCBs Disposal to Land (assume PCBs to be 30% of total solid wastes)					
From PCBs manufacture				0.03	± 50%
From capacitor industry				0.48	± 50%
From transformer industry				0.27	± 50%
From investment casting				0.4	± 30%
Incineration of Scrap PCBs					
From PCBs manufacture				0.52	± 15%
From capacitor industry				1.45	± 20%
From transformer industry				0.64	± 20%
Industrial Discharges to Water and Sewers (as PCBs)					
From PCBs manufacture				0.0011**	± 40%
From capacitor industry				0.0021**	± 60%
From transformer industry				0.0001**	± 60%
Spills during Transport				0.01	± 50%
Totals	40.916	40.916	35.45	3.80	

* From Monsanto data

** Developed from data supplied by industry. Most analyses for PCBs concentrations in industrial wastewaters are probably not more accurate than ± 50 per cent.

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The total current environmental load of "Free" PCBs was estimated to be about 150 million pounds. An analysis of environment load (Free PCBs) average chlorine content per molecule indicated that, if mono-, di-, and trichloro isomers were disregarded, the average chlorine content of Free PCBs would be within seven per cent of the value for Aroclor 1254.

1.5 Foreign Production of PCBs

Known current producers of PCBs besides the United States include the United Kingdom, Czechoslovakia, France, Germany, Spain, and the U.S.S.R. Japan was a producer until 1972. In 1973, total foreign production of PCBs is estimated at 43 million pounds, corresponding to a 50 per cent reduction since 1971. On this basis, the U.S. production appears to be about half of the world total. Usage of PCBs in all countries is expected to decrease further as a result of recent findings on adverse environmental effects and potential human health hazards from PCBs, and this usage is expected to be essentially confined to use in capacitors and transformers.

2.0 CHARACTERIZATION OF INDUSTRY PRACTICE AND WASTE HANDLING FOR THE PCBs PRODUCER AND MAJOR FIRST-TIER USERS

2.1 Manufacture of PCBs and PCB-Containing Capacitors and Transformers

PCBs are produced domestically only by Monsanto at Sauget, Illinois. The process involves the batch chlorination of biphenyl and subsequent separation and purification of the desired chlorinated biphenyl fractions. The degree of chlorination is determined by the contact time in the reactor. Depending on the distance and size of shipment, transport is via tank car, tank truck, or common carrier (drums).

There are 17 capacitor plants and 18 transformer plants utilizing PCBs in the United States. Manufacture of both types of units involves initial preparation of internal and external cases, filling with PCBs under vacuum, cleaning and degreasing, and performance testing. The greatest PCB wastes occur in the filling operations. Filling of small capacitors (less than 2 pounds of PCBs) and most large capacitors is performed in chambers holding many small capacitors or fewer large ones. The chamber and the capacitors are evacuated and then flood-filled with the PCB liquid. Excess liquid is removed from the chamber, the filled

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units are cleaned and sealed, and then the sealed units are degreased, painted, and tested. Transformers and the largest types of capacitors are filled individually after evacuation; this produces relatively less chance of PCBs loss than the flood-filling process.

Of the 38 plants in the above categories, 10 discharge their effluents into the water ways while the remainder discharge into the sewage treatment plants. All plants in these categories have discharges under heavy rainfall conditions. There are three types of waste materials generated at these plants that require treatment and proper handling in order to minimize the PCB into the environment. These are:

(a) Waste waters containing trace quantities of PCBs (10 to 500 ppb PCBs);
(b) Waste PCBs, scrap oils and small quantities of process water highly contaminated with PCBs; and
(c) Burnable and non-burnable solid materials contaminated with PCBs.

Quantitative estimates of these wastes are given below:

	Waste Loads, Daily Average		
	PCB Discharge in Waterways or Sewers	Land-Destined PCB Wastes	Scrap Oils to Incineration
PCB Manufacturer	3.06 lbs	301 lbs	1425 lbs
Capacitor Industries	5.86 lbs	4440 lbs	3968 lbs
Transformer Industries	0.17 lbs	Unknown	1750 lbs

The above waste loads represent current industrial practice. It may be assumed that, prior to knowledge of the adverse environmental effects of PCBs, much of the types of material currently landfilled or incinerated was not disposed of properly and thus entered the environment directly.

As yet, very little is being done at these plants to control air emissions. The general industry assumption is that the vapor pressure of PCBs is so low that there will be essentially no air contamination. A few facilities, however, were reported to be filtering and chilling exhaust air from PCBs impregnation areas,

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and plant personnel are beginning to realize that evaporation of PCBs may make a significant contribution to general contamination of the plant area.

Since most water used at these facilities is for non-contact cooling purposes, at most plants it is possible to significantly reduce the effluent volume by segregation of wastewaters, recycling and proper housekeeping measures. Most user plants and the PCB producing plants have already undertaken PCBs containment programs in order to minimize the entry of PCBs into the environment. While the emissions of PCBs to water are expected to decrease due to improved pollution abatement of waterborne wastes, the release of PCBs to air and land may increase. One potential source of increasing air emissions is the increase in incineration due to proper handling of wastes which were previously discharged into the waterways or sewers. The quantities of land-destined wastes are expected to increase due to improved housekeeping measures.

Rivers receiving PCBs discharges for a number of years vary greatly in PCBs content with time, apparently depending upon PCB content in storm water runoff and the degree to which contaminated bottom sediments are agitated and suspended. Whereever there have been PCB operations in the past, there are probably high concentrations in local waterways bottom sediments.

Over the past 45 years, waste PCBs from transformer and capacitor operations have been used as local road oiling compounds. Sometimes they were discarded in dumps adjacent to manufacturing facilities. These are sources of long term leaching of PCBs into waterways, particularly with storm water runoff.

2.2 Treatment and Disposal of Industrial Wastes Containing PCBs

A study was performed to determine and compare the methods available for the treatment of PCB-containing wastes from the PCBs production, capacitor manufacturing, and transformer manufacturing industry categories. A full treatment of this technology, including cost estimates for treatment, may be found in the Task II Report under Contract 68-01-3259. Much of the technical portion of this work is reproduced herein and summarized below.

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2.2.1 Incineration

The most advanced treatment technology in use is incineration. The PCBs manufacturer and one user have plant scale facilities capable of destroying PCBs with very high efficiency. There are at least two commercial services available, with four incinerator locations in the Eastern and Southern U.S., for PCBs incineration.

Incineration is primarily applicable to waste PCBs and scrap oils contaminated with PCBs. Incinerators for PCBs destruction have the capacity of "burning" some contaminated wastewater but, of course, the proportion of that water to the exothermic oil burning must be kept low. Only one commercial incineration service (Rollins) can routinely handle all kinds of PCBs contaminated transformer and capacitor components, sludges, fuller's earth and other solids, as long as they can be contained in a 47 gallon fiber drum. One PCB user company incinerates transformer internals for purposes of metal recovery.

Waste liquid PCBs and scrap oils (contaminated PCBs) are best handled, as a guideline, by high temperature (2000-2400°F) and long residence time (2-3 seconds) incineration. However, because of incinerator design variables, the conditions should be chosen in each case to lead to 99.999% destruction. The best incinerator combination for handling wastes from these industries is a rotary burner fired by a liquid burner, and followed by an afterburner and scrubber system for HCl and particulate control. The rotary burner can be designed to handle a variety of solid materials, and the liquid burner can handle both the oily and water type wastes.

2.2.2 Treatment of PCB-Contaminated Wastewater

There is no commercial scale wastewater treatment for PCBs removal being practiced beyond those of gravity settling of the heavy PCBs layers as a sludge from the bottom of sumps or tanks, and skimming of a contaminated oil-layer from the water surfaces.

Adequate methodology is available for those plants wishing to control the release of PCBs to the environment. Currently available technologies can

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be applied to the efficient removal of PCBs from wastes, or their destruction with the other wastes. The PCBs content of wastewaters can be lowered to the 1 ppb level or below by removal of solids (and oil layers, where applicable), followed by adsorption of PCBs onto carbon, macroreticular polymer resins or possibly other adsorbents.

Carbon adsorption is currently the best available technology for plant scale treatment of PCBs wastewaters. This conclusion is based on laboratory tests with PCBs in water, and on the long background of plant scale use of carbon adsorption for removal of organics from water.

Polymeric resins (AMBERLITES) were found in laboratory tests to be approximately as effective as carbon in removing PCBs from water. Further pilot scale testing is needed with this newer (than carbon) technology to accurately assess its potential.

Ultraviolet catalyzed ozonation was determined to be the best method, demonstrated on a laboratory scale, for destruction of PCBs in wastewaters when the streams occur in large volume, on a relatively continuous flow basis and with PCBs at the ppb concentration levels. This technology has the potential for conversion of PCBs to CO_2, H_2O and HCl. However, significant development and optimization work would be required before application of the process becomes practical. In addition, the potential exists for production of toxic degradation products by UV-ozonation.

Although still in the laboratory stage, catalytic reduction of PCBs offers the possibility of reduction to biphenyl and HCl; and catalytic oxidation is another process which offers a potential for destruction of PCBs to CO_2, H_2O and HCl.

It is believed that wastewater treatment systems employing activated carbon and possibly UV-ozonation could produce effluents which would be at or below the limits of detectability for PCBs with current analytical techniques. However, since no full scale systems for the treatment of PCBs are in operation at this time, this possibility cannot be confirmed.

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Unfortunately, no methodology is presently available which can guarantee "zero discharge" of PCBs to the environment. "Zero discharge" objectives can be best met now by eliminating discharge streams and developing recycle systems. All streams that are high in pollutants and cannot be treated for reuse, including rainwater runoffs, could be collected and incinerated under a "zero discharge" objective.

2.3 Characterization of the Investment Casting Industry

Investment casting is a lost-wax process by which metal castings which are of intricate shapes or which require close dimensional tolerances are mass-produced. The pattern wax, some of which contains PCB filler, is molded and then used to make a ceramic shell (investment) whose internal dimensions are those of the desired product. The wax is typically melted from the shell, and the shell is fired (sintered), which removes the last traces of the wax. Then molten metal is poured into the mold (shell) and cooled to form the castings.

There are currently 135 investment casting foundries and four major investment casting wax manufacturing plants in the United States. The Yates Manufacturing Company, Chicago, Ill., is the sole known U.S. supplier of decachlorobiphenyl (deka) waxes. The deka content is 30 per cent of the total wax by weight. Yates currently imports deka from Italy and manufactures between 1 and 1.5 million pounds of deka wax annually. Very little is known about the wax manufacturing process. Wax manufacturers are also believed to use polychlorinated terphenyls (PCTs) imported from France.

The major losses of the virgin and used waxes appear to occur during the dewaxing of the ceramic mold. The mold is fired in a furnace to set the mold and remove the wax. Depending on furnace conditions, the deka or PCT in the wax is either burned or released to the atmosphere. The magnitude of these emissions is not known.

Most foundries recover the drained pattern wax and reuse it several times. It is estimated that the purchased wax is used an average of 2.5 times. Little of the wax is destroyed in the process; therefore, it is considered probable that the investment casting foundries store or dispose of relatively large amounts of used PCB- or PCT-containing wax.

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2.4 Transformer Service Industry

Most servicing of transformers is performed by electrical repair shops rather than by the utility or the owner of the transformer. Thirteen companies were identified as offering transformer service at a total of 131 locations. Servicing of askarel-filled transformers may include the filtering of the askarel to remove degradation products and moisture or the replacement of the askarel with new liquid. PCB wastes include filter media, scrapped askarel, and miscellaneous solvents, rags, etc. The proper disposal of these wastes is specified by a voluntary NEMA standard. Liquid PCBs are incinerated in most, but not all, cases. The total usage of PCBs by the transformer repair industry is about 800,000 lb/year, or about seven per cent of the amount used to manufacture new transformers.

3.0 SUBSTITUTES AND USE ALTERNATIVES FOR PCBs

Potential substitute materials and use or process alternatives which would eliminate or reduce the current requirements for PCBs were investigated. Important points from this study are summarized below.

3.1 Substitutes for PCBs in Capacitors

PCBs (primarily Aroclor 1016) are currently used in almost all U.S.-made capacitors for AC service (liquid-filled capacitors) and are uniquely suited for this application because of their high dielectric constant, high resistance to current flow and electrical breakdown, chemical stability, and non-flammability. A number of different liquid materials now under development or testing have been proposed as substitutes for PCBs in capacitors, including phthalate esters, synthetic hydrocarbons, alkylated chlorodiphenyl oxide, alkylated PCBs, diaryl sulfones, and silicones.

Since each of these materials is relatively more flammable than Aroclor 1016, it appears that use of any liquid substitute will probably pose more of a fire hazard than use of PCBs. Vulnerability of capacitor manufacturers to liability for damages from capacitor failure is a major factor in industry acceptance of a substitute capacitor fluid. The conservative code structure now in force could also pose significant barriers to reduction or elimination of PCBs usage in

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capacitors. In addition, data on electrical performance, toxicity to humans, and environmental effects of the potential substitutes are not presently sufficient to allow meaningful comparisons with PCBs.

Dry AC capacitors (film-type) are in the development stage. These capacitors are significantly larger than liquid-filled capacitors and are limited to a maximum of 280 volts. Satisfactory dry film capacitors will not be available until there are two separate technological breakthroughs: 1) the development of a plastic film that combines a high dielectric constant with a low loss-tangent; and 2) the development of winding techniques that exclude all air from the winding of the capacitor.

Although it is considered probable that satisfactory substitutes for PCBs will be developed within the next 5 years, no such material is presently available and much additional research remains to be done. On the other hand, a significant portion of the large capacitors used by utilities, and some in industry, are situated out-of-doors. These could be replaced by capacitors containing a more flammable fluid without significantly increasing the risk of fire.

Although direct replacement of existing PCB-filled capacitors with units containing substitutes appears possible for many large capacitors, anticipated size differences will present severe problems in retrofitting. The new fluids also cannot be directly substituted for PCBs in existing capacitors. In addition, disposal of obsolete or replaced units will probably be in landfills for many years to come. It is probable that the best replacement scheme for capacitors, assuming cessation of PCBs production and use, would be use of non-PCB replacements as units become obsolete or fail.

3.2 Substitutes for PCBs in Transformers

Aroclors 1242 and 1254 are currently used in about five per cent of U.S.-built transformers; most transformers are cooled with mineral oil. Transformers filled with askarel (60-70 per cent PCBs) are often specified for use in buildings and in hazardous locations where minimization of the fire hazard is of paramount importance. The National Fire Code requires that oil-filled units, and askarel-filled units rated for service over 35 kV, be enclosed in fireproof vaults when

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used in buildings. For units below 35 kV, the higher cost (by 20 to 30 per cent) of an askarel unit is more than offset by the savings on vault construction.

Open, air-cooled transformers are limited to a clean, dry environments, but are being increasingly used in commercial buildings. Closed, gas-cooled transformers are more expensive than askarel units. Both of the above types have voltage limitations and much less overload capacity than the askarel-filled type.

Several substitute liquids have been suggested for use in transformers which are less flammable than the currently used mineral oil, but which are more flammable than askarel. The most promising are a silicone oil and a synthetic paraffinic hydrocarbon. These liquids are characterized as being self extinguishing - i.e., they do not continue to burn after being ignited by a momentary electrical arc. Proposals have been submitted to the National Electrical Code to allow the use of these self extinguishing materials under those conditions where askarels are presently specified. Because of the relative lack of service experience with these liquids, it is unlikely that these proposals will be accepted. The next Code revision (1978) will probably continue to recognize only askarel and "oil filled" transformers.

It is likely that the "self extinguishing" liquids will prove to be satisfactory alternatives to PCBs. Substantial experience on the performance of the liquids will be required before the code requirements will be changed to allow their use. The restrictive Electrical Code, which has been incorporated into the OSHA Standards, may act to inhibit the accumulation of this data and thereby act to postpone the general acceptance of these substitutes for PCBs.

The major conclusion from this portion of the study was that technically acceptable alternatives to the use of PCBs in transformers exist and that their use should not result in a significant increase in fire hazards from transformer failure. At present the selection of PCB (askarel) transformers appears to be based primarily on cost rather than technical considerations.

As with capacitors, direct replacement of PCBs in existing transformers would present potentially severe problems. These include the extreme difficulty of removing more than 90-95 per cent of the PCBs, even by repeated flushing with

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a compatible solvent (trichlorobenzene), and the requirements of incinerating such large quantities of PCBs and contaminated solvent.

3.3 Alternatives to Other PCBs Applications

On a preliminary basis, there appear to be no overriding technical (or institutional) barriers to the use of alternatives to decachlorobiphenyl filler in investment casting waxes. (This also appears to be the case for the polychlorinated terphenyls.) Potential alternatives include use of materials such as isophthalic acid as the filler and use of the new low-shrinkage unfilled waxes. A cost increase of about ten per cent is projected for each of the above alternatives.

Since the voluntary restriction by Monsanto in 1971 of PCBs sales for use in closed electrical systems only, PCBs have largely been eliminated from usage in hydraulic and heat transfer systems. Adequate substitutes were generally available at the time of the Monsanto restriction, and the present usage of PCBs (believed to be minor) should be replaceable by alternatives with minimal disadvantage.

4.0 SOURCES OF INADVERTENT ENTRY OF PCBs INTO THE ENVIRONMENT

4.1 Paper Recycling

Over the period 1957 to 1971, approximately 45 million pounds of Aroclor 1242 was used by a single producer (NCR) in the production of carbonless copy paper. Some fraction of this material has entered the paper recycling stream and is apparently a major source of observed PCBs contamination of effluents from the secondary fiber recovery industry. PCBs were also added to paper in inks and possibly in other additives; this material was probably Aroclor 1254.

Thus, in its effort to conserve resources profitably, the secondary fiber recovery (paper recycling) industry is inadvertently releasing previously used and "stored" PCBs into the general environment, primarily to water. Reliable estimates of the amounts of PCBs so released are not available, and, although the significance of this release should diminish as office files are emptied, the amounts remaining to be released are not known.

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Results from an analysis of PCBs entering Lake Michigan, discussed later in Section 5.0, indicate that, although there is a significant concentration of paper recycling activities in the area of this lake, the contribution of paper mills to the total PCBs input to Lake Michigan is small in comparison to atmospheric fallout. However, effluents containing amounts of PCBs which are very small compared to the total environmental load can be extremely important on a local basis, and further investigation of this problem is urged.

It should be noted that water usage in the paper recycling industry is high and effluent PCB concentrations are typically 5 to 10 ppb. The cost of PCBs removal would therefore probably be higher per unit of profit than for the other industry categories described herein.

4.2 Effluent Contamination by PCBs in Other Industries

High concentrations of PCBs were recently reported in effluents from a number of plants engaged in the manufacture of machinery and mechanical products. These measurements have not been verified to data. PCBs were, in the past, used extensively in hydraulic and heat transfer systems, in lubricants, and in paints and plastics, so that it is not inconsistent that effluents from the machinery manufacturing industry contain PCBs. PCB contamination of effluents is known to have occurred via slow release of old deposits in sewers and elsewhere, although industrial usage in semi-open applications is believed to be continuing at a low level.

4.3 Inadvertent Production of PCBs in the Environment

Three general types of reactions were considered as potential sources of inadvertent production of PCBs. Of the three, the one considered most likely to occur is chlorination of biphenyl in wastewater during treatment. This refers specifically to the discharge of wastewater containing biphenyl to a municipal sewer and the subsequent chlorination of the material in the treatment plant.

Biphenyl is used extensively as a dye carrier for the dyeing of synthetic fibers; in this application, much of the biphenyl leaves the process as waste. The estimated U.S. industrial usage of biphenyl is about 50 million pounds per year, of which at least half is used in dyeing operations. Although chlorination of

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biphenyl in sewage treatment appears likely, the extent of neither the initial chlorination nor further chlorination is known. Further investigation of biphenyl chlorination as a possible source of PCBs is recommended.

Chlorinated biphenyls have been produced by the decomposition of DDT, although this requires recombination of phenyl radicals from cleavage of two DDT molecules. Significant production of PCBs in the environment by this mechanism is considered unlikely. Formation of PCBs via chlorination of the product formed from the combination of two substituted benzenes is also considered of less potential significance than direct chlorination of biphenyl in wastewater.

5.0 TRANSPORT AND DISTRIBUTION OF PCBs IN THE ENVIRONMENT

A first order mass balance model was developed and used to study the transport and distribution of PCBs in the environment. The total environmental load of "free" PCBs was regarded as a "pool" of mixed PCBs. In applying the model, the pool was assumed to exhibit properties roughly similar to those of Aroclor 1254. The model was applied to Lake Michigan; the boundaries of the region studied were taken to be the drainage basin of the lake. Lake Michigan is a nearly closed body of water of sufficient size to allow averaging of properties and of sufficient interest that some pertinent data were available.

The estimated total input of PCBs to Lake Michigan (1973-1974) was 13,400 lb/yr, of which 1,600 lb/yr came from point sources (summation of industrial and municipal discharges reaching the lake), 6,400 lb/yr represented fallout directly onto the lake, and 5,400 lb/yr was derived from fallout on the drainage basin (assumed to be 50 per cent of total fallout on the basin). Thus, it is estimated that about 88 per cent of the PCBs currently entering Lake Michigan arise from fallout.

Application of the model produced the following cumulative values for the period 1930 to 1975 (input function assumed proportional to domestic sales):

Total input	1.49×10^5 lb
Total in solution	1.0×10^5 lb
Total in biota	3.64×10^3 lb
Total in sediments	1.7×10^4 lb

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Total in outflow	9.07×10^3 lb
Total evaporated	1.93×10^4 lb

Since degradation of PCBs in the lake was assumed to be zero, the closing of the material balance depended upon total evaporation from the lake being 1.93×10^4 pounds, or about 13 per cent of the total input. This value is in excellent agreement with values derived both from kinetic theory and from co-distillation theory; this result substantiates both the model form and the material balance above.

Average water and biota concentrations derived from the analysis (using a bioconcentration factor over water of 4×10^4) are, for recent years:

	Water Conc. (ppt)	Biota Conc. (ppb)
1960	1.60	64
1965	2.92	117
1970	5.35	214
1975	9.10	364

The above agrees well with available data on lake and biotic concentrations since 1970.

Mean residence times of PCBs in air and water, and the transport mechanisms which operate at the various phase interfaces, are very important to the understanding of environmental transport and distribution. Lifetime values are extremely sensitive to the assumptions required for their calculation (required because of the lack of adequate experimental data). Estimates derived from work by others range from 20 days to eight years for the average lifetime to fallout of airborne PCBs. Residence times to evaporation in Lake Michigan appear to be on the order of ten hours, based on theoretical calculations, whereas residence times to evaporation from sea water may be one to two orders of magnitude lower.

The picture of gross PCBs transport consistent with all of the above findings is the one dominated by air transport. Terrestial components, including fresh water, are partial sinks responding primarily to input from fallout. Losses are to evaporation and to rivers, which enter the oceans where further (possibly rapid)

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evaporation occurs. Degradation of PCBs, which was assumed to be zero in the Lake Michigan analysis, appears too slow to have a significant effect. Industrial and municipal effluents and air emissions are sources of both old and new PCBs; large amounts enter landfills and a small fraction enters the cycle through leaching and evaporation.

If the above is even partially correct, then one possible answer to the question of why the restriction on uses beginning in 1971 has not caused the hoped for diminution in PCBs distribution is as follows:

(1) The systems which cause concern with regard to PCBs (freshwater systems and associated biota) serve as sinks for PCBs;
(2) Other possible sinks are not available or are ineffective in retaining PCBs; and
(3) The environmental degradation of PCBs is too slow to be significant over a five year period.

Further work in many aspects of PCBs transport and distribution are needed in order to estimate the real magnitude of the future environmental problem from these materials. Such work should also assist in identifying potential methods for reducing the environmental load of PCBs.

6.0 REGULATORY ACTIONS ON PCBs

Four government agencies, the Monsanto Company and NEMA comprise the regulatory forces currently restricting the use and distribution of PCBs. EPA, OSHA, FDA and USDA have, between them, authority to regulate and monitor food levels, disposal into waterways, industrial housekeeping, and safety practices in the work place. Each of these available authorities has a limited focus and is inadequate to prevent more PCBs from entering the environment.

There are currently no regulations to restrict the importation of PCBs as a chemical for use in applications banned by the Monsanto Company. As a result, PCB is being imported by a few companies for use in several "open-end" or "nominally-closed" applications.

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Several producing nations have voluntarily limited sales of PCBs. Since 1972, Japan has banned production and importation of PCBs. The United Kingdom has barred sales of PCBs to all applications except usage as dielectric fluids, while Germany has lessened this restrictive measure to include use in heat transfer and hydraulic systems. Among non-producing countries, Sweden and Norway have stringent regulations. In Sweden, only the Environmental Protection Board can authorize the use of PCBs or compounds containing PCBs, while in Norway only the Ministry of Social Affairs can authorize the use of PCBs.

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SECTION III

CONCLUSIONS AND RECOMMENDATIONS

1.0 Conclusions

Conclusions which have resulted directly from the work reported herein are presented below. Some of these have been discussed briefly in the preceding section, but each is believed to be justified by information contained in the text of the report and the appendices.

(1) It is estimated that approximately 1.25 billion pounds of PCBs have been sold for industrial use in the U.S. since initiation of production around 1930.

(2) Of this amount, at least 95 per cent are still in existence; most is in service in capacitors and transformers, but about 290 million pounds are believed to reside in landfills and dumps and about 150 million are believed to be "free" in the environment. The magnitude of these values indicates that there is a strong future threat from PCBs present in land disposal sites.

(3) In 1974, U.S. usage of PCBs sold by Monsanto, the sole domestic producer, was distributed between capacitor manufacture (22 million pounds) and transformer manufacture (12 million pounds). Imported materials amounted to about one per cent of U.S. industrial purchases of PCBs in 1974; about 400,000 pounds (of decachlorobiphenyl) were used in investment casting and and an estimated 50,000 pounds of new material were used in specialized heat transfer systems.

(4) Waterborne effluents from PCBs production and first-tier use currently release amounts to the environment which are very small in comparison to the amounts entering land disposal sites from these industries. However, these effluents can have severe local impacts, as evidenced by the current PCBs problem in the Hudson River.

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(5) Monsanto and portions of the electrical equipment industry utilizing PCBs have greatly reduced PCB releases to water and land over the past few years, primarily through improvement of plant housekeeping, improved waste collection and handling, and disposal of liquid wastes through incineration.

(6) There is no plant-scale process used at present for the specific purpose of removing PCBs from industrial wastewater.

(7) The best available treatment technology for removal of PCBs from wastewater is carbon adsorption coupled with solids and oil/grease removal. Carbon treatment can produce end-of-pipe PCBs concentrations of one ppb or less. Other adsorbents, such as resins, also appear effective to this extent.

(8) The most promising method, of those water treatment technologies under development, for PCBs destruction is ultraviolet-catalyzed ozonation.

(9) Incineration is an effective method of disposal for liquid PCBs. Landfilling is the only generally available disposal method for PCBs-contaminated solid wastes, but incineration of these wastes is technically feasible.

(10) "Zero discharge" to water of PCBs from production and first-tier use is available only through extensive water reuse plus extensive incineration of lightly contaminated wastewaters.

(11) Significant amounts of solid PCB (decachlorobiphenyl, or deka) wastes are stored or disposed of on land by the investment casting industry. Air emissions of deka may also be significant in amount, but no evidence of potential health hazards from this material has been reported.

(12) The total present usage of PCBs for open and semi-closed applications is not known but is believed to be small in comparison to closed electrical system usage. A few capacitor manufacturing

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plants report recent use of PCBs in vacuum pumps, and a significant amount of carbonless copy paper containing PCBs must still be in inventory and in files.

(13) Chlorination of waste biphenyl in industrial wastewaters discharged into municipal sewers is a potential mechanism for inadvertent production of PCBs.

(14) PCBs are uniquely suited to the requirements of capacitors for AC service. Although a number of potential substitutes for this application are under development and test, they are all more flammable than Aroclor 1016 and neither their performance in service nor their potential toxicity to man and other species have been evaluated sufficiently to allow a definitive comparison with 1016.

(15) Alternatives to PCBs usage in new transformers are available. In addition, testing of promising substitute fluids (termed "self-extinguishing") is underway; these fluids may gain industry-wide acceptance within three years as substitutes for PCB fluids. At present, specification of PCB-filled transformers appears to be based primarily on cost considerations.

(16) No technical barriers to substitution for PCBs (deka) in investment casting waxes are apparent. Several potential alternatives have been previously used by this industry.

(17) Atmospheric fallout is a major source of PCBs input to fresh water systems. In Lake Michigan, the PCBs contribution at present appears to be much larger than the total of PCBs inputs from point sources such as municipal sewage treatment and paper recycling.

(18) The importance of atmospheric transport of PCBs relative to other potential inputs to water indicates that the availability of environmental sinks from PCBs is limited, possibly due to short residence times to evaporation in sea water.

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(19) At present, regulatory authority over PCBs in the United States is insufficient to significantly reduce future PCBs inputs to the environment, although inputs directly to the waterways from industrial sources can be reduced from their present level. Current disposal practices, except for incineration, tend to delay instead of prevent the PCBs entry into the "free" (available to the biota) state, and these practices are regulated only minimally.

2.0 RECOMMENDATIONS

During December, 1975 and January, 1976, EPA Administrator Russell Train called for a cooperative effort between Government and industry to eventually eliminate PCBs from production and usage in the United States. The recommendations listed below were developed with this objective in mind, although each recommendation also reflects the still existing needs for further definition of the current and future PCBs problem and for the development of methods for reducing the potential damage to human health and the environment.

(1) The current distribution and losses to the environment of PCBs should be defined more accurately. Study is needed for the following aspects of past and present usage:

(a) Present extent and distribution of usage in semi-closed systems such as heat transfer and hydraulic systems (dissemination of information concerning PCBs effects and available substitutes will result in voluntary reduction of PCBs usage);

(b) Definition of past and present usage in investment casting, including quantification of air emissions, disposal on land, and waterborne contamination;

(c) Present distribution and projected future trends for PCBs in the pulp and paper industry, especially the secondary fiber recovery portion; and

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(d) Extent of inadvertent PCBs contamination in effluents from other industries which are currently not purchasers of PCBs.

(2) The basic transport properties of PCBs, particularly those relating to evaporation and atmospheric fallout, should be studied in depth. This and other information should be used to investigate global transport characteristics of PCBs and to predict the potential magnitude of the global PCBs problem. Potential sinks and destruction methods for PCBs should be investigated.

(3) The type of analysis presented herein for Lake Michigan should be further expanded and refined for application to other important fresh water systems. The model should be extended to a prediction of future effects and the influence of possible reductions in PCBs usage.

(4) Transport of PCBs from landfills should be investigated; in particular, potential methods for delaying or reducing PCBs release from landfills should be studied.

(5) Development and testing of potential substitutes for PCBs in capacitors, transformers, and investment casting waxes should be encouraged strongly. Technical and institutional barriers to the use of alternatives should be attacked on all possible fronts as soon as possible. Extensive toxicological testing of proposed substitute materials should be performed prior to acceptance.

(6) Methods for treatment of PCBs-contaminated water effluent should be developed and applied. Research and development activities on directly destructive treatment methods, such as UV-assisted ozonation and catalytic oxidation or reduction should be encouraged, but further work on adsorptive techniques is also needed.

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(7) Alternative approaches and schedules for PCBs elimination from U.S. commerce should be evaluated with regard to technical feasibility, institutional acceptability, and economic and environmental impact. Based on these considerations, an optimized path to PCBs elimination should be developed.

(8) Possible inadvertent formation of PCBs in the environment should be studied; in particular, it is recommended that the chlorination of biphenyl in wastewaters be evaluated as a potential source of PCBs.

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SECTION IV

CHEMICAL AND PHYSICAL PROPERTIES OF CHLORINATED BIPHENYLS

1.0 INTRODUCTION

The purpose of this section is to present a précis of the salient characteristics of the commercial preparations of the polychlorinated biphenyls which have generated concern as environmental pollutants. The emphasis is directed to those properties that have led to the relatively widespread use of these materials. In addition, attention will also be directed to those physical and chemical properties that contribute to the environmental effects arising from the general distribution of these materials. The discussion is not meant to be exhaustive, but rather to offer the basic technical information that is used to support the other sections of the total report. The most complete compilation of the relevant information that has been published to date is that by Hutzinger et al (O. Hutzinger, S. Safe, and V. Zitko, "The Chemistry of PCBs", CRC Press, 1974) and the authors express their debt to this publication.

1.1 The Chemistry of the Chlorinated Biphenyls

The polychlorinated biphenyls (PCBs) constitute a large class of compounds produced by the partial (or complete) chlorination of the biphenyl molecule. Since their introduction in 1929 in commercial quantities, these compounds, or rather commercial mixtures of various members of the class, have been applied in a considerable variety of industrial applications. The unique physical and chemical properties of these compounds, including low vapor pressure at ambient temperatures; resistance to combustion; remarkable chemical stability; high dielectric constant and high specific electrical resistivity have been utilized in such applications as electrical insulating fluids; fire resistant heat transfer and hydraulic fluids; lubricants for use at high temperatures and pressures in critical applications and as a constituent in a variety of elastomers, adhesives, paints, lacquers, varnishes, pigments and waxes.

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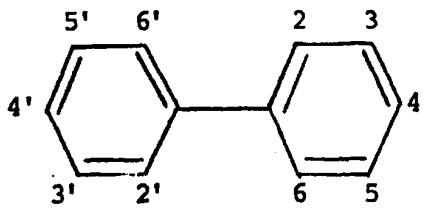
PCBs and mixtures of chlorobiphenyls have been produced in a number of countries and marketed under several trade names including Aroclor, Clophen, Phenoclor, Kanechlor and Fenclor. The essential characteristics of all these mixtures, which depend in detail on the specific mixtures of chlorobiphenyls that make up the specific preparation, are sufficiently alike that it will suffice to discuss all in terms of the Aroclors, which is the trade name of the preparations of Monsanto Chemical Company. In those special cases wherein there is some particular property peculiar to one of the foreign PCB mixtures, a note will be made.

A great deal of confusion has appeared in the literature because of the nomenclature that is used to describe the commercial preparations and the individual authenticated chlorobiphenyls. In order to clarify the nomenclature to be used herein, it is appropriate to digress briefly as follows. The biphenyl molecule has a total of ten (10) carbon-hydrogen bonds at which chlorine substitution can be accommodated. A schematic representation of the biphenyl molecule with the various positions at which substitution can be accomplished numbered in the American Chemical Society standard notation is presented below:



ACS Convention for Numerical Assignments
of Biphenyl Substitution

In the interest of a common usage, the following rules will be followed in this report:

a. When referring to a mixture of different species, as occurs in the commercial products, we will use the term polychlorinated biphenyls or the acronym PCB.

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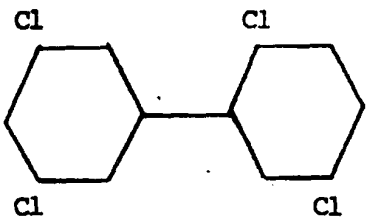
b. Those species of chlorinated compounds that arise from a specified number of chlorine substituents on the biphenyl molecule will be referred to as chlorobiphenyls with a suitable numerical prefix to define the number of substituted chlorines; i.e., dichlorobiphenyl. Thus, there are a total of ten (10) chlorobiphenyls that might appear in the commerical mixtures.

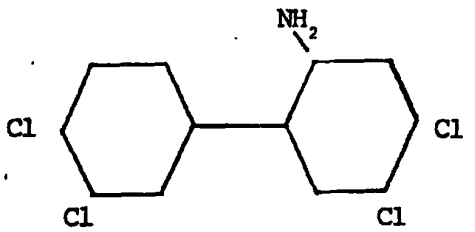
c. Those specific compounds that represent the class of compounds formed by a specific number of substituent chlorine atoms but differ in the locations at which substitution has taken place are referred to as isomers.

Thus, in terms of the above, the proper manner of referring to a commercial PCB mixture is as a "mixture of chlorobiphenyls containing various proportions of the iosmers of each".

To illustrate the utility of the numbering system indicated previously, the correct names of the compounds shown below are:



2,3',5,5'-tetrachlorobiphenyl



3',4,4',5-tetrachloro-2-biphenylamine

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The ten chlorobiphenyls and some of the salient chemical data are listed in Table 1.1-1; note that the total of all the isomers of the chlorobiphenyls are 209 separate compounds.

1.2 Commercial Production and Chemical Makeup of the Aroclors

The commercial process by which the PCBs are made involves the chlorination of biphenyl with anhydrous chlorine in the presence of a catalyst which may be either iron filings or ferric chloride. The crude product is generally purified to remove color, traces of hydrogen chloride, and the catalyst by treatment with alkali and subsequent distillation. The resulting product is then a more or less complex mixture of the chlorobiphenyls, the precise composition depending on the conditions under which chlorination was carried out. The approximate composition of selected Aroclors is given in Table 1.2-1.

By way of explanation, the products made by Monsanto under the tradename Aroclor are designated as to the starting material, with biphenyl represented by the 12 prefix, and with the approximate chlorine percentage by the second set of digits; i.e., Aroclor 1248 is a chlorinated biphenyl containing approximately 48 percent chlorine.

From the data presented in Table 1.1-1 and 1.2-1, it might be inferred that all of the isomers of the individual chlorobiphenyls are to be found in each of the commercial mixtures. To illustrate the actual situation, Aroclor 1248, which is made up primarily of the di-, tri-, tetra-, penta- and hexa- chlorobiphenyls, could be expected to contain something of the order of 140-150 separate isomers. In point of fact, there are less than 50 identifiable peaks observed in the high resolution gas chromatogram of typical specimens of Aroclor 1248 as is illustrated in Table 1.2-2.

The observations relative to the high resolution studies of the commercial Aroclor mixtures have been summarized by Hutzinger, et al (ibid), in the form of Figure 1.2-1 which indicates the structural units of which the significant isomers are constructed.

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Table 1.1-1
Empirical Formulation, Molecular Weights
and Chlorine Percentage in PCBs

Empirical formula chlorobiphenyls	Molecular weight*	Percent chlorine*	No. of isomers
$C_{12}H_{10}$	154	0	1
$C_{12}H_9Cl$	188	18.6	3
$C_{12}H_8Cl_2$	222	31.5	12
$C_{12}H_7Cl_3$	256	41.0	24
$C_{12}H_6Cl_4$	290	48.3	42
$C_{12}H_5Cl_5$	324	54.0	46
$C_{12}H_4Cl_6$	358	58.7	42
$C_{12}H_3Cl_7$	392	62.5	24
$C_{12}H_2Cl_8$	426	65.7	12
$C_{12}HCl_9$	460	68.5	3
$C_{12}Cl_{10}$	494	79.9	1

*Based on Cl^{35}

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Table 1.2-1

Approximate Molecular Composition
of Selected Aroclors

Chlorobiphenyl	Aroclor Type or Grade (percent composition)					
	1221	1242	1248	1254	1260	1016
$C_{12}H_{10}$	11	<0.1		<0.1		<0.1
$C_{12}H_9Cl$	51	1		<0.1		1
$C_{12}H_8Cl_2$	32	16	2	0.5		20
$C_{12}H_7Cl_3$	4	49	18	1		57
$C_{12}H_6Cl_4$	2	25	40	21		21
$C_{12}H_5Cl_5$	0.5	8	36	48	12	1
$C_{12}H_4Cl_6$	ND	1	4	23	38	<0.1
$C_{12}H_3Cl_7$	ND	<0.1		6	41	ND
$C_{12}H_2Cl_8$	ND	ND		ND	8	ND
$C_{12}H_1Cl_9$	ND	ND		ND	1	ND
$C_{12}Cl_{10}$	ND	ND		ND		ND

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Table 1.2-2

High Resolution Gas Chromatography of Aroclor 1248

Peak number*	No. of Cl	% In Aroclor 1248	% In fatty tissue
1			
2			
3			
4	2	0.4	
5	3	1.0	0.9
6	2	3.2	1.4
7	3	11.2	0.9
8	3	3.2	2.4
9	3	3.1	0.5
10	3	2.0	0.2
11/12	3,4	1.4	4.8
13	3,4	1.4	0.8
14	3,4	0.8	0
15	3	8.5	1.6
16	3	9.7	1.6
17	3	2.1	0.8
18	3,4	7.4	0.5
19	3,4	7.4	-
20	3,4	6.0	7.0
21	3,4	4.5	4.1
22	4	3.1	0.3
23	4	2.6	0.4
24	3,4,5	0.8	-
25	4,5	1.2	1.0
26	4,5	1.0	-
27	4	0.2	-
28	4	5.0	5.3
29	4	3.3	2.0
30	4	2.0	0.4
31	4	2.1	0.5
32	4,5	1.0	2.9
33	4,5	0.5	29.0
34	4,5	0.5	1.4
35	4,5	0.8	-
36	5	1.0	1.7
37	5	0.4	1.4
38	6	<0.1	0.1
39	4	<0.1	0.1
40	6	0.2	11.0
41/42	5	0.3	1.1
43	5,6	0.2	8.0
44	6	<0.1	5.3
45	6	0.2	0.9
46	6,7	(0.7)	(1.1)

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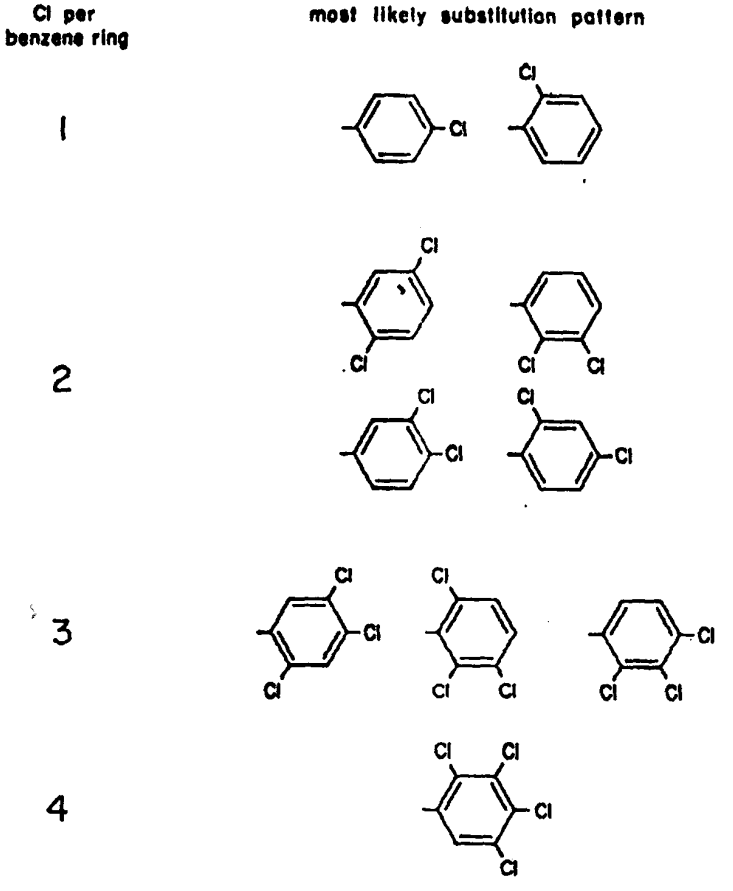
Figure 1.2-1

Moieties from Which Principal
Chlorobiphenyl Isomers are Formed



The most common substitution patterns for the chlorobiphenyls found in PCB preparations. Only one phenyl-ring is shown. The most abundant tetrachlorobiphenyls, for example, are those from the dichlorophenyl-moieties shown. One di- and one trichlorophenyl- would give most abundant penta-chlorobiphenyls, etc.

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Several comments are necessary at this point: The importance of such detailed determination and identification of the isomers characteristic of the commercial PCBs lies in the observations, to be discussed below, that bio-accumulated chlorobiphenyls show what appear to be significant differences in the distributions of the individual isomers from the source materials. The most probable explanation for these observations seem to be that at least some of the chlorobiphenyls are metabolized principally to hydro-chlorobiphenyls. Only after very complete isomeric spectra are available can such effects be properly studied.

Secondly, the detailed study of the PCBs has shown that there are no major compounds in these mixtures aside from the chlorobiphenyls. On the other hand, products formed by the addition (rather than by substitution) of chlorine to the biphenyl molecule in laboratory studies, yield significant concentrations of partially saturated structures. These structures are apparently either not formed under the conditions of chlorination that prevail during the industrial processing or alternatively are destroyed during the purification steps of the process. In contrast to the Aroclors, some of the foreign products have shown traces of polychlorinated naphthalenes and polychlorodibenzofurans; a fact that may have considerable toxicological significance in view of the rather more toxic nature of these latter products. However, recent information published by FDA indicates that impurities of chlorodibenzofurans have been also detected in Aroclors.

1.3 Physical Properties of the PCB Aroclors

The relevant physical properties of the Aroclor mixtures naturally separate into two groups; those properties that have led to the widespread industrial use of these materials, and those properties that result in the introduction of these materials into the environment with what appears to be considerable potential danger.

1.3.1 Physical Properties of Industrial and Technical Interest

The most useful compilation of the physical properties of the various Aroclors that has so far appeared in the literature is that given by Hutzinger, et al (ibid), a portion of which is herein reproduced (with minor changes) as Table 1.3.1-1.

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NR = not reported
a - some chlorine content as diaryltriphenyl
aa - polychlorinated terphenyls

Table 1.3.1-1

Chemical and Physical Properties of Representative Aroclors

Property	Aroclor 1221	Aroclor 1232	Aroclor 1016	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268	Aroclor 1270a	Aroclor 5442	Aroclor 5460aa
Appearance	Clear, white oil	Clear, white oil	Clear, white oil	Clear, white oil	Clear, white oil	Light-yellow viscous liquid	Light-yellow soft, sticky resin	Light-yellow sticky viscous resin	White to off-white powder	White crystalline powder	Tailor, transparent sticky resin	Clear yellow-to-amber brittle resin
Color, maximum	100 APHA	100 APHA		100 APHA	100 APHA	100 APHA	150 APHA	150 APHA	1.5 HPA (melten)			
Chlorine, percent	20.5-21.5	31.4-32.5	~41	42	48	54	60	61.5-62.5	68	71	42	68
Acidity, mg KOH/g maximum	0.014	0.014		0.015	0.019	0.019	0.014	0.014	0.05			
Moisture, ppm, maximum	-	-		50	50	50	50	-	-			
Ave. coefficient of expansion, cc/cc/°C	0.00071 (15°-40°C)	0.00073 (25°-100°C)		0.00068 (25°-65°C)	0.00070 (25°-65°C)	0.00066 (25°-65°C)	0.00067 (20°-100°C)	0.00064 (25°-65°C)	0.00067 (20°-100°C)			
Specific gravity	1.182-1.192 (25°/15.5°C)	1.270-1.280 (25°/15.5°C)	1.362-1.372 (25°/15.5°C)	1.381-1.392 (25°/15.5°C)	1.405-1.415 (65°/15.5°C)	1.495-1.505 (65°/15.5°C)	1.555-1.566 (90°/15.5°C)	1.572-1.583 (90°/15.5°C)	1.804-1.811 (25°/25°C)	1.944-1.968 (25°/25°C)	1.470 (25°/25°)	1.670 (25°/25°)
Density, lb/gal, 25°C	9.85	10.95	11.40	11.50	12.04	12.82	13.50	13.72	15.09	16.20	12.25	13.90
Distillation range, °C, corrected (ASTM D-20, modified)	275-320	290-325	323-356	325-366	340-375	365-390	385-420	390-425	435-450	450-460	215-300	280-335
Evaporation loss, %, 100°C, 6 hr (ASTM D-6, mod.) 161°C, 5 hr	1.0-1.5	1.0-1.5		0-0.4 3.0-3.6	0-0.3 3.0-4.0	0-0.2 1.1-1.3	0-0.1 0.5-0.8	0-0.1 0.5-0.6	0-0.06 0.1-0.2			
Flash point °C (Cleveland Open °F Cup)	141-150 286-302	152-154 305-310	170	176-180 348-356	191-196 375-384	none to boiling point	none to boiling point	none to boiling point	none to boiling point	none	247	none
Fire point °C (Cleveland Open °F) Cup)	176 349	238 460	none to boiling point	none to boiling point	none to boiling point	none to boiling point	none to boiling point	none to boiling point	none to boiling point	none	>350	none
Pour point °C (ASTM E-97) °F	1 (crystals) 34 (crystals)	-31.5 -32		-19 2	-7 19.4	10 50	31 88	25-38 99	-		46	—
Softening point °C (ASTM E-28) °F	-	-		-	-	-	-	-	150-178 302-338 (hold point)	249-300	46-52	90-105.5
Refractive index, n D-20 20°C	1.617-1.618	1.628-1.622	1.622-1.624 (@ 25°C)	1.627-1.629	1.630-1.638	1.629-1.641	1.647-1.649	1.6501-1.6517	-			1.660-1.665
Viscosity, sec Saybolt Universal (ASTM D-83) 100°F (37.8°C) 130°F (54.5°C) 210°F (98.9°C)	38-41 35-37 30-31	44-51 39-41 31-32	71-81 NR NR	82-92 49-56 34-35	185-240 73-88 36-37	1800-2500 260-340 44-48	1200-4500 72-78	600-850 (140°F; 71°C) 86-100	-			
Average No. of Cl/mol	1.15	2.04	NR	3.18	3.30	4.96	6.30	6.80	8.70	NR	NR	NR

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In addition to the chemical stability and resistance to combustion illustrated in Table 1.3.1-1, the electrical properties of the PCB Aroclors are of extreme significance in the utilization of these materials. A compilation of the relevant data is presented as Table 1.3.1-2, which illustrates the nature of the problem that is encountered when one undertakes a search for a suitable substitute for these compounds in such segments of the electrical industry as the manufacture of capacitors. Specifically, the dielectric constants for most dielectric liquids lie in the range up to perhaps half of that of the polychlorinated biphenyls.

1.3.2 Physical Properties of Environmental Interest

The essentially world-wide distribution of the chlorinated hydrocarbons such as the PCBs suggest that a major route by which such compounds are transported is through the atmosphere either in the form of vapor or perhaps sorbed onto dust particles. In addition, it is observed that there is a widespread accumulation of these compounds within the biota ranging from the smallest on up the food chain until truly enormous loads are found in the highest members of the chain. Since this bioaccumulation also includes the aquatic biota, the possibility of considerable transport via the solubility of these compounds in water must also be taken into account. Table 1.3.2-1 lists some of the vapor pressure and solubility data for several of the Aroclors (D. MacKay and A. W. Wolkoff, Env. Sci. and Tech., 7, 611 ff (1973)).

The analysis of co-evaporation (MacKay, ibid) of dilute solutions of the Aroclors by equilibrium thermodynamics suggests that, because of the very high activity coefficients of the chlorobiphenyls in water, the potential for evaporation is quite high enough that this mechanism is a major portal by which such compounds enter the atmosphere. The fourth column of Table 1.3.2-1 indicates the theoretical time for a fifty percent reduction in the concentration of the Aroclor from a saturated water solution (pure water plus PCBs), assuming the water depth to be 1 meter thick. Clearly, the results of this analysis need to be experimentally verified.

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Table 1-3.1-2
Electrical Properties of Some Aroclors

Aroclor	Dielectric constant at 1000 cycles[a] 25°C	100°C	Volume resistivity,[b] 8 cm at 100°C 500 V, de	Dielectric strength,[c] kV	Power factor,[a] 100°C, 1000 cycles, %
1232	5.7	4.6			
1242	5.8	4.9	above 500 x 10^9	>35	<0.1
1248	5.6	4.6	above 500 x 10^9	>35	<0.1
1254	5.0	4.3	above 500 x 10^9	>35	<0.1
1260	4.3	3.7	above 500 x 10^9	>35	<0.1
1268	2.5				
5442*	3.0	4.9	above 500 x 10^9	—	—
5460*	2.5	3.7	—	—	—

[a]ASTM D-150-47T

[b]ASTM D-257-46

[c]ASTM D-149-44

*Polychlorinated terphenyls

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Table 1.3.2-1

Solubility, Vapor Presure and Halflife for
Vaporization from Water of Selected Aroclors at 25°C

PCB Type	Solubility (mg/l)	Vapor Pressure (mm Hg)	Theoretical halflife for vaporization from 1 m. water column
Aroclor 1242	0.24	4.06×10^{-4}	5.96 hr.
Aroclor 1248	5.4×10^{-2}	4.94×10^{-4}	58.3 min.
Aroclor 1254	1.2×10^{-2}	7.71×10^{-5}	1.2 min.
Aroclor 1260	2.7×10^{-3}	4.05×10^{-5}	28.8 min.

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As pointed out above, not only is each of the Aroclors a mixture of several chlorobiphenyls, but there are a number of isomers present for each of the chlorobiphenyls. Thus, the solubility of an Aroclor, or the vapor pressure of an Aroclor, represents an average over the various species that make up the mixture. To illustrate the effect of the structural complexity, Table 1.3.2-2 (Hutzinger, ibid) details the measured vaporization rates of the several Aroclors. On the other hand, the changes in the mixture corresponding to Aroclor 1254 on extended heating are displayed in Table 1.3.2-3 (Hutzinger, ibid).

The possible implications of these data lie in the fact that much of the Aroclor that is found in typical environmental samples seems to demonstrate lesser amounts of the lower chlorine number chlorobiphenyls than is characteristic of freshly manufactured samples. This observation has frequently been attributed to possible metabolism of the more lightly chlorinated species coupled with enhanced fixation of the higher chlorinated species.

A partial listing of the measured solubility in water of identified authentic chlorobiphenyls is shown in Table 1.3.2-4 (Hutzinger, ibid) and the effect of the solubility differences of the individual chlorobiphenyls on the constitution of Aroclor 1254 solutions is illustrated in Table 1.3.2-5 (Hutzinger, ibid).

A factor that is most probably of considerable importance in the admission of such compounds as the PCBs into the environment is a measure of the partition coefficients between such interface systems as soil-air; soil-water; lipids-water; and, more generally, water-solid particles. At the present time there seems to be very little actual data available in direct form, although much should be possible to infer from the effects of various combinations of stationary phase and support in gas chromatography on the retention index. An interesting and probably significant point of datum has been presented by D. R. Branson of the Dow Chemical Co., who reports that the distribution of 2,2',5 trichlorobiphenyl between sludge-water-air was 92%-3%-5%, respectively.

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Table 1.3.2-2

Vaporization Rates of Aroclors

Aroclor (Surface area: 12.28 cm^2)	Wt. loss (g)	Exposure at 100°C (hr)	Vaporization rate ($g/cm^2/hr$)
1221	0.5125	24	0.00174
1232	0.2572	24	0.000874
1242	0.0995	24	0.000338
1248	0.0448	24	0.000152
1254	0.0156	24	0.000053
1262	0.0039	24	0.000013
1260	0.0026	24	0.000009
1270 (Deca)	0.0015	24	0.000005

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Table 1.3.2-3

Percent Loss in Area of Seven Chromatogram Peaks of Aroclor After Heating

Aroclor 1254 peak	% Peak Remaining After Heating with water 25 min	with water 60 min	without water 10 min
1	34	17	13
2	59	26	15
3	78	27	20
4	60	46	20
5	86	49	27
6	100	85	28
7	100	67	16

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Table 1.3.2-4

Solubility of Chlorobiphenyls in Water

Compound	Solubility mg/l (ppm)
Monochlorobiphenyls	
2-	5.9
3-	3.5
4-	1.19
Dichlorobiphenyls	
2,4-	1.40
2,2'-	1.50
2,4'-	1.88
4,4'-	0.08
Trichlorobiphenyls	
2,4,4'-	0.085
2',3,4-	0.078
Tetrachlorobiphenyls	
2,2',5,5'-	0.046
2,2',3,3'-	0.034
2,2',3,5'-	0.170
2,2',4,4'-	0.068
2,3',4,4'-	0.058
2,3',4',5-	0.041
3,3',4,4'-	0.175
Pentachlorobiphenyls	
2,2',3,4,5'-	0.022
2,2',4,5,5'-	0.031
Hexachlorobiphenyl	
2,2',4,4',5,5'-	0.0088
Octachlorobiphenyl	
2,2',3,3',4,4',5,5'-	0.0070
Decachlorobiphenyl	0.015
4,4'-Dichlorobiphenyl	
+Tween 80 0.1%	5.9
+Tween 80 1%	>10.0
+Humic acid extract	0.07

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Table 1.3.2-5

Relative Peak Heights (Peak 5 = 100) in Saturated Aqueous Solutions of Aroclor 1254

Peak No.	Saturated aqueous solution (26°C)	Saturated aqueous solution (4°C)	Aroclor 1254 standard
1	172	144	35
2	91	72	16
3	47	41	30
4	14	9	1
5	100	100	100
6	33	28	23
7	57	59	55
8	5	5	10
9	21	24	25
10	8	13	31
11	4	4	6
12	11	24	50
13	6	10	11

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1.4 Chemical Properties of the Chlorobiphenyls

Considerable detail on the most important chemical reactions that are known to occur with the chlorobiphenyls is presented in Chapter 5 of the treatise on "The Chemistry of the PCB" by Hutzinger, et al. Suffice it to say here that oxidation and hydrolysis can be carried out, but only under conditions which are considerably more rigorous than would be obtained in industrial applications. This relative stability is, of course, one of the most attractive features of these compounds in technological practice.

The class of reactions to which the chlorobiphenyls are susceptible and which is of most interest in terms of their possible toxicological significance are those which result in cyclization. Of particular interest in this context is 2,2' dichlorobiphenyl, which on cyclization yields the compound dichlorodibenzofuran. The toxicological data on these two compounds indicates the nature of this change: the LD_o for oral doses to rats is of the order of 250 mg/kg for the dibenzofuran whereas the corresponding toxicity for the chlorobiphenyl is in excess of 4000 mg/kg. (Data from the "Toxic Substances List", HEW, 1973).

The close proximity of the 2 and 2' substituents on the biphenyl molecule facilitates intermolecular cyclization reactions under a variety of conditions. Of special interest is the observation that alkali fusion of 2-chloro-2'-hydroxybiphenyl and the dehydration of 2,2'-dihydroxychlorobiphenyl yield the corresponding chlorodibenzofurans; hydroxylation of the chlorobiphenyls is the common initial step in the metabolism of these compounds. The immediate biological significance of this is unknown at this time since the chlorodibenzofurans have not been isolated from animal experiments.

1.5 Photochemical Reactions Involving the PCBs

A great deal of effort has been directed to the study of the effects of ultraviolet (UV) radiation on the chlorobiphenyls since photodestruction is believed to be a possible major mechanism for the environmental decay of chlorohydrocarbon pesticides such as DDT. There has been much speculation as to the role that UV photodisintegration might play in terms of the chlorinated biphenyls. The earlier work was carried out using mercury vapor UV sources with the result

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that, because of the significantly harder radiation (mercury source 250 nm, solar radiation at surface of the earth with an effective cutoff at 290 nm), cross section and reaction paths are difficult to extrapolate to environmental situations. In more recent times, such irradiation studies have been carried out using General Electric "Black Light" sources which much more nearly approximate the spectral distribution of solar radiation.

A number of types of effects have been observed including partial dechlorination and even, in some cases, the formation of very viscous semi-solids that apparently arise from complex polymerizations. Again, the extension of the experimental results to environmental conditions is somewhat limited in value since the majority of the irradiation studies have been carried out in solvents other than water. The very low solubility of even the least chlorinated chlorobiphenyls in water makes the experimental study of aqueous solutions especially difficult, particularly when the information of concern is the quantitative evaluation of the reaction products that are formed. It must be said, at this time, that the probability of UV disassociation being a major source for the environmental decay of the chlorobiphenyls seems to be significantly less than that for the chlorinated hydrocarbon pesticides.

Since it is assumed that a major portion of the chlorinated biphenyls are transported and distributed throughout the world through the medium of adsorption on dust particles or as a vapor, it follows that studies of the stability of thin sorbed films or of vapors of the chlorinated biphenyls against long term UV irradiation are of importance. The earlier attempts to discover the presence of reaction products resulting from long term exposure of selected chlorobiphenyls to solar radiation were subject to the differential evaporation of the less chlorinated species; this result seriously biased the observations. The recent experiments that have been conducted within quartz containers seem to obviate evaporation problems and, further, seem to indicate that the mono- and dichlorobiphenyls are essentially completely destroyed when exposed to hard UV for times of the order of weeks or months. Problems of detection sensitivity continue to plague attempts to elucidate the detailed mechanisms and pathways.

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Studies of thin films of chlorobiphenyls sorbed onto appropriate surfaces have also been carried out within a quartz enclosure. To date, the major objection to such experiments, in terms of extrapolation to environmental conditions, seems to be that the concentration, or rather the absolute density of the surface layer, is sufficiently high that the activated species remain in contact for sufficiently long times as to allow the formation of products that might well be very rare events in corresponding environmental concentrations.

At this time there appears to be significant research being directed to the determination of the stability of chlorobiphenyls against ultraviolet radiation and that it is to be expected that the situation which obtains in typical environmental conditions will be greatly illuminated in the near future.

1.6 Metabolic Chemistry of the Chlorobiphenyls

The very combination of physical and chemical properties that have made the chlorobiphenyls and their technical mixtures of such wide technical interest also result in these compounds being of significance as environmental pollutants, especially in terms of their impact on the biota. The very low chemical activity, coupled with high lipid-water partition coefficients, apparently contribute to the bioaccumulation whereby the chlorobiphenyls, pecially the more highly chlorinated species, tend to become fixed within the body fats and particularly in higher members of the food chain. There is evidence that this fixed load of refractory chlorinated organic materials, or the circulating levels of the same compounds that must accompany such fixed loads, represents a serious hazard to the bearer or progeny. The toxic consequences of body burdens of chlorobiphenyls is more fully discussed in the section of this report concerned with toxicology of the chlorobiphenyls.

The mechanisms by which an organism can deal with ingested refractory compounds are naturally separated into physical and chemical processes. The physical processes are primarily associated with the requirements of free energy across the boundary between differing phases such as a water-lipid boundary, or a cell wall, etc. Since there does not exist a significant body of partition coefficient data for various combinations of interfaces, little of a quantitative nature can be stated as to the biological significance of such physical processes.

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On the other hand, as is pointed out in Section 2.4, hydroxylation is a rather easily accomplished process for at least the less chlorinated chlorobiphenyls. Thus, it might be assumed that one should observe the hydroxylated chlorobiphenyls as intermediate metabolic products in a variety of organisms. Experimental data is available to indicate that such hydroxylation processes are indeed exhibited by a wide variety of organisms. The principle species related differences seem to be in the rate at which such processes are found to occur — very rapidly in rodents and very slowly in fish. In addition, once the target chlorobiphenyl has been hydroxylated to a more or less degree, there appear to be available a wide variety of species-specific addition processes which could make use of the hydroxylated molecule. Interestingly, there is to date no evidence of biologically or metabolically induced cyclization; it thus appears likely that the chlorodibenzofurans are not biologically formed.

The salient observations to date on the metabolism of chlorobiphenyls might best be summarized as follows:

a. When the challenge to the animal is a technical mixture of chlorobiphenyls, there is a preferential storage of the more highly chlorinated species, with the result that the homologue spectrum of stored PCBs often represents a more heavily chlorinated mixture than the original test mixture.

b. There is conflicting and often species-dependent data as to the mechanism by which the less chlorinated species are differentiated; whether the processes involve metabolism, physical partitioning, or some combination of such processes has not been settled.

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c. Conflicting and confusing evidence exists indicating marked differences in accumulation and differentiation between specific isomers especially at the middle levels of chlorination. These differences also seem to be species-dependent in a number of cases.

d. There is significant evidence that PCB metabolism proceeds through an intermediate step of hydroxylation (often this appears to be the terminal step whereby the increased aqueous solubility of the hydroxylated species accomplishes the end of its removal).

e. There are several observations indicating that isomerization can be accomplished during metabolic reactions. In this context, the results of Bagley and Cromartie (Bagley, G.E. and E. Cromartie, J. Chrom. 75, 219-226, (1973)), with the elimination of Aroclor 1254 in the Bobwhite, are most pertinent.

In conclusion, there has been much work directed to the study of the mechanisms whereby living organisms are able to eliminate chlorinated biphenyls from their system. In spite of this effort and because of the inherent complexity of this subject, the nature of these mechanisms remains a mystery.

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SECTION V

INDUSTRIAL CHARACTERIZATIONS

1.0 INTRODUCTION

This section discusses polychlorinated biphenyls (PCBs) production and each PCBs user (capacitor, transformer, investment casting, paper recycling and miscellaneous) manufacturing process. When known, for each operation the following information is given:

- Name and the location of companies in each category;
- A description of the processes at the facilities studied and pertinent flow diagrams, where appropriate;
- Raw waste load data per ton of PCB used and sources of these wastes;
- Water usage data in terms of gallons per day;
- Treatment and housekeeping measures practiced at the facilities and on-going PCB containment programs;
- Plant waste effluents found and their composition.

2.0 MANUFACTURING PROCESS - POLYCHLORINATED BIPHENYLS (PCBs)

2.1 Process Description

Monsanto, the sole domestic manufacturer of PCBs, manufactures this chemical in their Sauget, Illinois plant. The basic raw material is biphenyl which is manufactured from pure benzene in another Monsanto plant. The PCB manufacturing operation is conducted in two steps. First, biphenyl is chlorinated with anhydrous chlorine in the presence of ferric chloride to produce crude PCBs and then the crude PCBs are distilled to obtain the finished product. A schematic flow diagram of this process is given in Figure 2.1-1A and B.

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FIGURE 2.1-1A. PREPARATION OF CRUDE CHLORINATED BIPHENYLS-MONSANTO KRUMMRICH PLANT

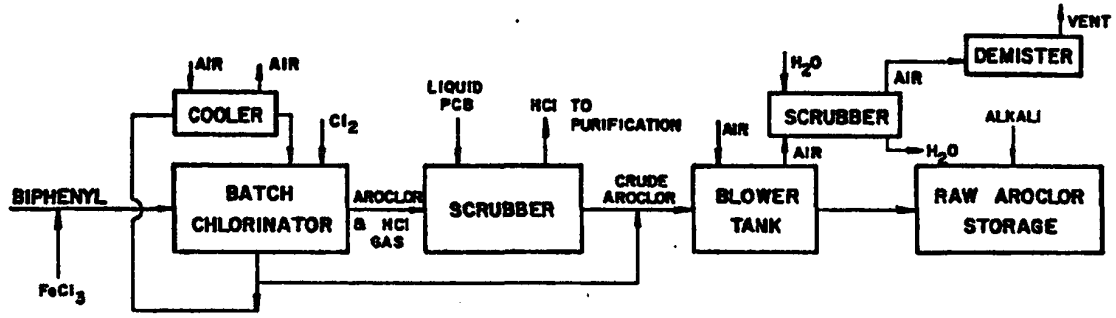
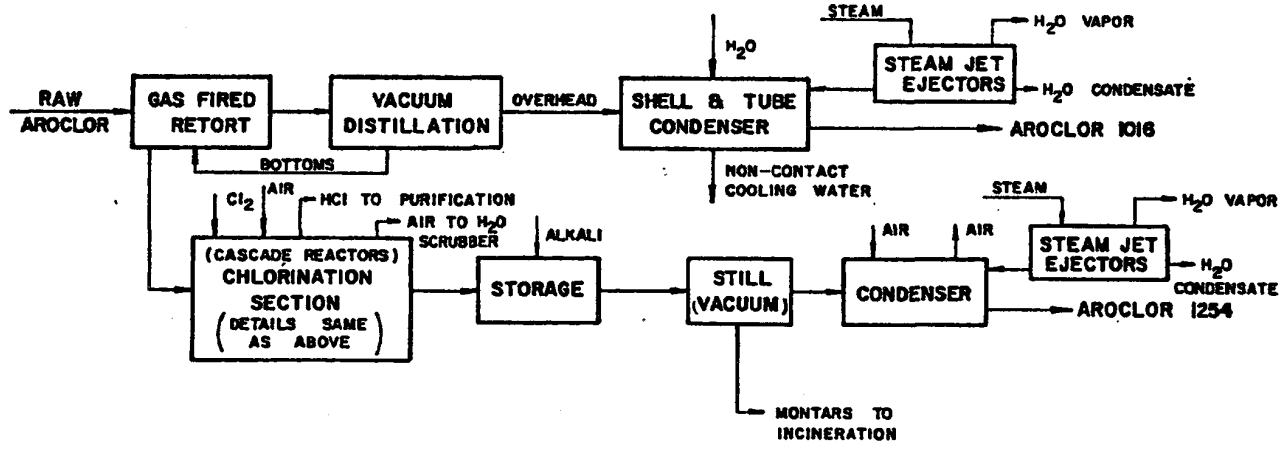


FIGURE 2.1-1B. DISTILLATION OF CRUDE PRODUCTS-MONSANTO KRUMMRICH PLANT



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The reaction section consists of 6 reactors (3 batch and 3 cascade). Currently, Monsanto manufactures four different types of Aroclors (1242, 1016, 1254 and 1221). For the manufacture of any given product, the chlorinator is charged with proper quantities of biphenyl and catalyst and heated above the melting point of biphenyl. The flow of vaporized chlorine is then started and the charge is circulated with a pump. Throughout the chlorination, the temperature is kept above the melting point of the mixture, but below 150°C to avoid excessive sublimation and plugging of the line discharging the hydrogen chlorine produced by the chlorination. The reaction pressure is maintained near atmospheric. The degree of chlorination is principally determined by the time of contact with anhydrous chlorine. The contact time varies from 12 to 36 hours for the manufacture of different Aroclor types. The degree of chlorination is measured by the specific gravity of the mixture or the ball and ring softening point when the product is viscous.

The vapors from the chlorinator (HCl containing PCBs) are scrubbed with liquid Aroclor and the gaseous HCl is sent to another plant at the Sauget complex for purification. The crude product is held at an elevated temperature and blown with dry air for several hours, after which it is sent to the raw Aroclor storage tank where a few tenths of 1 percent of alkali are stirred with the material to react with any remaining hydrogen chloride or ferric chloride. The air from the blower tank is scrubbed with water and vented to the atmosphere through a demister.

The raw Aroclor is subsequently batch distilled under reduced pressure to remove the color, and the traces of hydrogen chloride and ferric chloride. The methods of purification are different for the different types of end products. Raw Aroclor 1254, 1242 and 1221, each are distilled in stills under reduced pressure, achieved via steam jet ejectors; the condensate from the still is the finished product while the bottoms are the Montars which are drummed and sent to incineration.

The distillation section for the 1016 product consists of a gas fired retort and a vacuum distillation tower. The latter is used to allow the separation of the higher chlorinated, less biodegradable compounds from the relatively

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lower chlorinated and more biodegradable ones. The raw Aroclor (42% chlorinated material) is fed into the reboiler. The vacuum in the tower is maintained at about 100 mm Hg by steam jet ejectors. The steam is partially condensed and the condensate is discharged into the plant discharge sump. The first cut from this tower is recycled back to the retort. At a preset overhead temperature the 1016 product is collected and sent to the product storage. The high boiling residue from the tower is sent to a subsequent chlorination cycle and the resulting raw Aroclor is distilled in a still. The overhead from this still is the finished product. The bottoms from this tower are the Montars. The spent ferric chloride catalyst, used in PCB manufacturing, is sent to incineration with Montar residues.

For special orders, in order to increase electrical resistivity, the Aroclors are stirred at an elevated temperature with a few tenths of 1% of well-dried fuller's earth and then filtered through paper.

All Aroclors are stored at 150°F. Steam coils are used on the storage tanks for heating these tanks.

2.2 Raw Wastes

The raw wastes from the manufacturing area consist of the liquor from the scrubber, the condensate from the steam jet ejectors, water used for showers and eye baths, miscellaneous floor wash downs, waste oil collected in drip pans and drums, and montars which are the bottom cut from their stills. The composition and the quantities of the individual waste stream are not monitored. All effluent streams generated in the manufacturing area are directed into the sumps in this area. The waste oil collected in the drip pans and the Montars are emptied into 55 gallon drums and sent to incineration.

The raw wastes generated in the incinerator consist of the venturi scrubber liquor and the water phase from the separator sump in the incinerator area. The composition of the combined stream is monitored. However, the composition of the individual streams is not known. Non-product PCB discharges are shown in Figure 2.2-1. It has been estimated that this plant generates

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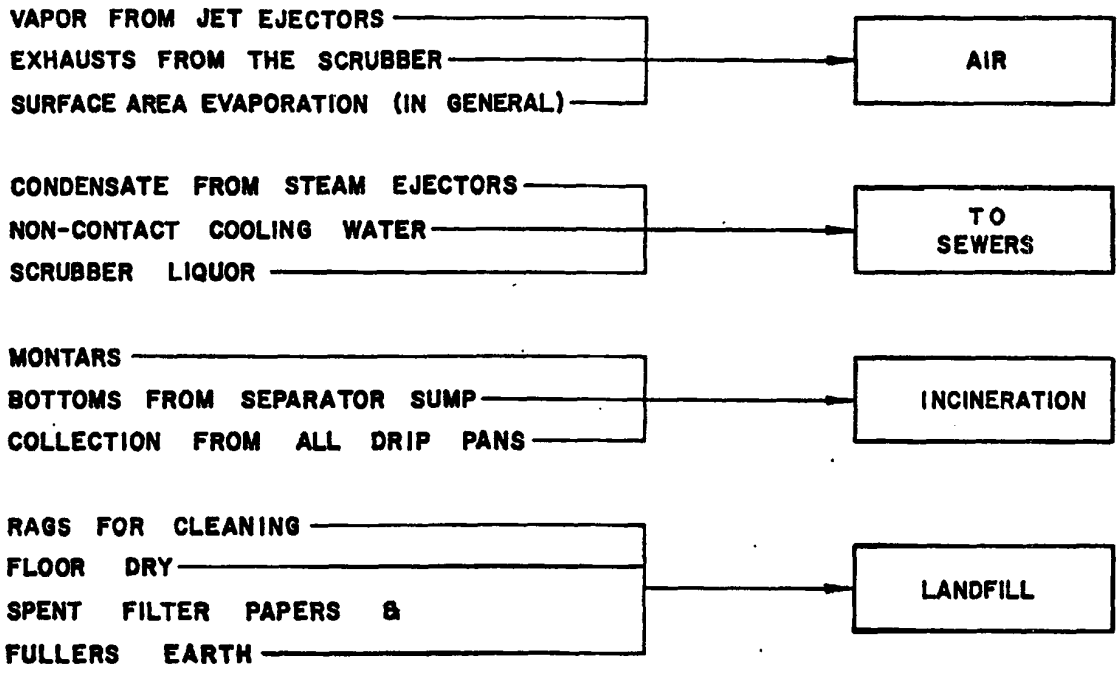
FIGURE 2.2-1. NON-PRODUCT PCB DISCHARGES AT MONSANTO'S KRUMMRICH PLANT



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about 25 lbs of scrap oil and Montar per ton of PCB produced. Additionally, the quantities of material sent to landfill approximates to 5.4 lbs per ton of PCB produced. Further, Monsanto reports that the plant's PCB contribution to the air is under 1 lb/day.

2.3 Plant Water Usage

On the average, the PCB plant uses a maximum of 388,800 gallons of water and a maximum of 360,000 lbs of steam daily. Water is used for non-contact cooling purposes in shell and tube condensers, in a water scrubber, for floor washings, for showers and in eye baths. Steam is used in the steam jet ejectors and for steam tracing purposes. The plant uses municipal water and purchased steam.

The process water from this facility consists of the liquor from their scrubber and the steam condensates which are discharged in one of the two sumps in the manufacturing area.

Additionally, 273,600 gallons of water are used in the incinerator daily for quenching the hot gases from the fire box. The resulting weak muriatic acid in the quench pot is used in the venturi scrubber and in the packed tower.

The type and quantities of water used and discharged at this plant are summarized below:

Water Balance

. Manufacturing Plant

	Quantities, GPD	
	Used	Discharged
Process Water		
in water scrubber	14,400	14,400
misc. floor wash downs	7,200	7,200
condensate from steam jet ejectors	—	14,400

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Water Balance (Con't)

. Manufacturing Plant

		Quantities, GPD	
		Used	Discharged
Non contact cooling water		360,000	360,000
showers, eye bath		7,200	7,200
condensate from steam tracers		—	28,800
	Total	388,800	432,000
. Incinerator			
water used for hot gas quenching		273,600	273,600
water phase from the sump		—	14,400
	Total	273,600	288,000

2.4 Wastewater Treatment and Housekeeping

Monsanto reports significant environmental controls at their Krummrich, Sauget plant. Since 1969, they have invested more than 22 man-years of work and millions of dollars in this program. The in-house goals have reduced the PCB discharges into water to about three pounds per day.

A John Zink designed incinerator was erected at Sauget in 1970 to safely dispose of PCBs. A schematic flow diagram of this operation is given in Figure 2.4-1. Aroclor is steam atomized and fed into the fire box. Natural gas is used for combustion and the feed is incinerated at temperature above 2200°F at 5 percent excess oxygen with a retention time of 2-3 seconds. The gases are quenched with water and the exhausts from the quench pot are passed through a high-energy venturi scrubber, then through a packed column which is irrigated by the weak muriatic acid originating from the quench pot. Exhausts are then vented to atmosphere through a demister. These exhausts as well as the effluent from the incinerator section are monitored.

In the incineration area, drainage is directed to trenches and piping which flow into a 10,000 gallon underground concrete basin. The water

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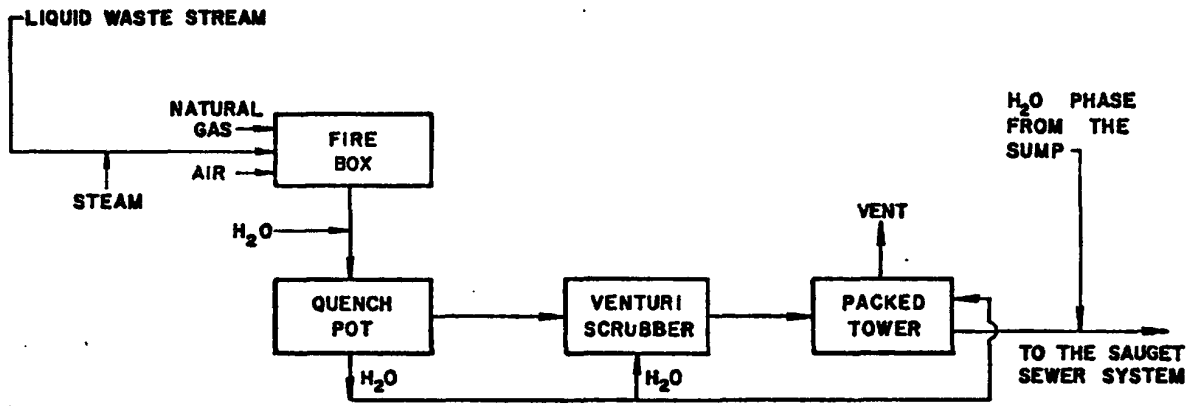
FIGURE 2.4-1. PROCESS FLOW DIAGRAM OF THE JOHN ZINK INCINERATOR AT MONSANTO'S KRUMMRICH PLANT



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layer from this basin is pumped continuously, combined with the scrubber liquor, metered, monitored and discharged into the sanitary sewers of the Sauget complex and from there it is sent to the East St. Louis municipal sewers. The organic phase from the sump is periodically pumped into waste storage tanks for incineration.

The incineration unit has a rated design capacity of 10 million pounds per year. However, since the start of its operation this unit has achieved a service factor of about 0.60. Monsanto reports that this incinerator can achieve a maximum of 6 million pounds of capacity annually; the unit is plagued with various mechanical problems.

Monsanto uses their incinerator to process both their own wastes and as a service to other industries. The service charge for incineration is an average of 5¢ per lb of material, but the cost appears to be increasing.

The incinerator feed is brought into the plant either by truck in 55 gallon sealed drums, by tank trucks or by rail. The drums are opened, picked up by a fork lift and emptied into a concrete pit. The tank truck carrying the waste liquids enters the incinerator area and the liquid waste is then pumped from the truck into the pit. The material in this pit is periodically pumped via a vertical certrifugal pump into one of the four 20,000 gallon incinerator waste feed tanks.

The rail car is brought into a designated area close to the incinerator site. The material from the rail car is normally pumped into a long term, 500,000 gallon storage tank. The material from this tank is pumped into the incinerator feed tanks located on the incinerator pad when required.

Drainage is provided along the rail tracks. These drains empty into the 10,000 gallon sump located under the incinerator pad.

In the manufacturing area, Monsanto has taken a number of significant steps to prevent loss of PCBs to the environment. Drainage is directed to trenches and piping, and then to one of two concrete 3,000-gallon underground settling basins. This insures PCB containment in case of accidental spill or

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equipment failure. Relief valve lines and atmospheric vents are routed through catch tanks, or are redirected to settling basins.

When small quantities of PCBs are collected in the settling basins of the manufacturing area they are later pumped into 55 gallon drums, and eventually incinerated. The overflow from these sumps is combined with the non-contact cooling water used at the plant, monitored and then discharged into the Sauget complex's sanitary sewer and from there to the East St. Louis municipal system.

PCBs are packed and shipped in galvanized-steel 55 gallon drums, or in railroad tank cars. All tank cars are top loaded. In the drum filling area spills are cleaned via rags or floor dry and these materials are drummed and sent to landfill located in the town of Sauget.

In the PCB truck or rail car loading area, drainage is directed into a small concrete pit. The material accumulated in this pit is periodically pumped into the basins located in the manufacturing area.

Nitrogen blanketing is provided on storage tanks to eliminate any "breathing" of the tanks and resultant PCB escape.

Mist eliminators have been installed in vapor lines to eliminate the possibility of PCBs leaving the manufacturing area through these lines.

Finally, underground sewers have been replaced with above-ground sewers, and repaired or combined with others, so that the effluent from the department can be monitored. In addition, this step will prevent any unknown buildup of PCBs in the sewer systems or any contamination of PCBs into other sewers.

A high housekeeping level is maintained in the plant itself. Housekeeping responsibilities which the operators have assumed are as follows:

- All pumps are checked for leakage on every shift. Drip pans that collect leaks are emptied into scrap PCB drums.

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- All leaks are reported and documented so that corrections can be made and settling basins observed.
- "Floor Dry" is used to absorb any PCBs that have spilled or leaked. If it becomes necessary to flush PCBs to the settling basin, a minimum amount of water is used.
- Sampling drums and scrap PCB drums are quickly palletized, labelled and transferred to the incineration area.

2.4.1 Treatment Facility for the Effluent from Sauget Complex

The processing and incineration departments' aqueous effluent enters the plant sewer system, and this system discharges into the Sauget Village waste sewer system. The combined streams then flow to the village primary treatment plant. The village treatment plant is under expansion to a secondary chemical treatment plant, scheduled for 1976 completion.

Additionally, evaluations are being conducted to include the village plant discharge in a projected regional biological treatment plant.

2.5 Plant Effluents

This plant has no point source discharge from their operation. There is a single discharge from the manufacturing operation (the combined stream of process and non-contact cooling water) to the main sewer system of the Sauget complex and there is a second discharge from the incinerator area to the same sewer system. The composition of these streams as reported by Monsanto are as follows:

	Effluent from the Manufacturing Operation	Effluent from the Incineration area
flow rate, gpd	432,000	288,000
PCBs, ppm	0.75	0.15
PCBs, lbs/day	2.70	0.36

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It has been reported that these effluents are clear liquids with essentially no suspended solids. The incinerator effluent may contain some amounts of chloride. However, no information is available on the chloride content.

3.0 PCB USER INDUSTRIES

3.1 Askarel Capacitor Manufacturing Industry

Presently 90-95 percent of all impregnated capacitors manufactured in the U.S. are of the PCB type. Two important types of capacitors are phase correctors on power lines and ballast capacitors for fluorescent lighting. Aroclor 1016 is the principal PCB used in this application; at some plants Aroclor 1242 and 1221 are also being used in limited quantities. The principal types of Aroclor impregnated capacitors and their applications are given below.

A. High Voltage Power

Generally AC capacitors are used to improve the power factor of a circuit. Power factor is the ratio of true power in watts to the apparent power as obtained by multiplying the current flowing to the load by the circuit voltage. The power factor correction can be made directly at the load or at utility substations. In the latter case high voltage units will be designed for 4,800 to 13,800 volt service. To the utility engineer the use of capacitors is purely a matter of economics. The main benefits that result from the use of capacitors are:

1. Reduction of losses associated with the delivery of electrical power to the point of use.
2. Reduction of the investment required in equipment for delivering electrical power to the point of use, which may be broken down into:
   a. Reduction of line current for the same kilowatt load.
   b. Reduction of the kva rating of equipment required to handle the same kilowatt load.

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c. Reduction of the transmission line voltage drop for a given kilowatt load.

d. Control of delivered voltage if the capacitor kva is varied.

Electric utilities also use capacitor banks in series with distribution circuits to improve voltage regulation.

B. Low Voltage Power

Capacitors installed in industrial plants at the demand site (typically large motors and welders) are designed for 230 to 575-volt service. Capacitors installed near the loads are the most efficient way to supply the magnetizing current to produce the flux necessary for the operation of inductive devices. Rates for the sale of power are generally structured to encourage power factor correction at the site, eliminating the need for the electric utility to transmit both power-producing current and magnetizing current all the way from the generator to the plant site.

The same considerations apply to induction heating applications, the principal difference being that capacitors for this application are designed for operation at 960 to 9600 Hz.

C. Lighting

Capacitors improve the efficiency of lighting systems. A fluorescent or mercury vapor lamp can be ballasted without the use of a capacitor, but the power factor of the lighting system would then be in the range of 50 to 60%. For commercial or industrial lighting with either fluorescent or high intensity discharge lamps, the use of a capacitor in the circuit provides part of the lamp ballasting and brings system power factor into the range of 90 to 95%.

D. Air Conditioning

As in the lighting applications, the capacitor improves system efficiency. Air conditioners could be made to operate without capacitors, as do home refrigerators, but because of the higher capacity required for air conditioners,

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the resultant line current would virtually eliminate home "plug-ins" and would still further overburden a seriously threatened national power network. Almost all air conditioner pump motors are of the split-winding type on which the capacitor provides phase differential for the so-called start winding, thus delivering good starting torque. The proper size capacitor permits high (90%) power factor after start-up.

E. Industrial Electronics

This market category is a catchall covering many varied applications, two important ones being motor run and power supply applications. Motor run applications are for pumps, fans, and farm feed equipment, and do not differ significantly from air conditioning applications. The power supply market uses capacitors principally to provide high power factor, but through careful design the capacitor can also provide wave shaping where desired.

3.1.1 Askarel Capacitor Manufacturing Plants

There are seventeen companies in the U.S. which manufacture askarel capacitors at nineteen plants. The name and the location of these plants are given in Table 3.1.1-1. Some plants manufacture industrial capacitors only and others manufacture power capacitors.

Ten major companies were contacted. Detailed information was obtained on six plants. Four plants were visited. The data herein represents approximately 50 percent of 1974 PCB usage in capacitor application. The PCB usage in this category was approximately 22,000,000 lbs. in 1974. The PCB usage in individual plants is considered by these companies to be confidential information. The range of PCB usage at these plants was 64,000 fold in 1974. Plant ages range from five to thirty-seven years.

Capacitors used in lighting and air conditioning applications contain 0.05 to 1.0 lbs. of Aroclor. The largest power capacitors contain about 77 lbs. of Aroclor. The most popular size contains 36 lbs. A sketch of a medium size industrial capacitor is shown in Figure 3.1.1-1. Capacitors are not rebuilt and returned to service after failure. They are disposed of and replaced by new units. G.E. reports that high voltage utility capacitors, low voltage

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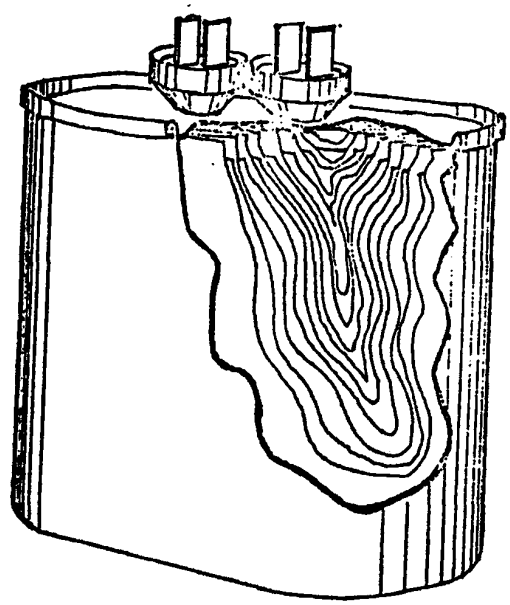

FIGURE 3.1.1-1. MEDIUM SIZE INDUSTRIAL CAPACITOR

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Table 3.1.1-1

U.S. Capacitor Manufacturing Industry Using PCBs

Company Name (In order of PCBs Usage)	Location of the Plant
General Electric Company	Hudson Falls, N.Y. Ft. Edward, N.Y.
Westinghouse Electric Corp.	Bloomington, Ind.
Aerovox	New Bedford, Mass.
Universal Manufacturing Corp.	Bridgeport, Conn. Totowa, N.J.
Cornell Dubilier	New Bedford, Mass.
P.R. Mallory & Co., Inc.	Waynesboro, Tenn.
Sangamo Electric Co.	Pickens, S.Carolina
Sprague Electric Co.	North Adams, Mass.
Electric Utility Co.	LaSalle, Ill.
Capacitor Specialists Inc.	Escondido, Calif.
JARD Corp.	Bennington, Vt.
York Electronics	Brooklyn, N.Y.
McGraw-Edison	Greenwood, S. Carolina
RF Interonics	Bayshore, L.I., N.Y.
Axel Electronic, Inc.	Jamaica, N.Y.
Tobe Deutschmann Labs.	Canton, Mass.
Cine-Chrome Lab, Inc.	Palo Alto, Calif.

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power capacitors, and induction heating capacitors are manufactured at a rate of 200,000 per year, about 2 to 3% of which are replacements; the balance are for new installations. The current market for capacitors used in lighting applications is about 44,000,000 units annually of which 10% are estimated to be replacement ballasts. The current market for capacitors in air conditioning application is above 12,000,000 units annually, with 5% of these estimated to be for replacement usage. The market for capacitors in industrial electronics applications is estimated at 23,000,000 units per year with no estimate as to the relative size of the replacement market.

3.1.1.1 Askarel Handling

In most plants PCBs are shipped via tank car to a rail siding several miles from the plant. Individual plants provide a designated tank truck for the transfer of the PCBs from the rail yard to the manufacturing plant. To large plants, PCBs are brought via rail cars into the plant site.

In most plants PCBs are unloaded and transferred to the PCB storage tank without the benefits of any curbs or dikes. At a very few plants, the unloading operation of the PCBs from the tank car to the storage facility is confined and the receiving area is roofed and diked.

PCBs from the raw storage PCB tanks are filtered through fuller's earth and stored in finished product storage tanks. PCBs are next pumped from the storage tanks to the impregantion areas for use. Excess PCBs from these areas are recycled back to a designated tank and from there either filtered and reused or, if defective, are pumped into the scrap storage tank.

Spent fuller's earth employed at these plants is either drummed and stored at the plant site or is sent to a landfill.

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3.1.1.2 Process Description

Most plants in this category manufacture either large power capacitors or small (including less than 2 lbs. of PCBs) industrial type units. The large capacitors are either flood filled or manifold filled. All small capacitors are flood filled either in a vacuum tank or in an automatic "carousel" arrangement where loading and unloading occurs at one station, and the capacitors in each cell are progressively dried, evacuated and filled.

A generalized schematic flow diagram for the manufacture of large capacitors and small industrial capacitors are given in Figures 3.1.1.2-1 and 3.1.1.2-2, respectively. The basic manufacturing operation at these plants can be divided into two major operations.

a) Non PCB related operations consist of the following steps:

- Fabrication of capacitor cans, covers and brackets from sheet aluminum or steel. Smaller plants, however, purchase capacitor casings, capacitor terminals, connectors and foil.
- Vapor degreasing or detergent washing of metal components. At some plants, ultrasonic cleaning is used to clean smaller components.
- Roll winding the capacitor paper or polypropylene film with aluminum foil.
- Complete assembly of capacitor components and sealing the covers. In some units fill holes are provided for PCB introduction; in others PCBs are introduced through bushings or a valve.
- Leak testing via mass spectrometer and pressure testing prior to vacuum drying.

b) PCB related operations

Three completely different impregnating techniques are employed by this industry.

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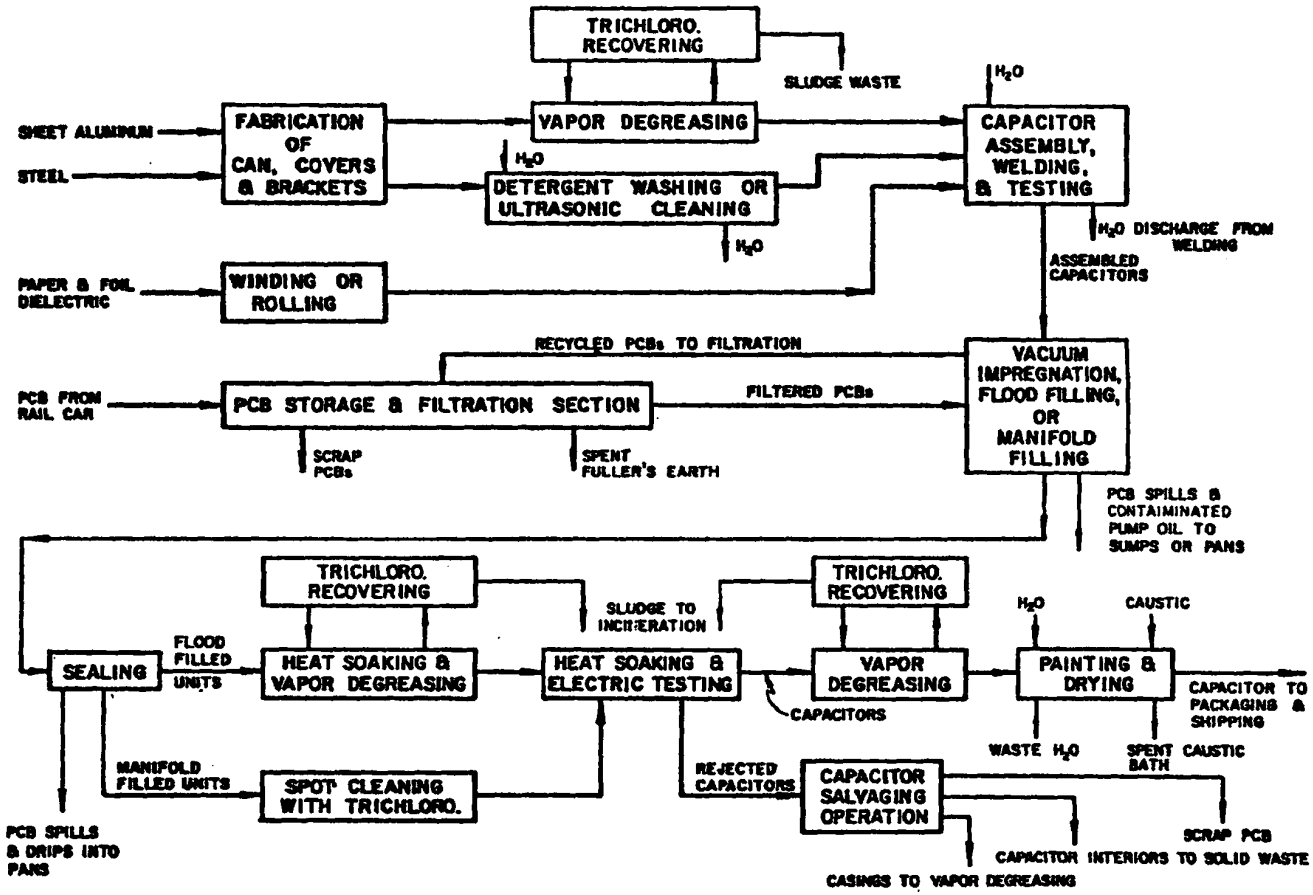

Figure 3.1.1.2-1

GENERALIZED FLOW DIAGRAM FOR THE MANUFACTURING OF LARGE CAPACITORS

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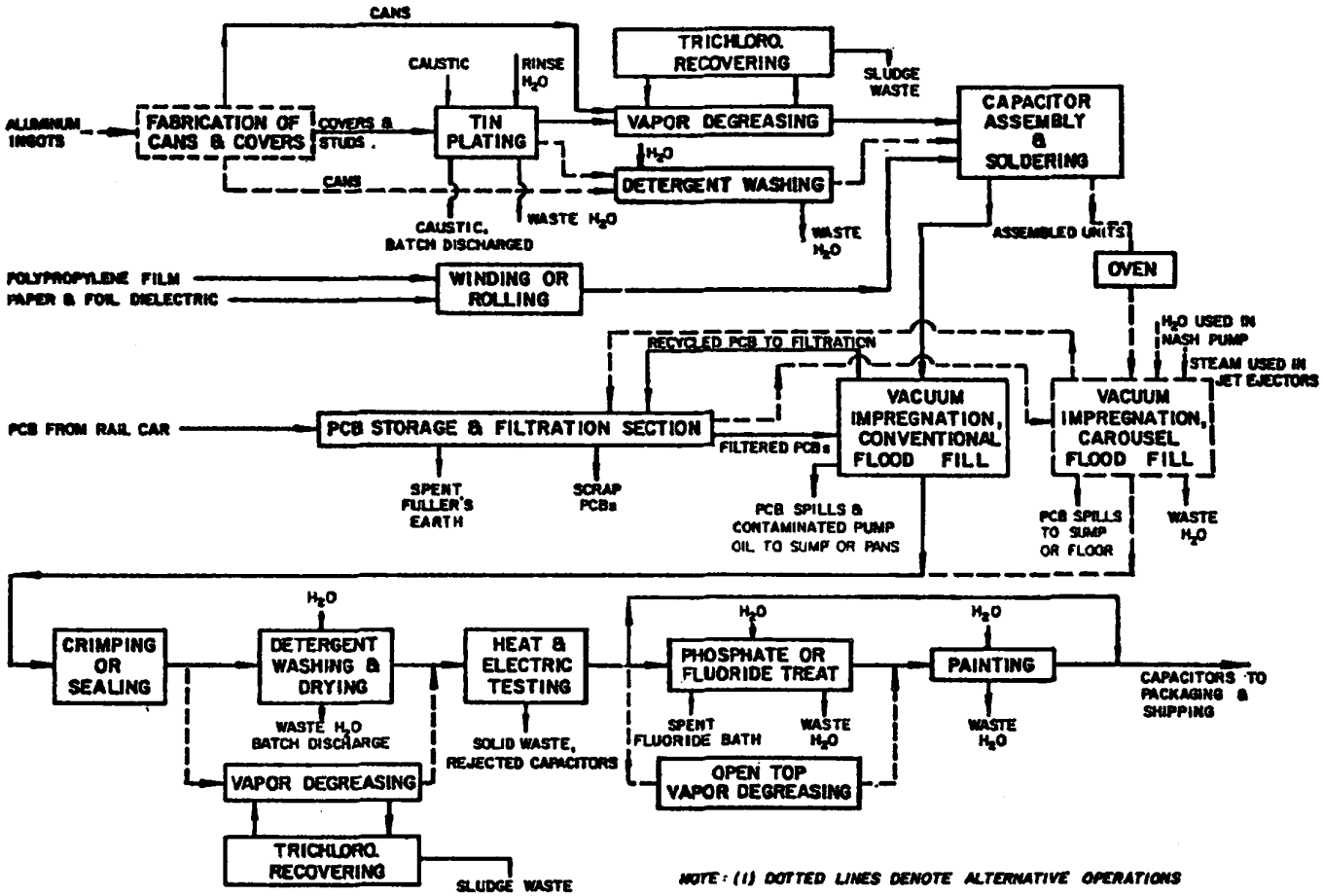

Figure 3.1.1.2-2
GENERALIZED FLOW DIAGRAM FOR THE MANUFACTURING OF SMALL CAPACITORS

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(1) Conventional flood filling of capacitors

This type of filling operation is used for impregnating large power and small industrial capacitors. Here the capacitors are arranged in baskets or in large tanks which are subsequently transferred into vacuum chambers. Vacuum is then drawn and the capacitors are kept under vacuum at an elevated temperature for a specific period of time in order to evaporate the moisture from the capacitor interiors. The temperature of the tank is next lowered and PCBs are introduced under vacuum. The capacitors are allowed to soak for some time after which they are transferred to the sealing or crimping station via mobile car, sealed, and excess PCBs are then drained. The sealed capacitors are next sent to vapor degreasing or detergent washing for cleaning the exterior of these units. The clean units are heat soaked and heat tested in an oven and then sent to 100% electrical testing.

Subsequent to electric testing, the capacitors with steel casings are pretreated prior to painting. The pretreatment is either vapor degreasing for painting in an electro-static field or it is several stages of phosphatizing and rinsing operations, prior to automatic spray painting, where water is used to scrub the vapors generated during painting. Most capacitors with aluminum casings are marketed unpainted. However, at some plants a portion of capacitors with aluminum casings are fluoride treated and then spray painted. The capacitors are next either air dried or dried in an infrared oven prior to packaging and shipping.

(2) Automatic Flood Filling Operation (Carousel)

In this method of capacitor impregnation, the assembled units are placed in ovens for the removal of moisture from the capacitor interiors. The baskets containing these capacitors are next transferred to the carousel chamber which is at the loading position. The carousel passes through 13 subsequent cycles consisting of

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various degrees of vacuum applications and then subsequent PCB filling and soaking positions. The PCBs are next drained out of the chamber, and the capacitor baskets are removed from the vacuum chamber and tilted to drain excess PCBs into a sump located adjacent to the carousel loading and unloading station. The capacitors are next transferred to the crimping or sealing stations. From this point on the remainder of the manufacturing steps are identical to those employed in conventional flood filling operation.

In general, vacuum in conventional flood filling operations is achieved via mechanical pumps, whereas vacuum in each automatic flood filling station is achieved via a vacuum pump and several stages of steam jet ejectors.

Rejected industrial capacitors are disposed of in 55 gallon drums either directly or after disecting. Rejected power capacitors which are flood filled are returned to the salvaging operation. Here the capacitor covers are cut on an end mill, the PCBs drained and the interiors examined to find the cause of the electrical failure. Where possible the rejected units are then repaired and reprocessed. Otherwise, the capacitor interior is discarded in a designated solid waste drum. The capacitor casing is sent to vapor degreasing and it is subsequently sold to a scrap dealer.

(3) Manifold Filling Operation

At some plants, large capacitors are filled by this method. Here, the capacitors are completely assembled, sealed and vacuum tested; then each unit is filled individually under vacuum through a manifold. The capacitor valve is next sealed, the exteriors spot cleaned with trichloroethylene and then these units are transferred into an oven where they are heat soaked for a given period of time prior to electrical testing. Those capacitors which pass the electrical tests successfully are vapor degreased, painted, dried, packaged and shipped. The rejects are returned to the filling station where

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the majority of the PCBs are retrieved through the fill valve under vacuum. The rejects are next transferred to the salvage operation.

Mechanical pumps are used throughout the system to achieve vacuum.

3.1.1.3 Raw Wastes

The raw wastes originating from these plants consist of scrap PCBs collected in sumps, drums and drip pans, contaminated vacuum pump oils, the fractionator bottoms from the trichloroethylene recovery, the caustic bath used, at some plants, for purposes of paint stripping, spent detergent wash and rinse water from capacitor or component cleaning operations, rinse water used in the welding and plating operations, steam condensate from jet ejectors, the seal water used in vacuum pumps, water used in phosphatizing and fluoride baths, water spray used in the paint booths, boiler blow downs and cooling tower blow downs.

Furthermore, in at least one plant in this category, water infiltrating at a subgrade elevator shaft creates an additional waste stream.

Solid wastes from these plants consists of scrap capacitors or capacitor interiors, floor dry and rags and newspapers used for cleaning spills, spent fuller's earth and other filtering media used for PCBs filtration and waterless cleaners used at some plants for hand cleaning purposes.

Non-product PCB discharges, their source and disposition are given in Table 3.1.1.3-1. Adequate data to quantify the various wastes generated at these plants is not available. Information on waste loads reported by some plants are given in Table 3.1.1.3-2.

3.1.1.4 Water Use

The water used at these plants is in the range of 12,500 to 1,260,000 gallons per day. In most plants, water is used primarily for once-through non-contact cooling in vapor degreasers, in pumps and in vacuum tanks. Plant 101 recycles their non-contact cooling water through a cooling tower.

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TABLE 3.1.1.3-1. NON-PRODUCT PCB DISCHARGES

Source	Plants 100	101	102	104	105	106
Vacuum pump exhaust	Air	Air	Air	Air	Air	Air
Evaporation & ventilation	Air	Air	Air	Air	Air	Air
Vapors from last stage of jet ejectors	None	None	None	None	Air	None
Personal hygiene	Sewer	Sewer	Septic tank	Incineration[1]	Incineration[1]	Sewer
Laundry water	None	None	Septic tank	None	None	None
Water phase from pump oil/water separator	Sewer	None	None	None	None	None
Sanitary & domestic water	Sewer	Sewer	Septic tank	Sewer	Septic tank leach field system	Sewer
PCB contaminated water	River	-	Treatment plant then river	River	River	Sewer
Non-contact cooling water	River	Recycled	Treatment plant then river	River	River	Sewer
Rainfall & surface runoff	River	Storm sewer	Treatment plant then river	River	River	Storm Sewer
Rinse water from component detergent washing	None	Dry well	None	River[2]	None	None
Water used in non-PCB electrolytic capacitor operations	None	None	Treatment plant then river	None	None	None
Ground water infiltration	None	None	None	Decant then to river	None	None
Controlled sink drains[3]	None	Sewer	None	River	River	None
Rinse water used in the caustic bath & welding	None	None	None	River	None	None
Water used in paint scrubbing	None	None	None	Decant then to river	River	None
Phosphatizing bath & rinse	None	None	None	None	River	None
Scrap oil in drip pans, drums & sumps	Incineration	Incineration	Incineration	Incineration	Incineration	Incineration
Spent fuller's earth, clay & filter cartridge	Incineration	None	Incineration	Stored on site	Stored on site	Landfill
Rinse water from dry-well	None	Incineration	None	None	None	None
Fractionator bottoms (sludge) from trichloro recovery	Incineration	None	Incineration[4]	Incineration	Incineration	Incineration
Spent detergent wash of capacitor exteriors	None	Landfill	None	None	Incineration	None
Spent fluoride wash	None	None	None	None	Incineration	None
Reject capacitors or capacitor internals	Landfill	Landfill	Landfill	Stored on site	Stored on site	Landfill
Newspaper, floor dry & rags	Landfill	Landfill	Landfill	Stored on site	Stored on site	Landfill
Caustic bath	None	None	None	Stored on site	None	None

Notes: [1]Sinks at the impregnation areas are contained; water from the sumps are sent to incineration.
[2]Rinse water from non-PCB, component washing operation.
[3]Employees are advised to use waterless hand cleaning material prior to washing their hands.
[4]Only liquids from this operation are sent to incineration. The sludge from this operation is sent to a municipal landfill.

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TABLE 3.1.1.3-2 QUANTITY OF WASTE LOADS
(lbs/ton of PCB used)

	Plants					
	100	101	102	104	105	106
Land Destined Waste	73[1]	129	65	-[4]	-[4]	-[5]
Wastes to Incineration	100	56	98	109	127	300
Spent Fuller's Earth to Incineration	4.1	None[2]	-[3]	-	-	Unknown

Notes:

(1) Reported as PCBs. We estimate an additional 175 lbs/ton of PCB contaminated solid material which is being landfilled locally.

(2) PCBs are filtered through packed Porocell cylindrical filters. The filter media has an estimated life cycle of 20 years.

(3) This plant uses clay for PCB filtration. The quantity of spent clay sent to incineration is not known.

(4) These plants store their solid wastes consisting of spent fuller's earth, rejected capacitors, rags and floor dry, on site. Plant 104 generates ten 55-gallon drums of waste and plant 105 forty 55-gallon drums of waste each week.

(5) The weight of materials sent to landfill is not known. However, this company reports that during 1974 approximately 650 capacitors were rejected. The rejected units were drained and then sent to a landfill.

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Process water used at various plants consists of water used in detergent washing, in ultrasonic washing, condensate from the steam jet ejectors, seal water from the vacuum pumps, water used in phosphatizing and in fluoride baths and rinses, and water used in caustic treatment and painting operations. Additionally, water is used for sanitary purposes and in some plants it is also used as boiler feed.

The quantities and types of water used at these plants are given below:

	Plants					
	100	101	102	104	105	106
Intake gallons/day	740,000	12,500	1,000,000[1]	1,260,000	480,000	336,500
Water Usage in gallons/day						
Non-contact cooling	655,000	3,000[2]	388,000[3]	1,195,000	387,000	326,500
Process water						
Rinse water from hot solder dip	200	-	-	-	-	-
Detergent washing & rinsing	-	8,000	-	25,000[4]	200	-
Phosphatizing baths	-	-	-	-	400	5,000
Water used in tin plating	-	-	-	-	12,000	-
Fluoride bath & rinse	-	-	-	-	50	-
Water used in painting					50	-
Pump seal water & steam condensate					44,000	-
Sanitary	44,940	1,500	52,000	10,000	65,000	5,000
Boiler feed make-up	40,000	-	-	30,000	15,000	-

Notes: (1) 560,000 gallons/day of this water is used as process rinse water in non PCB associated, electrolytic capacitor operation
(2) Make-up water
(3) It has been estimated that only 150,000 gallons of this water is associated with the plants PCB operation. The balance is used in the manufacture of Mica capacitors
(4) It includes water used in paint stripping and welding operations.

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3.1.1.5 Wastewater Treatment

The major in-plant PCB wastes which reach water streams originate in the impregnation areas. Due to the nature of water requirements in this industry, at some plants it is possible to significantly reduce the quantities of wastes entering the water systems by adoption of proper housekeeping measures. Since there is no demonstrated technology available for the terminal treatment of PCBs in wastewaters, there are no PCB wastewater treatment techniques currently in use at any facility. Details on wastewater treatment techniques used at various facilities for purposes of oil recovery or neutralization and on-going containment programs undertaken by some plants to prevent the entry of PCBs into the environment are given in Task II report, "Assessment of Wastewater Management, Treatment Technology, and Associated Cost for Abatement of PCBs Concentrations in Industrial Effluent", February 3, 1976, pages 46 through 52.

3.1.1.6 Effluent Composition

Effluent from plants in this category range from 2500 to 1,260,000 gallons per day. As indicated in the waste treatment section, these effluents are sent either into receiving waterways or into municipal sewers without any PCB treatment. Available information on effluent flow rates and their PCB contents, for most plants in this category, are given in Table 3.1.1.6-1. More detailed effluent information were obtained on four plants and Table 3.1.1.6-2 compares the discharges from these plants. Table 3.1.1.6-3 lists PCB concentration of the plant intake water from various sources.

It is of interest to note that one plant (plant 100) reported large variations in the PCB content of the receiving waters even at the time when the plant was not in operation. They attributed the variations to storm conditions, stirring-up the sediments from the bottom of the river and greatly increasing the PCB concentration in the water phase.

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TABLE 3.1.1.6-1 RANGE OF FLOW RATES & PCB CONCENTRATION IN EFFLUENTS FROM CAPACITOR MANUFACTURING PLANTS

Plant No.	Outfalls	Effluent Flow Rate gal/day	Effluent PCB Content ppb avg/max	Effluent PCB Content lbs/day avg/max	Disposition of effluent
100	001	800,000	17/55	0.1134/0.3670	River
101	None	9,000	161/161	0.0121/0.0121	Sewer
102	001	807,000	9	0.0605	River
	002	165,000	3.2	0.0044	River
	003	36,000	3.4	0.0010	River
104	Major outfall	1,060,000	21	0.1856	River
	Cooling water & roof drains	100,000	7.8	0.0065	River
	Lab & roof drains	32,000	4.4	0.0011	River
	Compressor cooling water	72,000	3.7	0.0022	River
	Paint strip rinse	50	4800	0.0002	River
105	Major outfall	650,000	370	2.0058	River
	From spray paint booths	1,500[1]	13,300	0.1664	River
106	None	336,500	26.6	0.075	Sewer
107	None	150,000	1900/4000	2.3769/5.7546	Sewers
108	Cooling water & boiler blowdown	48,000	45/108	0.0180/0.0432	River
	Cooling water	129,000[2]	338/705	0.3636/0.7585	Sewer
	Roof runoff	2,900	1360/2370	0.3290/0.0573	River
	Storm runoff	unknown	3/11	- -	River
109	001	100,000	57/83	0.0475/0.0692	River
110	None	2,570	821	0.0176	Sewer
111[3]	None	18,000	8.7	0.0013	Sewer
112[3]	None	10,224	130	0.0110	Sewer
113	001	12,000	14.3	0.0014	River
126	None	580	6200[3]	0.03	Sewer

Notes: (1) Discharged once every 4-5 weeks.
(2) Contains 10,000 gpd sanitary sewage and 8000 gpd of surface water infiltration
(3) These facilities recycle most of the non-contact cooling water used at the plant. These effluents consist of a small fraction of the cooling water plus their sanitary discharge.

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TABLE 3.1.1.6-2

Comparison of Discharges

Plant	100	102			104				105
Outfall	001	001	002	003	002	003A	003B	006	004
pH	7.3	7.4	7.3	7.2	6.5-12.0	5.5-9.8	4.0-9.1	6.8-11.6	5.5-8.6
TSS, mg/l	3	16.6	1.54	2.8	5.2	4.7	4.0	3.1	9.5
PCB, ppb	17	9	3.2	3.4	21	7.8	4.4	3.7	370
Oil & Grease, mg/l	UK	3.10	3.38	2.18	7.20	14.40	30.70	2.66	12.8
Aluminum, mg/l	UK	ND	ND	ND	0.15	0.06	0.11	2.0	
Lead, mg/l	<.05	UK	UK	UK	UK	UK	UK	UK	UK
Copper, mg/l	<.003	UK	UK	UK	0.03	0.02	0.04	0.03	UK
Chromium, mg/l	<.005	UK	UK	UK	0.003	ND	ND	ND	0.03
Phenols, mg/l	<.001	UK	UK	UK	UK	UK	UK	UK	UK
Iron, mg/l	<.19	UK	UK	UK	0.29	0.30	0.34	1.66	0.52
BOD, mg/l		4.37	2.45	1.7	UK	UK	UK	UK	UK

ND - Non detectable
UK - Unknown

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Table 3.1.1.6-3

Intake Water PCB Concentration

Plant	100	101	104	105	106	111	112
Source	Municipal	Municipal	River	Well Water	Municipal	Municipal	Municipal
PCB, ppb	0.09-2.5	4-7	57.0	40.0	0.25	1.0	1.0

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3.2 Askarel Transformer Manufacturing Industry

All plants in this category manufacture transformers using mineral oil as the dielectric fluid. This dielectric fluid is the principal impregnant used at these facilities. PCB transformer oils (blends of 60 to 70 percent Aroclor 1254 or 1242 and 40 to 30 percent trichlorobenzene) are used in only 5-10 percent of these plants' manufacturing volume.

In general, a transformer consists of a core and coil immersed in a dielectric fluid. There are two broad classifications of transformers: distribution transformers, which are used to step down voltages, and power transformers, which are used primarily to step up voltages. The precipitation power supply units can be actually classified as a third class of askarel transformer. However, the larger plants in this category have only two manufacturing departments — distribution and power; and they manufacture the precipitator transformers in their distribution transformer department. The following types of askarel transformers are manufactured at these plants:

A. Askarel Distribution Transformers

1. Network (Receive up to 14,400 volts and deliver 120, 240 and 480 volts)
2. Pad - mounted (Receive up to 14,400 volts and deliver 120, 240 and 480 volts)
3. Pole - mounted (Receive up to 14,400 volts and deliver 120, 240 and 480 volts) The application of these transformers in power distribution systems places a great premium upon their reliability and high overload capability.
4. Precipitator power supply (Receive 480 AC volts and deliver 50-60 kilovolts low amperage DC) These units are generally installed close to hot gas stacks in an atmosphere that would be a fire hazard to oil-insulated transformers and a corrosive hazard to open dry-type transformers. Sealed dry-type transformers are impractical for high-voltage DC.

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Voltages listed cover the majority of askarel distribution transformers. Product scope includes up to 34,500 primary volts and virtually any secondary voltage, 34,500 and below.

Quantities of askarel used in this class of transformers are in the range of 500 to 5,000 lbs. in each unit depending on the rating and the size of the transformer.

A great majority of distribution type transformers have provision for venting. Many of these units are equipped with spring loaded venting devices which vent upon a pressure excursion, and diaphragm rupture discs are offered as a customer option.

B. Askarel Power Transformers

1. Secondary substation
   (a) Load center units
   (b) Secondary substation generation units
   (c) Switchboard units
   (d) Internal units
   (e) Motor control units

   These 5 comprise the largest group of askarel-insulated transformers and they find widespread application in the automobile, paper, chemical, textile, steel, nonferrous metal, cement, mining and petroleum industries. They are used in commercial and public buildings, such as schools and hospitals; in defense and nuclear energy installations; and by private and public utilities.
2. Master unit substation
3. Primary unit substation
4. Limited ampere substation
5. Industrial furnace

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Furnace transformers used in the hot, dirty atmosphere in proximity to glass melting and induction furnaces, which require high current, low voltage power supplies (receive up to 15,000 volts and contain 2000 to 4000 lbs. of askarel each). Existing technology does not permit construction of sealed dry-type transformers for these power ratings.

6. Rectifier

Rectifier transformers used for large rolling mills and DC industrial power supplies (receive up to 15,000 volts AC and deliver low voltage high amperage DC. Each unit contains about 19,000 lbs. of askarel). These units are covered by the same comments given for industrial furnace transformers.

7. Transportation

Railroad transformers used on-board in electric locomotives or multiple unit electric railroad cars (receive up to 25,000 volts and contain 700 to 2400 lbs. of askarel in each unit depending on the rating and size of the transformers).

(a) Third rail

These transformers are used for rapid transit systems, and are basically serving a rectifier function

(b) Locomotive

Prior to 1932, all on-board transformers were open dry type. Because of problems with them, railroads went to askarel-insulated transformers. The changes in locomotive design since the 1930's would not now accomodate open dry-type transformers as replacements for askarel units. A recent trend has been to replace askarel by oil units, and this will continue unless new Department of Transportation regulations require nonflammability.

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3.2.1 Transformer Manufacturing Plants

There are thirteen companies in the U.S. which manufacture askarel transformers at eighteen plants. The name and location of these plants are given in Table 3.2.1-1. Some plants manufacture various types of transformers described above and others manufacture only one specific line of transformers.

All plants in this category were contacted to obtain information on their waste water. Detailed information was obtained on two plants which were visited. The largest U.S. transformer plant (based on quantity of PCB use) was not visited because of lack of cooperation. The data base represents approximately 20 percent of the 1974 PCB usage for transformer application. The PCB usage in this category was 12,000,000 lbs. in 1974 (equivalent to 15.0 to 17.0 million lbs. PCB transformer oil). The PCB usage in individual plants is considered by these companies to be confidential information. The range of plant PCB usage was 975 fold in 1974. Plant ages range from three to eighty-five years.

The amount of askarel used in individual transformers ranges from 40 to 1500 gals. (516 to 19,350 lbs.) with an average of about 232 gals. (3,000 lbs.). A sketch of a large substation transformer is shown in Figure 3.2.1-1. G.E. estimates that the total askarel-insulated units that have been put into service in the United States since 1932 is 135,000, and virtually all of these units are still in service. The lifetime-before-failure is often longer than 30 years, and almost all units that do fail are rebuilt and returned to service. The current production rate of askarel transformers is about 5,000 units per year.

3.2.1.1 Askarel Handling

Few plants in this category purchase PCBs and trichlorobenzene and do their own compounding. Most plants purchase pre-compounded askarel from Monsanto. Smaller plants purchase their askarel in 55 gallon drums, filter the askarel and pump directly into the transformer tanks. To large plants askarel is shipped via rail cars. Rail cars enter in a designated area at the plant site. Askarel is then pumped from the rail cars into the raw askarel storage tank. Any spillage in this area is cleaned by rags or floor dry. The raw askarel

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However, since a tunnel fire in 1940 caused by an oil filled locomotive transformer, Penn Central will not allow any oil containing transformer equipped locomotive into New York City.

(c) Multiple-unit car (MU)

These transformers are mounted under the flat-bed of passenger cars. They ride along in this location, about 8 inches above the rail, at speeds up to 150 mph. The transformer must be ruggedly built to withstand the impact of flying debris and constant vibration. Power to the cars is brought in through an overhead catenary and is fed to the underside of the car where the transformer, controls, and propulsion equipment are located.

Space and weight are critical in this application. There are only about 33 inches above the rail. The width of the transformer is limited by the width of the car.

Only oil- or askarel-insulated units would provide the required performance levels in the space available. As with locomotive applications, present Department of Transportation regulations do not restrict the use of flammable liquids, and the use of askarel units has been dictated largely by the economic considerations of fire insurance rates, and by Penn-Central safety regulations.

8. Reactors

These units provide reactance (receive up to 15,000 volts under normal operating conditions. During normal operating conditions, they deliver volts and current as received. During power surges they choke the voltage and deliver the normal output).

9. Grounding,transformers (receive up to 15,000 volts).

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Table 3.2.1-1

U.S. Transformer Manufacturing Industry Using PCBs

Company Name	Location of the Plant
Westinghouse Electric Corp.	South Boston, Va. Sharon, Pa.
General Electric Company	Rome, Ga. Pittsfield, Mass.
Research-Cottrell	Finderne, N.J.
Niagara Transformer Corp.	Buffalo, N.Y.
Standard Transformer Co.	Warren, Ohio Medford, Oregon
Helena Corp.	Helena, Alabama
Hevi-Duty Electric	Goldsboro, N.C.
Kuhlman Electric Co.	Crystal Springs, Miss.
Electro Engineering Works	San Leandro, Calif.
Envirotech Buell	Lebanon, Pa.
R.E. Uptegraff Mfg. Co.	Scottsdale, Pa.
H.K. Porter	Belmont, Calif. Lynchburg, Va.
Van Tran Electric Co.	Vandalia, Ill. Waco, Texas

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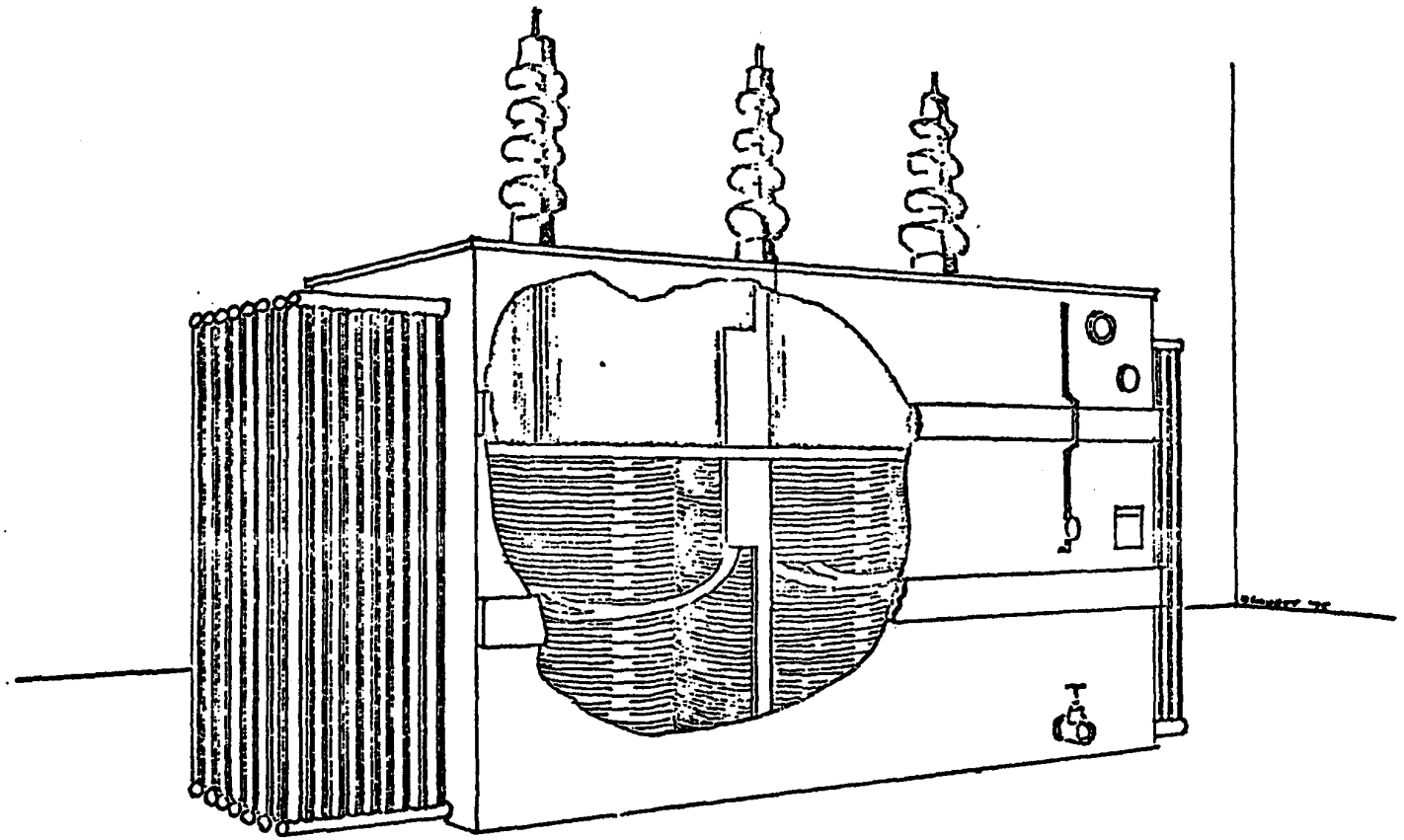

FIGURE 3.2.1-1. SUBSTATION TRANSFORMER

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is next filtered through attapulgite clay or fuller's earth and is often passed through a plate and frame type filter for final cleaning and then stored in the finished product storage tanks. Spent clay or fuller's earth from this operation is drummed and stored on site or sent to a landfill.

In some plants, the entire storage area is located within dikes and curbs designed to contain at least the contents of the largest single tank plus sufficient free board to allow for precipitation.

At most plants the askarel is distributed from the tank farm area to the filling station, but at one plant (Plant 103) the finished askarel is next trucked from a covered/curbed storage area to an uncovered/ bermed tank farm area. Here the truck enters a shelter area, and the askarel is then pumped from the truck into distribution storage tank.

Recycled askarel from the manufacturing operations is generally returned through pumps into a storage tank or into 55 gallon drums and from there it is either filtered for reuse or is sent to incineration if it is proved to be defective.

3.2.1.2 Process Description

Most plants manufacture all the hardware and components necessary for the transformer assembly. The transformer interiors and the containers are brought to the askarel filling stations where transformers are assembled, filled and sealed.

The filling operation is done in a designated station. At plants where small quantities of askarel are handled, spills and drips are cleaned via floor dry or rags. At plants where large quantities of askarel are handled, filling operation is conducted on gratings located on sumps. All drainage is directed into these sumps. The sumps are inspected and cleaned periodically. All scrap askarel from sumps is pumped into drums and sent to incineration.

Various transformer assembling and filling procedures are being practiced throughout this industry. In general, all transformer assembling and filling operations consist of a predrying step for removing moisture

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from the transformer interiors, several stages of askarel filling and askarel topping, addition of electrical connections and bushings, electrical testing and sealing.

At plants where relatively small quantities of askarel are used, the assembly and filling procedure for distribution and power transformers are alike. Some plants manufacture only a given size of transformers (single tank size operations). At larger plants different assembling and askarel filling procedures are employed for various transformer subcategories. Some of the askarel transformer assembling and filling procedures practiced within this industry are described below.

3.2.1.2.1 Assembly and Askarel Filling Procedure for the Distribution and Power Transformers

A. Vapor Phase Drying Prior to Filling

This procedure is primarily used in the filling of network and pad-mounted transformers. The drying of the transformer internals is a vapor phase treatment with a kerosene-like petroleum distillate. A schematic flow diagram depicting this system is given in Figure 3.2.1.2.1-1. The assembling steps for these transformers include the following:

- First the transformer interiors are placed in large vacuum chambers heated with steam coils. The petroleum liquid is admitted, vacuum and heat are applied. The petroleum vapors rise to be condensed on the interiors, exchanging latent heat for sensible heat and raising the temperature of the interiors. After a specific time the liquid is pumped out; vacuum and heat are continued to dry the internals.
- The internals are next removed and placed in their own containers and flushed with askarel at atmospheric pressure. The askarel is kept in the tank until the liquid temperature is lowered to a preset level at which time it is pumped out of the tank. The purpose of askarel flushing is to chill the transformer interiors prior to final filling.

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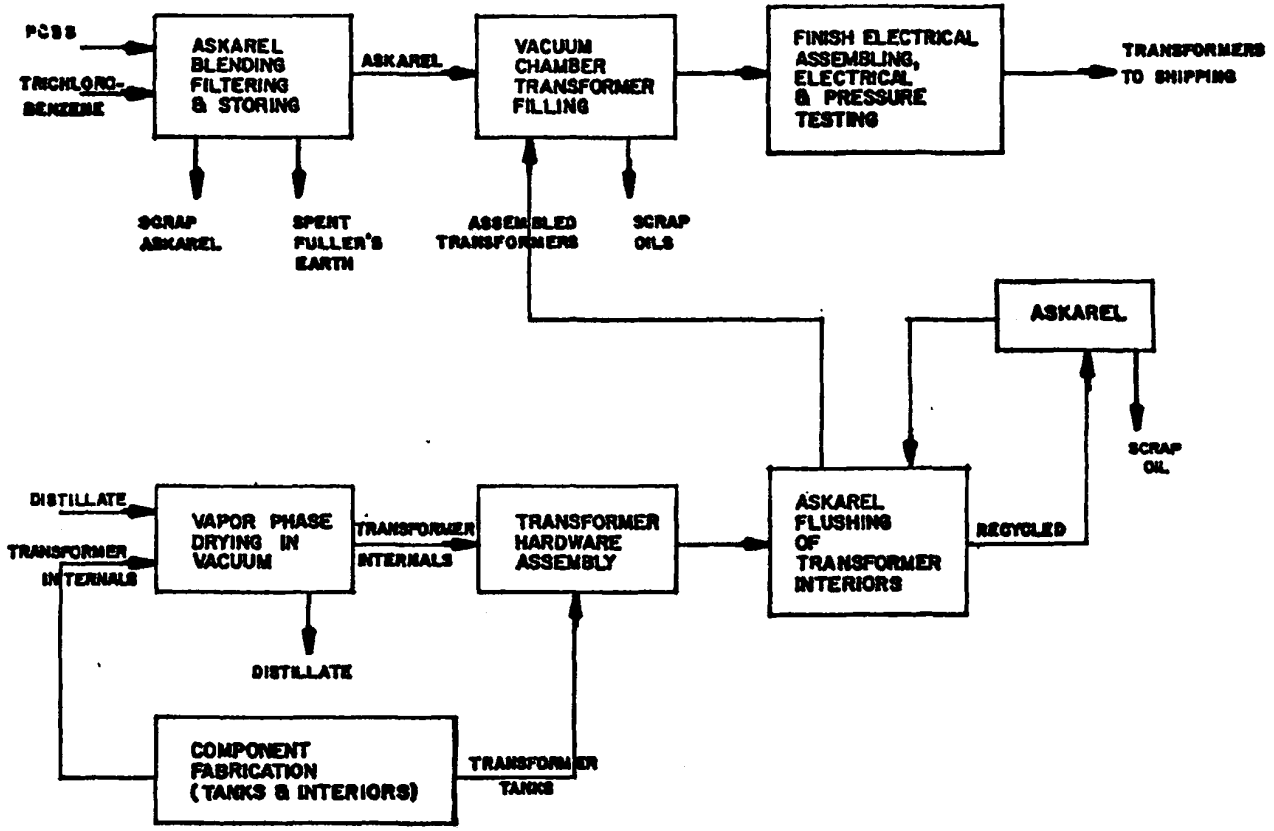

Figure 3.2.1.2.1-1
TRANSFORMER FILLING WITH VAPOR PHASE PREDRYING OF INTERIORS

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- The tank is next placed in a designated vacuum chamber. Vacuum is drawn and then fresh askarel is metered in slowly to avoid foaming or flooding.
- The vacuum chamber is next opened, the electrical connections are made and the liquid level in the tank is then brought to the operating level at atmospheric pressure. The transformer tank is then crane lifted and lowered onto conveyors and sent to specified test stations for a series of electrical tests before the transformer is completely sealed.
- If a transformer fails the electrical tests, it is returned; the askarel is drained and reprocessed. Otherwise, the transformer is sent to cover welding operations.
- The tank is next lifted and sent back via conveyor belts to the filling station where it is topped with askarel through an access overhead pipe. The transformer is next pressure tested for leaks. The bottom drain valve is then sealed and the top opening is pipe fitted and sealed. Sealing is accomplished primarily by teflon tape. However, for some transformers, the sealing is done by an air cured sealant at customer's request.

B. Oven Drying of Transformer Internals Prior to Filling

This procedure is used primarily in the assembly of pole type or precipitator transformers. The drying of internals for this category of transformers is accomplished in a convection oven. The internals are then placed in their own casings and the bushings and electrical connections are next made. Vacuum is then applied via a mechanical pump and the tank is filled with askarel while the transformer internals are still at a predetermined elevated temperature. Exhausts from this operation are pulled through a venting system.

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Most transformers in this subcategory have gasketed covers with barrel band type connections. Subsequent to the filling operation, the transformers are sealed and pressure tested for leaks. The large units are liquid pressure tested while the smaller ones are air pressure tested. A schematic flow diagram depicting this system is shown in Figure 3.2.1.2.1-2.

The contaminated oil from the vacuum pump is treated as waste askarel and is sent to incineration.

C. Oven Drying of Assembled Units Prior to the Filling

This procedure is used primarily in the assembly of the precipitator transformers. Here the transformer internals are placed in their own casings, the covers are welded on the casings and the assembled tank is placed in the convection oven all sealed. At an elevated temperature, vacuum is applied at predetermined intervals. The tank is then transferred to the filling station where askarel is added through an upper pipe opening under vacuum. Both the top piping and the drain valve are next sealed and the unit is then pressure tested. A schematic flow diagram depicting this system is shown in Figure 3.2.1.2.1-3.

D. Procedure for Assembling the Askarel Filled Power Transformers

The same procedure is used to assemble all types of askarel filled power transformers. The transformer internals are dried in sealed vacuum tanks, then they are placed in their own containers and the cover is welded and sealed. The unit is then pressurized and checked for leaks by a helium detector. The tank is next transferred to the filling station where low vacuum is drawn for a period of 24 hours. The askarel line is then connected and the tank is filled slowly while under vacuum up to the operating level. The unit is then sealed and sent to electrical testing. After the tests the transformer is returned back to the filling station where it is nitrogen pressure tested just prior to shipping. The schematic flow diagram depicting this system is shown in Figure 3.2.1.2.1-2.

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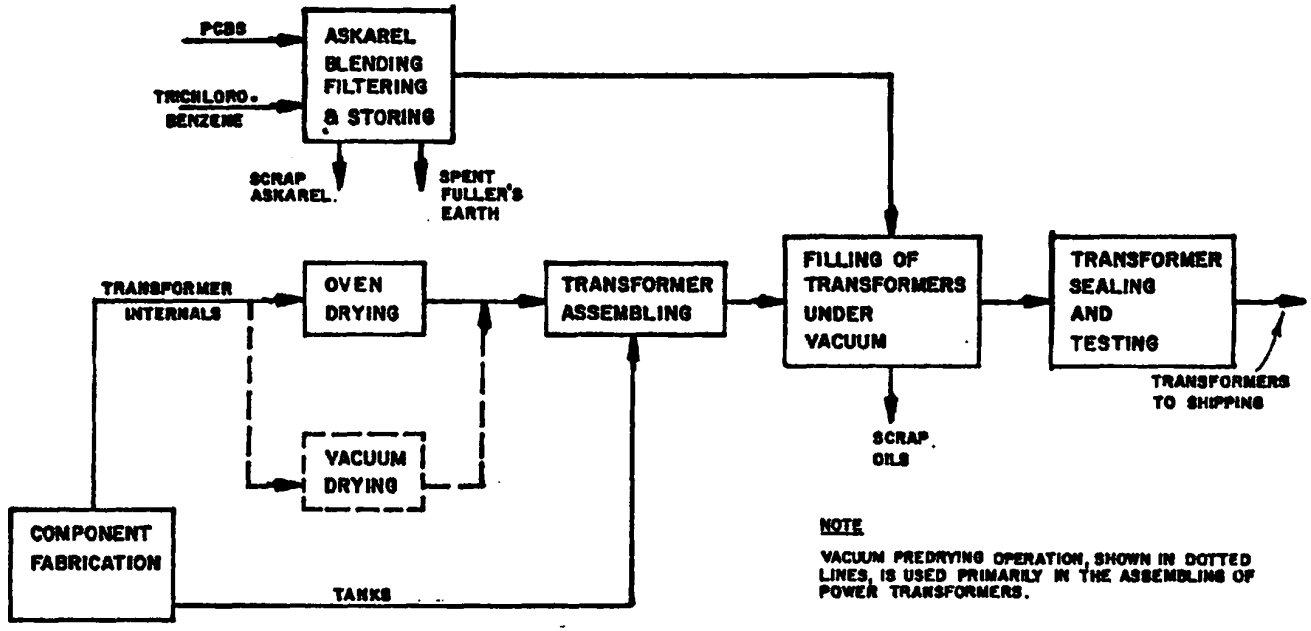

Figure 3.2.1.2.1-2
TRANSFORMER FILLING WITH OVEN OR VACUUM CHAMBER PREDRYING OF TRANSFORMER INTERNALS

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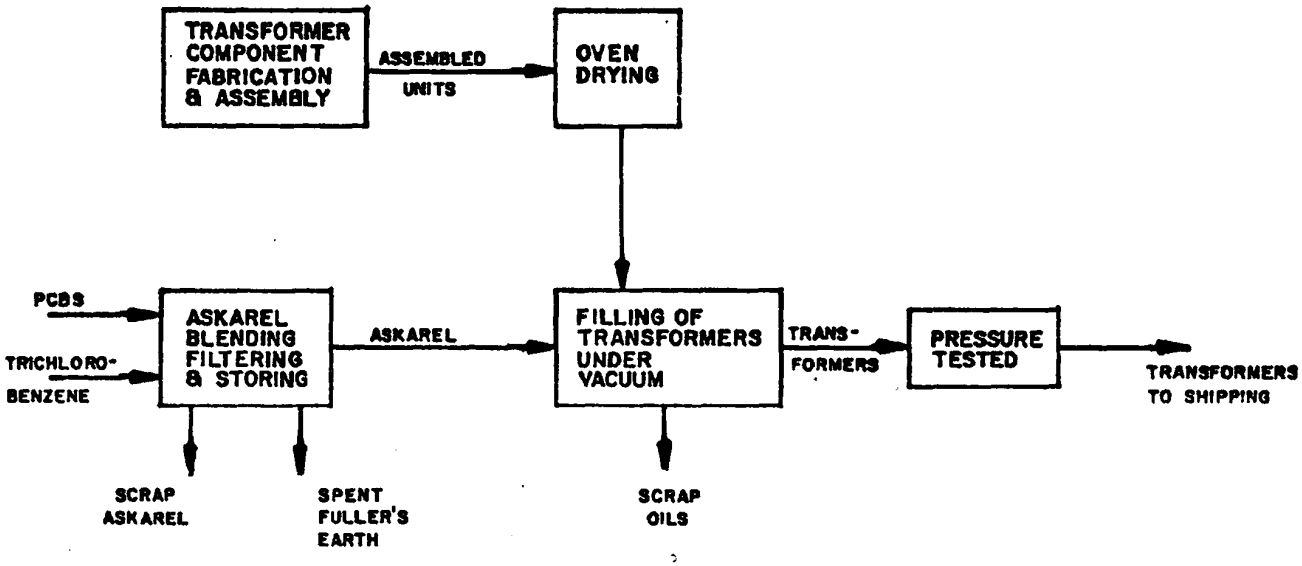

Figure 3.2.1.2.1-3

TRANSFORMER FILLING OPERATION WITH OVEN PREDRYING OF ASSEMBLED HARDWARE

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All power transformers have air space on the top and are equipped with an air cooled circulation system. Additionally, each unit has a spring loaded relief valve as standard equipment. These transformers have a greater potential for environmental contamination through the vent system, via leaks on the pump and the valves.

3.2.1.3 Raw Wastes

In general, the process raw wastes from these plants consist of waste askarel collected in sumps or pans at the filling stations, contaminated vacuum pump seal oil, contaminated kerosene-like petroleum distillate (used in at least one plant in the vapor phase drying operation), contaminated askarel used for transformer interior flushing and contaminants in the plant effluent.

Additionally, plant 103 has a unique waste stream consisting of contaminated ground water which is being pumped from three caissons at the plant site. Plant 103 also has a bleedwater discharge from their incineration system.

Solid wastes from these plants consist of rags and floor dry used for miscellaneous cleaning purposes and spent clay used for Aroclor filtration. Additionally, at plant 103 it includes the sludge from oil/water separators.

Non-product PCB discharges are shown in Table 3.2.1.3-1. Estimates on the quantities of raw waste generated in two plants which were visited are given below.

	Plants	
Quantities of Waste Loads	103	114
Wastes to incineration, lbs/ton of PCB used	115	98.0
Solid waste material stored on site in 55 gallon drums	135 units	Unknown

3.2.1.4 Water Use

Water is not an essential component of the transformer manufacturing process. PCB wastes which reach water streams at these plants are due to inadvertent occasional loss during handling and residuals accumulated

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TABLE 3.2.1.3-1

NON-PRODUCT PCB DISCHARGES

Source	103	114
Plant exhaust	Air	Air
Incinerator exhaust	Air	None
Personal hygiene and sanitary water	Sewer	Sewer
Ground water pumped through caissons	To oil separators then river	None
Water used at plant	To oil separators then river	Sewer/river
Contaminated oils and waste PCBs	incineration	Incineration
Floor sweepings and rags used for cleaning	decapsulator	Incineration
Rejected transformer interiors for copper recovery	decapsulator	Stored on site
Contaminated and defective empty drums	To steel furnace in steel mill	Shipped to the company which handles their contaminated oils
Sludge from the oil separator	Stored on site	None
Clay used for askarel filtration	Stored on site	None

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around the drainage systems from past operations when no precautions were taken in handling and disposal of PCBs.

This category uses water primarily for non-contact cooling purposes in vacuum pumps, compressors and at some plants as contact cooling in their welding and plating operations and in phosphatizing of the steel surfaces prior to painting. All contact cooling operations listed above are primarily non-PCB related operations. Only plant 103 has a PCB related process water which consists of the water used in their waste incineration system for quenching the hot gases from the reaction section. Plant 103 is also the major water user in this category.

In most smaller plants all cooling is accomplished by air. At these plants water is primarily used for hygiene and sanitary purposes and for occasional compressor or pump cooling purposes. The only water that comes into contact with PCBs at these latter plants is that used for personal hygiene. The types and quantities of water used at two plants visited are given below.

	Plant No.	
Water Usage in Gallons/day	103	114*
Non-contact cooling	1,646,000	38,000
Process water		
. Contact cooling	183,000	None
. Detergent washing	2,000	None
. Incineration quench	122,000	None
Hygiene	Unknown	300
Boiler make-up	Unknown	200
Sanitary	Unknown	9,000
Non PCB related		
. Water used in a lab	Unknown	500
. Water used for external cleanups	None	4,000

*Breakdown of the water usage was estimated.

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3.2.1.5 Wastewater Treatment

There are no effluent treatment techniques in practice at any plant in this category for the removal of PCBs. However, in 1972, a John Zink designed thermal oxidation incinerator was erected at plant 103 to safely dispose of PCBs. A schematic flow diagram of this unit is given in Figure 3.2.1.5-1. This unit consists of two steam atomized burners and a long cylindrical chamber to provide residence time for thermal degradation. Following the chamber is a water spray quench pot and a counter current packed scrubber column located at the base of the stack.

The waste oils are brought into the incinerator site in 55 gallon drums or by truck trailers. These waste oils are next pumped from the drums or from the trailers into the incinerator feed tanks. The steam atomizing burners inject the combustible liquid wastes into the combustion section with air, in such a manner to create a vortex type turbulence. This produces high heat release and effective combustion promoting the thermal degradation process. After combustion, the waste gases proceed through the oxidation chamber which provides 3 to 12 seconds of residence time at temperatures 1600 to 1800°F for the degradation reactions to go to completion. The flue gases from the chamber pass through a quench pot which contains a series of water sprays to cool the gases. An induced draft fan then forces the cooled gases through the packed bed scrubber column. Here, acidic ions produced during the combustion process are absorbed in the scrubber liquor. The scrubber liquor is then neutralized and disposed into the sewer.

A high temperature decapsulator has been incorporated in the thermal oxidizer unit for solid incineration and copper recovery. The exhaust of this unit is routed to the upper end of the oxidizer chamber.

Details on wastewater treatment techniques utilized at one facility (plant 103) for purposes of oil recovery and on-going containment programs undertaken by two plants (plants 103 and 114) in order to prevent the entry of PCBs into the environment are covered in the Task II report, "Assessment of Wastewater Management Treatment Technology, and Associated Costs

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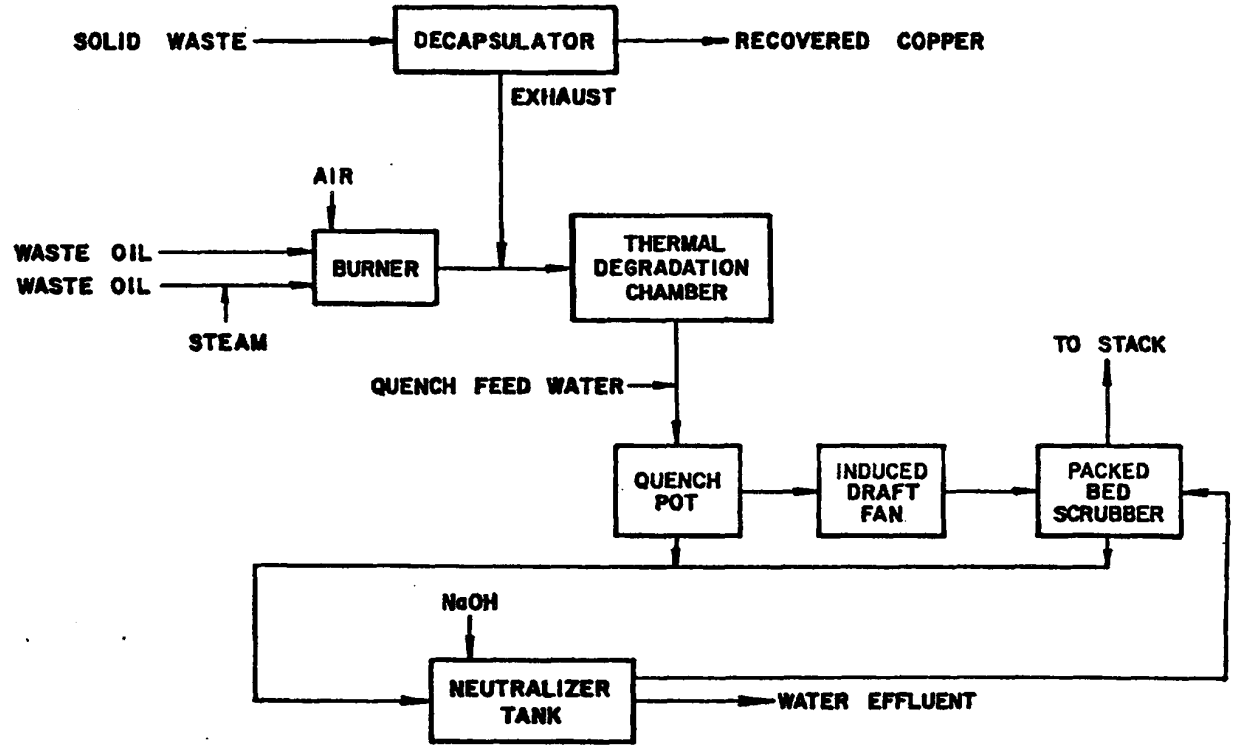

Figure 3.2.1.5-1. PROCESS FLOW DIAGRAM FOR THERMAL OXIDIZER INCINERATOR AT PLANT 103

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for Abatement of PCBs Concentration in Industrial Effluents", February 3, 1976, pages 71 through 75.

3.2.1.6 Effluent Composition

Effluent flow rates and PCB contents are available from the three plants which discharge into the rivers and from two plants which discharge primarily into sanitary sewers. Detailed effluent composition is available only on Plant 103. This information is given in Tables 3.2.1.6-1 and 3.2.1.6-2, respectively.

The remaining plants in this category which discharge to sanitary sewers report that their water usage, for reasons other than for sanitary purposes, is minimal. However, they have no data available on the quantities and composition of water discharged.

3.2.2 Askarel Transformer Repair Industry

A total of 13 companies repair transformers containing PCBs at a total of 131 locations. The current industry structure has been identified, and several potential problems were noted. No estimates have been made of the pollution which occurs from this industry.

3.2.2.1 Transformer Inspection and Maintenance

Askarel transformers are very reliable and have lifetimes that range up to 40 years. The failure rate of askarel filled transformers has been estimated by the manufacturers to be 0.2 percent per year. Failure occurs primarily due to the degradation of the PCB fluid caused by electrical arcing within the transformer.

Nine electrical utilities were contacted to determine their inspection and repair procedures. All of these companies have some type of program, usually informal, for the checking of their transformers. In most cases this consists of a simple annual inspection which may include a general cleaning operation of the facilities adjacent to the hardware (e.g., the vaults may be cleaned and vacuumed). Inspection involves looking for evidence of leaks. One utility performs an annual power factor test on the windings, and if this test indicates a problem in the transformer, then its dielectric fluid

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TABLE 3.2.1.6-1

PCB CONCENTRATION IN EFFLUENTS FROM TRANSFORMER MANUFACTURING PLANTS

Plant No.	Discharge Designation	Effluent Flow Rate Gal/Day	Effluent PCB Content ppb Avg/Max	Effluent PCB Content lb /day Avg/Max	Disposition of Effluent
103[1]	005	1,310,000	4.9/120	0.0535/1.311	River
	006	550,000	7/75	0.0321/0.344	River
114	None	50,000[2]	Unknown	Unknown	Sewer
	None	2,000[2]	Unknown	Unknown	River
115	002	36,000	<1/2	<0.0003/0.0006	River
	003	24,000	2/113	0.0004/0.0226	River
	004	150,000	<1/3	0.0013/0.0039	River
116[3]	#1	252,000	3.4/11	0.0071/0.0231	River
	#2	378,720	2.1/3.8	0.0066/0.0120	River
	#3	504,000	8/19.1	0.0336/0.0803	River
117	Batch discharge	13,500	28.6/unknown	0.0032/unknown	Sewer

Notes: (1) This plant has other discharges out of their properties. Discharges listed above are those associated with PCB related operations.

(2) Estimated.

(3) Discharges designated as #1, #2, and #3 are the combined effluents from their power house, and one each from their two manufacturing areas, respectively. According to the plants' Corps of Engineers permit application form, filed in July 1971, this plant has 13 outfalls.

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TABLE 3.2.1.6-2

INFLUENT AND EFFLUENT COMPOSITIONS OF PLANT 103

	Incoming Municipal Water	Outfall 005		Outfall 006	
Average flow rate million gpd	1.86	1.31		0.55	
pH yearly average	6.4	7.7		5.5	
pH min.-max.	—	6.4-8.0		3.1-7.1	
		Avg/Max Conc.	Avg lbs/day	Avg/Max Conc.	Avg lbs/day
Alkalinity, mg/l	14	25/25	273	15/20	69
BOD, 5-day, mg/l	2	3/3	28	27/30	124
Chemical oxygen, mg/l	9	23/34	251	75/92	344
TS, mg/l	69	70/70	765	364/497	1671
TDS, mg/l	68	67/67	735	341/483	1565
TSS, mg/l	1	3/9	31	23/30	106
TVS, mg/l	34	19/22	208	89/96	408
Ammonia, mg/l (AN)	0.05	<0.2/1.0	<2	2.8/3.0	13
Kjeldahl Nitrogen, mg/l	0.45	0.8/1.0	9	4.6/5.1	21
Nitrate AsN, mg/l	0.15	0.55/0.9	6	0.98/1.02	5
Phosphorus Total, mg/l	0.01	0.04/0.05	<1	54/124	248
Color (As P)	30	25/30	-	30/30	-
Turbidity, mg/l	<25	<25/<25	-	<25/<25	-
Total hardness, mg/l	44	31/44	340	33/44	152
Organic Nitrogen, mg/l	0.5	0.6/0.7	6.6	1.8/2.0	8
Sulfate, mg/l	9.0	14/18	153	9.0/9.0	41
Sulfide, mg/l	<0.1	<0.1/<0.1	<1.0	<0.1/<0.1	<0.5
Chloride, mg/l	6	6/8	61	11/13	50
Cyanide, µg/l	<0.00	0.00/<0.01	0.04	<0.00/<0.00	<0.02
Fluoride, mg/l	0.16	-	-	9.5/12.0	44
Aluminum - total, µg/l	100	500/550	5	200/200	0.9
Boron - total, µg/l	70	-	-	9/70	0.04
Calcium - total, mg/l	6.5	7.0/7.5	77	7.7/8.0	35
Chromium - total, µg/l	<10	30/30	0.3	310/350	1.4

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TABLE 3.2.1.6-2 (CON'T)

	Incoming Municipal Water	Outfall 005		Outfall 006	
Cobalt, total, µg/l	<7	4/4	0.04	-	-
Copper - total, µg/l	500	20/500	0.2	30/500	0.13
Iron - total, µg/l	330	150/330	1.6	3200/3500	15
Lead - total, µg/l	<30	<10/30	<0.1	80/90	0.36
Magnesium - total, µg/l	7	3/7	36	3/7	16
Manganese - total, µg/l	200	50/200	0.5	120/200	0.55
Mercury - total, µg/l	<1	<1/<1	<0.004	2/2	0.01
Molybdenum - total, µg/l	<7	-	-	90/99	0.41
Nickel - total, µg/l	100	<10/100	<0.1	10/100	0.04
Potassium - total, mg/l	1.1	0.88/1.10	9.6	0.99/1.1	4.5
Silver - total, µ	<10.0	-	-	2.0/2.0	0.009
Sodium - total, mg/l	5	6/10	66	25/30	117
Tin - total, µg/l	<7	7/10	0.07	-	-
Titanium - total, µ	2	-	-	3/3	0.01
Zinc - total, µg/l	30	70/75	0.76	730/800	3.4
Oil & Grease, mg/l	1.0	2/10	21	3.0/9.0	13.7
Phenols, µg/l	3	101/110	1.1	168/180	0.77
Surfactants, mg/l	<0.02	0.11/0.15	1.2	0.22/0.30	1.0
Chlorinated hydrocarbons, mg/l (except pesticides)	<1.000	1.000/5.000	11	1.000/1.000	4.6
PCBs, µg/liter	-	4.9/120	0.05	7/75	0.03

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is tested - at least this is the theoretical method of operation since the company has only two PCB-type transformers in use and neither has ever failed the power factor test. Another company measures the operating temperature of the units and makes a visual inspection for leaks; this company also claims that transformers located in the generating facility are inspected daily (visual inspection) and that units located in vaults are checked at least weekly. While most major inspections are carried out annually, the range of time intervals between inspections is 6 months to 18 months, with one company saying that they inspect at least once every 2 or 3 years, and another saying that substation transformers are inspected weekly.

These companies perform no sampling and analysis work on their askarel transformers. One company has annual inspection of all transformers, but only the mineral oil-type units have samples withdrawn for analysis to see if there is deterioration or contamination. A company which used to perform power-factor tests until about 8 years ago has since abandoned such tests and does not withdraw askarels for analysis.

Servicing of transformers is only rarely performed in-house. The response of most companies was that servicing of askarel-type transformers had yet to be required. One company did its own servicing up until 8 or 10 years ago, but since then, because of the special handling problems associated with askarels, such work has been farmed out to G.E. and Westinghouse service centers. The general trend seems to be that major servicing is more likely to be done at special facilities outside the utility companies while minor servicing, such as the repair of small leaks is taken care of at the transformer site by the utility.

More than half of the companies have not scrapped transformers in the past five years, and most have not scrapped any in the past 10 years. One utility company has had no transformer failures in 20 years (except for a minor leak of less than 1 gallon ten years ago). These companies have no specific disposal methods for such instances. One company said that scrap transformers are handled through a local junk company and that askarel disposal is the junk company's problem. A company which says it has scrapped no transformers says that when the PCB capacitors fail they are shipped back to

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the manufacturer; presumably, though it was not stated directly, failed transformers would also be returned to their manufacturers. One company which is proud of its disposal practices has disposed of 200 to 400 gallons of askarel per year since 1970 (most of it comes from failed capacitors); until this year it was all sent to Monsanto for incineration, but starting this year they have been sending it to Sheffield, Ill., where it is dumped in a landfill that has been approved by EPA for the disposal of radioactive wastes. This company stated that many utility companies dump their PCB-related wastes in local landfills.

There has been little PCB lost to the environment through the safety release valve on the transformers. The consensus response was that if the valve released there would be askarels "all over the place". The spokesman for one utility did not know whether the transformers they used had safety valves. One company said that a transformer vented several years ago when a fuse that was supposed to protect the transformer did not protect it.

Very seldom is a failed transformer scrapped. However, sometimes the repair work needed in a failed unit could be rather extensive and very costly. The owner of the unit may request to scrap his unit. If the repair shops scrap a transformer, they follow the procedure recommended by NEMA. However, if the owner of the transformer decides to handle the disposal of the unit himself, the unit is shipped back to the owner. Disposal is then usually made through a local junk dealer.

3.2.2.2 Repair of Failed Transformers

In talking with a major transformer manufacturing company which specializes in the servicing of transformers, it was learned that PCBs used by service shops are primarily for refilling the units which have failed and have to be repaired. Apparently, very few facilities handle their own servicing. Major service work is almost always handled by repair shops while minor service work, such as changing a gasket, to prevent a minor leak, may be taken care of by the owner of the transformer. Additionally, the repair

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shops often handle askarel conditioning services. In such a case, the serviceman carries the filter press to the costomer's site and performs this service on site. Several gallons of PCBs are used in this service for topping the unit and adjusting the level. The procedure for the repair or disposal of failed transformers and the handling of the PCB liquid in those transformers is summarized in Figures 3.2.2.2-1 and 3.2.2.2-2.

A number of potential sources of environmental contamination have been identified, and are discussed in detail in the following notes to the figures.

1) Testing and analysis of PCB transformer fluid has been largely discontinued due to the strict requirements imposed on the disposal of the samples. This change in procedure may be expected to increase the probability of major failures of transformers containing PCBs.

2) Accidental spills of PCBs from transformers can occur due to leaks, venting caused by short circuits, or mechanical damage to the transformer case. In most cases, the transformer is contained in a vault or is surrounded by dikes which will limit the spill to a controlled area. Only in the case of railroad transformers would the leakage resulting from an accident be expected to be uncontrolled.

3) Transformers which are scrapped by the owner/user may be a serious potential source of pollution. Those transformers built during the past several years are well marked with the hazards of the PCBs which they contain. Disposal of junked transformers by electrical repair shops is governed by a detailed specification of the National Electrical

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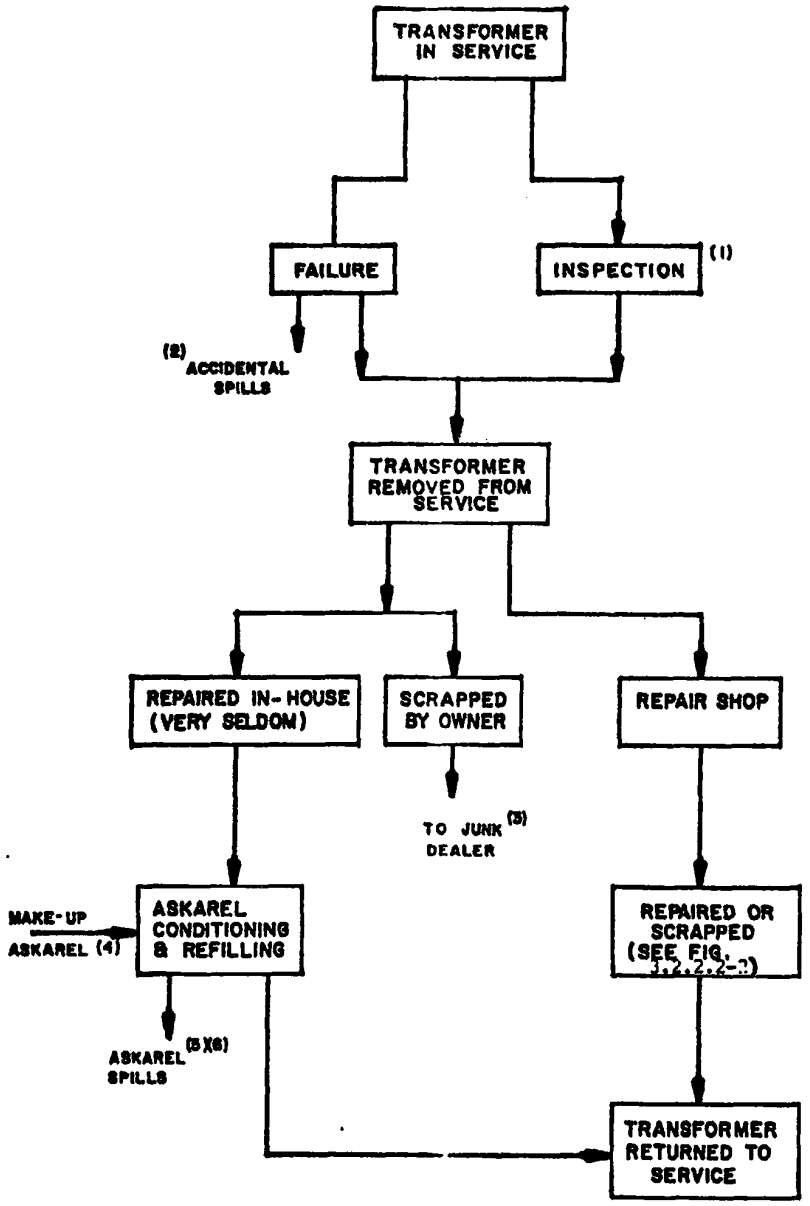

FIGURE 3.2.2.2-1. TRANSFORMER MAINTENANCE & SERVICING

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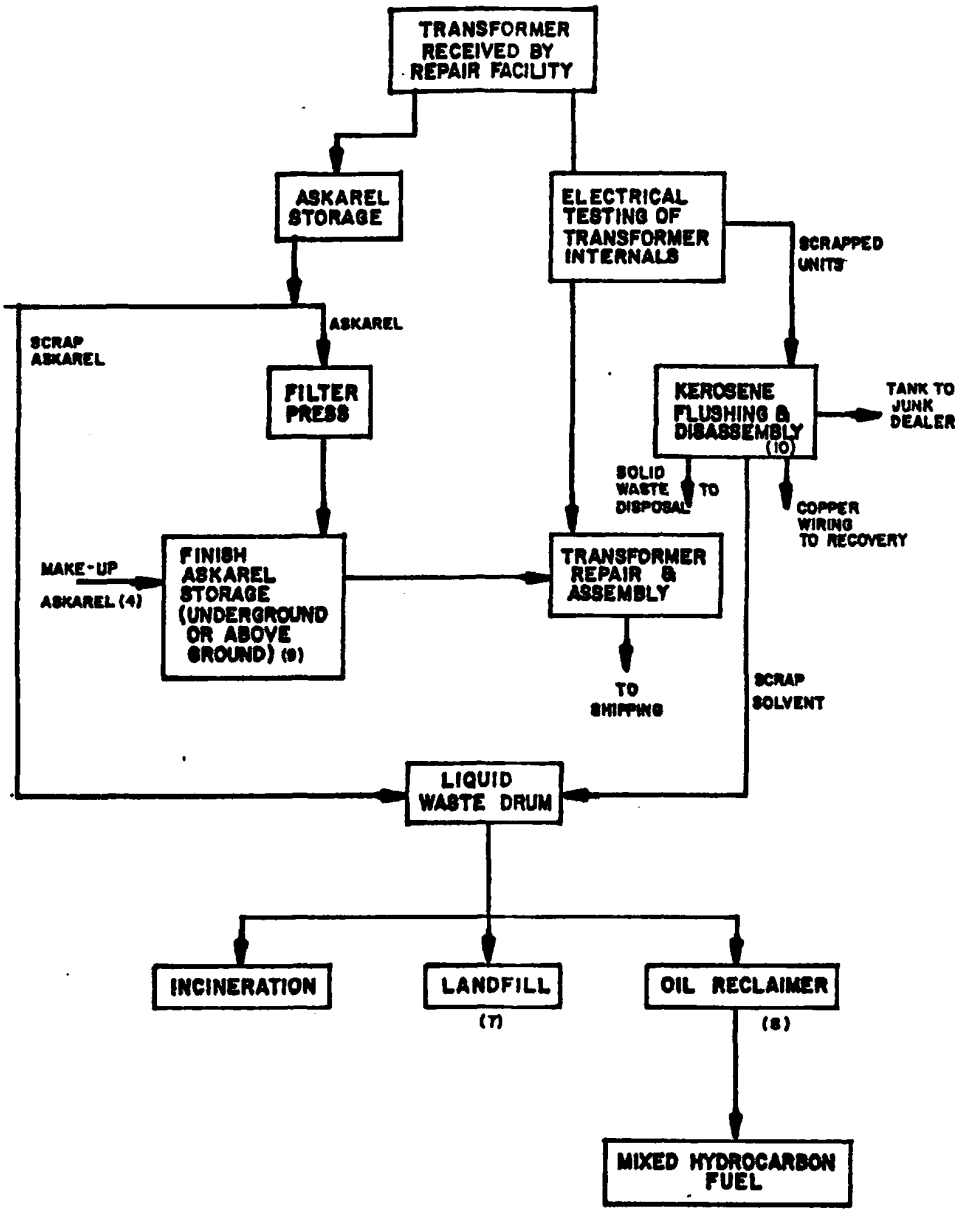

FIGURE 3.2.2.2-2. TRANSFORMER REPAIR

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Manufacturers Association (NEMA). However, the disposal of transformers through small local junk yards may result in significant pollution because:

a) The junk yards are not familiar with PCB handling procedures.

b) The older transformers are not marked with special instructions.

c) 90 to 95 percent of the transformers seen by the junk yards would contain mineral oil, and the occasional transformer containing PCB would be noted only as containing non-flammable transformer oil. This would not result in any special handling of the PCBs.

d) Disposal of PCBs by open burning in a trash incinerator will not completely destroy the PCBs, but will vaporize this material and disperse it into the atmosphere.

This is only a potential problem at this time, as uncontrolled scrapping of transformers has not been documented. However, several responses to the questionnaire claimed that uncontrolled handling of PCB filled transformers by junk yards was thought to have occurred in the past.

4) Considerable PCB is shipped in 55 gallon drums to repair shops and users. The residue in each drum after it is emptied may contain up to a pound of PCB. Empty drums which are recycled to drum reclaiming facilities or scrap yards would introduce this relatively small, but significant, amount of PCB into an uncontrolled environment. All drums presently in use have detailed handling instructions painted on the drum, and this information

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should minimize any potential problems from this source.

5) Filter residues and losses are in general treated as any other waste containing PCBs and are being placed in drums and held for controlled disposal.

6) Scrap PCB is packaged in 55 gallon drums. The NEMA instructions are very specific as to the required disposal procedures for this material. Small repair shops which do not have access to controlled disposal sites or services have been known to mishandle the scrap PCB by disposing into uncontrolled landfills (note 7) or through oil recovery services (note 8).

7) Landfills are a satisfactory disposal method for scrap PCB transformer oil if the leach water is monitored. In a few cases scrap PCB and PCB contaminated material is sent to a municipal dump.

8) At least one case is suspected where PCB transformer oil may have been sent to an oil reclaiming company which mixed it with other hydrocarbon wastes and sold it to a power company as fuel. It should be noted that the mineral oil used in 90 to 95 percent of the transformers presently in service. Problems may result when PCB transformer oils are mixed with mineral oils and handled in this manner.

9) New and conditioned PCB transformer oil is normally stored in large surface or underground tanks at the repair shop. Leakage may occur from

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these tanks into ground waters. No standards have been established for checking for such losses.

10) The scrapping of unrepairable transformers is covered by the NEMA standard (ANSI C107.1-1974). This standard requires that the transformer be drained and then flushed with solvent to remove PCB residues before the metal values are reclaimed. Possible sources of contamination would be incomplete flushing and the mixture of used solvent with hydrocarbon rather than with PCB residues. This is considered unlikely in the major transformer repair shops.

3.2.2.3 PCB Usage in the Transformer Repair Industry

The PCB usage figures for the transformer manufacturing and repair industries are summarized below.

	PCBs Use, lbs				
	1971	1972	1973	1974	1st half-1975
New PCBs used to repair transformers	590,000	580,000	440,000	780,000	480,000
PCB reclaimed and reused in repair of transformers	2,000	64,000	160,000	110,000	78,000
PCB shipped to user to replace transformer losses	3,000	3,000	4,000	2,000	2,000
PCB disposed in transformer repair				570,000*	
PCB used in transformer manufacturing				11,000,000	
Total PCB in service in transformers				270,000,000	

* This figure may include PCBs contaminated wastes as well as PCB.

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3.2.2.4 Transformer Service Life

There have been relatively few failures of PCB filled transformers, and statistically significant data is not available to support service life estimates. General estimates by transformer manufacturers indicate the following expected service life of this equipment:

Service life of substation transformers	40+ years
Service life of power transformers, including those on railroad locomotives	30 years

Transformers exhibit a small but significant infant mortality rate (failure within the first year of service). Overall transformer failure rate estimates are in the range of 0.2 percent per year.

3.2.2.5 Usage rate of PCBs in Transformer Repair

The total PCB used in 1974 in the repair of transformers was approximately 0.3 percent of the estimated total PCBs in service in transformers. This figure is consistent with the estimated failure rate of 0.2 percent per year for in-service transformers.

The usage of PCB in the transformer repair industry is approximately 7 percent of that of the transformer manufacturing industry.

3.3 Investment Casting

The investment casting industry produces precision-cast metal parts and shapes for the aircraft and other machinery manufacturing industries. Approximately 25 of the 135 investment casting foundries in the United States currently use PCB filled waxes in the manufacture of metal castings. The PCB incorporated in the waxes is decachlorobiphenyl (deka). The remaining foundries use either polychlorinated terphenyl (PCT) filled waxes or unfilled waxes. This section presents a review of the usage of deka filled waxes in the industry, including available information on use history, process technology, and potential

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PCB-bearing waste streams. Currently available information on PCTs usage in the industry is also included.

3.3.1 Background

There are currently 135 investment casting (IC) foundries and five investment casting wax manufacturing plants in the United States. The IC industry had its start in the United States during World War II when urgent demands for arms and aircraft parts required more efficient methods of producing finished, precision parts than standard machining techniques offered. During the war the waxes used by IC foundries consisted of a blend of carnauba wax, beeswax, paraffin, and rosins. However, over the last decade wax formulations have evolved which consist of a variety of polymeric compounds and other fillers such as decachlorobiphenyl and PCTs. By reducing the wax content through low-shrinkage fillers (such as PCBs and PCTs) volumetric shrinkage of the ceramic mold is controlled. This allows the production of metal castings with smaller dimensional tolerances than were available with the original unfilled waxes.

The major wax manufacturing companies are:

1. Yates Manufacturing Company, Inc.
2. M. Argueso and Company, Inc.
3. Freeman Manufacturing Company
4. J. F. McCoughlin Company

The Yates Manufacturing Company, Chicago, Ill., is the sole known U.S. supplier of deka waxes. The decachlorobiphenyl content is 30 percent of the total wax by weight (Solomon, P., Yates Manufacturing). Yates currently imports deka from Caffaro S.P.A., Italy, at a rate of 300,000 to 500,000 lbs. per year, which corresponds to the manufacture of between 1 and 1.5 million pounds of deka wax, annually. At a cost of $0.70 per pound, (Lewis, W.H., Signicast Corp.) the annual volume of sales of deka wax should be in the range of $700,000 to $1 million per year.

All the wax manufacturers listed previously are believed to use imported PCTs as pattern wax fillers. Since the general properties of the deka and PCTs are similar, it is believed that the wax production and use

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processes are similar also. Contacts with industry indicate that the volume of PCTs in wax is probably about the same as or greater than that of deka PCBs. Monsanto was the leading (and probably only) U.S. producer of PCTs prior to their voluntary cessation of production in 1972. Domestic production of PCTs by Monsanto through 1972 was as follows:

Year	Million of Pounds Aroclor 5460
1968	8.87
1969	11.60
1970	17.77
1971	20.21
1972	8.13

It is believed that a relatively small fraction of this production was used in casting waxes, probably on the order of a million or so pounds per year. Aroclor 5460 (Monsanto's trade name for their 60-percent-chlorine PCTs) was used primarily in adhesives, lubricants and paper coatings.

The current source of imported PCTs is believed to be Prodelec (France), which markets the material as Electrophenyl T-60 (60 percent chlorine), which, it should also be noted, may contain PCB contaminants.

In summary, the investment casting process, which is described more thoroughly in Sections 3.3.2.1 and 3.3.2.2, is a lost-wax casting process in which the shape to be cast is molded from wax and then invested or surrounded by a slurry of refractory ceramic. After the ceramic mold has hardened to an appropriate strength, the wax is melted or burned out leaving a molded cavity. Molten metal is then poured into the cavity, and cooled to form the casting.

The major losses of the virgin and used waxes occur during the dewaxing of the ceramic mold. As the ceramic mold is heated to remove the wax, a small portion of the wax diffuses into pores of the mold. Later, the mold with the trapped waxes is fired in a furnace to set the mold and remove the wax. Depending on furnace conditions, the decachlorobiphenyl in the wax may be burned or released to the atmosphere. At least several percent of that used is believed to be emitted via this route.

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It is a normal practice by many foundries to recover the drained pattern wax and reuse it several times in sprues and gates. Purchased wax is apparently used an average of 2.5 times. During the dewaxing process the virgin wax (used to form the pattern) and the old wax (used to form the gates and sprues) are collected as one mixture. Little of the wax is destroyed in the process; therefore, it is considered probable that the investment casting foundries store or dispose of relatively large amounts of used PCB-containing wax.

3.3.2 Investment Casting Technologies

3.3.2.1 Principles of Investment Casting

The principles of investment casting are the same for both the solid mold and shell processes, but the method of forming the ceramic mold differs somewhat between the two. Both require a pattern, gating to a central sprue, removal of the pattern by melting, pouring metal into the cavity left by the melted pattern, removal of mold material from the cast cluster, and cutting of castings from the sprue.

The investment shell process is depicted in Figure 3.3.2.1-1.

The Pattern: The process begins with production of a one piece heat-disposable pattern. This pattern is usually made by injecting wax or plastic into a metal die. Dies range from simple, hand-operated single-cavity tools to fully automated multi-cavity devices, depending on production quantities and complexity of the parts to be cast.

A heat-disposable pattern is required for each unit being cast. Each pattern has the exact geometry of the required finished part, but they are made slightly larger in order to compensate for volumetric shrinkage during the pattern production stage and during solidification of the metal in the mold.

The pattern carries one or more gates which are usually located at the heaviest casting section. The gate has three functions:

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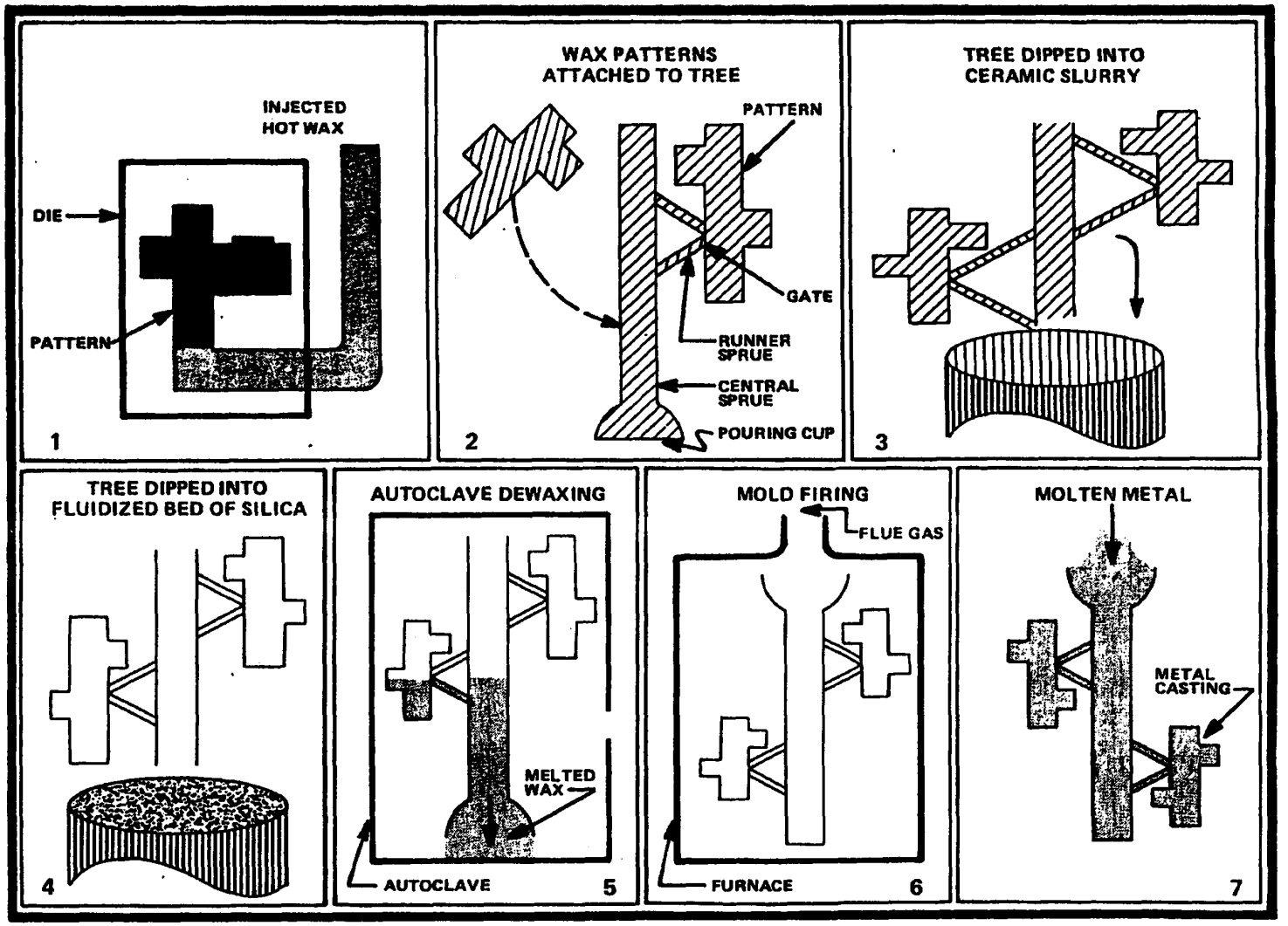

Figure 3.3.2.1-1. INVESTMENT SHELL PROCESS

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(1) To attach patterns to the centrally-located sprue or runner, thus forming a tree-shaped cluster;

(2) To provide a passage for the draining of pattern wax once the mold is sufficiently hardened and has been heated; and

(3) To guide molten metal entering the mold cavity in the pouring operation.

Clustering: Patterns are fastened by the gate to one or more runners. The runners are attached to a pouring cup. All of these parts are usually made of wax. Patterns, runners and pouring cup comprise the cluster or tree upon which the ceramic mold is formed. The number of runners and their arrangement on the pouring cup may vary considerably, depending on alloy type and the size and configuration of the casting.

Molding: Up to the point of forming the ceramic mold, all foundries operate in essentially the same manner. After assembling the pattern to a tree, however, they may form the mold by either the investment flask process or the investment shall process.

Solid Mold or Investment Flask Process: There are two investment flask techniques, depending on the type of alloy to be poured. Ferrous alloys require highly refractory materials and binders. The entire cluster is dipped into a ceramic slurry, drained and stuccoed with fine ceramic sand. This step is usually repeated after the first coating has dried. This coated cluster is then placed in an open-end metal can (the flask) which is filled with a coarse slurry of ceramic backup material (investment). The investment hardens to comprise a green mold. When the flask with its contents are placed into an autoclave, the whole cluster (consisting of wax patterns, runners and sprues) melts and runs out through the pouring cup. The resulting monolithic mold contains cavities of the desired casting shape, with passages leading to them.

Nonferrous alloys are cast in ceramic molds bonded with plaster of paris. The entire tree (heat-disposable patterns, gates, runners, and pouring cup) is placed in an open-end metal flask without a first

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ceramic coating. Investment slurry is poured into the flask, completely surrounding the cluster. Before the binder sets up, the flask is placed under vacuum to remove all air entrapped during mixing of the investment. When the investment becomes hard, patterns are melted out exactly as in ferrous casting.

The Investment Shell Process: This technique, as described in Figure 3.3.2.1-1, involves dipping the entire cluster into a ceramic slurry, draining it, then coating it with fine ceramic sand. After drying, the process is repeated several times, using progressively coarser grades of ceramic material, until a self-supporting shell has been formed. The thickness of the shell is usually between 3/16 and 5/8 inch.

The coated cluster is then placed in a steam autoclave where the wax melts and runs out through the gates, runners, and pouring cup. The resulting ceramic shell contains cavities of the desired casting shape, with passages leading to them.

Casting: Monolithic shell molds and solid molds must be fired to burn out the last traces of pattern material and to attain a degree of permeability before the molds can be filled with metal. In the case of solid molds, this heating has to proceed slowly, in a controlled cycle which stretches over 12 to 18 hours, to avoid cracking of the mold. The shell molds, made of ceramic material with an extremely low coefficient of expansion, can be placed immediately into a hot furnace. Because the shell molds have relatively thin walls, they can be fired and ready to pour after only a few hours in the furnaces.

The hot molds may rely on gravity alone to carry the molten metal into the intricacies of the mold, as is common in sand casting, or the process may use vacuum, pressure and/or centrifugal force in order to faithfully reproduce intricate details of the wax patterns.

Melting equipment employed depends on the alloy. For nonferrous alloys, gas fired or electric crucible furnaces are usually used. For ferrous alloys, high frequency induction furnaces and indirect arc furnaces are common.

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Cleaning: After cooling, mold materials are removed from the casting cluster with vibrating equipment. Individual castings are usually removed from the cluster by means of cut-off wheels, and any remaining protrusions left by gates or runners are removed by belt-grinding. Generally, castings are sand blasted for smooth finish, then they are ready for such secondary operations as heat treating, straightening and machining.

Reclaiming of Pattern Waxes: The present cost of virgin pattern wax is approximately $.79/lb. In the future, it may be more economical to reclaim wax for use as pattern waxes, in addition to its present use in gates and runners. Furthermore, through a precipitation method, it is possible to remove fillers, including PCBs, from used wax in order to prepare unfilled wax.

Improvement of Investment Casting Processes: Several improvements in the investment casting techniques and procedures have been suggested by TRW Metals in Minerva, Ohio, which developed them through a two-year Air Force contract (AFML-TR-74-237). The areas of improvement were in wax pattern formation, mold production processes and metal pouring.

Wax pattern formation techniques were improved through simultaneous multiple injections of the gates and runners. The usual procedure requires separate steps.

Two suggestions for improvements were made for the mold production process: (1) elimination of the drying cycle between slurry dipping and sand coating, and (2) the use of microwave ovens to melt pattern wax out of the ceramic mold or shell.

The use of microwave dewaxers would have the advantage of reducing wax emissions in flue gas and drain condensates of autoclave ovens. However, microwave dewaxing may not eliminate wax losses occurring during mold firing as a result of wax trapped in the pores and cavities of the ceramic mold.

3.3.2.2 Foundry Process - Use of PCT and PCB Filled Waxes

A flow chart which typifies the use of PCBs and PCTs in investment casting is presented in Figure 3.3.2.2-1. PCB filled waxes are

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FIGURE 3.3.2.2-1
FLOW CHART OF PCBs USAGE IN INVESTMENT CASTING

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purchased from wax manufacturers in bulk quantities of 10,000 or more pounds, sealed in plastic bags and contained in boxes for shipment. The received pattern wax is stored in a stockroom at the foundry until melted for the production of wax patterns. Once melted, the wax is injected into a pattern die where the wax is allowed to solidify. The pattern die is then disassembled and the wax pattern removed. Several wax patterns are produced before forming the tree. The formation of the tree entails attaching the individual wax patterns to the sprues and gates, and after the trees are assembled, the sprues are coated with a dip-seal wax to fill the voids on the rough sprue surfaces.

The next step in the process is the formation of the ceramic mold. This is accomplished by dip-coating the wax trees in a ceramic slurry and a fluidized bed of silica, and air drying of the coated tree. This process is repeated several times before the wax is melted out of the mold.

Dewaxing is accomplished by one of three techniques: steam autoclave, microwave oven, or flash firing in a mold furnace. Most foundries apparently use the autoclave technique, which involves subjecting the ceramic coated trees to steam until the wax within the mold is melted out, leaving the ceramic shell. The melted wax is either disposed of or reclaimed for use as sprues and gate wax. The new microwave technique involves heating the molds with microwave energy. Microwave units of 5- and 10-kilowatt output are commercially available for this application. The third technique of flash firing combines dewaxing and mold firing in one step. The ceramic coated wax trees are placed in a furnace where all the wax is removed from the tree by flash firing. Most of the wax is vaporized and leaves the furnace with the stack gases. It is not known how many facilities use flash firing.

If the foundry dewaxes the trees using autoclave or microwave techniques, the dewaxed ceramic molds must be fired in the mold furnace to strengthen the ceramic and to remove wax residues. The ceramic molds are raised to temperatures of between 1900 and 2000°F for approximately two hours. The vaporized wax residues leave the furnace with the stack gases. The foundries claim that only 1 to 2 percent of the wax remains in the molds before mold firing. This estimate of trapped or wall absorbed wax appears to be low for two reasons:

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(1) The porosity of the ceramic mold can be as high as 30 percent, and

(2) Trapped waxes in the cavities of the pattern vary in amount, depending on the pattern's geometric configuration.

After firing, the ceramics are ready for metal pouring. The steps involved in pouring, and the subsequent recovery of the castings are evident in Figure 3.3.2.2-1, starting with metal pouring.

The high cost of pattern wax has stimulated foundries to reclaim used wax. For example, the PCB filled waxes sell for approximately 70 cents per pound. The average weight ratio between pattern wax and wax in sprues and gates is about 40:60. Therefore, reclaiming of used wax, especially for use in sprues and gates, ahs become a very important part of the foundry process.

Reclaiming involves placing the used wax in open kettles or tanks and heating it above the boiling point of water until all the water (from the steam autoclave) is eliminated. After dewatering, the reclaimed wax is reconstituted by adding paraffin and other additives until certain melting-point specifications are met. It is claimed that wax fillers are not added to adjust the filler content (Wurster, W., Consolidated Casting Corp.).

For those foundries which practice wax reclamation on their used wax, it is estimated that 5 to 10 percent of the wax is deliberately disposed of. The major source of the discarded wax is probably the dregs from the dewatering kettles.

3.3.2.3 Waste Streams

Idealized waste streams (containing PCBs and PCTs) leaving an investment casting foundry are shown in Figure 3.3.2.3-1. The broken lines within the process box in Figure 3.3.2.3-1 indicate potential PCB and PCT escape routes via air emissions from the foundry unit processes. The solid lines between the processes indicate the production routes of the waxes.

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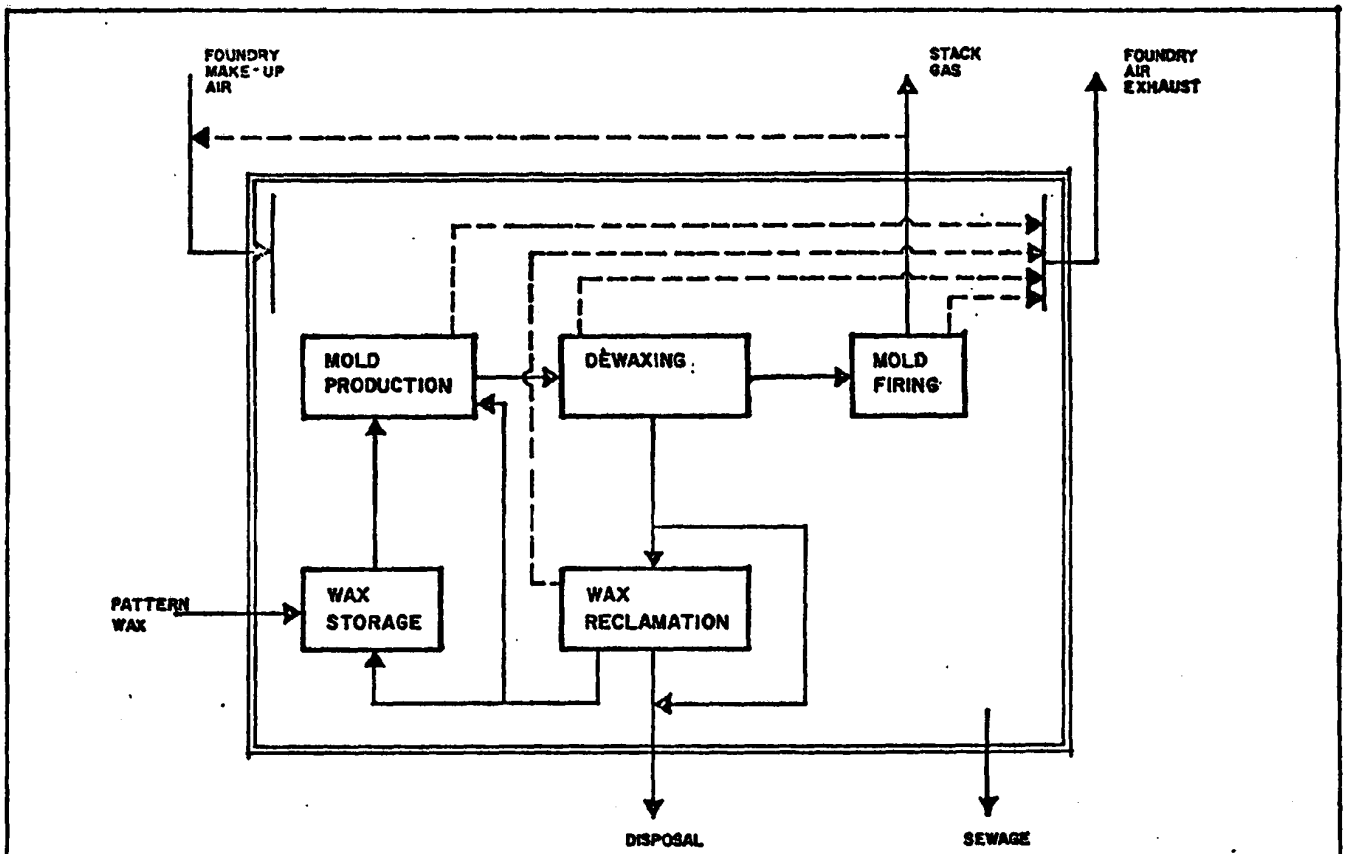

FIGURE 3.3.2.3-1

IDEALIZED FLOW CHART FOR AN INVESTMENT CASTING FOUNDRY, SHOWING WASTE STREAMS

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The solid lines at the top of the figure indicate the two general ambient air escape routes, namely the stack gas from the mold firing furnace and the foundry exhaust air system. The two solid lines leaving the foundry (at the bottom of the figure) represent PCB and PCT escape routes: solid waste, which is usually sent to landfills, and raw sewage, which goes to municipal sewage treatment in most cases. The broken line outside the facility (at the top of the figure) indicates the possibility for inadvertent recycling of escaped PCBs or PCTs in stack gas or foundry air exhaust back into the foundry facility.

PCB-PCT-containing waxes enter the foundry as pattern wax packaged in plastic lined boxes which are stored until needed in the casting process. During mold production, when the wax is melted and injected into metal dies, wax fumes may escape. The type of dewaxing method employed by the foundries has a direct effect on the amount and mode of PCB or PCT loss to the environment, not only during dewaxing but also during process steps that follow. For example, the use of a steam autoclave, in addition to its own potential emission of PCBs or OCTs, also imparts moisture to the wax, and this water must be removed before the wax can be reused. Dewatering by evaporation at high temperature also likely contributes to air emissions. Flash firing, which combines mold firing and dewaxing into one step, probably emits high levels of PCBs or PCTs, and so far as is known, emission controls are not used.

Solid wastes can include unreclaimed used wax, excess reclaimed wax, bottoms from reclamations, and wastes from spills, equipment cleanout, etc. Although process water does not appear to be used, some plants may use cooling water. The steam autoclave appears to be a source of water vapor only.

3.3.3 Wax Manufacturing

To date, very little is known about the wax manufacturing process. However, it is known that in the process PCB or PCT compounds are added in powdered form to the wax base. Reduction of PCB or PCT particle size prior to mixing may be desired. Losses of dust to the environment by air routes from both size reduction and mixing operations would be expected.

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3.3.4 Recommendations

The information presented herein represents the current knowledge of decachlorobiphenyl and polychlorinated terphenyls usage as wax fillers in the investment casting industry. This knowledge should be used as a basis for the development of an accurate assessment of the importance of PCB and PCT waste from the industry, and of the adequacy of available substitutes. Significant information gathering efforts would be required to establish a complete picture of the practices, processes and product of the investment casting foundries and wax manufacturers. Definition of the waste streams and emissions from the processes used would require sampling and analysis efforts in addition to the gathering of available process data and other information from the industry. The objectives of such a plan would necessarily include the following:

(1) Verification of the magnitude of PCB and PCT wax filler production and use;

(2) Development of detailed process descriptions, including waste streams, leading to a complete mass balance for the production and use processes (including significant variations);

(3) Definition of quantities and concentrations of waste streams, including waste form, abatement techniques, and ultimate disposal methods; and

(4) Evaluation of all reasonable alternatives to the use of PCBs and PCTs in casting.

A study plan to accomplish the above objectives was developed for OTS under Task III of this program (Contract 68-01-3259).

3.4 Secondary Fiber Recovery (Paper Recycling)

The secondary fiber recovery industry converts wastepaper from industrial, commercial, and municipal sources into reusable pulp, which is subsequently used to produce paper products, either as is or blended with virgin pulp. In the United States, there are approximately 230 paper mills

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which produce pulp completely derived from wastepaper and 550 mills whose generated pulp contains secondary fiber (typically 10 to 15 percent).

Wastepaper stands third behind pulpwood and wastes from other forest products as a source of paper pulp in the United States. In 1974, fiber recovery mills removed almost 13 million tons of wastepaper from the nation's solid waste streams.

The effluent discharges from some of the secondary fiber mills has been documented by Kleinert to contain Aroclor 1242,[1] an apparent incidental PCB contaminant occurring in the pulp production process. Table 3.4-1 shows the PCB (as Aroclor 1242) concentrations and discharge rates for some paper recovery within the State of Wisconsin. These data were collected in 1975 by the Wisconsin Department of Natural Resources in an effort to survey PCB discharges.

The following subsections present a review of the historical usage of Aroclor 1242 in carbonless copy paper production and a brief description of a secondary fiber recovery process.

3.4.1 Historical Use of PCBs in the Paper Industry

Aroclor 1242 (which appears to be the predominant PCB found in mill effluents)[1] was used in the manufacture of carbonless copy paper sold by the Appleton Paper Division of the NCR Corporation during the period 1957 to 1971. Tables 3.4.1-1 through 3.4.1-3 provide data indicating: (1) The magnitude of Aroclor 1242 consumption in the manufacture of NCR carbonless paper; (2) Production quantities of NCR carbonless paper; and (3) The weight percent of Aroclor 1242 in carbonless paper.

From these tables, several significant facts are derived concerning the magnitude of PCB use in the manufacture of carbonless paper products. Some of these facts are:

(1) Approximately 44 million pounds of Aroclor 1242 were purchased (from Monsanto) for the manufacture of NCR carbonless paper;

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TABLE 3.4.1-1

HISTORY OF AROCLOR 1242 CONSUMPTION
IN THE MANUFACTURE OF NCR CARBONLESS PAPER
FOR THE YEARS 1957 THROUGH 1971[1]

YEAR	(THOUSANDS OF POUNDS)
1957	587
1958	779
1959	1019
1960	1149
1961	1643
1962	1953
1963	2281
1964	2705
1965	3489
1966	4246
1967	4355
1968	5801
1969	6278
1970	6611
1971	1266
TOTAL - 1957 through 1971	44162

Note: [1] From data compiled and reported by Appleton Papers Division, NCR Corporation.

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TABLE 3.4.1-2

HISTORY OF NCR CARBONLESS PAPER PRODUCTION
FOR THE YEARS 1957 THROUGH 1971

YEAR	ESTIMATED NCR CARBONLESS PAPER PRODUCTION - TONS
1957	10010
1958	13264
1959	17434
1960	20703
1961	25504
1962	29708
1963	34583
1964	41762
1965	51855
1966	60594
1967	69512
1968	83250
1969	87336
1970	91576
1971	88977
TOTAL,[1] 1957 through 1970	726068

Note: [1] Total excludes 1971 because use of Aroclor 1242 was discontinued in May, 1971 but estimated production of NCR carbonless paper is for full year.

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TABLE 3.4.1-3

RATIO OF AROCLOR 1242 CONSUMPTION FOR CARBONLESS
TO NCR CARBONLESS ESTIMATED PRODUCTION

Year	(A) Aroclor 1242 Consumption Thousands of Pounds (1)	(B) NCR Carbonless Estimated Production Thousands of Pounds	PCB Content $\frac{(A)}{(B)}$ x 100
1957	587	20020	2.9
1958	779	26528	2.9
1959	1019	34868	2.9
1960	1149	41406	2.8
1961	1643	51008	3.2
1962	1953	59416	3.3
1963	2281	69166	3.3
1964	2705	83524	3.2
1965	3489	103710	3.4
1966	4246	121188	3.5
1967	4355	139024	3.1
1968	5801	166500	3.5
1969	6278	174672	3.6
1970	6611	183152	3.6
1971	1266	177954	-
TOTAL (2) 1957 thru 1970	42896	1274182	Avg. 3.4%

Notes: (1) From data compiled and reported by Appleton Papers Division, NCR Corporation.

(2) Total excludes 1971 because use of Aroclor 1242 was discontinued in May, 1971 but estimated production of NCR carbonless paper is for full year.

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(2) The average weight percent of Aroclor 1242 in carbonless paper was 3.4 percent;

(3) Of the total PCBs sold in the United States during 1957-1971, 6.3 percent were sold for the NCR carbonless paper application; and

(4) 28 percent of the total Aroclor 1242 sold by Monsanto for plasticizer applications was purchased for the manufacture of NCR carbonless paper.

Although NCR developed and sold the product, the actual manufacturing step whereby Aroclor 1242 was incorporated into the paper was performed by the Mead Corporation of Dayton, Ohio, who exclusively supplied carbonless paper to NCR. NCR, in turn, either used the supplied paper to manufacture ledger (business) forms or sold and distributed the carbonless paper to other form manufacturers. Aroclor 1242 is reported to be the only Aroclor type used in the production of carbonless paper. Specifically, Aroclor 1242 was used as a solvent for certain color reactants which were encapsulated into microspheres 10-20 microns in diameter and applied to one side of the paper during the coating process. The walls of the microspheres consisted of a gelatin-gum arobic formulation which was hardened by treatment with an aldehyde (such as formaldehyde). Since 1971, alkyl biphenyl compounds have been used in place of Aroclor 1242 as the dye carrier.

Very little is known about other uses of PCBs in the paper industry. Past usage of PCBs in paper coatings and adhesives appears likely, although the quantities used could not have been near the magnitude of PCB usage in the carbonless copy paper. Almost certainly PCBs were used in some of the inks, and possibly paper colorants, which can also be expected to occur in wastepaper. According to Monsanto, the favored Aroclor type used in inks was 1254, which contains most of the same isomers as 1242 but at different relative concentrations.

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In addition, PCBs can enter the pulping process through contamination of intake water and in virgin pulp. Little is known about the magnitude of any of these sources, or even how much carbonless copy paper containing PCBs remains in files, etc. to enter the paper recycling processes in the future.

3.4.2 Fiber Recovery Mill Process

The following is a generalized description of the mill process for recovering paper fiber. Portions of this description was provided by the Bergstrom Paper Company in Neenah, Wisconsin. Figure 3.4.2-1 depicts the general process, up to the paper making section, in block form.

The fiber recovery process is a purification process wherein fibrous materials are deinked and separated from non-fibrous materials through controlled cleaning and mechanical treatment, followed by washing and cleaning. The color is next removed from the pulp by a multi-stage bleaching system accompanied by intermittent washing and centrifugal dewatering.

Pulping and Deinking: The fiber regeneration process starts with feeder crews loading the sorted paper onto a belt conveyor. The conveyor feeds a hydropulper, where wastepaper is pulped and deinked through the action of hot water, steam, caustic soda, and deinking chemicals. The breaking down of the paper stock is accomplished through a combination of mechanical and chemical treatment. At this point, larger metallic objects and other non-paper materials mixed with the wastepaper are collected into traps at the bottom of the pulper. The pulped stock leaves the hydropulper via extrusion through perforated plates, and goes to blending chests for additional retention time and agitation. From the blending chests the stock passes over a vacuum filter which is used for heat and chemical recovery. Much of the filtrate is recycled to the hydropulper; excess filtrate goes to treatment. The stock is then diluted and sent to centrifflers where small metallic particles such as pins and staples are removed.

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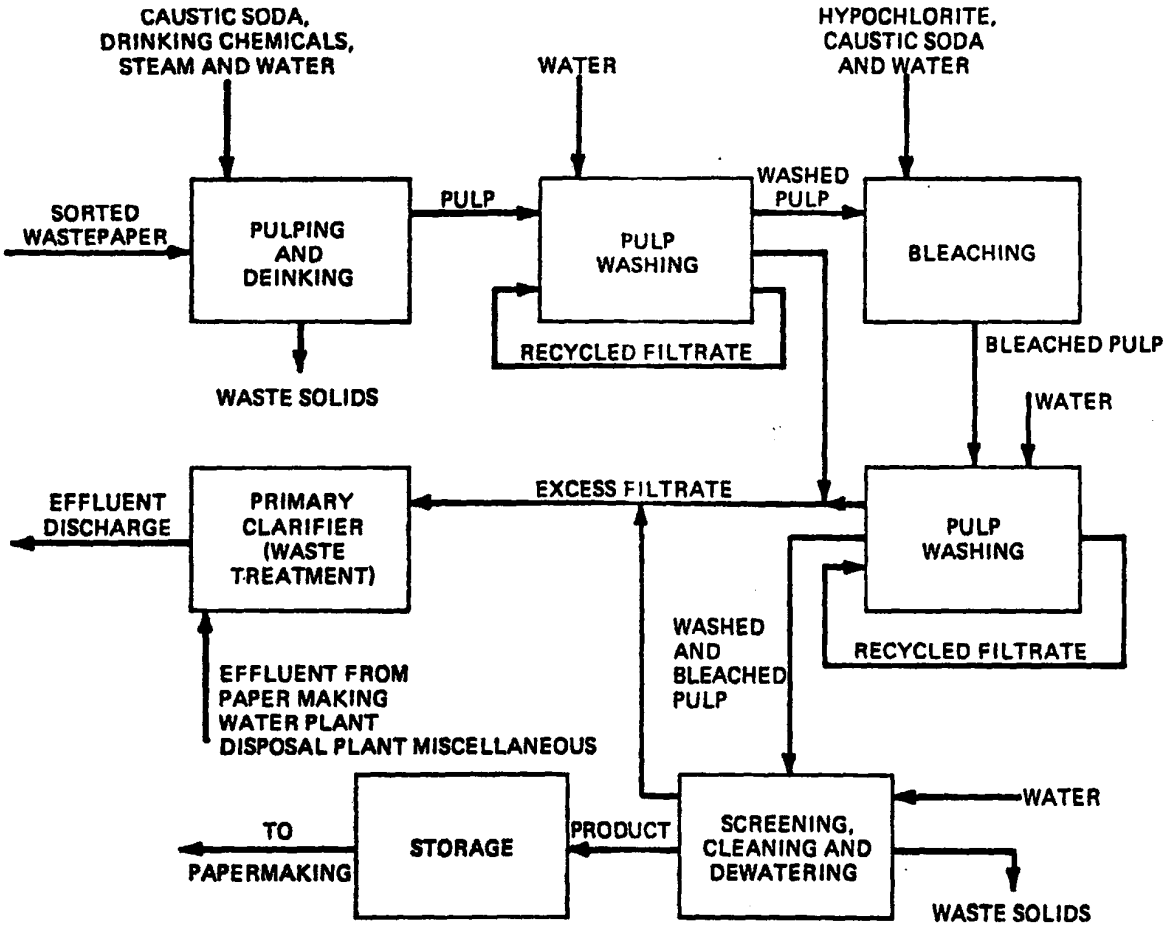

Figure 3.4.2-1. MILL FIBER RECOVERY PROCESS AND WATER EFFLUENTS

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Pulpwashing: Accepted stock from the centrifflers goes on to the washing stage. Stock washing is accomplished in a four-stage counter-flow washing system. The first stage consists of cylinder washing, the second and third stages consist of sidehill washers, and the fourth stage is another cylinder washer. The cleanest water is used for dilution at the fourth stage, and the filtrate is fed to the preceding stage, finally reaching the first stage from which the filtrate is discharged for waste treatment.

Bleaching: Following washing, the stock goes to a three-stage bleachery. At the first stage the stock is chlorinated by sodium hypochlorite solution in a tower. After chlorination, the stock is washed on a vacuum filter. In the next stage the stock is treated with caustic soda and sodium hypochlorite. After retention in a second tower the stock is diluted and again washed on a vacuum filter. It is then treated again with sodium hypochlorite in a third tower.

Screening and Cleaning: After retention in the third tower, the bleached stock is diluted for the next cleaning process, which is a three-stage pressure screen system. Accepted stock from the first stage pressure screen goes to a five-stage centrifugal cleaner system for removal of small-sized heavy contaminants. Following this, the pulp is sent to a four-stage system of centrifugal cleaners for removal of lightweight contaminants.

After the cleaning, the stock goes to a final washing stage and is then dewatered (thickened) and stored in high density towers for paper making.

Flow Rates and Composition of Discharges: At Bergstrom the separate waterborne discharges from the paper and the paper making process are combined with other facility waste streams and directed to a central waste treatment system. Only the effluent from the primary clarifier of the waste treatment system is discharged to the environment. The average effluent flow rate for Bergstrom during 1975 was 3.9 million gallons per day. This volume rate is broken down as follows:

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Process	Volume Rate to Waste Treatment Million Gallons/Day
Deinking	2.5
Paper Making	.9
Water Plant	.3
Disposal Plant and Miscellaneous	.2

Table 3.4.2-1 is a tabulation supplied by Bergstrom of the 1974 averages for various parameters in their raw water source and waste clarifier effluent. The average Aroclor 1242 concentration in the effluent was reported to be less than 8 ppb.

Recommendation (Paper Recycling): The information presented herein with regard to PCBs in paper recycling processes is based on a very limited study effort on the secondary fiber recovery industry. It is recommended that a more detailed study be performed of PCBs involvement in this industry. Important aspects which should be addressed include:

(1) Definition of paper recycling processes and the PCBs material balance therein (PCBs input versus PCBs content in effluent and product);

(2) Definition of past PCBs usage in paper and routes into recycled paper;

(3) Development of present distribution of PCBs originally used in paper;

(4) Determination of applicable effluent treatment methodology and associated cost estimates; and

(5) Projecting future contribution of PCBs to the environment from this industry.

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TABLE 3.4.2-1

COMPOSITION OF RAW WATER AND CLARIFIER EFFLUENT (1974 DATA)
(Bergstrom Paper Co.)

	Raw Water	Clarifier Effluent
Aldrin, µg/l	<0.1	<0.4
Ammonia Nitrogen, mg/l	0.32	1.72
Arsenic, µg/l	<8	<8
Barium, µg/l	14	140
Beryllium, µg/l	<0.3	<5
Boron, µg/l	33	235
Cadmium, µg/l	<16	<16
Chloride, mg/l	10	482
Chlorine, mg/l	<0.5	<0.5
Chromium, µg/l	<4	26
Cobalt, µg/l	<14	14
Copper, µg/l	<5	78
Cyanide, mg/l	<0.005	0.12
Dieldrin, µg/l	<0.03	<0.03
Fecal Coliform Count/100 ml	4	<10
Fluoride, mg/l	0.46	0.48
Heptachlor, µg/l	<0.07	<0.5
Lead, µg/l	<42	85
Manganese, µg/l	10	50
Mercury, µg/l	0.7	0.5
Nickel, µg/l	<33	<33
Nitrate Nitrogen, mg/l	0.29	1.32
Nitrite Nitrogen, mg/l	<0.005	0.43
Kjeldahl Nitrogen, mg/l	0.82	19.0
Oils, Fats, Grease, mg/l	<1	26.4
Phenol, µg/l	4	26
Phosphorus, mg/l	0.11	0.57
PCBs, µg/l	<0.5	8.0 (1242)
Selenium, µg/l	<8	<8
Sulfate, mg/l	45	74
Sulfide, mg/l	<0.05	<0.05
Sulfite, mg/l	<2	<2
Suspended Solids, mg/l	<1	465
Thallium, µg/l	<1	<25
Zinc, µg/l	67	420
BOD_5, mg/l	1.1	665

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3.5 Industrial Use of PCBs as Hydraulic and Heat Transfer Fluids

3.5.1 General

The use of PCBs in hydraulic and heat transfer systems increased rapidly during the 1950s and 1960s until, in 1970, the maximum sales by Monsanto for these uses, plus lubricants, were about 11.3 million pounds, or over 15 percent of the total 1970 reported domestic sales. Since 1971, Monsanto has not marketed PCBs for these uses, and although it should be noted that such usage of PCBs in deep mining equipment is expressly allowed by the OECD agreement to which the U.S. is party.

When PCBs sales for heat transfer and hydraulic uses were eliminated by Monsanto in 1971, the affected industries turned to substitutes or, in a very few cases, imported PCBs. Phosphate esters have found acceptance in many types of hydraulic systems where PCBs were formerly used. Glycols and other alcohols have replaced PCBs in some heat transfer systems, and there are a number of other substitutes used for this purpose (including other chlorinated hydrocarbons).

It is surmised that there are industrial concerns still using PCBs in these semi-closed systems. Hesse reported at the National Conference on PCBs in November, 1975 that a number of such users had been found in Michigan. Later contacts with these same firms indicated that all had voluntarily replaced the PCBs in their systems with substitute fluids. Very little work has been done to ascertain the magnitude of current PCBs usage for hydraulic and heat transfer purposes. Of the total reported Monsanto domestic sales of PCBs over the period 1957-71 for heat transfer fluids, hydraulic fluids, and lubricants, 81 million pounds, it seems reasonable that at least 95 percent have been replaced by substitutes or were in systems now obsolete. On this basis the maximum amount still in use would be on the order of four million pounds. A figure of two million pounds still in use is probably more accurate.

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3.5.2 Use of Imported PCBs by Joy Manufacturing

Until recently, Joy Manufacturing Co. (Pittsburgh, Pa.) manufactured mining equipment which utilized a PCB motor coolant. Joy imports PCBs, as a mixture similar to Aroclor 1242, from France (Prodelec). Presently, the PCB type motors are no longer manufactured and have been replaced on new units by an air-cooled motor. However, PCB coolant fluids purchased from France are being used for servicing the old liquid coolant motors. Currently, there are approximately 1100 of the old motors in the field, each of which contains an estimated 3 - 4 gallons of PCB type coolant fluid. The operating time of these motors before complete overhaul is between 1 and 2 years. The major benefit derived from using the PCB type coolant was its fire retardant characteristics.

From the information received by representatives of Joy Manufacturing Company, and from available physical properties, it is estimated that between 40,000 and 60,000 pounds of the imported PCB type coolant fluid would be necessary to replace and "top off" the fluids in the old motors each year.

3.6 Recent Use of PCBs in Product Development Activities

Since the voluntary limitation on the sale of PCB compounds in the United States by Monsanto, small quantities of PCB compounds have been imported for new product development by at least one U.S. company. Such a use application, by E. I. duPont de Nemours and Co., Wilmington, Del., was for development work on a new polymer which is derived from the reaction of decachlorobiphenyl (deka) and Bisphenol A.

According to duPont representatives, they have imported small quantities of deka from Caffaro (Italy) for experimental purposes with the intent to develop a new product called NR-140 polymer. Approximately 2000 pounds of deka were imported in 1974; however, duPont did not import any deka in 1975. A decision was made not to commercialize the new product because of the uncertainties associated with the regulation of PCBs.

It is estimated by duPont that, if the new product had been commercialized, the annual purchase of deka would be in the range of 5-10 million pounds.

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SECTION VI

WASTE TREATMENT TECHNOLOGIES

1.0 INTRODUCTION

This section includes descriptions and discussions of existing and proposed technologies for the treatment of various types of wastes generated at PCB-producing and PCB-using plants. Also included are discussions of the presently available control technologies and technologies to be available within three years, plus technologies that will not be available for five or more years. The treatment and control costs included here have been developed and presented in the Task II report "Assessment of Wastewater Management, Treatment Technology, and Associated Costs for Abatement of PCBs Concentrations in Industrial Effluents", EPA Contract No. 68-01-3259, issued February 3, 1976.

1.1 Summary of Waste Management Problem Areas

Based upon detailed plant inspections and examinations of the processes in the production of PCBs and their use in capacitors and transformers, it has been determined that there are four major categories of wastes to be considered: waste liquid PCBs, PCBs in wastewater, PCB contaminated solid wastes, and airborne PCB emissions. It has also been determined that the characteristics of wastes in PCBs producing and using operations are similar enough that the same kinds of control and treatment technologies can be used.

1.1.1 Waste Liquid PCBs and Contaminated Scrap Oil

The users of dielectric materials have strict requirements for purity. Typical requirements are:

Inorganic chlorides	100 ppb maximum
Acidity, mg KOH/g	0.01 maximum
Water content	30 to 35 ppm maximum
Resistivity, 100°C, 500 V, 0.1 inch gap	100 to 500 x 10^9 ohm-cm, minimum
Dielectric strength, 25°C	35 kv minimum

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When these or other properties cannot be met at the producer's facility, or by the user during transformer and capacitor filling operations, and it is found that the properties cannot be restored to askarel specifications by filtering and drying, disposal is required. The types of PCB contaminated liquids requiring disposal are:

1. PCBs contaminated with mineral oil
2. Mineral oil contaminated with PCBs
3. Nonreclaimable contaminated transformer askarels - arced askarels, askarels from manufacturing spills and sump accumulations, and askarels from holding basins, drip and drain pans, washings, sample jars and containers

1.1.2 PCBs in Wastewaters

The most likely pathways by which PCBs enter wastewater streams are operator wash-up after PCB handling and groundspills that mix into rainwater runoff. The significance of the first pathway can be illustrated by the realization that sixteen operators (or 4 operators 4 times a day) washing 1 ounce per day of PCB from their hands, account for one pound per day of PCB discharge.

Other wastewater categories discussed in the industrial characterization section of this report are:

1. Incinerator scrubber and quench water
2. Steam jet ejectors in vacuum distillation
3. Capacitor detergent wash solutions

1.1.3 PCB-Contaminated Solid Wastes

Solid wastes can be divided into two categories, burnable and nonburnable.

1.1.3.1 Burnable Solid Waste Materials Containing PCBs

Burnable wastes can be disposed of by high-temperature incineration. Such wastes consist of cellulosic materials, rags, pressboard, wood, sawdust, fuller's earth in bulk or in cloth bags, blotter papers, nitrile or cork gaskets, and similar materials.

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1.1.3.2 Nonburnable Solid Waste Materials Containing, or Contaminated with PCBs

Nonburnable wastes may consist of capacitor and transformer internal components; steel, copper and aluminum components; filter units of the steel mesh construction type; and askarel drums and cans. Wastes of this type should be drained, with the liquid collected in drip pans, before disposal.

1.1.4 Air Emissions of PCBs

Although PCBs have very low vapor pressures they can be emitted to the atmosphere from the following operations and practices:

1. Aroclor scrubbing of air in PCBs manufacture
2. Vapor exhaust from steam jet ejectors
3. Evaporation from accidental spills
4. Evaporation from hot surfaces as part of flood-filling, inspection or holding operations
5. Vacuum pump exhausts
6. Evaporation from plant wastewater

1.2 Summary of Current PCBs Waste Control Practices

1.2.1 Control of Waste Liquid PCBs and Contaminated Scrap Oils

Plant visits have shown the major control methods to be incineration and disposal in sealed drums sent to sanitary landfills. Both incineration and landfilling may be carried out by the facility generating the waste, or the facility may engage a contractor.

Monsanto, the only U.S. producer of PCBs, has an incinerator (designed by John Zinc, Inc.) that vaporizes PCB liquids and sustains them in a turbulent burning gas at more than 2200°F for 2 seconds. One transformer manufacturer uses a John Zink designed incinerator that vaporizes PCBs and burns them at 1600 to 1800°F for 3 seconds or longer; this facility can also destroy PCBs soaked into transformer internal parts, but cannot routinely handle spent fuller's earth.

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Several plants use methods to keep the quantity of PCB contaminated wastewaters as small as possible. A few plants planned adsorption tests with carbons and other adsorbents, but there were no full-scale operations.

1.2.3 Control of Solid Wastes Contaminated with PCBs

The two current methods of disposal of solid or semi-solid PCBs wastes are incineration and landfill. Since we found only one PCB-using manufacturing facility with partial incineration capability, and Monsanto's incinerator cannot handle solids, all facilities except one must ship their solid wastes away from the plant site for either treatment. The one plant with partial capability can incinerate transformer internals to recover copper, and also can incinerate paper, rags, cardboard and the like. However, they do not as yet, incinerate fuller's earth, contaminated dirt, and similar materials. These are drummed and stored for later disposition.

Although there are a number of experimental facilities throughout the U.S. that could undboutedly incinerate all types of solid materials, one commercial venture has received the bulk of the work. Rollins Environmental Services can handle liquids incineration. For solids incineration of almost all types, the tumble burner or rotary kiln is used. When PCB contaminated materials are to be destroyed, the kiln temperature is brought up to 2200°F. All kinds of solids, packed in 47-gallon lined fiber drums and not posing unusual safety hazards are accepted. The current (late 1975) fee is about 7-1/2¢/pound. Additional charges of $3/fiber-drum handling, plus transportation charges, and possibly other charges for unusual problems, might be made.

Rollins will not accept impact sensitive, radioactive materials, or heavy metals concentrations of more than 25 ppm in the PCBs wastes. For wastes packed in steel drums, Rollins charges a $10/drum handling charge. As a general rule, anything packed according to the latest ICC tariff for hazardous materials will be accepted.

As with the liquids incineration, the gases from the kiln at 2200°F pass to the afterburner at a temperature of about 2500°F. Gases exit

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the afterburner to a long hot duct that completes combustion and maintains the temperature at 2400°F until the gases enter the venturi scrubber, and thence to the lower scrubber and then the stack. Rollins has experimented with lower temperatures of 2000 to 2200°F and has not found destruction of PCBs to be at the 99.999 percent level desired. The residence time for gases at the 2400°F must be 3 to 4 seconds in a turbulent regime.

With regard to landfilling, one commercial venture has handled a large quantity of the PCB solid wastes under supervised conditions. The Chemtrol Pollution Services Co. of Model City, N.Y., operates a landfill located on the shore of Lake Ontario, under New York State EPA supervision, in a geologic setting claimed to be ideal for complete containment.

This "scientific landfill" is located entirely above ground on a bed of 40-feet-thick clay. Constructed on this foundation are cells for receipt of drummed solid wastes. The cells are lined with 30-mil chlorinated polyethylene film, and when loaded, are sealed, or covered with 5-feet of clay. At the bottom of each cell there is a sump, so that all leachate is collected and removed. That leachate is pH controlled, settled, filtered, and treated by flow through a carbon bed. The ground and surface waters are checked monthly for chemical content by an outside analytical laboratory. The facility has been approved for usage as a PCB disposal site by the New York State EPA, and thousands of drums have been landfilled over the last five years. An inventory is kept of the contents of each cell.

Chemtrol has the capability of converting semisolids and sludges to solids by using silicate cement powders and proprietary gelling agents.

Our review and analysis of the industrial situation for PCBs solid wastes control shows there are adequate options, at higher prices, for safe disposal and destruction. There is no longer a justification for open dumping to the ground or in lagoons.

1.2.4 Control of Air Emissions of PCBs

Most air emissions from ambient temperature PCBs are not controlled or collected for treatment in any way. PCB emissions generally are

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collected as part of the overall plant air exhaust, which frequently is ducted to roof exhausts without treatment. Several plants used exhaust chilling and/or fibrous or granular filtration of air; these methods offer the potential for PCB emission reduction.

The hot flood-filling of capacitors is followed by a cool down period before the filling tank is opened to the plant atmosphere. However, the temperature is still between 100 and 150°F; the area of the opening is several square meters, through which tank gases can reach the plant atmosphere. The tanks have individual exhaust ducts, but they lead directly to a roof exhaust system. The PCB-covered capacitors are held in an oven at 100 to 150°F to prevent any moisture condensation before sealing. Vapors from this storage are ducted to the roof and vented also.

In some cases, waste scrap oils containing PCBs are burned together with fuel oil in standard boiler systems. In these instances much of the PCB content is probably vaporized and exhausted to the air, rather than incinerated.

2.0 CANDIDATE PCBs WASTE TREATMENT TECHNOLOGIES CONSIDERED

As part of the examination phase of this study of alternative methods, we have contacted a number of equipment suppliers, developers, and researchers, in both the U.S. and elsewhere.

Key information was obtained on potential methods of PCBs removal from, and destruction in, wastewaters, by cooperative testing between Versar, Inc., and several materials suppliers and process developers. Their assistance is gratefully acknowledged.

We visited the U.S. producer, Monsanto, and several transformer and capacitor manufacturers to ascertain the nature, characteristics and quantities of plant effluents that now contain measureable amounts of PCBs, or might contain PCBs following a spill or other incident. This has provided the background for weighing the advantages and disadvantages of all available technology for potential application to PCBs wastewater treatment. We discussed and evaluated the control methods now used, possible shortcomings, and ideas for more optimized systems.

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In order to find the new technology and approaches that might be forthcoming, we made a computer search of Chemical Abstracts from 1972 to the present, and focused on degradation, decomposition and waste treatment data. Searches were also made of the Lockheed Engineering Index, National Technical Information Service, and Predicasts for information on new developments.

The text reference used as a source of summarized data prior to 1972 was: The Chemistry of PCBs, by Hutzinger, Safe and Zitko, published in 1974 by CRC Press.

Candidate treatment technologies have been divided into the same four categories listed in Section 1.1. Also, as we evaluated technologies, they were placed into categories, as follows, indicating their level of development:

1. Demonstrated Full-Scale Treatments
2. Pilot-Scale Methods
3. Research Approaches to PCBs Removal or Destruction

Some treatment methods were designed for disposal of compounds similar to the PCBs, e.g., chlorinated hydrocarbons and other refractory organics.

The full-scale plant treatments are ready for application to PCB waste problems now. The pilot-scale methods are expected to take one to five years to be developed to the point where they will be determined suitable, or unsuitable, for plant-scale PCBs applications.

Methods currently under development are expected to take three years or more before being ready for plant-scale applications.

Section 2.5 contains a discussion of the applicability of various treatments to the zero discharge objective.

2.1 Treatment of Waste Liquid PCBs and Contaminated Scrap Oils

Only two kinds of treatment or disposal methods are considered suitable for waste liquid PCBs and contaminated scrap oils, and they are now being used. However, there are improvements and design features needed to prevent PCB transfer into the water, air or land.

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2.1.1 Incineration

The standard configuration, long cylindrical steel combustion chamber, having a length to diameter ratio of between 4/1 and 8/1 and well insulated with high alumina refractory brick, is suitable as a primary chamber. Two injectors should be provided: one for a high-BTU gas or fuel oil, and one for the PCB waste liquid. Primary air or steam is provided to vaporize oils, and secondary air is added to complete combustion and provide excess air. These feeds should be made tangentially, or with adequate baffling to assure turbulent flow throughout, and to prevent hot or cold spots in the chamber. It is obvious that almost any residence time may be allowed for a gas flowing through a cylindrical chamber. However, there is a maximum residence time above which turbulence is assured throughout the chamber. Turbulence throughout is assured when wall temperatures are uniform in all parts of the chamber. Most fuel flames provide adiabatic combustion temperatures of about 3000°F. When the more endothermic PCBs are being destroyed, the flame can be rapidly cooled to 2200 to 2500°F; for the very high destruction efficiences desired, 99.999 percent or higher, this is the minimum temperature range required, for a residence time of 3 to 4 seconds. After combustion there should be allowance for afterburning, which may be accommodated in insulated ducts. These can be of sufficient length to assure total residence time of 3 to 4 seconds. Following the combustion phase there must be rapid cooling of the gases, usually by the injection of cold water from a peripheral ring of sprays or jets. Also, the cooling water should be neutralized so that hot hydrochloric acid contact with further components is obviated.

In some systems a high energy venturi scrubber is used to control particulates, if they are expected in the gas stream. In all systems the gas stream is then washed counter currently with water, or water plus neutralizing agent, in some form of a packed tower. Usually a demister is the last element contacted by the gas before it is exhausted through the stack.

The stack gas emissions and the scrubber effluent liquid should be monitored periodically for PCBs levels, and the incinerator should

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have adequate automatic controls to prevent PCBs from being emitted undestroyed. The chief fail-safe control is a pyrometer that causes burner shutdown if the combustion chamber or duct temperature drops below about 2150°F. There are other controls that can warn if such an occurrence might take place. These flow rate controls on the primary and secondary feeds can be monitored so that low fuel flow, or high PCBs-to-fuel flow ratio can indicate a temperature drop. Inadequate air flow can also cause temperature decreases. All such parameters should be monitored, and adequate operator warnings provided. And, of course, to prevent destruction of the venturi scrubber sections, shutdown should automatically take place if cold water flow is ever insufficient.

2.1.2 Sanitary or Scientific Landfill

Sanitary landfilling is an alternative to incineration for PCB users who cannot justify incineration facilities just for PCBs, and who have no waste pickup service organization within reasonable distance. Landfills that will adequately contain PCBs should have all the features described in Section 1.3.3 above, plus there must be assurance that the liquid containers will be sealed and leak proof, and have long life in the landfill.

2.2 Treatment of Wastewaters Containing PCBs

Treatment of wastewaters containing PCBs has received very little attention in practice thus far. Our survey has found a variety of methods for reduction, and even for achieving "zero discharge", of PCBs in wastewaters.

2.2.1 Carbon Adsorption

Carbon adsorption is a well-known water purification and industrial product purification technique. The use of carbon adsorption is well-suited to removing PCBs from wastewater since it is most effective in removing high molecular weight, non-polar, relatively insoluble compounds from water. All these requirements are met by the PBCs.

As will be discussed later, Versar has conducted tests, in cooperation with carbon suppliers, demonstrating the relative effectiveness of

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various activated carbon products. PCB concentrations on the order of 1 ppb were taken as a reasonable effluent objective.

The disadvantage of carbon adsorption is that once used, the carbon may have to undergo destruction by high temperature incineration rather than be regenerated, as is the usual practice. The great advantage of carbon treatment is that a wide spectrum of other toxic organics can simultaneously be effectively removed from water.

Carbon adsorption is currently being used in large-scale municipal water purification systems. Thus capital costs, operating costs and reliability factors are well-known. At the 68th Annual AIChE Meeting in November 1975, G. Strudgeon of Zurn Industries described design features for a 30-million-gallon-per-day carbon system to be built for municipal wastewater treatment at Garland, Texas. This system will cost $5 million, including carbon regeneration. Operating costs are expected to be $6,000 per day.

Although carbon adsorption is the only mechanism thus far proven effective in removing PCBs, three other carbon-based treatment techniques are under study: biodegradation, whereby bacteria-coated carbon particles break down pollutants in wastewater; catalytic action, wherein a very active surface holds pollutant molecules while other degradation or oxidation reactions take place; and chemical reaction, in which carbon is actually depleted as part of a chemical reaction that removes pollutants. The techniques were also discussed at the 68th Annual AIChE Meeting.

As an adjunct to this evaluation study, Versar conducted cooperative laboratory adsorption isotherm tests with Carborundum Company and ICI-US. These tests have extended the ranges of carbon adsorption data published by Calgon Corp. into higher and lower concentrations. Laboratory adsorption isotherm testing is a reliable technique for determining the feasibility of adsorption treatment for PCBs removal from wastewaters and specifically indicates:

1. The effluent levels of PCBs concentration obtainable by adsorption treatment
2. The weight of PCBs adsorbed at the concentrations being studied

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On the other hand, the laboratory test does not determine the necessary contact time for granular carbon beds to effect the desired reduction. This determination is usually performed in small pilot carbon beds under hydraulic flow conditions.

Laboratory and pilot plant tests involving PCBs must be designed to prevent losses of PCBs. The root of the problem is the very low, parts per billion, solubility of PCBs in water. Examples of pathways of experimental loss are:

1. Evaporation to the air
2. Adsorption on a variety of solid surfaces and sediments

2.2.1.1 PCBs Adsorption Testing by Carborundum Company

Versar, Inc., together with Carborundum Co., conducted a preliminary study to determine the ability of an experimental, coal-based activated carbon in removing PCBs from water. This study also provided an analytical check in that both companies made electron-capture gas chromatograph analyses on the same samples, and there was close agreement on results.

The coal-based activated carbon had a surface area of 950 to 1050 square meters per gram. The iodine number was approximately the same as the surface area, indicating that almost all of the pores had a diameter greater than 10 to 15 Angstroms.

The control and test samples were filtered before extraction and gas chromatographic analysis. The removal of PCBs by solids, surfaces, filter media, and the like, was known and expected prior to these tests, thus a high PCB concentration in the filtered control and test samples was the target.

The PCB mixture used was Aroclor 1254. It was solubilized by methanol to give a 1000 ppm stock solution. This was diluted with distilled water to prepare 1000-ppb test solutions.

Table 2.2.1.1-1 presents the data. The filtered control level is considered the actual level the carbon was adsorbing, rather

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TABLE 2.2.1.1-1

CARBORUNDUM CO. TESTS OF PCBs (AROCLOR 1254)
REMOVAL FROM WATER BY AN EXPERIMENTAL ACTIVATED CARBON

Prepared PCBs Concentration (ppb)		Carbon Dosage[1] (mg/l)	PCBs Conc. Before Treatment [Control Conc. After Filtering] (ppb)	Effluent PCB Conc. After Carbon Treatment (ppb)	Percent PCBs Removal
Control -	1000	—	160	—	—
Test	1000	1.0	160	59	63.1
Test	1000	2.0	160	20.6[2]	87.1
				22.0[3]	86.2
Test	1000	10.0	160	2.6[2]	98.4
				2.4[3]	98.5

NOTES: [1] Experimental material, coal-based, 950-1050 square meters/gram.
[2] Versar Inc.'s analysis.
[3] Carborundum Co.'s analysis.

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than the prepared level. The filter removed 84 percent of PCBs in these test runs.

As shown in Table 2.2.1.1-1, the percent PCBs removed from a concentrated water solution (160 ppb) at low carbon dosages was quite good. During plant surveys we found PCBs concentrations in wastewater destined for river discharge to range from 50 to 500 ppb, so the 160-ppb concentration treated in this study was an intermediate value; it was, however, also the highest value treated in the cooperative studies under this program.

Carborundum Co. plans to continue this effort to determine the effects of other carbon dosage levels on various feed PCBs concentrations. The data given here are only considered preliminary.

2.2.1.2 PCBs Adsorption Testing by ICI-US

In a cooperative program with Versar, ICI-US performed preliminary adsorption tests to determine the ability of powdered carbon in removing Aroclor 1254 from water. Versar conducted all analytical tests for this program.

The Aroclor was solubilized with methanol so that a 1000-ppm concentration of Aroclor 1254 in water was achieved. Two types of granular activated carbon were tested: lignite base, and coal base. Both types were ground to a fine powder (90 percent through 325 mesh) before adsorption testing. Prior to grinding, the lignite-base and coal-base carbons had a surface area of about 650 square meters per gram and 1000 square meters per gram, respectively.

The test solutions were made up from distilled, deionized water to a volume of 1 liter. Four levels of Aroclor concentrations were treated: 10 ppb, 100 ppb, 500 ppb and 1000 ppb. Both the control and treated solutions were filtered before analysis. The great affinity of PCBs for all solid surfaces was not fully anticipated, during these tests. The filtration was uniform for all samples through 2.4-cm Reeve Angel fiberglass discs (Grade 934AH). As can be seen in Table 2.2.1.2-1, most of the PCBs were

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TABLE 2.2.1.2-1

ICI-US TESTS OF PCBs (AROCLOR 1254) REMOVAL
FROM WATER BY TWO TYPES OF COMMERCIAL CARBONS

Prepared PCBs Concentration (ppb)	Carbon		PCBs Conc. Before Treatment (Control Conc. After Filtering) (ppb)	Effluent PCBs Conc. (After Carbon Treatment) (ppb)	Percent PCBs Removal
	Type	Dosage (mg/l)			
Control, 10	—	—	1.07	—	—
Test, 10	Lignite[1]	4	1.07	0.177	83.5
Test, 10	Coal[2]	4	1.07	0.190	82.2
Control, 100	—	—	11.15	—	—
Test, 100	Lignite	30	11.15	0.213	98.1
Test, 100	Coal	30	11.15	0.111	99.0
Control, 500	—	—	5.32	—	—
Test, 500	Lignite	100	5.32	0.09	98.3
Test, 500	Coal	100	5.32	0.114	97.9
Control, 1000	—	—	37.5	—	—
Test, 1000	Lignite	100	37.5	0.32	99.2
Test, 1000	Coal	100	37.5	0.24	99.4

NOTES: [1] Larger pore, 650 square meters per gram.

[2] Smaller pore, 1000 square meters per gram.

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removed in filtration. However, by using the filtered "control sample" as an approximation of the amount the filter removes from all feed samples, we can get a good preliminary estimate of the PCBs removal ability of the two kinds of commercial carbons at various wastewater pollutant levels, and at various carbon dosages.

The results of these laboratory tests indicated that powdered carbon was highly effective in removing PCBs from water at four levels from 1 to 40 ppb. There was not a great deal of difference between the effectiveness of the two carbons. The lignite carbon has relatively large pores and smaller surface area than the coal-based carbon. The lignite-based carbon simulates the activity of the coal-based carbon after the latter has a number of thermal regenerations. Thermal regeneration tends to increase the pore size, and lower the surface area of any given carbon. These kinds of activated carbons, however, tend to stabilize at about 550 square meters per gram, even after many regenerations.

The conclusion from these results is that carbon-adsorption can be effective in removing PCBs from wastewaters, even after many thermal regenerations. It is quite significant that in all these tests, the treated effluent PCBs levels ranged from 90 to 320 parts per trillion, which are well below the target maximum PCB level of 1 ppb.

Further testing is needed to get confirmatory isotherm data and column test data. In column tests, the granular form of carbon was used, and, therefore, some of the interior portions of the carbon were not as accessible as they would have been in the powdered form. Thus the tests with powdered carbon, given on a weight fraction basis (i.e., pounds PCBs removed per pound of carbon), yield the maximum weight fraction of PCBs that that can be removed in a scaled-up commercial system.

2.2.1.3 PCBs Adsorption Testing by Calgon Corp.

Adsorption isotherms were run on Aroclor 1242 and 1254. Stock solutions of each compound were prepared in acetone at 100 mg/l.

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Filtrasorb(R) 300 (FS-300) activated carbon was used throughout. Carbon was added from a stock suspension of 1 g or 2 g of pulverized FS-300 per liter of distilled water.

Isotherms of Aroclor 1242 and 1254 were prepared by the following method. Exactly 1 ml of PCB solution was added to seven flasks, each containing slightly less than 1 liter of distilled water. Measured volumes of the 2 g/l carbon stock solution was added to each flask to give carbon concentrations of 0,2,5,10,25,50 and 100 mg/l. The total volume of each flask was 1000 ml. After four hours agitation on a wrist shaker, each solution was filtered through 0.45 micron millipore pads and stored prior to analysis in a refrigerator in quart amber glass bottles having Teflon-lines caps.

A nickel-63 electron capture gas chromatograph was used for analysis; all samples were extracted and concentrated approximately 100 times before analysis. The method is described in the 1971 EPA report, "Methods for Organic Pesticide Analysis in Water and Wastewater."

Table 2.2.1.3-1 shows the PCBs removal data, and gives comparative data for Aldrin. It appears that the Aroclors are removed as effectively as pesticides. Removal from the 50-ppb level to the 1-ppb level seems possible.

Figure 2.2.1.3-1 shows the Calgon data plotted to give the weight percent of PCBs that Filtrasorb-300 carbon can adsorb, at levels down to 1 ppb. As can be seen, the curves take a downward break at about 2 to 3 ppb, indicating that the weight of activated carbon required to remove a unit weight of PCBs is rising rapidly. If this kind of data is confirmed with larger-scale column testing, it would mean that removal of PCBs from water in the parts per trillion range is far more difficult than removal in the parts per billion range.

Also from the figure it can be seen that the initial concentrations (C_o) of the Aroclors were about 100 ppb. However, filtration before testing removed PCBs so that the starting concentrations for the tests were 45 and 49 ppb.

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TABLE 2.2.1.3-1

RESULTS OF CALGON CORP. LABORATORY ISOTHERM TESTS FOR CARBON REMOVAL OF PCBs

Carbon Dosage (mg/l)	Residual (ppb)		
	Aroclor 1242	Aroclor 1254	Aldrin
Control	45	49	48
1.0	—	—	—
2.0	7.3	37	26
2.5	—	—	—
5.0	1.6	17	15
10.0	1.1	4.2	12
12.5	—	—	—
25.0	—	1.6	6.3
50.0	—	1.2	4.4

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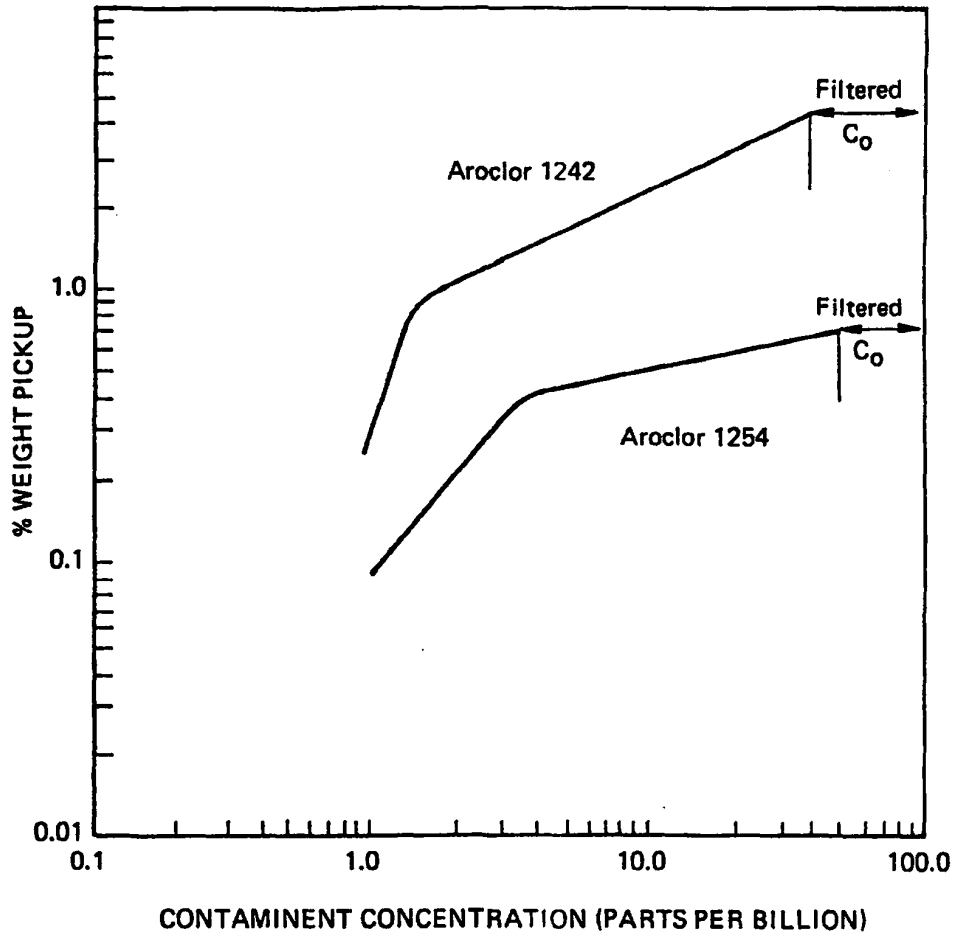

Figure 2.2.1.3-1. EQUILIBRIUM CARBON ADSORPTION OF PCB'S FROM WATER AT LOW CONCENTRATIONS (CALGON DATA)

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Carbon beds are normally in excess of 10 feet deep and usually fall into one of four basic configurations:

1. moving beds
2. beds in series
3. beds in parallel
4. expanded beds

The type of configuration selected depends on a number of variables; principal among them are total water flow, suspended solids, and degree of contaminant reduction desired.

2.2.1.3.2 Reactivation of the Granular Carbon

Thermal oxidation, using either multiple hearth furnaces or rotary kilns, is generally employed to reactivate the exhausted carbon. The size of the thermal reactivation equipment is based on the carbon exhaustion rate, i.e., pounds of carbon exhausted per thousand gallons of wastewater treated, and the weight of contaminant on the carbon. Excess capacity is designed into the thermal reactivation unit to allow for variances in carbon use rate due to changes in the wastewater flow and organic loading.

The exhausted granular activated carbon is heated to 1600 to 1800°F to effect volatilization and oxidation of the dissolved organic contaminants. Oxygen in the furnace is normally controlled at less than 1 percent to effect selective oxidation of contaminants over activated carbon. A 5 percent loss of activated carbon per reactivation cycle is an acceptable bench mark upon which to base granular carbon system economics. Particularly for the PCBs, which require an incineration temperature in excess of about 2200°F plus several seconds residence time, the reactivation equipment must include an afterburner. An air scrubber with HCl neutralization would be the last element of the reactivation train. Thus far, the regeneration of carbon used for PCBs adsorption has not been proved.

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2.2.1.3.3 Carbon Transport

Granular spent carbon is usually transported between the adsorbers and the reactivation equipment by water slurry. Various pumping designs can be employed including centrifugal and diaphragm pumps as well as hydraulic or pneumatic pressure. The transport piping should include flush ports and wide radius bends. Typical loading is between 1 and 3 pounds of carbon per gallon of water, depending upon distance and elevation considerations.

2.2.1.3.4 Materials of Construction

Special consideration should be given to the selection of materials of construction with regard to corrosion and erosion.

1. Galvanic Corrosion - Any tendency toward galvanic corrosion due to water characteristics, such as conductivity and pH, will be enhanced in granular carbon beds. Mild steel tanks or adsorbers holding granular carbon under water should be lined. Tanks can also be constructed of cement or reinforced synthetic resins or plastics.

Carbon-in-water slurry piping, which experiences only periodic exposure, is usually exempted from special corrosion considerations.

2. Erosion - Periodic replacement of the carbon beds can cause lining failures at exit ports in carbon tanks and adsorbers. Special grades of stainless steel are usually employed for such wear points.

2.2.1.4 Carbon Regeneration Alternatives - Wet Catalytic Oxidation

For small installations, it might prove feasible to dispose of spent carbon by incineration. Carbon supply companies also offer spent carbon removal services and off-site regeneration.

However, there is a new wastewater treatment technique which might be applicable to carbon regeneration, namely wet catalytic

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oxidation. Several laboratory studies in wet catalytic oxidation are described in Appendix C. Lockheed Missiles and Space Co. (Waste Treatment Systems Section) of Sunnyvale, California, announced in January, 1976, that they have a process ready for pilot plant evaluation and commercial scale-up.

In a preliminary look at the PCBs destruction potential of wet catalytic oxidation, a wastewater sample from an unnamed user of PCBs was subjected to treatment. The PCB mixture approximated Aroclor 1221 most closely, and was very concentrated to 5 ppm in the wastewater sample. Since 5 ppm is much higher than that Aroclor's solubility in pure water, it is believed that solubilizing agents or particulates were carrying most of the PCBs. Within 20 minutes of treatment time, however, about 90 percent of the PCBs had been destroyed, and no large quantities of reaction products were detected. However, this is just one data point and confirmation is needed. The test reactor was a continuously stirred batch system, with air continuously sparged in. The test conditions used were: reactor pressure, 1500 psig; temperature, 550°F; catalyst concentration, 0.5 gram; and reactor volume, 1.5 liters.

The proposed use of wet catalytic oxidation is for carbon regeneration while in spent water slurry form.

Since the capital and operating costs of the catalytic system are tied to the hydraulic load, it might be practical to trap PCBs with carbon in wastewater, and then treat the carbon slurry by catalytic oxidation to destroy the PCBs. In this way, PCBs would be removed from the wastewater by the highly efficient carbon adsorption method, while the volume handled by the catalytic system would be greatly reduced.

Feasibility testing for regeneration of activated carbon by catalytic oxidation is needed. The activated carbon industry has long sought alternatives to thermal regeneration of carbon, because of the loss of carbon by oxidation. With solvent regeneration, or acid or base treatment, the first regeneration only produces about 40 percent of the active surface, which then usually decreases to 30 percent after several more treatments.

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Such degradation is unacceptable. Thus the questions to be answered are: a) Can catalytic oxidation destroy adsorbed PCBs on carbon, converting them to CO_2, H_2O and HCl? b) Will the regenerated carbon have, say, 90 to 95 percent of its original activity? c) Can the process be operated economically? The last question must take into account the necessary operation pressures (500 to 2000 psi), operating temperatures (300 to 650°F), source of oxygen (air, O_2 or ozone), type and lifetime of catalyst, residence time, and materials of construction, among other variables.

2.2.1.5 Further Applications Data

ICI-US provides an excellent booklet entitled "A Symposium on Activated Carbon", providing considerable detail on applications. ICI also provides information on special graphical procedures helpful in the scale-up from isotherm to column testing.

2.2.2 Ultraviolet-Assisted Ozonation

Both UV radiation, and ozone, separately, have been used in water purification for some time. But only in the last five years or so has the synergism of the combination been appreciated in the destruction of organics in water.

Two commercial organizations, Houston Research, Inc., of Houston, Texas, and Westgate Research Corp. of Marina Del Rey, California, are engaged in development of UV-assisted (or catalyzed) ozone oxidation of refractory organics. Both organizations have cooperated in preliminary tests of PCBs destruction, and the method has shown great promise as a large-scale, economic water treatment method. The companies are working mostly with 253.7 nanometer, near-UV, radiation, but they plan to investigate far-UV mercury radiation at 184.5 nm.

It is of particular significance that these methods promise destruction of hydrocarbon organics completely to CO_2 and water. Thus they are likely candidates for zero discharge and total recycle systems.

Related to this is the work of Lawrence at Environment Canada (Burlington, Ontario), who is studying the use of near-UV radiation (about

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365 nm), available from sunlight, in conjunction with titania or alumina photocatalysts rather than the combination of UV and ozone. The ultraviolet region extends to 380 nm, and then blends into visible violet. Studies using visible light are described further below.

UV radiation is generally provided by commercially available tubes, which when operated at low power (and low pressure in the emitting tube) are quite efficient in transferring UV radiation to water. The range of effectiveness is quite short, probably of the order of a few inches maximum, because UV transmissibility in water is poor, and is degraded further by even small amounts of particulate matter.

Ozone is sparged into the reactor, and vigorous stirring is provided until increasing turbulence or mixing power input does not further increase reaction rate.

Various kinds of efficiency values are given to rate different systems, flows, arrangements, etc. For overall efficiency, the units of measure are total organic carbon removed per watt-second of UV input, or per gram of ozone introduced.

Since ozone generation is expensive, work is directed toward optimum use of the ozone introduced. The cost is almost completely that of the electric power used in the silent discharge tube method of making ozone from air. And, of course, UV generation is also an electric power cost factor.

The following subsections discuss UV radiation and its molecular interactions, the photodegradation of PCBs, and UV-assisted ozonation experiments with PCBs.

2.2.2.1 Molecular Responses to Ultraviolet Energy

Energy absorbed in the ultraviolet region (10 to 380 nm) causes electronic transitions within molecules. The principal characteristics of an absorption band are its wavelength and intensity. The wavelength of maximum absorption (λ max) corresponds to the wavelength of radiation having energy equal to that required for an electronic transition. A molar

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absorptivity at maximum absorption (E max) of 10,000 calories per mole or greater is regarded as high intensity absorption. Low intensity absorption is considered an E max of less than 1,000 calories per mole; biphenyl in alcohol at 250 nm has an E max of 18,000, and in hexane at 246 nm, an E max of 20,000.

This would seem to indicate that the basic structure of the PCBs would be readily activated by a mercury lamp generating 253.7-nm radiation. However, this absorption will be modified by the number of chlorine atoms attached to the biphenyl groups. If at any point in the destruction of PCBs, saturated hydrocarbons are formed, they will be unresponsive to 253.7-nm radiation. Saturated hydrocarbons contain sigma electrons exclusively. Since the energy required to bring about ionization of the sigma bonds is of the order of 185 kcal per mole it is only available in the far ultraviolet, below 200 nm. Single carbon-carbon and carbon-chlorine bonds have about the same high bond energy, and are similarly resistant to rupture; however, there is a mercury emission at about 185 nm, which should be capable of activating those bonds, thus making them highly reactive in the presence of oxidizers such as ozone.

Thus it appears possible to produce the excited states in PCB molecules necessary to make them highly receptive to oxidation. Since ozone is a powerful oxidizing agent, and it too is excited in the same regions making it even more effective, the possibilities for a wide range of oxidations are present. This would seem to make complete destruction of PCBs to CO_2, water and HCl feasible.

2.2.2.2 Photodegradation of PCBs

Because of the strength of the C-Cl bond, it has heretofore been assumed that little photochemical cleavage occurs. Further, in the photochemical breakdown of DDT and related compounds, cleavage of the aromatic C-Cl bond is usually not involved. However, Safe and Hutzinger reported in Nature in 1971, that hexachlorobiphenyl photolyzed readily in organic solvents when irradiated at 310 nm. The resultant products are formed by stepwise loss

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of chlorine, rearrangement, and condensation. Other researchers have found that certain pure chlorobiphenyls and PCB mixtures can be decomposed by laboratory UV sources and by sunlight, over long time periods.

The wavelength of the UV radiation appears critical to photochemical decomposition. Low-pressure mercury lamps emitting 254 nm seem to be several times as effective as the UV from sunlight, which is greater than 295 nm. Studies have been carried out in organic solvents and water, and in both liquid and vapor states.

Much of the past work has been on organic solvent solutions of PCBs in order to have high working concentrations. Vapor phase studies have been run to simulate treatment of atmospheric emissions in environmental studies.

Reductive dechlorination, the main photoreaction of chlorobiphenyls, is faster in hydroxylic solvents such as methanol and isopropanol. Even chlorobenzene loses chlorine rapidly on irradiation in isopropanol. Complete dechlorination of a PCB mixture has been observed in 15 minutes in an alkaline isopropanol solution, using a mercury lamp (Anon., Chemical Marketing Reporter, Nov. 6, 1972, page 22). Biphenyl and sodium chloride were identified in the reaction mixture.

Photosensitizers can increase the decomposition rates. Tryptophan, diethylaniline, benzophenone and triphenylene sensitized the photoreaction of dichlorobiphenyl. The reaction was quenched by n-hexyl mercaptan and di-n-butyl sulfide. Experiments in water solution have been hampered by adsorption of the PCBs on the walls of reaction containers, particularly ones made of glass.

Attempts have been made to use surfactants to keep the PCBs in suspension. Adsorption on such solids as calcium carbonate, silica, and soils, in water suspension, has been tested as an aid to photolysis. However, UV radiation will not penetrate deeply into solids, so adsorbed PCB must be kept close to the surface.

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2.2.2.3 Experimental Factors in UV-Assisted Ozone Oxidation of PCBs

For several decades the advantages of ultraviolet radiation in the sterilization of aqueous and dry media have been known. Likewise, the powerful sterilizing, oxidizing effects of ozone have been known. Only with the relatively recent advent of requirements for removing refractory organics from water, and the ability to detect these organics in parts per trillion and even lower concentrations, has the need for powerful oxidizing capability been felt. It was quite natural to combine the two effects into a single treatment or staged treatments, with the result being a strong synergism in many cases.

Enough data has now accumulated to show that UV/ozone wastewater treatment is a powerful method for removal of refractory organics. It has the potential of removing organics to an effective zero discharge level. However, as the decrease in very small concentrations becomes exponential with time, the residence time required in UV/ozone treatment equipment becomes a critical factor. The following variables have been identified as affecting residence time:

1. Molecular structure of the organic
2. Concentration
3. UV transmissivity of the wastewater
4. UV intensity
5. UV wavelength
6. Ozone concentration
7. Liquid turbulence and gas-liquid contact (transfer coefficients)
8. pH
9. Temperature

The following subsections present experimental findings about the relative significance of these variables.

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2.2.2.4 Destruction of PCBs and Refractory Organics at Houston Research, Inc.

2.2.2.4.1 PCB Destruction Data

In preliminary experimentation on the feasibility of PCBs destruction, a high pressure 650-watt mercury tube generating 253.7-nm radiation was used in a 21-liter reactor. Figure 2.2.2.4.1-1 shows the arrangement for a smaller reactor. Oxygen, with an ozone concentration of 2 percent, was sparged in at 3 liters per minute. This was felt to be excess ozone usage, but a good starting point for tests. A 1000-ppm solution of Aroclor 1254 in methanol was used to get a 514-ppb solution of Aroclor 1254 in water. Otherwise the solubility of Aroclor 1254, which is about 50 percent pentachlorobiphenyl, is only 12 ppb in water. It was theorized that significant destruction of this compound would forecast even greater destruction of the other Aroclors now produced, which are all less chlorinated and more soluble in water.

Figure 2.2.2.4.1-2 is a plot of the normalized residual concentration of Aroclor versus time of UV-assisted ozonation. It can be seen that in 1 hour about 2/3 of the PCBs had been decomposed; and in 3 hours, only about 7 percent of the original PCBs remained.

2.2.2.4.2 Operating Data Obtained from Refractory Organics Tests

Houston Research has been studying ozonation for water purification for more than four years. Comparison tests have shown that the addition of UV radiation enhances the reaction rate by 10 to 100 fold. Further it was found that, for the most refractory compound they had tested prior to the PCBs, acetic acid, there was essentially no reaction without UV assistance. However, with UV radiation, the oxidation proceeds rapidly at room temperature.

Figure 2.2.2.4.2-1 shows the effects of UV and temperature on acetic acid destruction. The ordinate is the fraction of total organic carbon remaining, showing that for the 30°C or 50°C tests, with

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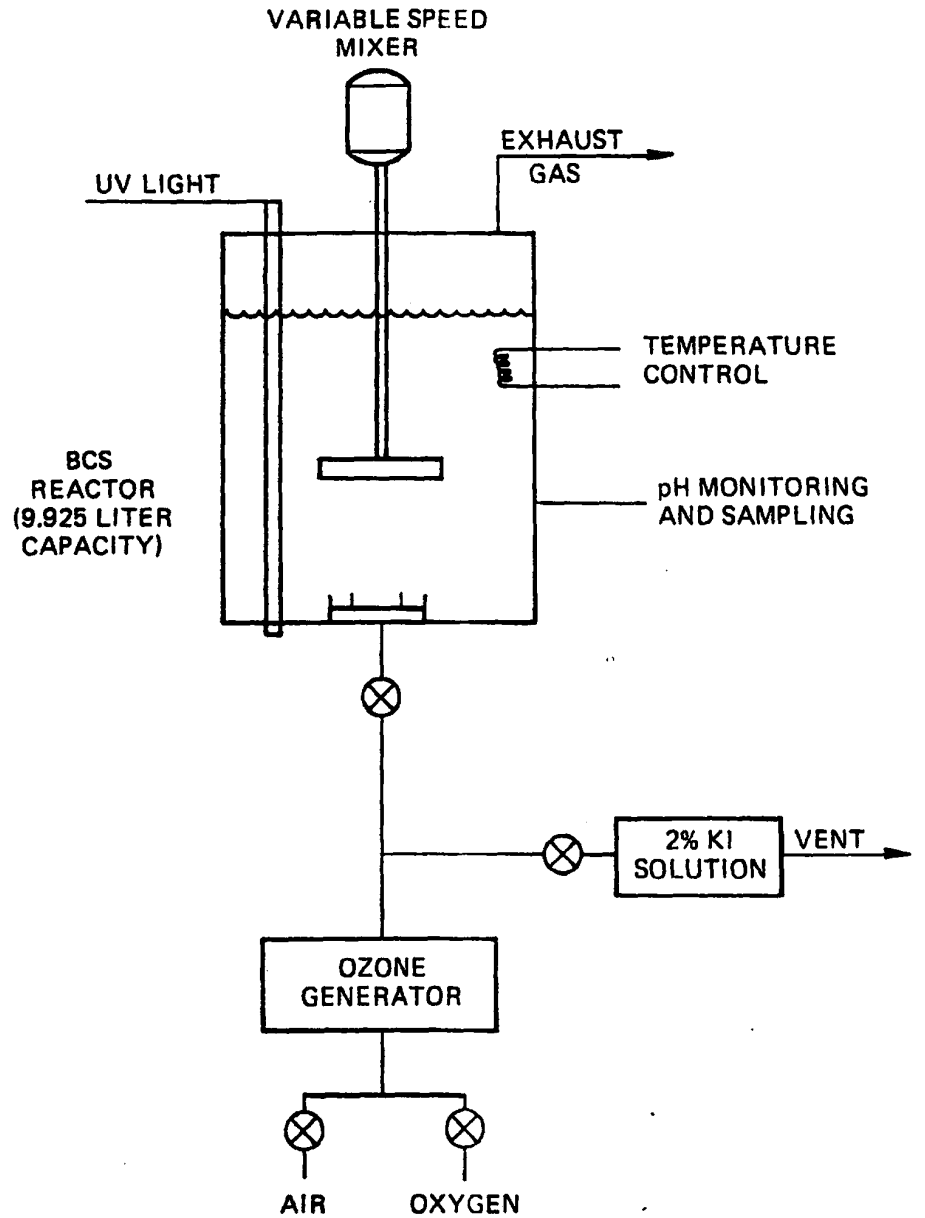

Figure 2.2.2.4.1-1. LAB SCALE APPARATUS FOR REACTION AND MASS TRANSFER STUDIES AT HOUSTON RESEARCH, INC.

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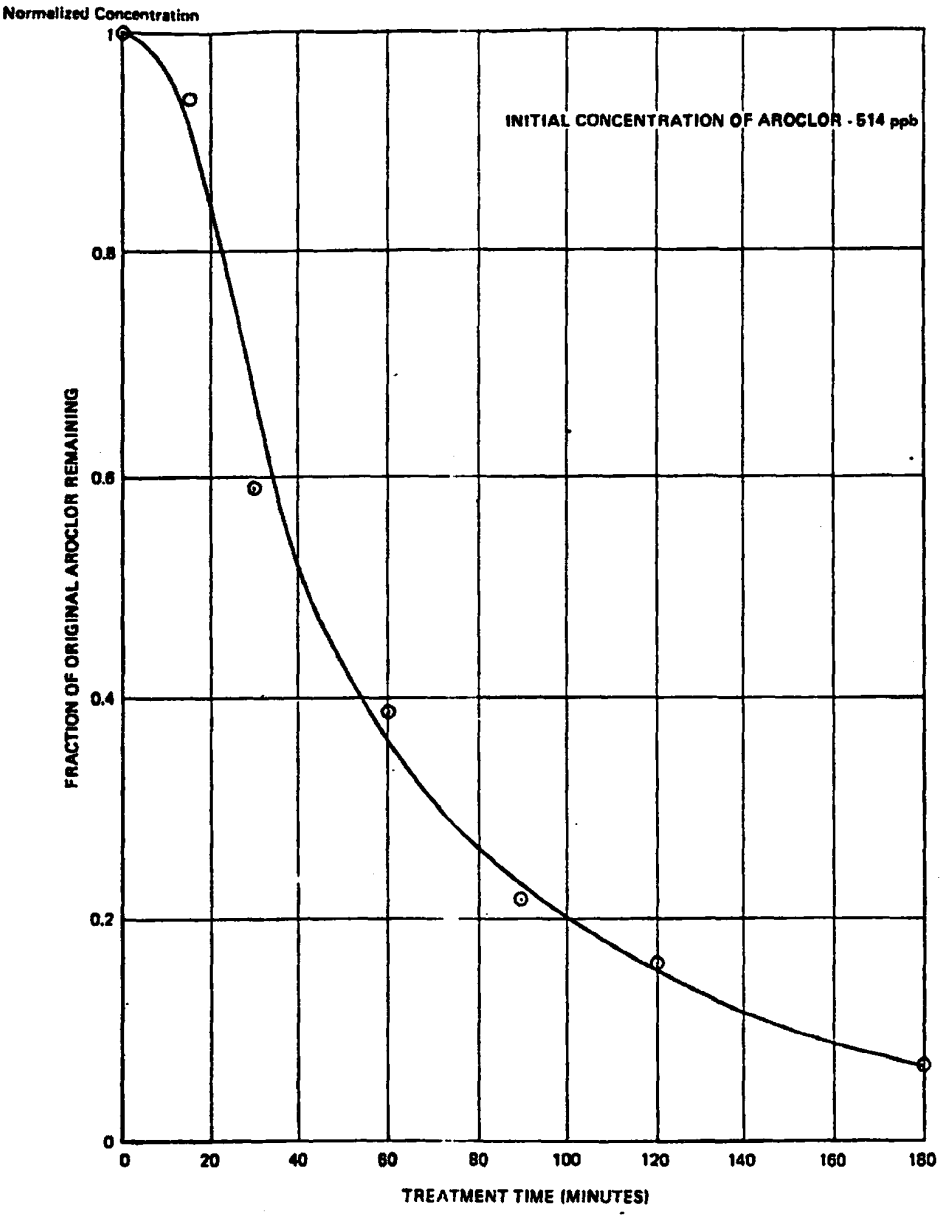

Figure 2.2.2.4.1-2. AROCLOR 1254 DESTRUCTION BY UV-ASSISTED OZONATION

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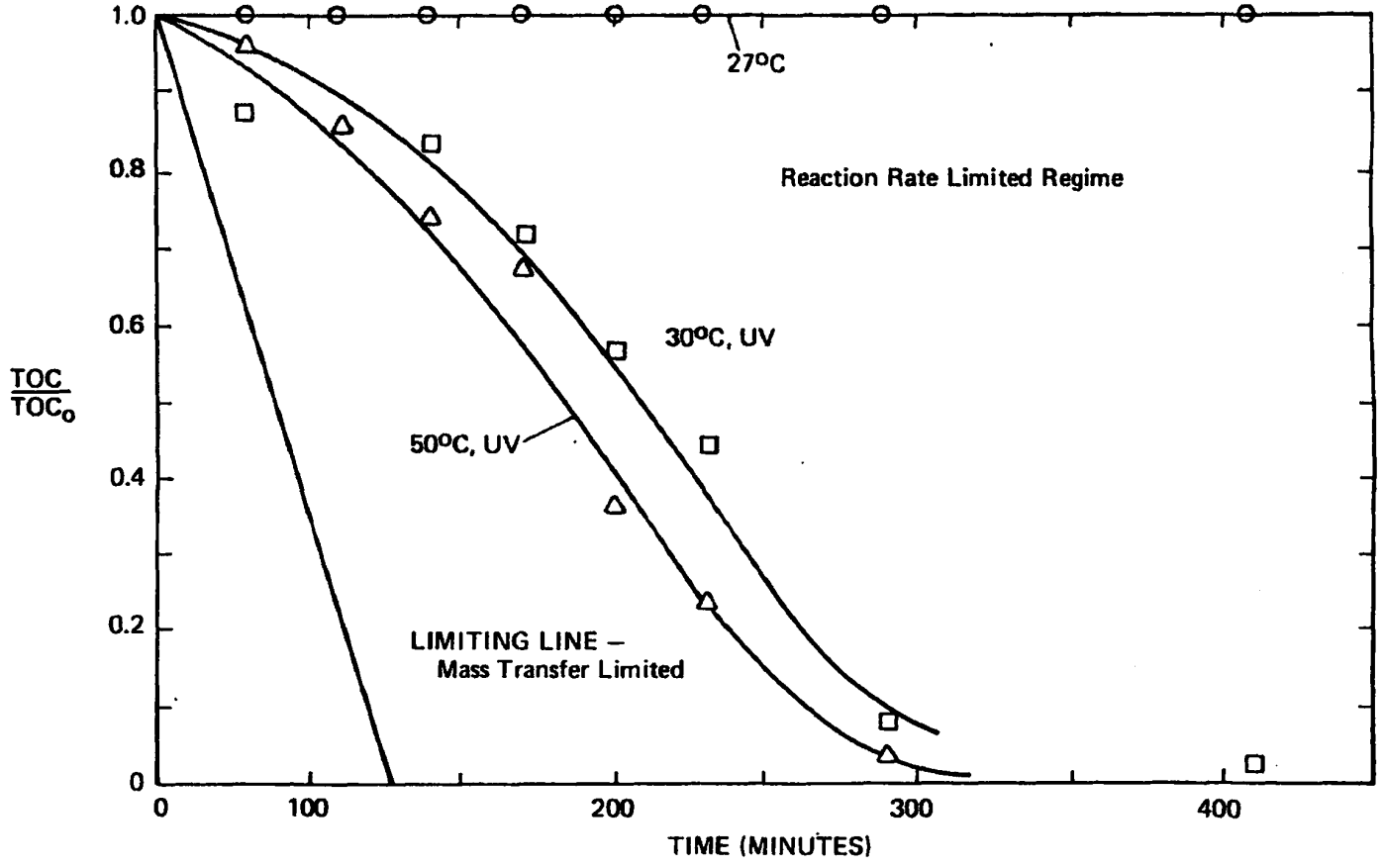

Figure 2.2.2.4.2-1. OZONE OXIDATION OF ACETIC ACID, EFFECT OF UV AND TEMPERATURE (INITIAL CH_3COOH - 105 mg/1, O_3(l) = 3.5 mg/1)

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UV, there is nearly complete destruction to CO_2 and water within 4 to 5 hours The fact that the curves are displaced to the right of the mass transfer limiting line shows that some chemical reaction rate improvement can be sought.

Figure 2.2.2.4.2-2 shows the oxidation improvement achieved by doubling the UV power input, with near constant temperature. Further description may be found in: "Ozone/UV Process Effective Wastewater Treatment", by Prengle, Mauk, Legan and Hewes, in Hydrocarbon Processing, October, 1975.

These are a sampling of the kinds of optimization experiments that must be run with the PCB oxidation system to obtain good economy of design and efficiency of operation.

2.2.2.5 Destruction of PCBs and Refractory Organics at Westgate Research Corp.

2.2.2.5.1 PCBs Destruction Data

Cooperative testing and research between Versar, Inc., and Westgate Research, Inc., determined the effectiveness of Westgate's UV-assisted ozonation process in destroying PCBs. The following experimental conditions were used in the treatment of synthetic wastewaters containing Aroclors 1254 and 1016:

Reactor volume = 3 liters

Reaction time = 4 hours (excess time used to give best chance of destruction)

UV Source = one 43-watt, low-pressure Hg lamp operating at 253.7 nm

Reactor type = vertical, cylindrical, 18 inch long, 3 inch diameter (UV path length = 2 inches)

Pressure = atmospheric

Temperature = 23°C

pH = 6.2

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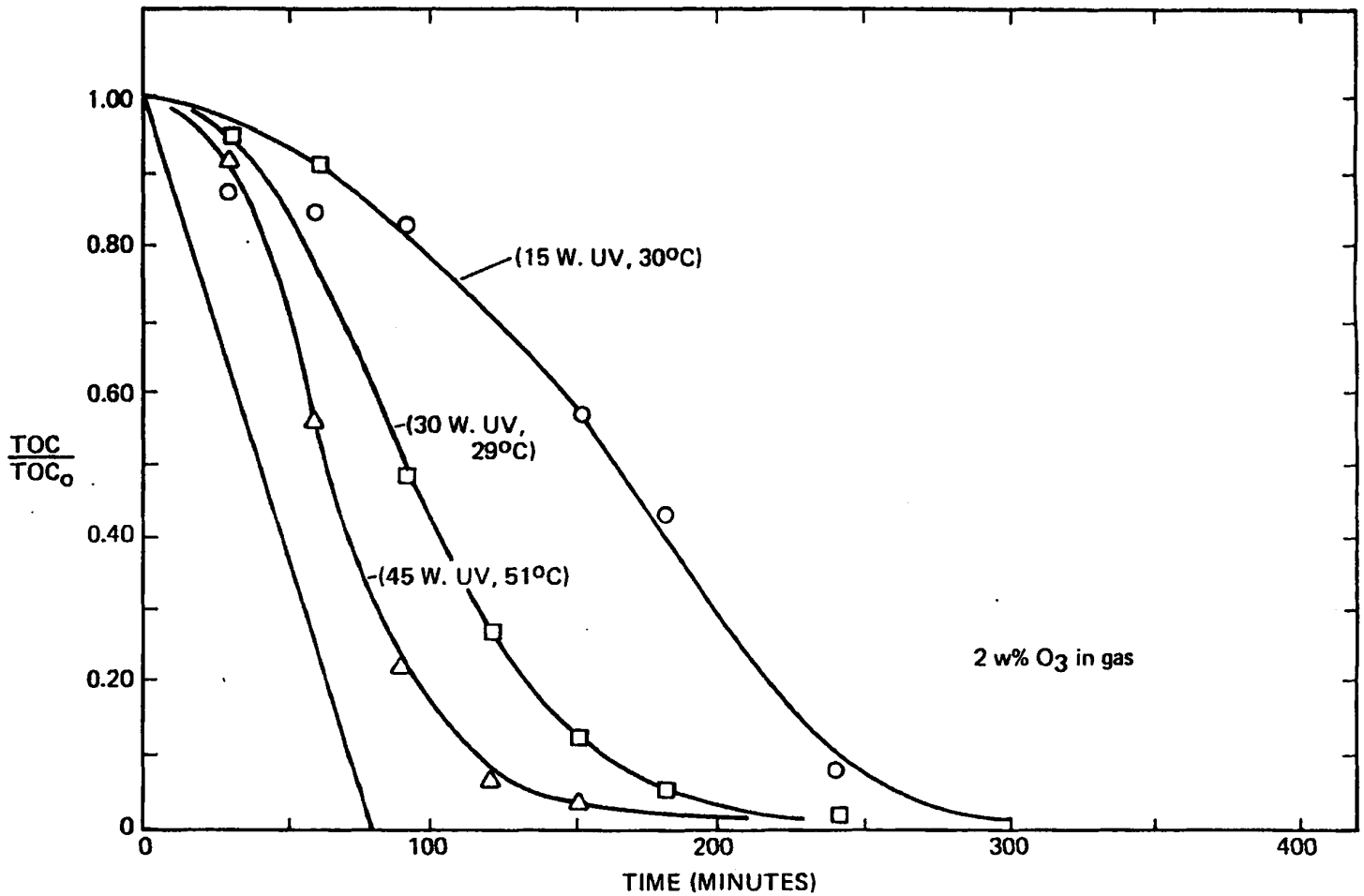

Figure 2.2.2.4.2-2. OZONE/UV OXIDATION OF ACETIC ACID; EFFECT OF INCREASED RADIATION INPUT

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Ozone feed = 70 milligrams ozone/minute in 3.4 liters per minute of oxygen; or about 1.4 percent by weight ozone in oxygen

Reactant preparation = Pure Aroclor 1254 was mixed with an equal portion of methanol, which was then mixed with distilled water to get an apparent true solution. A Hamilton syringe, with vernier calibration giving microliter increments was used to prepare an estimated 200-ppb concentration in a beaker. This solution was added to the reactor (3 liters). Then a 200-ml sample was withdrawn to get the "before" sample.

When preparing the Aroclor 1016 solution, a more concentrated PCBs solution of about 800 ppb was achieved. The before and after treatment concentrations of PCBs are shown in Table 2.2.2.5.1-1.

The data show that the destruction was highly effective in these pioneering tests; more than 99 percent of the original PCBs were destroyed. In addition, the final concentration was at the desired level of about 1 ppb. Such an effluent would be expected to be a reasonable stream for recycle operations and intermediate term zero discharge potential.

Of course the contact time and ozone expenditure were overly large, but the goal of this preliminary testing was to demonstrate destruction of two key Aroclors in use today.

A more comprehensive study of the UV-ozonolysis of Aroclor 1016 was run, with samples removed from the reactor every 15 or 30 minutes for up to 4 hours. As shown in Table 2.2.2.5.1-2, the initial PCB concentration was 237 ppb. Within 45 minutes the PCB level had been degraded to 1 to 2 ppb, a 99^{+}-percent decomposition. After 2 hours the PCB concentration was less than 100 ppt. The last column in the Table labeled

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Table 2.2.2.5.1-1

UV Ozonolysis Destruction of Typical Capacitor and Transformer PCBs at Westgate Research

	Aroclor 1016	Aroclor 1254
Initial (influent) Concentration (ppb)	790	200
Final (effluent) Concentration (ppb)	0.5	1.5

Table 2.2.2.5.1-2

Destruction of Aroclor 1016 by UV-Ozonation at Westgate Research

UV-Ozonation Time (minutes)	Aroclor 1016 Conc. (ppb)	Chlorinated Products Conc. (ppb)
0	237.0	0.00
15	14.7	33.8
30	7.76	25.86
45	1.73	21.80
60	1.73	18.47
75	0.52	17.63
90	5.2	21.43
120	< 0.1	12.64
150	< 0.1	16.91
180	< 0.1	9.12
210	< 0.1	23.07
240	< 0.1	12.58

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"Chlorinated Products Concentration" is of particular interest. This is the first time quantitative data on the residual compounds in the reaction mixture have been compiled. These residual compounds reach a 33.8-ppb level within 15 minutes from the start of the test and then erratically and slowly drop to about 10 to 20 ppb over the 4 hour period.

The only statements that can be made about these residual compounds is that they are non-PCBs, but chlorinated materials. Possibly a different UV wavelength, or ozone concentration, or the use of a catalyst or other agent could degrade these other products to the non-detectable level.

2.2.2.5.2 Pilot-Scale Tests of Refractory Organics Decomposition

Zeff has described pilot-scale tests of UV-assisted ozonation using 253.7-nm radiation ("UV-OX (TM) Process for the Effective Removal of Organics in Waste Waters", presented at the 68th Annual Meeting of the AIChE, November 20, 1975). This work has grown from a patented invention for a household appliance used to purify tap water. The effectiveness of the method is demonstrated by the reduction in total organic carbon (TOC) of 500 ml of tap water from 5 mg/l to 1 mg/l in 1 minute, using 0.07 mg of ozone and 0.1 watts of 253.7-nm UV. The bacteria plate count was also reduced by a significant amount.

In these studies, batch reaction conditions were optimized to get closest to complete TOC destruction with least O_3 and UV energy input. Then continuous and two-stage operations were investigated. As shown in Figure 2.2.2.5.2-1, a 6-inch-path length of UV was compared with a 3-inch path. In a batch test, the longer path condition took 3 to 4 times as long as the shorter path to achieve the same TOC reduction, in approximate accord with the inverse square law.

The laboratory-scale equipment arrangement is shown in Figure 2.2.2.5.2-2. Table 2.2.2.5.2-1 presents TOC reductions for a 5-part organic mixture under two experimental conditions, showing ozone usage

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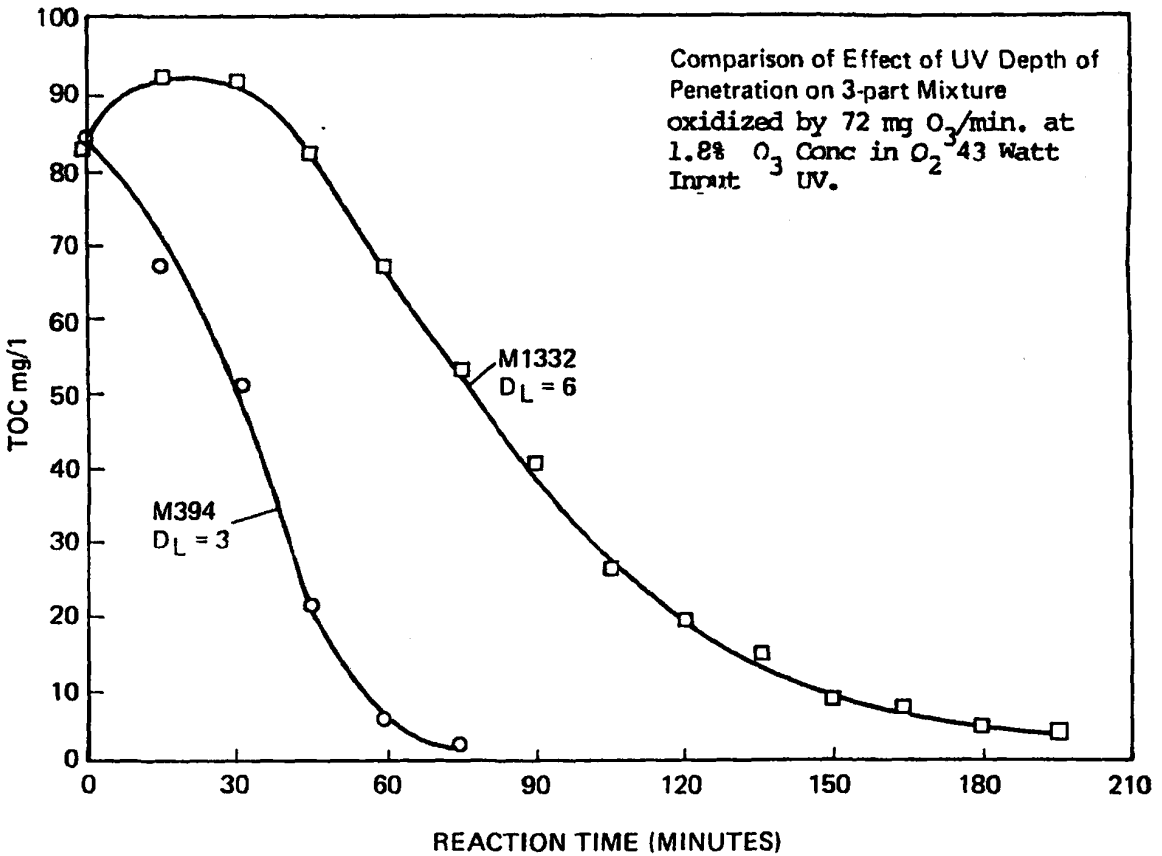

Figure 2.2.2.5.2-1. THE EFFECT OF UV PATH LENGTH ON TOC DESTRUCTION

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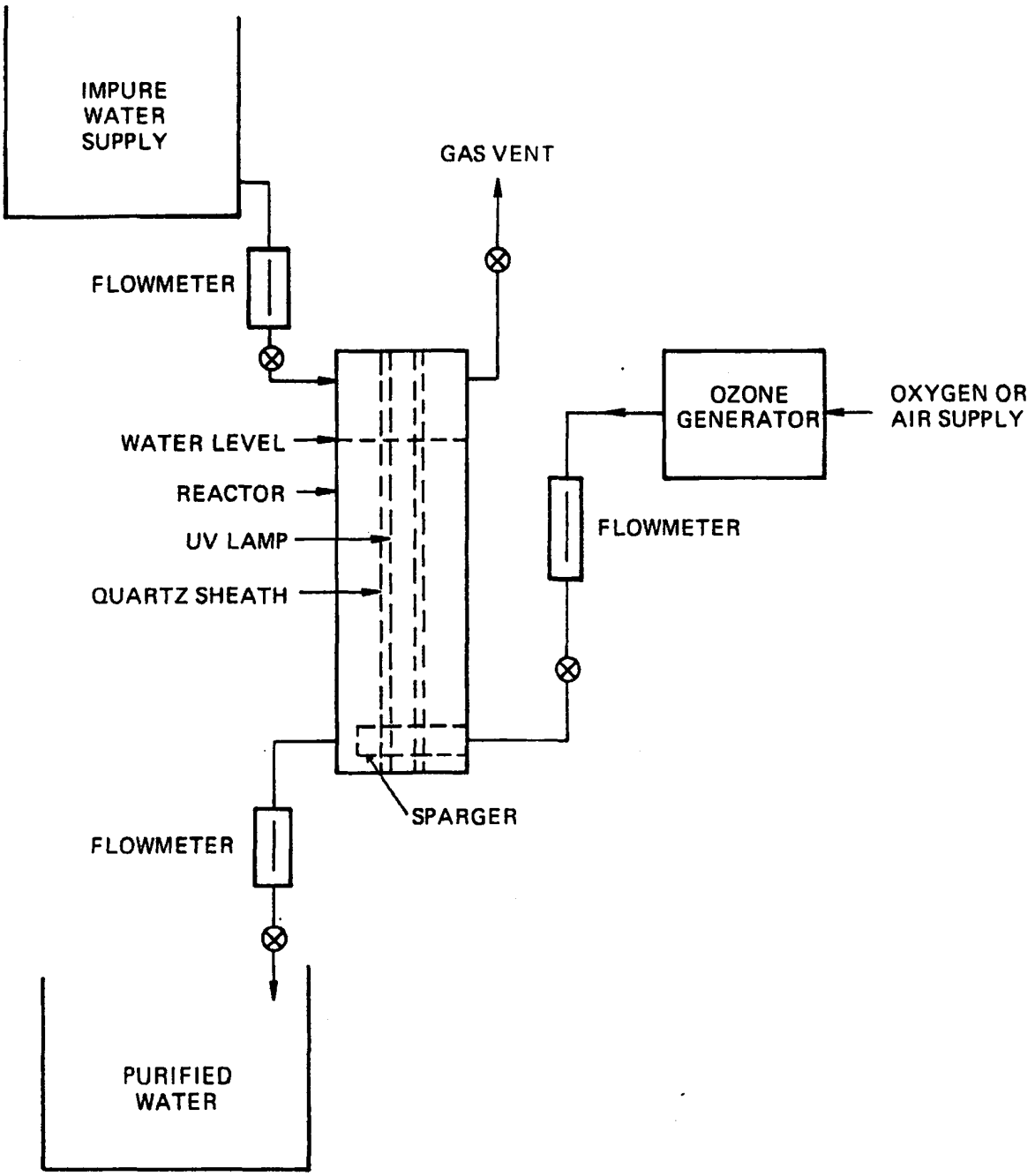

Figure 2.2.2.5.2-2. SCHEMATIC OF BENCH REACTION SYSTEM AT WESTGATE RESEARCH CORP.

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		REACTOR 1									REACTOR 2						OVERALL			
Experiment Number	Influent Conc TOC mg/l	Res Time/Real min	Input O_3 Conc % by^3 wt	Input O_3 Mass Flow mg/min	Output O_3 Conc % by^3 wt	Output O_3 Mass Flow mg/min	Effluent TOC Conc mg/l	Ave Rate of TOC Removal mg/min	UV Index w-m/mgC	Supplied TOC/O_3 Effic %	Input O_3 Conc % by^3 wt	Input O_3 Mass Flow mg/min	Output O_3 Conc % by^3 wt	Output O_3 Mass Flow mg/min	Effluent TOC Conc mg/l	Ave Rate of TOC Removal mg/min	UV Index w-m/mgC	Supplied TOC/O_3 Effic %	Ave Rate of TOC Removal mg/min	UV Index w-m/mgC	Supplied TOC/O_3 Effic %
S341	39.0	80	2.5	124	1.3	65	9.0	4.5	9.6	29.0	2.5	124	1.5	74	5.0	0.6	46.7	3.9	2.5	13.9	16.4
S342	75.5	48	2.7	171	1.8	113	21.0	13.6	3.2	63.7	2.7	171	1.9	120	6.0	3.7	7.5	17.5	8.7	4.1	40.6

TABLE 2.2.2.5.2-1

Simulated Two-Stage, Continuous UV-Ozonation of a 5 Component Mix at Westgate Research Corp.

(43 watt UV Input Reactor 1)
(28 watt UV Input Reactor 2)

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efficiencies, and energy usage efficiencies, with a simulated two-stage continuous operation. Zeff has calculated the prime energy costs for UV-assisted ozonation based on a scale-up of a pilot reactor. The pilot reactor handled 20 gph, so that 210 of these units in parallel would handle 100,000 gpd. The plant area needed for this equipment would be only 18 feet square, with a height of 3 feet.

Based on pilot tests of this reactor, it might be assumed that it could convert wastewater of 40 mg/l TOC to less than 5 mg/l, using six 43-watt UV lamps. It is assumed that a UV energy requirement of 5 watt-minutes per millgram of carbon oxidized will suffice. Also, the ozone requirement will be 2 moles per gram-atom of carbon oxidized, but at a 75-percent efficiency, or 2/.75 = 2.67 moles ozone per gram-atom of carbon. Assuming a power cost of 1.5¢/KWH; the ozone generating power cost would be $53.40 and the UV power would be $18.93; or a total of $72.33 per 100,000 gal. of water treated.

Zeff points out that the 210 reactor modules would require 1260 43-watt lamps (six per reactor). This appears to be a large number of lamps, but it is actually very practical. Such arrays of lamps are regularly used for room illumination in factories and large offices, and the low-pressure mercury lamps used here are nothing but fluorescent lamps without the phosphor coating. An extended array such as this is much more energy-efficient than fewer high-power high-pressure industrial UV irradiators; and maintenance and replacement of lamps is much simpler. The life of the low-power lamps is 7500 hours as compared to 1000 hours for the high-power lamps.

2.2.2.6 Laboratory Test Results from AiResearch Corporation

In the laboratory tests of the AiResearch Corporation, high-pressure 450-watt mercury lamps were used. The test solutions were very dilute mixtures of methanol, ethanol, isopropanol, and acetone in water. The ozone was introduced into the 4-liter organic mixture in an oxygen stream bubbled in at 2 liters per minute; ozone concentration in the oxygen was 33 mg/liter. With the expenditure of 7.9 grams of ozone, the mixture of alcohols and acetone was reduced from 115 mg/l COD to 10 mg/l in 2 hours.

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2.2.2.7 Comments on UV/Ozone Tests

These highly encouraging tests by three different companies in the destruction of some of the most refractory organics encountered in wastewater treatment, give confidence that scaled-up systems can adequately destroy PCBs in industrial wastewaters. The next step required is detailed cost effectiveness testing in pilot-scale equipment.

2.2.3 Non-Carbon Adsorbents for PCBs

A variety of non-carbon materials, some well-known for treating water and some that seem to be quite specific for PCBs removal, have been found. Limited cooperative laboratory testing of PCBs removal has been conducted in order to gain insight into potential effectiveness.

Materials considered or examined were:

1) Rohm and Haas Amberlite XAD series resins - These were laboratory-tested for PCBs removal
2) Polyvinyl chloride - Tested by Canadian investigators for PCBs removal
3) Clays and Humus - Tested by Monsanto for PCB removal
4) Polyurethane - Tested by Canadian, Swedish and other investigators for PCBs removal
5) Sphagnum Peat - Used in commercial water purification, but has not been tried with PCBs
6) Polyelectrolytes as floccing agent - Not really adsorbents, but could be aids to removing finely divided adsorbents from treated wastewaters; have not been tested
7) Coal - Not tested with PCBs, but being experimentally used for water treatment
8) Molecular Sieves - Not tried with PCBs, since they were judged to be of improper character; they would be expected to preferentially remove water from PCBs, rather than PCBs from water
9) Miscellaneous Sorbents - A number of proprietary Oil Sorbents, such as the "3M Brand" series, that were not tested with PCBs, might have some application

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2.2.3.1 The Amberlite XAD Series of Macroreticular Resins

2.2.3.1.1 PCBs Adsorption Testing

Cooperative preliminary experimental work was carried out between Versar and Rohm and Haas to test the PCB-adsorption capacity of XAD-4 resins. The tests confirmed the effectiveness of this resin (see Appendix D).

Since carbon adsorption is the more established technology for removal of organics, it was felt that a side-by-side comparison of a carbon and an Amberlite resin would be useful.

These tests showed that resin and carbon are comparable in PCBs removal effectiveness. The resin method includes on-site regeneration, with the concentrated waste PCBs treated by incineration. Details on the apparatus and materials used by Rohm and Haas and the results of their experiments are given in Appendix A.

2.2.3.1.2 Process Concept for Resin Adsorption of PCBs

Based upon the experiments described in Appendix A, the Rohm and Haas experience has led them to envision the following plant-scale process, subject to further experimentation.

The wastewater to be treated is passed through one or more columns, each containing polymeric adsorbent. Once the resin is loaded to capacity with PCB, it is taken off line for regeneration. A water miscible solvent is usually used for regeneration, and is in turn displaced from the adsorbent by water. The stream resulting from this operation is carefully fractionated to optimize solvent recovery. The final rinse usually contains a very low level of solvent in water and this must be collected as a PCBs wastewater.

The distillation column permits solvent recovery at high purity, leaving water and PCB in the bottoms. To minimize

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distillation costs, a patented variation of the process, called "superloading", is used to maintain a high PCB concentration in the final toxic material to be disposed. Part of this process includes a separator from which the organic phase is PCB while the aqueous phase is recycled to "superload" the adsorbent. A completely enclosed system can readily be designed to insure minimum operator exposure to PCB. A process concept flow sheet of such a PCBs removal system is shown in Figure 2.2.3.1.2-1.

The experimental work necessary to plant-scale design is as follows:

1. More extensive leakage data should be gathered for XAD-4 and other Amberlite polymeric adsorbents, encompassing several influent concentrations of PCBs; other Aroclors should also be tested.
2. The ability of the Amberlite polymeric adsorbents to be solvent regenerated should be demonstrated and the optimum solvent determined
3. The capacity of the Amberlite polymeric adsorbents should be determined over a number of loading/regeneration cycles to see the effect, if any, of long-term operation on capacity.

The description of XAD-4 resin and its comparison with other Rohm and Haas resins that might also have application to PCBs removal are given in Appendix B.

Further descriptions of non-carbon adsorbents are presented in the Appendix C. They contain relevant experimental work on PCBs and refractory organics, and are included to give a more complete picture of the options assessed under this program. Also included in Appendix C are summaries of catalytic reduction, catalytic oxidation, microorganism studies, ultrafiltration, and reverse osmosis. For the removal of PCBs from wastewater, all are considered to be in the research stages. Several have potential for contributing to zero discharge technology.

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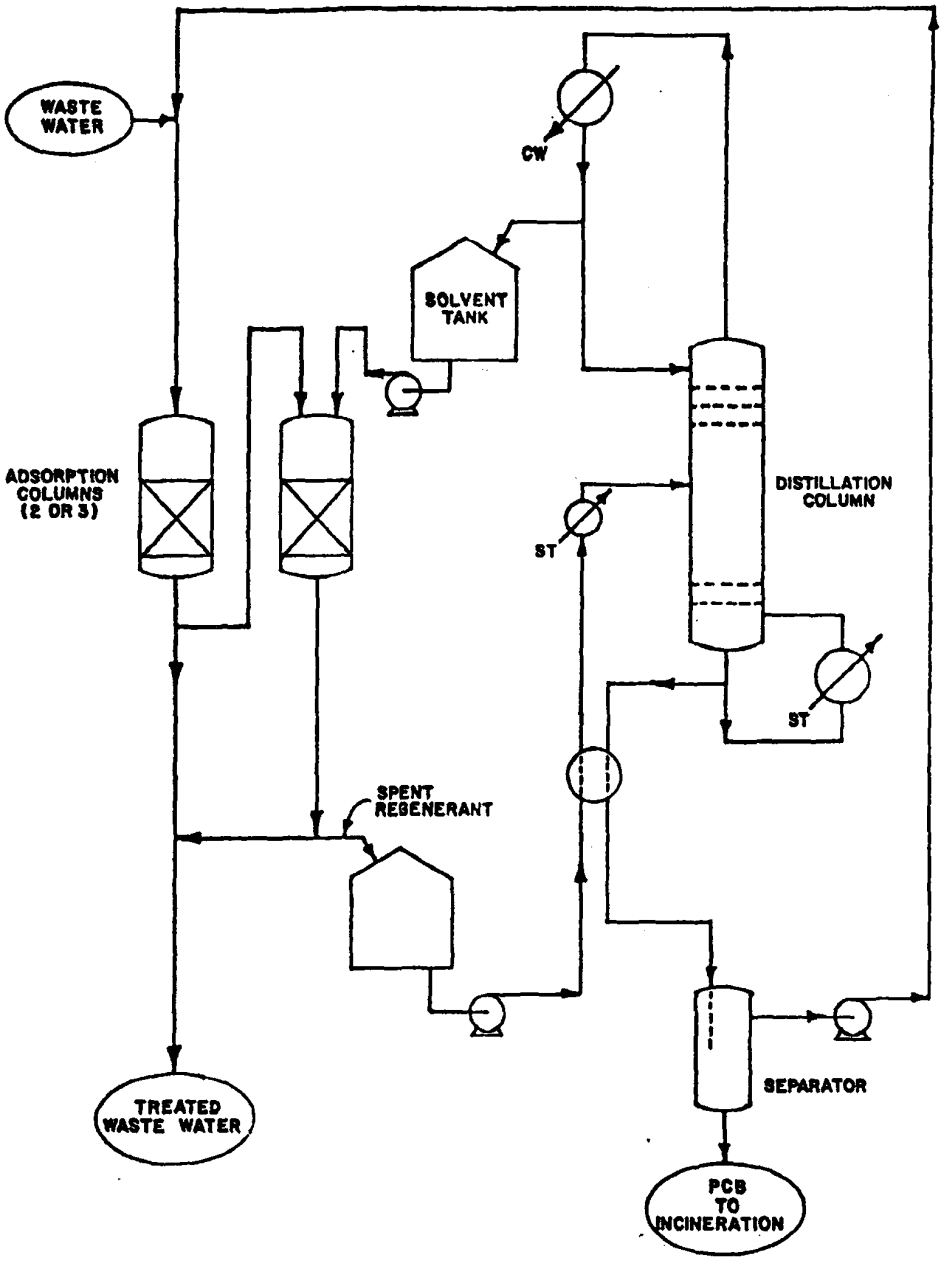

Figure 2.2.3.1.2-1
PCBs REMOVAL PROCESS CONCEPT FLOW SHEET
BY ROHM AND HAAS COMPANY

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2.3 Treatment of PCBs - Contaminated Solid Wastes

2.3.1 Incineration

Incineration has been described in Section 1.3.3. For the variety of solids ranging from granular particulate, such as fuller's earth, to large chunks of solids, such as transformer internals, the best destruction method is rotary kiln incinerator, followed with adequate afterburning to prevent PCB vaporization.

2.3.2 Sanitary Landfill

The best technology for segregation of the PCBs solid wastes so that spillage, leakage to waterways, or emissions to the atmosphere will not occur, is described under Section 1.3.3.

2.4 Treatment of Air Emissions

2.4.1 Condensation Methods

Our survey found one plant that was practicing chilling of exhaust gases from PCBs processing areas. With the low vapor pressure of PCBs even at room temperature, it might be expected that they could be effectively swept out of chilled air with the condensing water. Undoubtedly this does occur to some extent; however, the high activity coefficients of PCBs tend to keep them vaporized at levels near their pure liquid vapor pressure at that low temperature. Previous work by Versar has shown that PCBs in stack emissions from sludge incineration are not removed by water scrubbing (EPA Contract 68-01-1587).

2.4.2 Granular Adsorption Methods

Although no information was uncovered on the collection of PCBs from air streams by any form of granular filter, it would be expected that such treatment should be effective. In fact, it would be expected that the same adsorbents discussed under Sections 2.2.1 and 2.2.3 above would be the most effective. Activated carbon removal of organic vapors has been practiced in such widely divergent circumstances and devices as gas masks, kitchen range hood systems, and submarine air recycle systems.

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2.4.3 Catalytic Oxidation of Organics in Evaporated Effluents

Studies of vapor phase oxidation show the potential for PCBs destruction in air exhausts at lower than incineration temperatures. Catalysts would have to be resistant to HCl vapors, but fuel savings and insulation savings would be large. This procedure should be amenable to all proportions of water and organics in such air streams.

Borkowski passed PCB vapors over a catalyst at elevated temperatures ("The Catalytic Oxidation of Phenols and other Impurities in Evaporated Effluents," Water Research (1); 367 (1967)). Copper oxide was the most active of a large number of catalysts tested and oxidation to carbon dioxide and water appeared to be complete at temperatures over 300°C and at residence times of about 0.08 seconds. Without the catalyst, 1000 to 1200°C was required to achieve the same degree of removal.

Walsh and Katzer studied contaminated air-water vapor streams over supported copper oxide and showed that the rate was first order in phenol and relatively rapid between 150 and 270°C ("Catalytic Oxidation of Phenol in Dilute Concentration in Air", Ind. Eng. Chem. Process Design Develop, (12); 477 (1973)). At 150°C and a space velocity of 4100 hr^{-1} the phenol conversion was 99.6 percent, and there was little evidence of any intermediate organics in the condensate.

These methods of air purification are in the research stages, and actual testing of PCBs in air is required.

2.5 The Potential for Zero Discharge

The best method of achieving zero discharge, in the face of the practical problem of defining what a zero concentration is, is to establish total recycle. This appears feasible for wastewater, but not for solids or air emissions. Fortunately, for solids, incineration technology promises very high efficiency of destruction simply by setting the temperature and residence times high enough.

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For air emissions, although vapor pressures are low for PCBs, large surfaces have the potential for giving off significant quantities of PCBs. Versar research has found powerful adsorption and destruction methods for organics in air. If destruction equivalent to that achieved by incineration can be achieved at lower temperatures through catalyzed reactions, near zero emissions are possible.

For wastewater recycle, methods of adsorption and catalytic destruction promise PCBs reduction to levels low enough such that reuse is practical. Our survey has shown some municipal and fresh waters contain PCB concentrations of 1 ppb or greater, and many river waters can contain many times that. Thus the recycled water at 1 ppb of PCB would be very suitable for reuse.

3.0 RATIONALE AND SELECTIONS OF CURRENTLY RECOMMENDED WASTE TREATMENT METHODS

Based upon our plant surveys of the PCB-using capacitor and transformer manufacturers, the single U.S. PCB manufacturer, and waste treatment equipment suppliers, and upon the analysis and evaluation of all available technologies whether in commercial use, pilot plant, or research stages, Versar has developed recommendations for the most practical treatment methods available now. We have also made predictions of methods applicable over the short- and long-term future. Our current recommendations are based on technology that is either currently in use and doing an excellent job of PCB destruction or removal, or holds great promise of doing that job based upon success in similar but non-PCB, applications.

3.1 Incineration Recommended for Liquid PCBs and Scrap Oils

For liquid PCBs and contaminated scrap oils, we determined only two candidate methods: incineration and sanitary landfill. It is possible that some chemical degradation methods discussed under wastewater treatment might later become applicable to concentrated PCB liquids, but the prospect is not clear at this time.

Sanitary landfill is not recommended for liquids when incineration is available. The potential for liquids escaping in large quantities from ruptured

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containers, caused by any of a number of circumstances, and then causing massive leaching and liquid control problems at the landfill, is felt to be too great.

Incineration, on the other hand, offers a straight-forward and physically simple method of final destruction. Incineration facilities that have successfully handled PCB liquids are available in Massachusetts, New York, Delaware, Illinois, Texas and Louisiana. Pilot or experimental facilities are available in other parts of the country. With the increase in requirements for disposing of many other liquid organics, it is expected that new facilities suitable for PCBs destruction will be added.

Versar therefore recommends incineration, particularly if there is a choice of the kind of disposal facility to be constructed.

3.2 Carbon Adsorption and UV-Assisted Ozonation Recommended for PCBs in Wastewater

Our survey of wastewater treatment technology was extensive and excellent potential for current, near- and long-term methods was found. The longer term pilot- or research-scale methods hold great promise for achieving zero discharge.

For wastewater treatment, Versar's recommendation is carbon adsorption. This technology has been well proved in a wide variety of industrial adsorption problems. It is constantly being successfully applied to the removal of new organics from water. Our cooperative laboratory work with several suppliers has confirmed preliminary reports of success in removing PCBs. All of the aspects of commercial carbon adsorption, from favorable capital and operating economics to reasonable operating methods, materials of construction, and lack of transport of pollution to air or land, have been proven for PCB-like materials. There is every reason to expect commercial success with PCB removal from wastewater.

Potential problems with carbon adsorption includes the collection of backwash water and spent carbon for incineration or other treatment. With these limitations in mind, we studied the various alternatives and have determined

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that the UV/ozone method is the best. However, it must be appreciated that this technology is still somewhere in the pilot-plant and research stage, but our cooperative testing with two equipment suppliers shows the method to be effective in destroying PCBs. It offers the potential of degrading breakdown products all the way to CO_2, water and HCl. Any kind of process that generates no solids or liquids for later disposal must be considered for application where no wastewater treatment facilities now exist, and where facilities for incineration of carbon system wastes are not convenient.

The major factors yet to be determined for the UV/ozone systems are costs and operating practicality. Separately, UV and ozone systems are being used in commercial applications, and it is therefore anticipated that the combination will be practical. Choices of the proper UV-radiation wavelength and power levels still need to be made, as well as methods of improving ozone-use efficiency. It appears that commercial UV and ozone generators are suitable.

3.3 Incineration and Landfill Recommended for Contaminated Solids

Although incineration is recommended for PCB contaminated solids, because of its final destruction capability and prevention of any long-term problems, sanitary or scientifically-controlled landfilling must be considered a close second choice. At present, the only incineration facilities for handling the full spectrum of PCB-contaminated solids are those of Rollins Environmental Services in Delaware, Texas and Louisiana. This limitation on locations for treatment requires that the alternate, landfill, be considered.

Landfill, as practiced by Chemtrol Corp., appears perfectly suitable for containment of PCB-contaminated solids, at least over a medium term. Our reservation with this method is that it might be relegating a problem to the future. Our concern is that some decades in the future, when a landfill might be closed, no agency will be prepared to handle the sump emptying and maintenance necessary to prevent leaching. We anticipate that some time in the future, many landfills will have to be mined, and final destruction or recovery carried out for land use or hazard reasons.

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3.4 Dry Carbon Filter Adsorption Recommended for Control of Air Emissions

For much the same reasons listed in Section 3.2, we recommend that current emissions of PCBs in plant air be trapped in carbon-containing filters. It is recognized that other and better adsorbents may emerge from research, as described in Section 2.2.3, but it is felt that such advances will be readily applicable to any kind of filter pack, screen or cartridge system already in use.

The long record of proven capability of carbon adsorption is the main factor in its choice. However, since contaminated carbon must be either incinerated or regenerated, over the longer term we see the use of low-temperature catalytic oxidation methods as described in Section 2.4.3. Catalytic oxidation methods hold promise for near zero discharge, with the generation of no solid wastes.

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SECTION VII

PRODUCTION AND DISTRIBUTION

1.0 PRODUCTION AND CURRENT USE

1.1 Domestic Production of PCBs and PCTs

Currently there is only one known commercial scale PCB production installation in the U.S., the William G. Krummrich plant of the Monsanto Chemical Company in Sauget, Illinois. This facility is specifically designed for chlorobiphenyls production and has a design capacity of 48 million pounds per year.

Until 1971 PCBs were also manufactured at Monsanto's Anniston, Alabama plant which had a design capacity approximately equal to the Sauget plant. The Alabama operation was discontinued and the plant dismantled in 1971.

PCBs manufactured by Monsanto are marketed under trade name "Aroclor". Tables 1.1-1 and 1.1-2 present data from Monsanto related to production and sales of PCBs from 1957-1974 and production of polychlorinated terphenyls (PCTs) from 1959-1972. The production of PCTs were terminated in 1972. Until then in addition to PCBs (Aroclor series 12) Monsanto manufactured Aroclors 2565, 4465, 5442 and 5460. Aroclors 2565 and 4465 were blends of PCBs and PCTs and Aroclors 5442 and 5460 were two different grades of PCTs. Also given in these Tables are breakdowns of domestic sales per use category and by PCB grade. Detailed information and breakdown on PCB/PCT blends and PCT grades is not available. However, Monsanto reports that the predominant material produced was Aroclor 5460. When produced and marketed these materials were used in plasticizer applications. Figures 1.1-1 through 1.1-3 are graphical representations of these data.

As can be seen from Figure 1.1-1, the majority of the PCBs produced in the United States was marketed domestically. Production and sales of PCBs in 1974 were less than half of those for 1970, where production and sales of PCBs were at their maximum. The difference between production and sales on

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TABLE 1.1-1

PCB & PCT MANUFACTURE AND PCB SALES

MONSANTO INDUSTRIAL CHEMICALS COMPANY

1957 thru 1964
(Thousands of Pounds)

	1957	1958	1959	1960	1961	1962	1963	1964
U.S. PRODUCTION OF PCBs	(1)	(1)	(1)	37919	36515	38353	44734	50833
DOMESTIC SALES OF PCBs	32299	26061	31310	35214	37538	38043	38132	44869
U.S. EXPORT SALES OF PCBs	(2)	(2)	(2)	(2)	(2)	(2)	3647	4096
U.S. PRODUCTION OF PCTs	-	-	2996	3850	2322	4468	4920	5288
DOMESTIC SALES OF PCBs BY CATEGORY								
Heat Transfer	-	-	-	-	-	157	582	929
Hydraulics/Lubricants	1612	1549	2685	2523	4110	3915	3945	4374
Misc. Industrial	704	755	1569	1559	2114	1681	1528	1692
Transformer	12955	5719	5984	7921	6281	7984	7290	7997
Capacitor	17028	14099	16499	16967	15935	15382	15606	19540
Plasticizer Applications	(1)	3939	4573	6244	9098	8924	9181	10337
Petroleum Additives	-	-	-	-	-	-	-	-
DOMESTIC SALES BY PCB GRADE								
Aroclor 1221	23	16	254	103	94	140	361	596
Aroclor 1232	196	113	240	155	241	224	13	13
Aroclor 1242	18222	10444	13598	18196	19827	20654	18510	23571
Aroclor 1248	1779	2559	3384	2827	4023	3463	5013	5238
Aroclor 1254	4461	6691	6754	6088	6294	6325	5911	6280
Aroclor 1260	7587	5982	6619	7330	6540	6595	7626	8535
Aroclor 1262	31	184	359	326	361	432	414	446
Aroclor 1268	-	72	102	189	158	210	284	190
Aroclor 1016	-	-	-	-	-	-	-	-

(1) Production figures and Plasticizer Applications figures unavailable during year indicated.
(2) U.S. Export Sales figures unavailable during year indicated.

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TABLE 1.1-2

PCB & PCT MANUFACTURE AND PCB SALES

MONSANTO INDUSTRIAL CHEMICALS COMPANY

1965 thru 1974
(Thousands of Pounds)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
U.S. PRODUCTION OF PCBs	60480	65849	75309	82854	76389	85054	34994	38600	42178	40466
DOMESTIC SALES OF PCBs	51796	59078	62466	65116	67194	73061	34301	26408	37742	34406
U.S. EXPORT SALES OF PCBs	4234	6852	8124	11231	10624	13651	-	6388	8346	5395
U.S. PRODUCTION OF PCTs	6470	8190	9450	8870	11600	17768	20212	8134	-	-
DOMESTIC SALES OF PCBs BY CATEGORY										
Heat Transfer	1237	1766	2262	2529	3050	3958	3060	752		
Hydraulics/Lubricants	4616	4258	4643	5765	8039	7403	1552	0		
Misc. Industrial	1841	1779	1426	1283	1079	1627	1155	0		
Transformer	8657	8910	11071	11585	12105	13828	11134	25656	37742	34406
Capacitor	23749	28884	29703	29550	25022	26708	14141			
Plasticizer Applications	11696	13481	13361	14404	16460	19537	3259	0		
Petroleum Additives	-	-	-	-	1439	-	-	0		
DOMESTIC SALES BY PCB GRADE										
Aroclor 1221	369	528	442	136	507	1476	2215	171	35	57
Aroclor 1232	7	16	25	90	273	260	171	0	0	0
Aroclor 1242	31533	39557	43055	44853	45491	48588	21981	728	6200	6207
Aroclor 1248	5565	5015	4704	4894	5650	4073	213	807	0	0
Aroclor 1254	7737	7035	6696	8891	9822	12421	4661	3495	7976	6185
Aroclor 1260	5831	5875	6417	5252	4439	4890	1725	305	0	0
Aroclor 1262	558	768	840	720	712	1023	1	0	0	0
Aroclor 1268	196	284	287	280	300	330	0	0	0	0
Aroclor 1016	0	0	0	0	0	0	3334	20902	23531	21955

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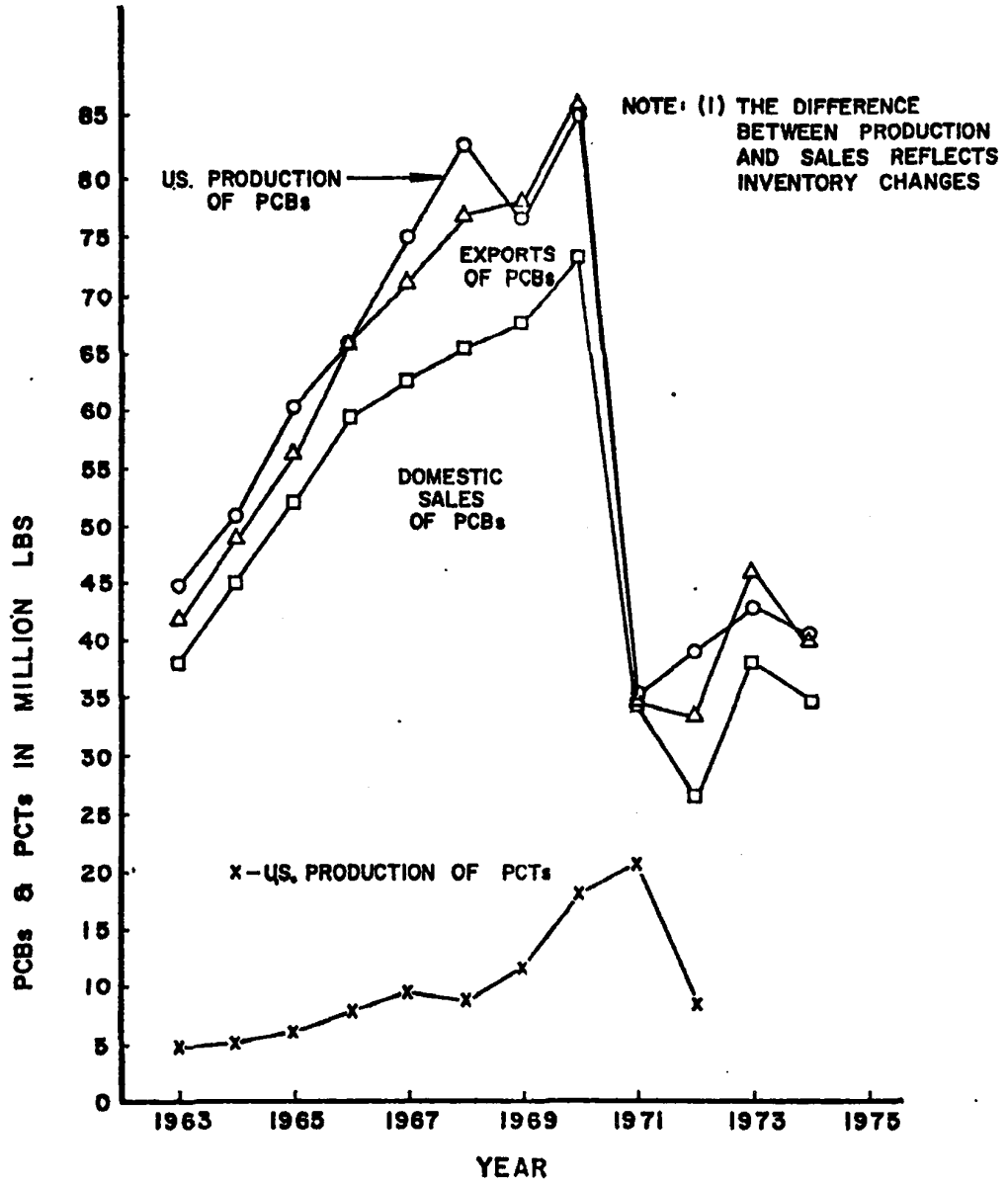

Figure 1.1-1 - U.S. Production of PCBs and PCTs and Domestic Sales and Exports of PCBs

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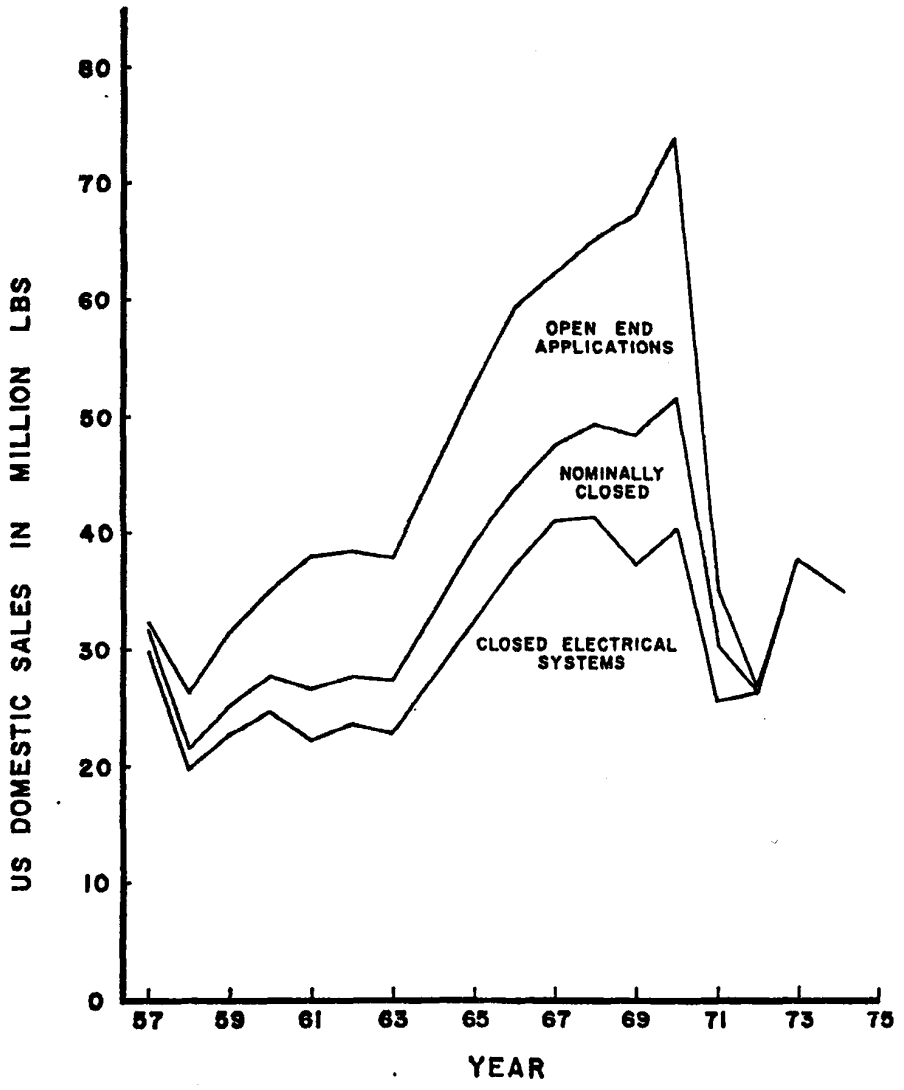

Figure 1.1-2 - U.S. Domestic Sales of PCBs by End Use Applications

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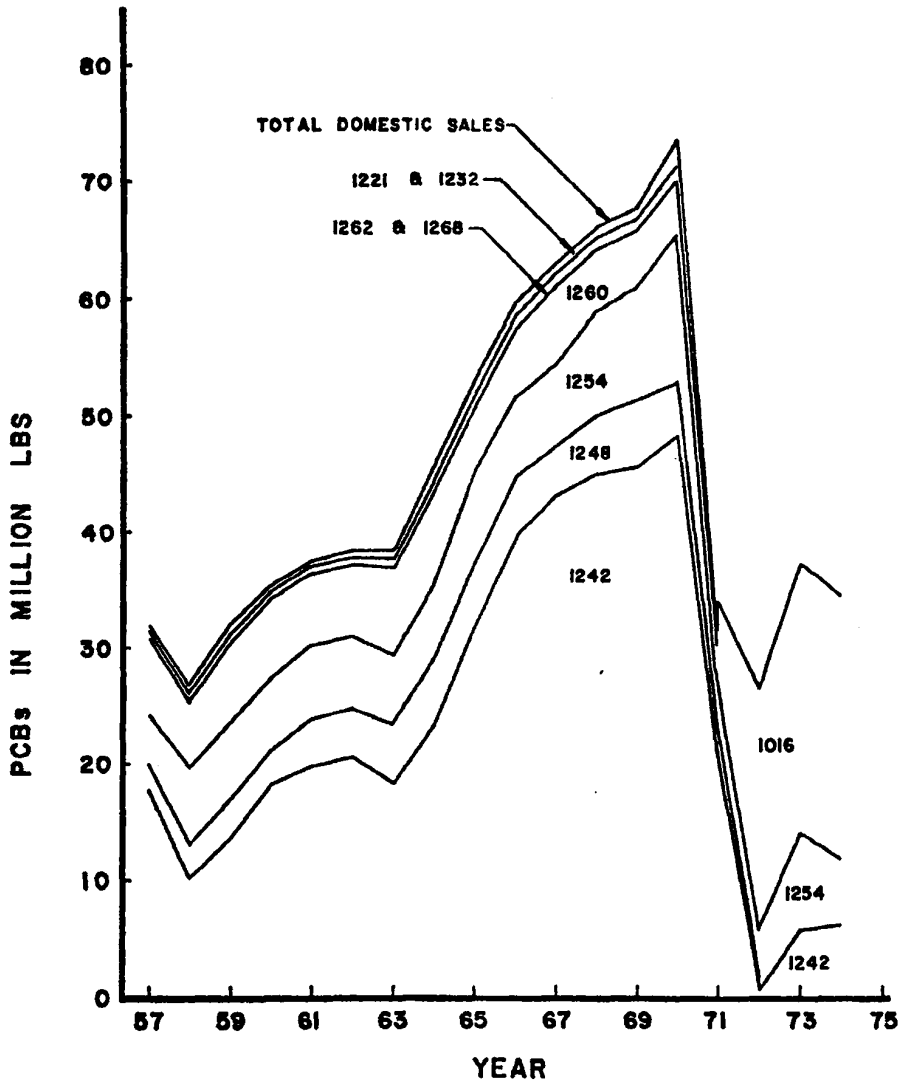

Figure 1.1-3 - U.S. Domestic Sales of PCBs by Type

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this graph reflects inventory changes of PCBs. Figure 1.1-1 also indicates that the production of PCTs increased steadily through 1971 when their production was at the maximum. The production of PCTs was terminated in 1972.

Table 1.1-3 shows production, sales and export of PCBs for the first quarter of 1975. Monsanto reports that sales for Aroclor are expected to increase at an average annual rate of 6-7 percent over the next few years. Additionally, exports of Aroclor are expected to maintain the same ratio to the U.S. production as in the past.

Figure 1.1-2 indicates that prior to Monsanto's voluntary restriction of sales to all applications with the exception of "closed electric systems", approximately 13 percent of the PCBs in the U.S. was used in "nominally closed" applications (heat transfer, hydraulic fluids and lubricants) and 26 percent was used in "Open End" applications (plasticizers, surface coating, ink, adhesives, pesticide extenders, and microencapsulation of dyes for carbonless duplicating paper) where entries of PCBs to the environment are more probable and PCB emissions are uncontrollable. At present, almost all domestic production is being used in "closed electric systems" (transformer and capacitor applications) where PCB emissions are more controllable.

Between 1957 and 1971 there were twelve different types of Aroclor manufactured by Monsanto with chlorine contents ranging from 21 to 68 percent. Aroclor 1242 and grades lower than 42 percent chlorine made about 48 percent of the total production consumed. U.S. Sale of Aroclor 1242 has dropped drastically since 1971 and has been replaced by Aroclor 1016. Sales of Aroclor 1254 remained about the same for the period 1957 - 1974. Currently, there are four different types of Aroclor manufactured by the Monsanto Company-Aroclors 1221 and 1016 for capacitor applications and Aroclors 1242 and 1254 for transformer applications.

Past and current end-use of PCBs by types are presented in Table 1.1-4. In the years prior to 1971 the largest "open-end" use of PCBs and PCTs has been in plasticizer applications. According to Monsanto, a large percentage of the production of Aroclor 1242 and lower chlorine content grades and the entire PCT production were used for this application. Following Monsanto's

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TABLE 1.1-3

PCB MANUFACTURE AND SALES

MONSANTO INDUSTRIAL CHEMICALS COMPANY

First Quarter - 1975

	(Thousands of Pounds)
U.S. PRODUCTION	8532
DOMESTIC SALES	7986
U.S. EXPORT SALES	1538
DOMESTIC SALES	
Transformer and Capacitor	7986
DOMESTIC SALES BY PCB GRADE	
Aroclor 1221	10
Aroclor 1242	2201
Aroclor 1254	2115
Aroclor 1016	3660
PREDOMINANT UTILIZATION OF AROCLORS	
Aroclor 1221, Aroclor 1016	Capacitors
Aroclor 1242, Aroclor 1254	Transformers

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TABLE 1.1-4

END-USES OF PCTs AND PCBs BY TYPE

End-Use	1016	1221	1232	1242	1248	1254	1260	1262	1268	PCTs
Existing Sales										
Capacitors	XX	X		XX through 1971		X				
Transformers				X		XX	X through 1971			
Sales Phased-Out										
Heat transfer				X						
Hydraulics/ lubricants										
. hydraulic fluids			X	X	X	X	X			
. vacuum pumps					X	X				
. gas-transmission turbines		X		X						
Plasticizers										
. rubbers		X	X	XX	X	X			X	
. synthetic resins					X	X	X	X	X	XX
. carbonless paper				XX						
Miscellaneous Industrial										
. adhesives		X	X	XX	X	X				XX
. wax extenders				XX		X			X	XX
. dedusting agents						X	X			
. inks						X				XX
. cutting oils						X				
. pesticide extenders						X				
. sealants & caulking compounds										XX

Notes: (1) X denotes use of a given Aroclor in a specific end-use, while XX denotes principal use
(2) PCTs denote series 25,44 & 54 Aroclors

Source: Monsanto Industrial Chemical Co.

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voluntary restrictions in 1972, Aroclor sales for plasticizer applications dropped to small percentage to that of the previous years. Historically, capacitors have always been the single largest PCB use category except for the years 1969-1971 when Aroclor usage for plasticizer applications was higher. The major uses of PCBs prior to 1969 in order of volume of material used is listed below:

- Capacitors
- Plasticizers
- Transformers
- Hydraulic fluids and lubricants
- Heat transfer fluids

1.2 Foreign Production and Distribution of PCBs

Known current foreign producers of PCBs are the United Kingdom, Czechoslovakia, France, Germany, Italy, Spain and the U.S.S.R. Detailed information on total production of PCBs outside the U.S. is not available. However, total foreign production of PCBs was roughly estimated by the Interdepartmental Task Force to be 80-85 million pounds annually prior to 1971. This value included 26 million pounds produced by Japan. Foreign production of PCBs has, however, decreased primarily due to Japanese action on banning the domestic production of PCBs. In 1973 foreign production of PCBs was estimated to be 43 million pounds, accounting for a 50% reduction. Production, trade and use of PCBs by OECD member countries for the year 1973 is given in Table 1.2-1. The combined PCB output of three major European producers, France, Italy and United Kingdom was about 36 million pounds in 1973. World commerce in PCBs is expected to decrease further, due to OECD member countries' activities, and to be essentially confined to capacitor and transformer applications.

1.3 Summary of Recent PCBs and PCTs Imports

A summary of estimated imports of PCBs since 1971 is presented in Table 1.3-1. Importation of PCBs appears to be steady or increasing, and currently is in the range of one percent of the domestic sales reported by Monsanto.

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Table 1.2-1 - Production, Trade and Use of PCBs
OECD Member Countries (1973)

Country	Total Production of PCBs	Total Import of PCBs	Total Export of PCBs	End of Use by Category								
				Transformer Application	Capacitors (large)	Capacitors (small)	Heat Transfer System	Hydraulic Equipment	Vacuum Pump	Lubricating & Cutting Oil	Plasticizers	Others
Australia												
Austria[2]	*											
Belgium	0	?	?	1.16	0.40	-	?	?	?	?	?	0
Canada	0	2.38	0	1.98[3]	0.44[4]	0.41[4]	0	0	0	0	?	0
Denmark												
Finland	0	0.53	0	0.09[3]	0.44[4]	0	0	0	0	?	0	0
France	21.33	0.66	10.12	6.48	2.87		0.16	0.17	0.01	0.49	1.45	0.25
Germany[2]	*											
Greece												
Iceland												
Ireland												
Italy	5.55	3.53	2.44	2.70	3.14[3,4]	0	0	0	0	0	0.64[4,5]	0.16[6,8]
Japan	0	(2)	(2)									
Luxembourg												
Netherlands	0	?	0	?	?	?	?	?	?	0	0	0
New Zealand	0	0.04[9]	0	0.075	0	0	0	0	0.005	0	0.02	0
Norway[10]	0	0.04	0	0	0.05[4]	0.005	0	0	0	0	0	0
Portugal												
Spain	*											
Sweden[10]	0	0.70	0	0	0.72	0	0	0	0	0	0	0
Switzerland												
Turkey	0	0	0									
United Kingdom	8.97	0.01	6.53	0.71[3]	← 1.82[9] →							
United States	42.18	0.57	8.35	← 37.87[13] →			?	0.04	?	?	0.04[12]	?

Notes:

(1) All quantities are in million pounds
(2) Information is not available
(3) PCB containing 54 wt % chlorine
(4) PCB containing 42 wt % chlorine
(5) PCB containing 64 wt % chlorine
(6) PCB containing 70 wt % chlorine
* indicates PCB producer country
(7) "Others" refers to PCBs were used to reseller and in research
(8) "Others" refers to PCBs used as a fire-retardant in plastics
(9) This figure includes about 6 percent from previously imported material
(10) Amount reported as import and quantities quoted in usage do not agree
(11) With regards to the use of PCBs in transformers and capacitors, definitive figures are not available
(12) Used in investment casting
(13) This figure includes 0.13 million pounds of imported material

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Table 1.3-1

Preliminary Summary of PCBs Import Data for
1971-75 Versus Monsanto Production and Sales Data

	Year or Portion of Year				
	1971	1972	1973	1974	1975
Estimated Imports (lb)	550,000	700,000	480,000	450,000	450,000 (6 mos)
Monsanto Domestic Sales (lb)	34,301,000	26,408,000	37,742,000	34,406,000	7,986,000 (3 mos)
Imports as Percentage of Domestic Sales	1.6	2.7	1.3	1.3	-
Monsanto Exports (lb)	-	6,388,000	8,346,000	5,395,000	1,538,000 (3 mos)
Ratio of Exports to Imports	-	9.1	17.3	13.5	-

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During 1971 and 1972 most of the PCBs imported into the United States originated in Japan, ostensibly corresponding to sales of stocks unsalable in Japan due to pending or established regulatory action. There apparently has been little or no U.S. importation of PCBs from Japan since 1972. The major importer was Marubeni America Corp., West Caldwell, N.J.

Since 1972, most of the imported PCBs originated in Italy, with a small amount imported from France (manufactured by Prodelec). This French material is similar to Aroclor 1242 and is used (40,000-60,000 lb. per year) as a coolant in mining machinery by Joy Mfg. Co., Franklin, Pa. Decachlorobiphenyl (Fenclor DK) is imported from Italy by Yates Mfg. Co., Chicago, Ill., for use in the manufacture of investment casting waxes. Estimated current usage is about 400,000 lb/year.

Polychlorotriphenyls, also used in pattern wax formulations, appear to be imported at an increasing rate. Estimated amounts are:

1973	1974	1975 (6 mos.)
160,000 lb.	330,000 lb.	200,000 lb.

Major importers of PCTs are Progil, Inc. (formerly Prochimie) and Intsel Co., both located in the New York City area. Most of the imported PCTs originate in France (Prodelec).

Use of PCBs and PCTs in casting waxes appears to be generally stable or increasing slowly, and under conditions of lack of regulatory control in the future, such use would be expected to continue at least at the current rate. On the other hand, Joy Mfg. Co. no longer manufactures mining equipment using PCBs as coolant; the amounts imported by Joy are used to service existing equipment. However, since Joy imports only 10 to 20 percent of the total, the overall imports will not be affected greatly by future decreases in imports by Joy.

2.0 FIFTEEN YEAR EXTRAPOLATIONS FOR PCB PRODUCTION AND USE IN ELECTRICAL EQUIPMENT

The subject data base was assembled from domestic sales figures for Aroclors reported by Monsanto – capacitor and transformer sales being summed

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to obtain totals. For certain years (1972-1973), sales data were reported in aggregate, and in such cases, the reported figures were taken as totals, and usage breakdown was accomplished by assigning total amounts of Aroclor 1221 and 1016 to capacitors and total amounts of Aroclor 1242, 1248, 1254, and 1260 to transformers. All 1975 totals were obtained by quadrupling the reported first-quarter sales figures - a process which very likely yields an approximate lower-bound to the actual yearly totals - and, ultimately, Table 2-1 was constructed.

Manifestly, the available data base is far too limited to form the basis for any rational statistical analysis. The strong pertubational decrement in the 1971-1972 interval precludes the application of incremental regression - even if a fifteen-year extrapolation were not required. In short, then, trend analysis becomes a generally risky proposition, and the optimum analytical approach seems to be limited to unbiased extrapolations of least-square linear fits to grouped subsets of the available data points.

Given this, three data base subsets appear promising:

(i.) the full base - using all reported and 1975-estimated data, unweighted and unbiased;

(ii.) a singly-deleted base - using all reported data, but eliminating the 1975 estimates. This tends to weight the extrapolations (however weakly) with regard to recent (last-decade) performance only, but the resulting curves can then be inspected without the bias of the estimated 1975 totals; and

(iii.) triply-deleted base - formed by extracting the depressed 1971 and 1972 totals from the singly-deleted base. This construction eliminated the bias of the 1975 estimates, and discounts the effects of the interval decrements caused by regulatory effects. (A perhaps more realistic picture might be obtained by placing a decremental weight on 1975 totals - under the assumption that some of the roll-back is reactively

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Table 2-1

Total PCB Breakdown by Use
1966 - 1975

Year	Total (10^6 lbs.)	Capacitors (10^6 lbs.)	Transformers (10^6 lbs.)
1966	37.794	28.884	8.910
1967	40.774	29.703	11.071
1968	41.135	29.550	11.585
1969	37.127	25.022	12.105
1970	40.536	26.708	13.828
1971	25.275	14.141	11.134
1972	25.656	20.321	5.335
1973	37.742	23.566	14.176
1974	34.406	22.000	12.000
1975 (est.)	31.944	20.644	11.300

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Dielec

MONSANTO

PCB LABELING MANUAL

11-1-73

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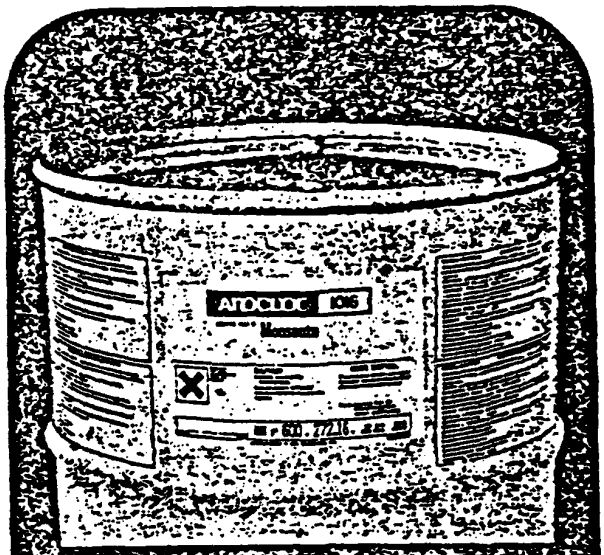
NEW FROM MONSANTO:

The "YELLOW DRUM"

...exclusively designed for dielectric fluids handling.



Effective immediately, Monsanto Company will ship dielectric fluids exclusively in the distinctive new yellow drum illustrated above. The new drum is of heavy gauge steel, was designed to minimize damage and leakage in transit. The bright yellow color makes identification easy, quick and certain.

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ENGLISH IMPORTANT CHLORODIPHENYLS (42 %- 54 %) (or 60 %) (PCB)

This product contains POLYCHLORINATED BIPHENYLS (PCB's) which some studies have shown may be persistent, an environmental contaminant and, possibly, injurious to certain forms of bird, aquatic and animal life.

PREVENT ANY ENTRY INTO THE ENVIRONMENT THROUGH SPILLS, LEAKAGE, DISPOSAL, VAPOURISATION, RE-USE OF CONTAINERS OR OTHERWISE.

SPILLS, LEAKAGES AND WASTE PRODUCT MUST BE COLLECTED.

Use of this product must be restricted to applications which can be controlled so that entry into the environment does not occur and to applications in which it cannot come into contact with food, animal feedstuffs or pharmaceuticals.

HARMFUL SUBSTANCE IF TAKEN INTERNALLY OR IF IN PROLONGED CONTACT WITH THE SKIN.

CAUSES IRRITATION OF SKIN AND EYES.

DURING SHIPMENT AVOID SPILLS AND LEAKAGE INTO INLAND WATERWAYS AND THE SEA.

Store away from food, animal feedstuffs and pharmaceuticals.

Keep container tightly closed.

Do not eat or smoke when using.

Avoid breathing vapours, mist or fumes.

Do not wear contaminated clothing.

Wash product from skin with soap and water.

Wash eyes by flushing with water.

THIS COPY, THIS SIZE, IN SEVEN LANGUAGES IS PAINTED ON 30 AND 55 GALLON DRUMS USED FOR PCB SHIPMENTS.

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WATER_PCB-SD0000073819

DEUTSCH WICHTIG **CHLORIERTE BIPHENYLE (42 % - 54 %) (oder 60 %) (PCB)**

Dieses Produkt enthält POLYCHLORIERTE BIPHENYLE (PCB's). Untersuchungen haben gezeigt, dass dieses Produkt die Umwelt dauerhaft verschmutzen und möglicherweise für bestimmte Vogelarten sowie Land- und Wasserlare schädlich sein kann.
JEGLICHES EINDRINGEN IN DIE UMWELT DURCH VERSCHÜTTEN, LECKAGEN, VERDAMPFEN, WIEDERGEBRAUCH VON BEHÄLTERN ODER ÄHNLICHES IST ZU VERHINDERN.
VERSCHÜTTETES UND ABFÄLLE MÜSSEN GESAMMELT WERDEN.
Der Einsatz dieses Produktes muss auf kontrollierte Anwendung beschränkt bleiben, so dass ein Eindringen in die Umwelt und die Berührung mit Lebensmitteln, Tierfutter oder Pharmazeutika verhindert wird.

GESUNDHEITSSCHÄDLICH BEI VERSCHLUCKEN ODER BEI LÄNGERER BERÜHRUNG MIT DER HAUT.
REIZT HAUT UND AUGEN.
VERSCHÜTTEN ODER LECKAGEN IN FLÜSSE ODER SEEN WÄHREND DES TRANSPORTES VERMEIDEN.
Von Nahrungsmitteln, Tierfutter und Pharmazeutika fernhalten.
Behälter dicht geschlossen halten.
Bei der Arbeit nicht essen oder rauchen.
Dämpfe nicht einatmen.
Beschmutzte Kleidung nicht wiederverwenden.
Nach Hautkontakt sehr gründlich mit Wasser und Seife waschen.
Nach Augenkontakt mit viel Wasser spülen.

FRANÇAIS IMPORTANT **DIPHENYLES CHLORES (42 % - 54 %) (ou 60 %) (PCB)**

Ce produit contient des DIPHENYLES CHLORES qui, selon certaines études, pourraient être persistants contaminer l'environnement et, de ce fait, être nocifs pour certaines espèces d'oiseaux, de vie animale et vie aquatique.
EMPECHER QU'IL NE SE REPANDE DANS L'ENVIRONNEMENT PAR SUITE DE FUITES, DEVERSEMEN PROCEDES D'ELIMINATION, VAPORISATION, RE-UTILISATION DES RECIPIENTS, ETC.
LES PERTES, FUITES ET DECHETS DOIVENT ETRE RECUEILLIS.
L'utilisation de ce produit doit être limitée aux applications contrôlables afin que le produit ne se répand dans l'environnement, ainsi qu'aux applications où il ne peut pas entrer en contact avec l'alimentation hu et animale ou les produits pharmaceutiques.
SUBSTANCE NOCIVE PAR INGESTION OU PAR CONTACT PROLONGE AVEC LA PEAU.
IRRITANT POUR LA PEAU ET LES YEUX.
DURANT LE TRANSPORT EVITER DEVERSEMENTS ET PERTES DANS LES COURS D'EAU ET LA MER
Tenir à l'écart d'alimentation humaine et animale et des produits pharmaceutiques.
Tenir le récipient bien fermé.
Ne pas manger et ne pas fumer pendant l'utilisation.
Eviter de respirer les émanations.
Ne pas porter de vêtements souillés par le produit.
Enlever le produit de la peau avec de l'eau et du savon.
Rincer abondamment les yeux avec de l'eau.

NEDERLANDS BELANGRIJK **GECHLOREERDE DIFENYLS (42 % - 54 %) (of 60 %) (PCB)**

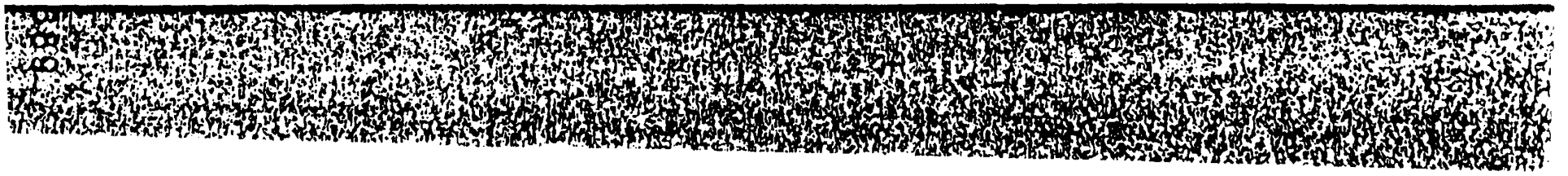
Dit produkt bevat GEPOLYCHLOREERDE BIPHENYLEN (PCB's) waarvan enige studies hebben aangetoond dat ze persistent en milieuverontreinigend zouden kunnen zijn en mogelijkerwijze schadelijk voor bepaalde vogels, dieren en het leven onder water.
BELET DAT HET PRODUKT IN HET MILIEU GERAAKT DOOR MORSEN, LEKKAGE, VERNIETIGEN, VERDAMPEN, HERGEBRUIKEN VAN CONTAINERS ENZ.
GEMORS, LEKKAGES EN VERSPILD PRODUKT MOETEN VERZAMELD WORDEN.
Het gebruik van dit produkt moet beperkt worden tot die toepassingen welke gekontroleerd kunnen worden zodat aanwezigheid in het milieu niet kan voorkomen en tot toepassingen waarbij het niet in kontakt kan komen met voedsel, dierlijk voedsel of farmaceutica.
SCHADELIJKE SUBSTANTIE WANNEER GEABSORBEERD OF BIJ LANGDURIG KONTAKT MET DE HUID.
VEROORZAAKT IRRITATIE VAN HUID EN OGEN.
VERMIJD GEMORS EN LEKKAGES IN BINNENWATEREN EN ZEE GEDURENDE VERSCHEPING.
Bewaar verwijderd van voedsel, dierlijk voedsel en farmaceutica.
Hou container behoorlijk gesloten.
Eet noch rook tijdens gebruik.
Vermijd inademen van dampen, nevels en uitwasemingen.
Draag geen verontreinigde kleding.
Verwijder produkt van de huid door wassen met zeep en water.
Was ogen met stromend water.

ENGLISH IMPORTANT **CHLORODIPHENYLS (42 % - 54 %) (or 60 %) (PCB)**

This product contains POLYCHLORINATED BIPHENYLS (PCB's) which some studies have shown may b persistent, an environmental contaminant and, possibly, injurious to certain forms of bird, aquatic and an life.
PREVENT ANY ENTRY INTO THE ENVIRONMENT THROUGH SPILLS, LEAKAGE, DISPOSAL, VAPOURISATION, RE-USE OF CONTAINERS OR OTHERWISE.
SPILLS, LEAKAGES AND WASTE PRODUCT MUST BE COLLECTED.
Use of this product must be restricted to applications which can be controlled so that entry into the environment does not occur and to applications in which it cannot come into contact with food, animal feedstuffs or pharmaceuticals.
HARMFUL SUBSTANCE IF TAKEN INTERNALLY OR IF IN PROLONGED CONTACT WITH THE SKIN.
CAUSES IRRITATION OF SKIN AND EYES.
DURING SHIPMENT AVOID SPILLS AND LEAKAGE INTO INLAND WATERWAYS AND THE SEA.
Store away from food, animal feedstuffs and pharmaceuticals.
Keep container tightly closed.
Do not eat or smoke when using.
Avoid breathing vapours, mist or fumes.
Do not wear contaminated clothing.
Wash product from skin with soap and water.
Wash eyes by flushing with water.

903820

THIS LABEL WAS USED ON 5 GALLON CANS UNTIL PAINTED UNITS WERE ESTABLISHED.



ITALIANO IMPORTANTE — CLOROBIFENILI (42 % - 54 %) (oppure 60 %) (PCB)

Questo prodotto contiene POLICLOROBIFENILI (PCB), che secondo i risultati di alcuni studi sembrano essere persistenti e contagiosi per l'ambiente, e probabilmente nocivi per alcune specie di uccelli, e di vita animale e acquatica.

PREVENIRE LA PENETRAZIONE NELL'AMBIENTE A CAUSA DI PERDITE, FUGHE, SCARICHI, EVAPORAZIONE, RIUTILIZZO DEI CONTENITORI OD ALTRO.

LE PERDITE, FUGHE O SCARTI DEVONO ESSERE RACCOLTI.

L'utilizzo di tale prodotto deve essere limitato a quelle applicazioni che possono essere controllate in modo di evitare la penetrazione nell'ambiente ed a quelle applicazioni nelle quali non possa venire in contatto con alimenti umani e per animali o prodotti farmaceutici.

SOSTANZA NOCIVA PER INGESTIONE O PER CONTATTO PROLUNGATO CON LA PELLE.

IRRITANTE PER LA PELLE E GLI OCCHI.

DURANTE IL TRASPORTO EVITARE PERDITE E TRABOCCHI IN ACQUE INTERNE E NEL MARE.

Mantenere lontano da prodotti farmaceutici e alimenti umani e per animali.

Mantenere il recipiente ben chiuso.

Non mangiare o fumare durante l'impiego.

Evitare di respirare le emanazione.

Non indossare indumenti contaminati dal prodotto.

Lavare la pelle con acqua e sapone, dopo il contatto.

Lavare abbondantemente gli occhi con acqua.

PORTUGUÊS IMPORTANTE — CLORODIFENILOS (42 % - 54 % 60 %) (PCB)

Este produto contém POLICLORODIFENILOS (PCB's) que certos estudos m[illegible] serem persistentes e contagiosos para o meio ambiente e mesmo nefastos para certas aves, anir[illegible] espécies aquáticas.

EVITAR QUALQUER INTRODUÇÃO NO MEIO AMBIENTE POR DERRAME, ESCOAMENTO, REJEIÇÃO, VAPORIZAÇÃO, UTILIZAÇÃO REPETIDA DE RECIPIENTES OU DE QUALQUER OUTRO MODO.

OS PRODUTOS ENTORNADOS, VERTIDOS OU REJEITADOS DEVEM SER RECUPERADOS.

O emprego deste produto deve ser limitado a applicações, que podem ser controladas de modo a que a introdução no meio ambiente não se produza, e a aplicações em que não pode ter contacto com alim[illegible] comida para animais ou com produtos farmacêuticos

SUBSTÂNCIA NOCIVA QUANDO ABSORVIDA OU SE EM CONTACTO PROLONGADO COM A PELE.

CAUSA IRRITAÇÃO DE PELE E DOS OLHOS.

DURANTE O TRANSPORTE MARÍTIMO EVITAR OS DERRAMES E ESCOAMENTOS NOS RIOS E NO MAR

Armazenar afastado dos alimentos, comida para animais, ou produtos farmacêuticos.

Conserver os recipientes cuidadosamente fechados.

Não comer nem fumar durante a sua utilização.

Evitar respirar os vapores, emanações ou fumos.

Não vestir roupa contaminada.

Lavar a pele com água e sabão.

Lavar os olhos com água, por asperção.

ESPAÑOL IMPORTANTE — DIFENILOS CLORADOS (42 % - 54 %) (o 60 %) (PCB)

Este producto contiene BIFENILOS POLICLORADOS (PCB) que, según ciertos estudios, han resultado ser persistentes, contaminadores del medio ambiente y, posiblemente, perjudiciales para determinadas clases de pájaros y vida acuática y animal.

EVITAR QUE ENTRE EN CONTACTO CON EL MEDIO AMBIENTE POR DERRAMES, FUGAS, DESECHO, VAPORIZACION, RE-UTILIZACION DE ENVASES, O POR CUALQUIER OTRA CAUSA.

DEBE RECOGERSE CUALQUIER DERRAME, FUGA O DESPERDICIO.

La utilización de este producto debe restringirse a aplicaciones que pueden ser controladas, para evitar su introduccion en el medio ambiente, y a aplicaciones en las que no pueda entrar en contacto con alimentos, piensos, o productos farmacéuticos.

SUBSTANCIA NOCIVA SI SE INGIERE O SE ENCUENTRA EN CONTACTO PROLONGADO CON LA PIEL. CAUSA IRRITACION, A LA PIEL Y LOS AJOS.

DURANTE EL TRANSPORTE, EVITAR DERRAMES Y FUGAS A CANALES O RIOS NAVEGABLES, Y AL MAR.

Almacenar lejos de alimentos, piensos, y productos farmacéuticos.

Mantener el envase herméticamente cerrado.

Abstenerse de comer o fumar durante su utilización.

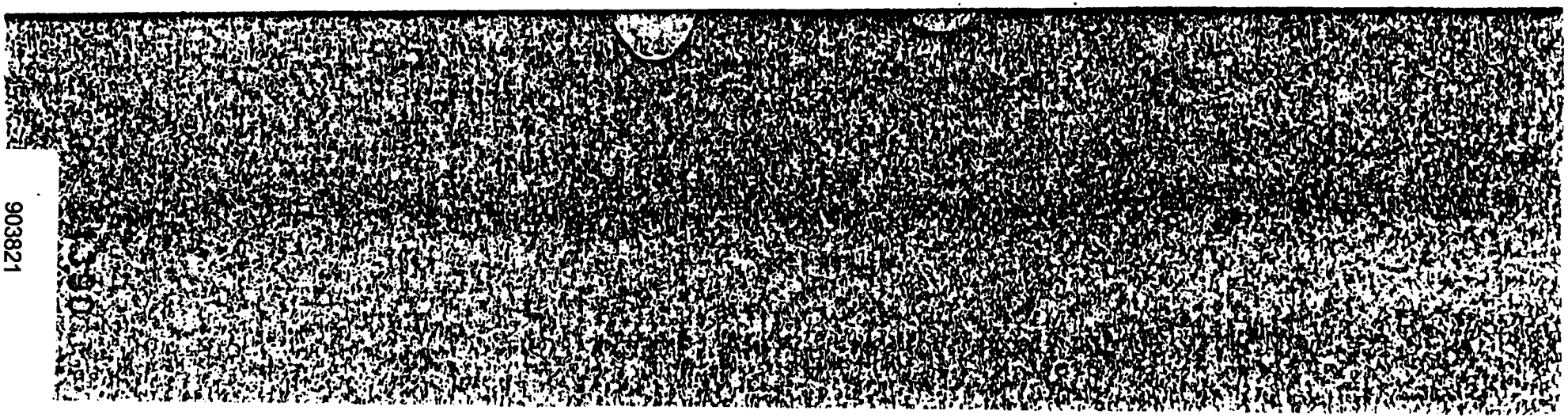
Evitar respirar los vapores y emanaciones.

No vestir prendas contaminadas.

Eliminar el producto de la piel, lavándola con agua y jabón.

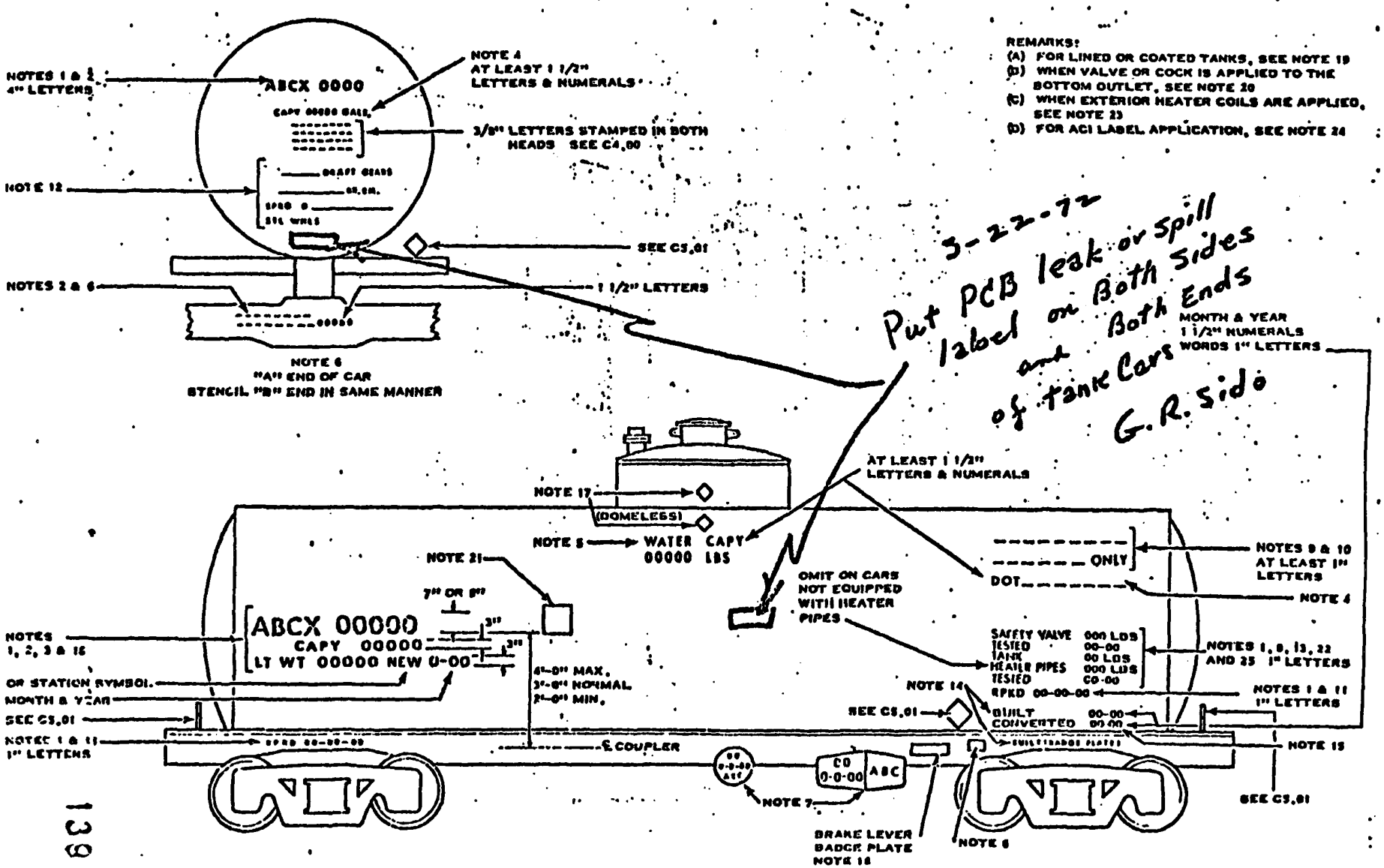
Lavar los ojos, enjuagándolos con agua.

1291



903821

WATER_PCB-SD0000073821



903822

FIGURE C1 — DOT AND AAR STENCIL REQUIREMENTS

WATER_PCB-SD0000073822

IN CASE OF LEAK OR SPILL, CALL COLLECT 618 271-5335

This product contains POLYCHLORINATED BIPHENYLS (PCB's) which some studies have shown may be persistent, an environmental contaminant and, possibly, injurious to certain forms of bird, aquatic and animal life.

PREVENT ANY ENTRY INTO THE ENVIRONMENT THROUGH SPILLS, LEAKAGE, DISPOSAL, VAPOURISATION, REUSE OF CONTAINERS OR OTHERWISE.

SPILLS, LEAKAGES AND WASTE PRODUCT MUST BE COLLECTED.

Use of this product must be restricted to applications which can be controlled so that entry into the environment does not occur and to applications in which it cannot come into contact with food, animal feedstuffs or pharmaceuticals.

HARMFUL SUBSTANCE IF TAKEN INTERNALLY OR IF IN PROLONGED CONTACT WITH THE SKIN.

CAUSES IRRITATION OF SKIN AND EYES.

DURING SHIPMENT AVOID SPILLS AND LEAKAGE INTO INLAND WATERWAYS AND THE SEA.

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Store away from food, animal feedstuffs and pharmaceuticals.

Keep container tightly closed.

Do not eat or smoke when using.

Avoid breathing vapours, mist or fumes.

Do not wear contaminated clothing.

Wash product from skin with soap and water.

Wash eyes by flushing with water.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at $0.08/lb. plus $8.00 per drum handling charge.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

1249/53

LABEL ATTACHED ON ENDS AND SIDES OF TANK CARS

903823

1392

WATER_PCB-SD0000073823

IN CASE OF LEAK OR SPILL, CALL COLLECT 618 271-5835

This product contains POLYCHLORINATED BIPHENYLS (PCB's) which some studies have shown may be persistent, an environmental contaminant and, possibly, injurious to certain forms of bird, aquatic and animal life.

PREVENT ANY ENTRY INTO THE ENVIRONMENT THROUGH SPILLS, LEAKAGE, DISPOSAL, VAPOURISATION, REUSE OF CONTAINERS OR OTHERWISE.

SPILLS, LEAKAGES AND WASTE PRODUCT MUST BE COLLECTED.

Use of this product must be restricted to applications which can be controlled so that entry into the environment does not occur and to applications in which it cannot come into contact with food, animal feedstuffs or pharmaceuticals.

HARMFUL SUBSTANCE IF TAKEN INTERNALLY OR IF IN PROLONGED CONTACT WITH THE SKIN.

CAUSES IRRITATION OF SKIN AND EYES.

DURING SHIPMENT AVOID SPILLS AND LEAKAGE INTO INLAND WATERWAYS AND THE SEA.

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Store away from food, animal feedstuffs and pharmaceuticals.

Keep container tightly closed.

Do not eat or smoke when using.

Avoid breathing vapours, mist or fumes.

Do not wear contaminated clothing.

Wash product from skin with soap and water.

Wash eyes by flushing with water.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

1249/53

LABEL ATTACHED ON ENDS AND SIDES OF TANK CARS

903824

1393

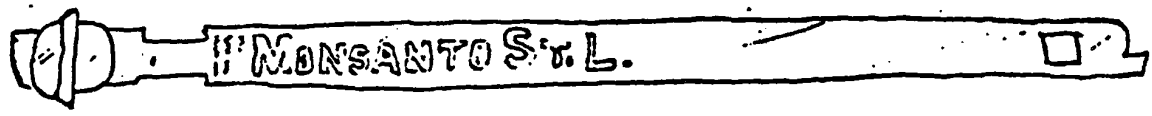
WATER_PCB-SD0000073824

BULK LOAD TAG

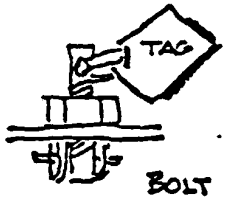
Monsanto

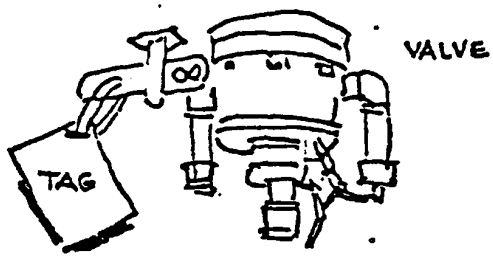
LABELING BULLETIN
Number 8

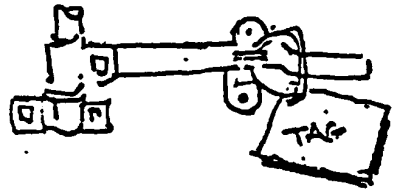
The bulk load tag is the standard drum label attached to a tough plastic sheet. A packing information envelope, if needed, is attached to the back of the same plastic sheet. The tag is folded and punched for easy hanging by the seal at the discharge outlet.



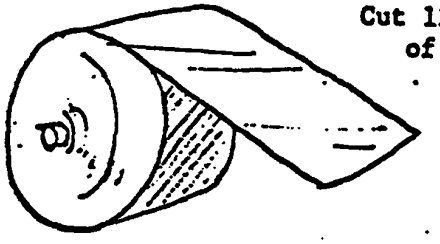
HANG THE TAG BY THE CAR SEAL, to the discharge outlet: bolt, valve or door latch.





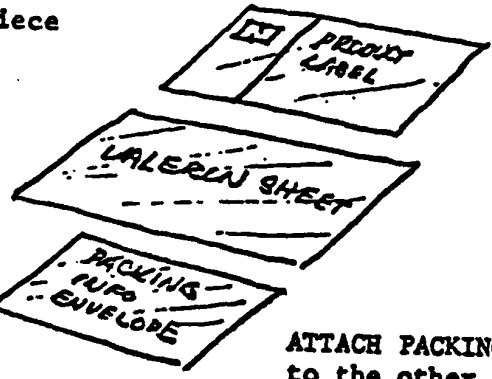


HOW TO ASSEMBLE THE BULK LOAD TAG



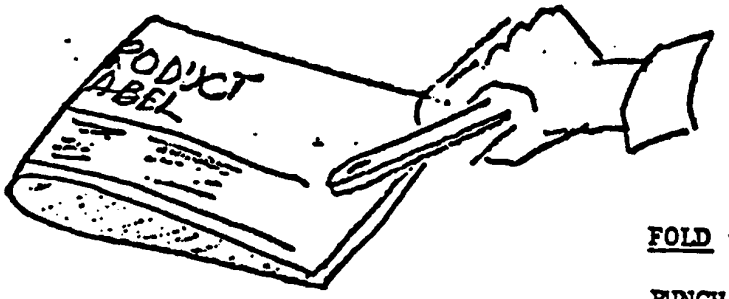
Cut 13" long piece of Valeron

6" wide roll of Valeron



ATTACH LABEL to one side of Valeron sheet.

ATTACH PACKING INFO ENVELOPE to the other side of the sheet.



FOLD tag

PUNCH upper folded corner

SLIP car seal thru punched hole and fasten to discharge outlet.

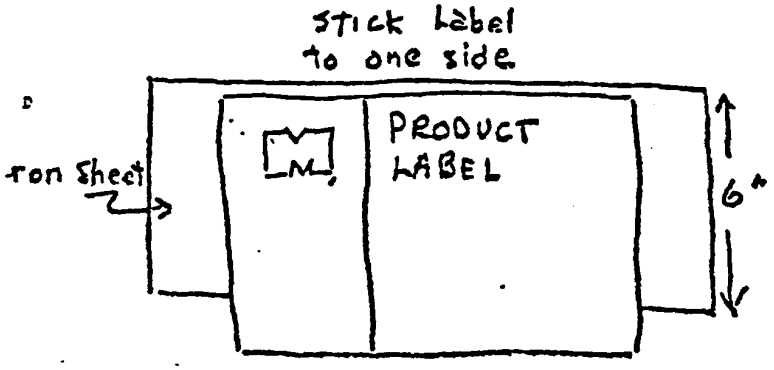
1394

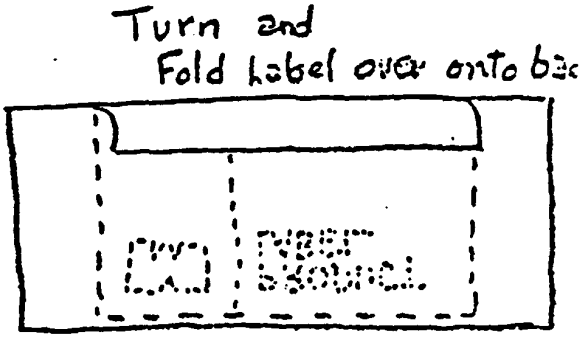
903825

3-22-72
C.R.S.d

WATER_PCB-SD0000073825

Do not cut Labels! fold over when label is more than 6" high.





1395

903826

WATER_PCB-SD0000073826

FROM MONSANTO COMPANY

SHIPPER'S NO.	DISTRICT		CUSTOMER'S ORDER NO.		DATE SHIPPED	CAR OR VEHICLE INITIALS AND NO.
77 05515	41		[illegible]		10/17/73	ISOM 6300

AND OR COLLECT - ROUTING

[illegible]

TO INSURE PAYMENT THIS SHIPPERS NUMBER MUST SHOW ON FREIGHT BILL

Your Statement must show Pro No. and Monsanto's Shipper's No. opposite each amount; also statement total.

Send Prepaid Freight Bills with your domestic statement (in duplicate) directly to:
MONSANTO COMPANY
Box 14307
St. Louis, Mo. 63178

SHIPPED FROM	WHSE. CODE
SAUGET, IL.	0003

FOR WESTINGHOUSE ELECTRIC CORPORATION
ATTN: RELEASE &
ACCOUNTS PAYABLE DEPT.
[illegible]
SOUTH BOSTON, VIRGINIA 24592

WESTINGHOUSE ELECTRIC CORPORATION
[illegible]
SOUTH BOSTON, VIRGINIA 24592

SHIP TO

SHIP TO AND DESTINATION—(MAIL OR STREET ADDRESS OF CONSIGNEE—FOR PURPOSES OF NOTIFICATION ONLY)

NOTICE TO CARRIER
IF FOR ANY REASON THIS SHIPMENT IS DELAYED IN EXCESS OF 24 HOURS, NOTICE MUST BE GIVEN TO MONSANTO SHIPPING LOCATION.

NO. PACKAGES	KIND OF PACKAGE, DESCRIPTION OF ARTICLES, SPECIAL MARKS, ** AND EXCEPTIONS	*WEIGHT (Subject to Corr.)	CLASS OR RATE	CK. COL.
	PLASTICS SYNTHETIC LIQUID NOIBN 1- 22000 GL TANK CAR ITEM 1 INERTEEN 94201 CH [illegible] FOB SAUGET IL full cap 8803 Wal [illegible]	GROSS OR LB G 137900 NT 41700 N 96200		

Subject to Section 7 of conditions of applicable bill of lading if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement:
The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

(Signature of Consignor)

NOTE FREIGHT TERMS ABOVE

If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carrier's or shipper's weight."

Where the rate is dependent on value, the shipper is required to state specifically in writing the agreed or declared value of the property as follows:
"The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding
50 CENTS PER POUND"

IMPORTANT FL 12 2nd pm

This material contains POLYCHLORINATED BIPHENYLS (PCB's) which [illegible] have been [illegible] to present a [illegible] environmental contamination if [illegible] injudicious to certain forms of [illegible] aquatic and animal life. Prevent any entry into the environment through spills, leakage, disposal, evaporation, reuse of containers or otherwise. Spills, leakage and [illegible] must be collected.

During shipment avoid spills and leakage into inland waterways and the sea.

Keep away from food, animal foodstuffs and pharmaceuticals.

☒ CAR LOADED SHELL FULL ☐ CAR LOADED SHELL NOT FULL ☐ THE TANK CAR INDICATED ON THIS BILL OF LADING IS TRIP LEASED TO

This is to certify that the above-named articles are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation.

(The fibre board used for this shipment conforms to the specifications set forth in the box maker's certificate thereon, and all other requirements of Uniform Freight Classification Shipper's imprint in lieu of stamp; not a part of bill of lading approved by the Interstate Commerce Commission.

MONSANTO COMPANY Shipper,

Per [illegible]
WRITTEN SIGNATURE ONLY

[illegible] Agent, Per [illegible]

Permanent post-office address of shipper [illegible]

EMERGENCY

In case of emergency concerning the chemicals in this shipment:

CALL COLLECT: W.G. KRUMMRICH PLANT (618) 271-5835
on
[illegible]

4
1396

903827

WATER_PCB-SD0000073827

MONSANTO COMPANY

SHIPPER'S NO. | DISTRICT | CUSTOMER'S ORDER NO. | DATE SHIPPED | CAR OR VEHICLE INITIALS & NO.

10/18/73

PREPAID OR COLLECT - ROUTING

PREPAID

TO INSURE PAYMENT THIS SHIPPERS NUMBER MUST SHOW ON FREIGHT BILL

Your Statement must show Pro No. and Monsanto's Shipper's No. opposite each amount; also statement total.

Send Prepaid Freight Bills with your statement (in duplicate) directly to:
MONSANTO COMPANY
Box 14307
St. Louis, Mo. 63178

SHIPPED FROM: SAUGET ILL | WHSE. CODE: 03

BENGO EGIA CAPACITORS LTD
534 MEDORS STREET
BOMBAY 400001 INDIA
3555

SHIP TO

NOTICE TO CARRIER
IF FOR ANY REASON THIS SHIPME
IS DELAYED IN EXCESS OF 24 HOU
NOTICE MUST BE GIVEN TO
MONSANTO SHIPPING LOCATIC

NO. PACKAGES	KIND OF PACKAGE, DESCRIPTION OF ARTICLES, SPECIAL MARKS ** AND EXCEPTIONS	*WEIGHT (Subject to Corr.)	CLASS OR RATE	CK. COL.
	CHLORINATED DIPHENYL	12024 #		
	AROCLOR 1248	N. 10800		
	LBCL			
	BOMBAY			
	MADE IN USA			
18	1/18 PLASTICS LIQUID NOIBN 18 X 660 POUND METAL DRUMS	30		
	AROCLOR 1242			
	1048-16-03-47-13			
	WEIGHTS LBS KILOS			
	GROSS 606.00 505.00			
	NET 600.00 272.16 10.715 CU FT			
	DIMENSIONS 23 15/32 X 24 3/4 INCHES			
	TOTAL GROSS 12024.00 LBS 5454.00 KILOS			
	TOTAL CUBE 192.87 CU FT			

IMPORTANT
This product contains POLYCHLORINATED BIPHENYLS which may be persistent in the environment. Some studies have shown injurious to certain animal life and possibly injurious to man. Due to the persistent nature of these compounds, disposal, conservation and future use of containers which have held these materials may be affected by various laws and regulations. Spills, leakages and waste product must be handled in accordance with applicable regulations. Spills, leakages and wastes should be contained and reported to the Environmental Protection Agency. Do not contaminate food, feed stuffs or water supplies with these materials.

NOTE FREIGHT TERMS ABOVE

50 CENTS PER PO

FOR EXPORT TO INDIA

☐ CAR LOADED SHELL FULL ☐ CAR LOADED SHELL NOT FULL ☐ THIS TANK CAR INDICATED ON THIS BILL OF LADING IS THIP LEASED TO:

This is to certify that the above-named articles are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation, according to the applicable regulations of the Department of Transportation.

MONSANTO COMPANY Shipper,

Per _____ 10/18/73
WRITTEN SIGNATURE ONLY

Permanent post-office address of shipper: _____

†The fibre board used for this shipment conforms to the specifications set forth in the box maker's certificate thereon, and all other requirements of Consolidated Freight Classification rules or other lawful agents of the carrier in effect on the date of issue of this Bill of Lading.

†Shipper's imprint in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission.

Per _____

Mr Side Stamps for Emergency
is usually on #2 Copy of
order

1392

903828

WATER_PCB-SD0000073828

FROM

SHIP TO

MONSANTO COMPANY
Department 831
SAUGET, ILLINOIS 62201

RETURNED

for Reclamation

or

Disposal only

PRODUCT NAME

WEIGHT

IMPORTANT—This product contains POLYCHLORINATED BIPHENYLS (PCBs) which some studies have shown may be persistent environmental contaminants and possibly injurious to certain forms of bird, aquatic and animal life. PREVENT ANY ENTRY INTO THE ENVIRONMENT THROUGH SPILLS, LEAKAGE, DISPOSAL, VAPORIZATION, REUSE OF CONTAINERS OR OTHERWISE. SPILLS, LEAKAGES AND WASTE PRODUCT MUST BE COLLECTED.

CAUTION: Contains chlorinated hydrocarbons. HARMFUL IF SWALLOWED OR IF IN PROLONGED CONTACT WITH THE SKIN. CAUSES IRRITATION OF SKIN AND EYES. DURING SHIPMENT AVOID SPILLS AND LEAKAGE INTO INLAND WATERWAYS AND THE SEA. Store away from food, animal feedstuffs and pharmaceuticals. Keep container tightly closed. Do not eat, drink or smoke when using. Avoid breathing vapours and mists. Do not wear contaminated clothing. Wash product from skin with soap and water. Wash eyes by rinsing with water.

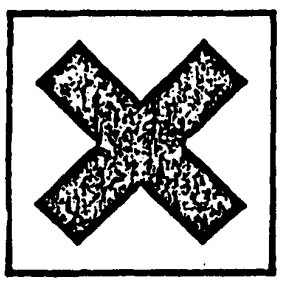
90829

68

WATER_PCB-SD0000073829

TRANSFORMER PYRANOL*

A 13 B-I



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for GENERAL ELECTRIC COMPANY

*Trademark of GENERAL ELECTRIC COMPANY.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

NET LEGAL 60 LB. 27.22 KG.

TARE 5 LB. 2.27 KG.
GROSS 65 LB. 29.49 KG.

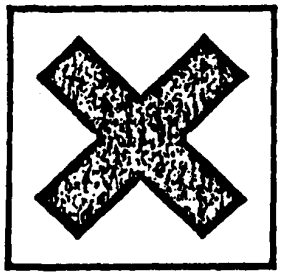
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.03-281.02/53

903830

WATER_PCB-SD0000073830

TRANSFORMER PYRANOL*
A 13 B-I



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for GENERAL ELECTRIC COMPANY

*Trademark of GENERAL ELECTRIC COMPANY.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

NET LEGAL 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

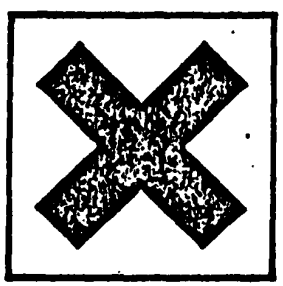
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.03-281.01/53

WATER_PCB-SD0000073831

TRANSFORMER PYRANOL*
A-13-B 3B-2

(REPLACES PYRANOL 1467 and PYRANOL 1470 and PYRANOL A-13-B 3B)



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for GENERAL ELECTRIC COMPANY

*Trademark of GENERAL ELECTRIC COMPANY.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903832

LOT NO. _____ PACKER _____

NET LEGAL 60 LB. 27.22 KG.

TARE 5 LB. 2.27 KG.
GROSS 65 LB. 29.49 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

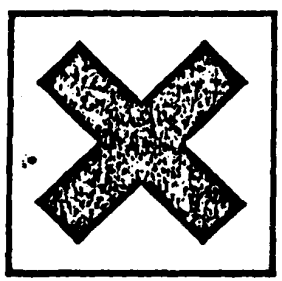
810.97-301.03/53

14C1

WATER_PCB-SD0000073832

TRANSFORMER PYRANOL*
A-13-B 3B-2

(REPLACES PYRANOL 1467 and PYRANOL 1470 and PYRANOL A-13-B 3B)



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for GENERAL ELECTRIC COMPANY

*Trademark of GENERAL ELECTRIC COMPANY.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

NET LEGAL 360 LB. 163.29 KG.

TARE 46 LB. 20.87 KG.
GROSS 406 LB. 184.16 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

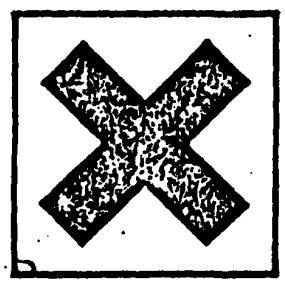
810.97-301.02/53

903833

WATER_PCB-SD0000073833

TRANSFORMER PYRANOL*
A-13-B 3B-2

(REPLACES PYRANOL 1467 and PYRANOL 1470 and PYRANOL A-13-B 3B)



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for GENERAL ELECTRIC COMPANY

*Trademark of GENERAL ELECTRIC COMPANY.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903834

LOT NO. _____ PACKER _____

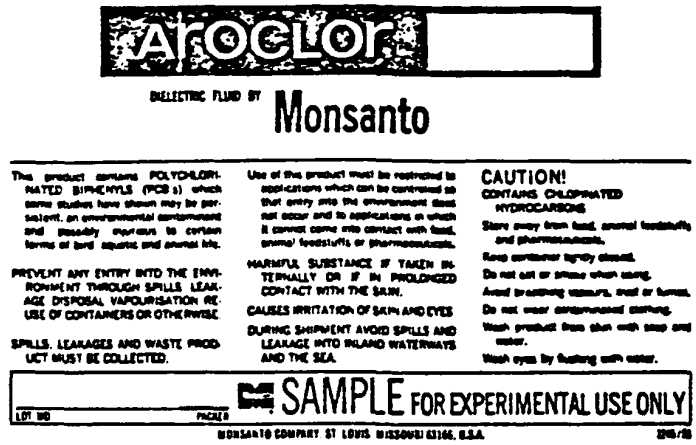
NET LEGAL 675 LB. 306.17 KG.

TARE 68 LB. 30.84 KG.
GROSS 743 LB. 337.01 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

810.97-301.01/53

WATER_PCB-SD0000073834



LABEL FOR PCB SAMPLES

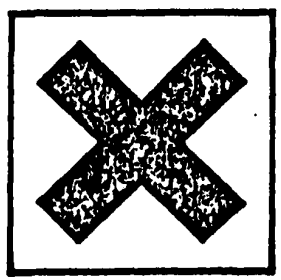
903835

WATER_PCB-SD0000073835

AROCLOR 1016

DIELECTRIC FLUID BY **Monsanto**

"Classified by Underwriters' Laboratories, Inc.
as to Fire Hazard Only.
Aroclor 1016. Classed 2 to 3
Less hazardous than paraffin oil in respect
to fire hazard.
See UL Index of Classified Products."



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

1405

)T NO. PACKER

LEGAL NET 55 LB. 24.95 KG.

TARE 5 LB. 2.27 KG.
GROSS 60 LB. 27.22 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.04-016 .07/53

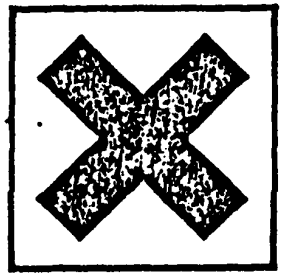
903836

WATER_PCB-SD0000073836

Aroclor 1016

DIELECTRIC FLUID BY **Monsanto**

"Classified by Underwriters' Laboratories, Inc.
as to Fire Hazard Only.
Aroclor 1016. Classed 2 to 3
Less hazardous than paraffin oil in respect
to fire hazard.
See UL Index of Classified Products."



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

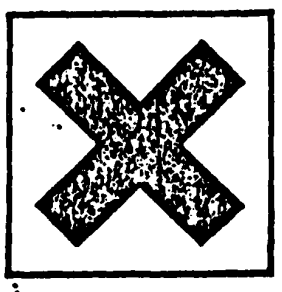
811.04-016.06/53

903837

WATER_PCB-SD0000073837

AROCLOR 1221

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903838

LOT NO. _____ PACKER _____

LEGAL NET 520 LB. 235.87 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

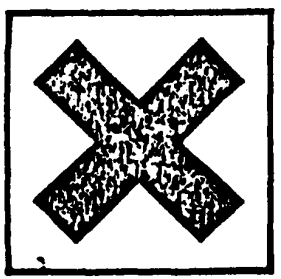
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.06-225.05/53

WATER_PCB-SD0000073838

AROCLOR® 1232

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

LEGAL NET 50 LB. 22.68 KG.

TARE 5 LB. 2.27 KG.
GROSS 55 LB. 24.95 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.09-230.13/53

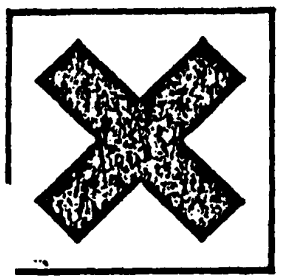
903839

14208

WATER_PCB-SD0000073839

AROCLOR® 1232

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903840

LOT NO. 14B PACKER

LEGAL NET 550 LB. 249.48 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

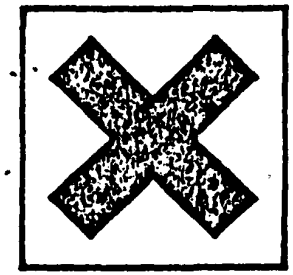
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.09-230.12/53

WATER_PCB-SD0000073840

AROCLOR® 1242

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903841

LOT NO. 1410 PACKER

LEGAL NET 55 LB. 24.95 KG.

TARE 5 LB. 2.27 KG.
GROSS 60 LB. 27.22 KG.

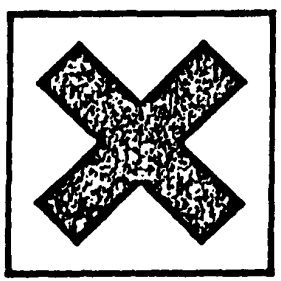
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.01-240.17/53

WATER_PCB-SD0000073841

AROCLOR® 1242

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903842

14 1
LOT NO. PACKER

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.01-240.16/53

WATER_PCB-SD0000073842

AROCLOR® 1248

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

14
LOT NO. PACKER

LEGAL NET 55 LB. 24.95 KG.

TARE 5 LB. 2.27 KG.
GROSS 60 LB. 27.22 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

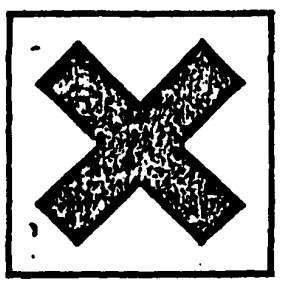
811.02-260.17/53

903843

WATER_PCB-SD0000073843

AROCLOR® 1248

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903844

141

LOT NO. _____ PACKER _____

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

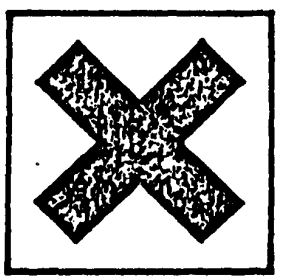
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.02-260.16/53

WATER_PCB-SD0000073844

AROCLOR® 1254

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903845

1414

LOT NO. _____ PACKER _____

LEGAL NET 60 LB. 27.22 KG.

TARE 5 LB. 2.27 KG.
GROSS 65 LB. 29.49 KG.

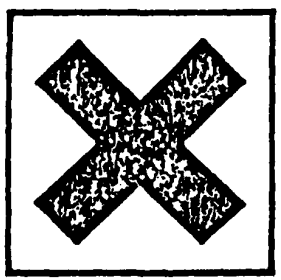
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.03-280.19/53

WATER_PCB-SD0000073845

AROCLOR® 1254

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.03-280.18/53

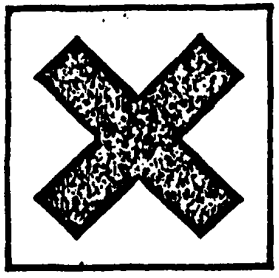
903846

1415

WATER_PCB-SD0000073846

CAPACITOR 21

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

903847

LOT NO. _____ PACKER _____

LEGAL NET 520 LB. 235.87 KG.

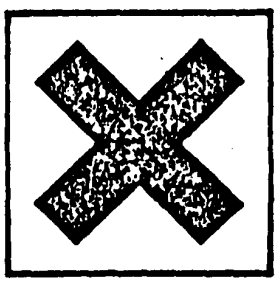
TARE 68 LB. 30.84 KG.
GROSS 588 LB. 266.71 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

811.06-225.04/53

WATER_PCB-SD0000073847

INERTEEN* 70-30



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

LEGAL NET 60 LB. 27.22 KG.

TARE 5 LB. 2.27 KG.
GROSS 65 LB. 29.49 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

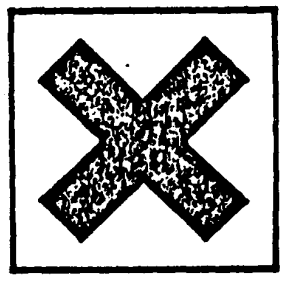
810.98-210.12/53

903848

14117

WATER_PCB-SD0000073848

INERTEEN* 70-30



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 360 LB. 163.29 KG.

TARE 46 LB. 20.87 KG.
GROSS 406 LB. 184.16 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

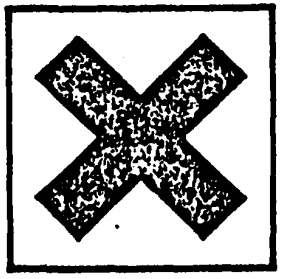
810.98-210.11/53

903849

14 18

WATER_PCB-SD0000073849

INERTEEN* 70-30



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 674 LB. 305.72 KG.

TARE 68 LB. 30.84 KG.
GROSS 742 LB. 336.56 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

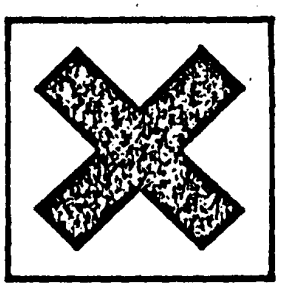
810.98-210.10/53

903850

1419

WATER_PCB-SD0000073850

INERTEEN* 100-42



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 55 LB. 24.95 KG.

TARE 5 LB. 2.27 KG.
GROSS 60 LB. 27.22 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

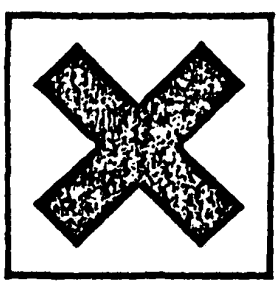
811.10-215.07/53

903851

1420

WATER_PCB-SD0000073851

INERTEEN* 100-42



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 320 LB. 145.15 KG.

TARE 46 LB. 20.87 KG.
GROSS 366 LB. 166.02 KG.

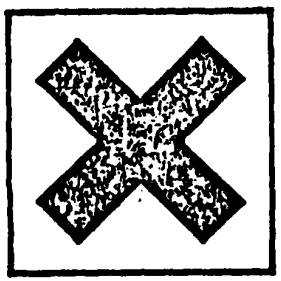
MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A. 811.10-215.06/53

903852

1421

WATER_PCB-SD0000073852

INERTEEN* 100-42



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

Xn

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

Made for WESTINGHOUSE ELECTRIC CORPORATION.

*Trademark of WESTINGHOUSE ELECTRIC CORPORATION.

WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

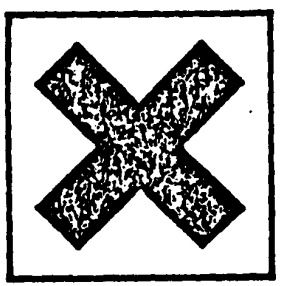
811.10-215.05/53

903853

14 22

WATER_PCB-SD0000073853

INERTEEN* 5420I CF



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

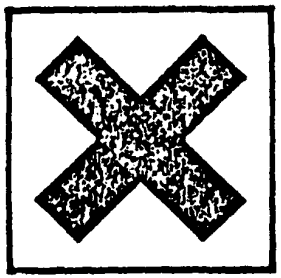
811.10-219.02/53

903854

14423

WATER_PCB-SD0000073854

INERTEEN* 5420I CM



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

LEGAL NET 55 LB. 24.95 KG.

TARE 5 LB. 2.27 KG.
GROSS 60 LB. 27.22 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

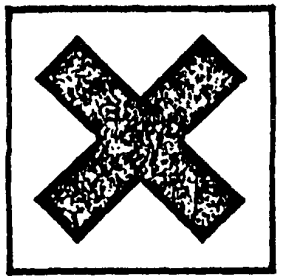
811.10-216.04/53

903855

1424

WATER_PCB-SD0000073855

INERTEEN* 5420I CM



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 320 LB. 145.15 KG.

TARE. 46 LB. 20.87 KG.
GROSS 366 LB. 166.02 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166. U.S.A.

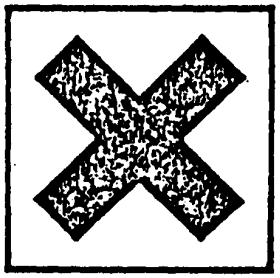
811.10-216.03/53

903856

1425

WATER_PCB-SD0000073856

INERTEEN* 5420I CM



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 600 LB. 272.16 KG.

TARE 68 LB. 30.84 KG.
GROSS 668 LB. 303.00 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

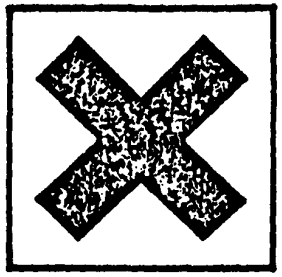
811.10-216.02/53

903857

1426

WATER_PCB-SD0000073857

INERTEEN* 5420I KA



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

With prior Monsanto notification used polychlorinated biphenyl fluids may be returned freight prepaid for proper incineration at 3¢ per pound.

Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 60 LB. 27.22 KG.

TARE 5 LB. 2.27 KG.
GROSS 65 LB. 29.49 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

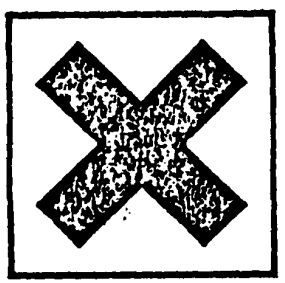
810.98-217.05/53

903858

14 27

WATER_PCB-SD0000073858

INERTEEN* 5420I KA



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 360 LB. 163.29 KG.

TARE 46 LB. 20.87 KG.
GROSS 406 LB. 184.16 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

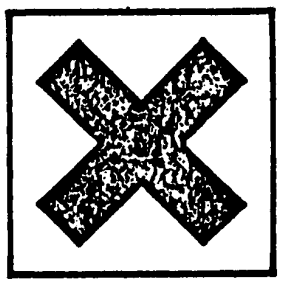
810.98-217.04/53

903859

1428

WATER_PCB-SD0000073859

INERTEEN* 5420I KA



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

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WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____

Monsanto

LEGAL NET 674 LB. 305.72 KG.

TARE 68 LB. 30.84 KG.
GROSS 742 LB. 336.56 KG.

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A.

810.98-217.03/53

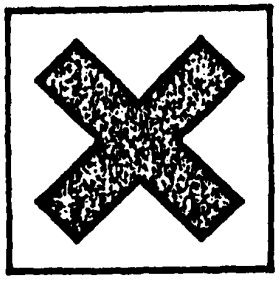
903860

1429

WATER_PCB-SD0000073860

MCS® 1489

DIELECTRIC FLUID BY **Monsanto**



Substances nocives
Harmful substances
Gesundheitsschädliche Stoffe
Schadelijke stoffen
Sostanze nocive

X_n

CAUTION!

CONTAINS CHLORINATED HYDROCARBONS

Read and follow all IMPORTANT safeguard instructions shown on this container.

WASTE DISPOSAL

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Ship to: Supervisor Dept. 831
MONSANTO COMPANY
SAUGET, ILLINOIS 62201

LOT NO. _____ PACKER _____ NET/LEGAL _____ LB. _____ KG. _____

MONSANTO COMPANY, ST. LOUIS, MISSOURI 63166, U.S.A. 800.02-017.01/53

903861

30

WATER_PCB-SD0000073861

Comments on COMPARATIVE TOXICITY of PCBs

Submitted to EPA August 19, 1976 (drafted for GE by John F Brown, Corporate R&D Center, Schenectady,

via J. [illegible] (J...)
J. Nel...

There is neither chemical nor biological justification for considering all PCB isomers and homologs to be equivalent in respect to the criteria for toxicity used by EPA in selecting pollutants for the list of toxic pollutants (38 FR 24342).

An interdisciplinary group of life scientists on the staff of GE's Corporate Research and Development Center recently conducted an exhaustive analysis of the available toxicological and environmental literature on PCBs. This analysis disclosed substantial evidence of large differences in toxicity, bioaccumulation, and environmental persistence among different commercial grades of PCBs and among different test species.

For example, large ranges of toxicity have been seen in animal studies that focussed on the nature of the effect produced by similar doses of different Aroclors, including studies conducted by the same group of workers in the same laboratory. Thus, the same group (Kimbrough, Burse et al) that reported that Aroclor 1254 or 1260 in rats could provoke a progression of hepatic changes, beginning with hypertrophy and hyperplasia, and going on to adenofibrosis, neoplastic nodules, and carcinomas (cited under "(4) Carcinogenesis" on p. 30472) also reported parallel studies indicating that none of these toxic manifestations occurred with Aroclor 1242 or 1016. Similarly, the initial liver response to Aroclors 1254 and 1260, i.e. marked induction of drug-metabolizing enzymes, was absent when Aroclor 1016 was used

The extensive Japanese investigations of the Yusho poisoning episode, particularly the more recent findings summarized by Dr. Kuratsune at the

PLAINTIFF'S EXHIBIT 2701

777624

CLINP 00922

WATER_PCB-SD0000073862

National Conference on PCBs in November 1975, have disclosed the origin of the huge ranges in toxicity exhibited by different grades and even different specimens of the same grade of PCB. The actual toxic agents in the PCBs have been identified as the polychlorodibenzofurans (PCDFs). Kuratsune showed that it was the PCDFs, not the PCBs, that were chronically accumulated in humans and that it was the levels of PCDF, not those of PCB, that correlated with toxic manifestations in man. It is remarkable that the very first clinical report on PCB poisoning in humans, that of Jones and Alden in 1936, clearly recognized that the toxic action had to come from an impurity; however, the impurity was not actually identified as PCDF until more than 35 years later. Clear-cut correlations of toxicity with PCDF level were reported for chickens by Vos et al in 1970-72.

We reviewed all relevant data in the scientific literature describing chronic PCB toxicity studies on mammals. We then constructed Table I, in which columns 3, 5, 6, and 7 present our best quantitative estimates or calculations, from these published data, of PCDF concentrations in the PCBs used, of "maximum no-effect" concentrations of PCB in food, of food intake rates, and of "maximum no-effect" dose rates. For comparison, we have included Kuratsune's data on humans. Among the animal studies, we note in particular that the lowest "maximum no-effect" concentrations and "maximum no-effect" dose rates were associated with the highest estimated PCDF concentrations (>> 1 ppm PCDF in PCB). Furthermore, the "no-effect" numbers for hepatic effects in rats are significantly higher for Aroclor 1016 (which was estimated to have no PCDF) than for the higher chlorinated Aroclors (which were estimated to have about 1 ppm PCDF in the PCB used.)

GENP 009223

WATER_PCB-SD0000073863

TABLE I. CALCULATION OF MAXIMUM NO-EFFECT DOSE RATE FOR PCB/PCDF COMPOSITIONS

(1) Test Object	(2) PCB/PCDF Tested	(3) Ppm PCDF in PCB (Estimated)	(4) Major Toxic Effect	(5) Max. no-effect, ppm PCB in food	(6) Intake rate, kg.food/kg. body wt.-day	(7) Maximum No-effect dose rate, mg.PCB/kg. body wt.-day
man	Kaneclor-400 (heat aged)	10,000[a]	Dermal	(0.5g.)[c]*	(~1000 day)[k]**	~0.007
monkey (adult)	Aroclor-1248 (shelf aged)	>>1[n]	Dermal	<2.5[d]	0.04	<0.1
monkey (infant)	Aroclor-1248	~1[b]	Dermal	>300.[e]	0.04	>12.
mink	Aroclor-1254 (metabolized)	>>1[o]	Hepatic	<0.6[f]	0.05	<0.03
"	Aroclor-1254	~1[b]	"	<5.[g]	"	<0.25
rat	Aroclor-1260	~1[b]	Hepatic	~10.[h]	0.03	~0.3
	Aroclor-1254	~1[b]	"	<100.	"	<3.
	Aroclor-1242	~1[m]	"	>100.	"	>3.
rat	Aroclor-1260	~1[b]	Hepatic	~10[i]	0.05	~0.5
	Aroclor-1254	~1[b]	"			
	Aroclor-1242	~1[m]	"			
	Aroclor-1016	0[b]	"	≳100[j]	"	≳5.

References

a. Kuratsune, 1976. b. Bowes et al., 1975. c. Kuratsune, 1972. d. Barsotti et al., 1975. e. Abrahamson and Allen, 1973. f. Platanow and Karsted 1973. g. Ringer et al., 1972. h. Keplinger et al., 1971; Calandra, 1975; as interpreted by FDA, 1973. i. Keplinger et al., 1971; Calandra, 1975; Kimbrough et al., 1972; as interpreted by FDA 1973. j. Burse et al., 1974. k. Assumption of FDA, 1973. m. Ax and Hansen, 1975. n. Estimated from progressive increases in toxicity observed in going from early to late (Ref.d) tests. o. Estimated from use of liver, known to concentrate PCDF relative to PCB (Ref.a) as mink food.

* This figure is the maximum no-effect dose in grams of PCB.

** ... is accumulated by humans.

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GENP 009224

WATER_PCB-SD0000073864

Even more significant was the demonstration by the Japanese group that the particular PCDF's chronically and specifically accumulated by the human liver were the penta- and hexachlorinated homologs. Since the PCDF's were found to arise from the PCBs upon aging, particularly under conditions favoring thermal oxidation of the PCB's, it is evident that the source of the chronically toxic penta- and hexachloro PCDF's must be the corresponding penta- and hexachloro PCBs.

In this connection, it is significant that Aroclor 1016, which is essentially the only Aroclor used by the capcitor industry since 1971, was specifically designed to contain virtually none of these more environmentally persistent and potentially toxic penta- and hexachloro homologs. The widely-quoted Monsanto prospectus indicates a total content of these "higher homologs as $< 1.1\%$; however, the product quality control limit was set at 0.4%; and the actual material shipped to GE during the past two years has usually contained less than 0.1%. This contrasts with the 100-fold higher level of "higher homologs" found in Aroclor 1242 (typically, around 9%) or the 1000-fold higher level in 1254 or 1260 ($> 70\%$). Thus, there is a clear chemical basis for the strikingly lower toxicity levels actually observed in mammals whose diet contained Aroclor 1016.

Toxicity in fish probably results from a general anesthetic effect of the PCBs themselves rather than PCDF activity in most cases; even so, there are significant differences in chronic toxicity among the various product grades, which appear only partly relatable to differences in bioaccumulation. Reported values for bioaccumulation of Aroclor 1016 in various species and life stages of fish run from 2,500 to 55,000, and are usually 10-20,000. Bioaccumulation of Aroclor 1254 is typically 2-5

GENP 009225

WATER_PCB-SD0000073865

fold larger. In continuous flow chronic toxicity tests, reported LC 50 values for various species and life stages of fish cover the range 11-81 ppb for Aroclor 1016 (Hansen, Parrish and Forester, 1974) and about 1-5 ppb for Aroclor 1254 (Nebeker and Puglisi, 1974). There is one report of "significant mortality" in sheepshead minnow fry at 0.1 ppb of Aroclor 1254; the same authors also reported, however, that 100-fold higher levels were required to produce a comparable effect with Aroclor 1016. (~~Nebeker~~ Hansen, Forester, 1975 ~~and Defoe, 1974~~).

In summary, all available evidence indicates that Aroclor 1016 is 10- to 100-fold less hazardous than the higher PCBs to fish; 100- to 1000-fold less hazardous upon direct exposure to animals, and probably 500- to 5000-fold less hazardous if exposed via the fish bioaccumulation - fish consumption route. Inasmuch as there is no analytical problem in distinguishing among the different degrees of chlorination present in a given PCB sample, it is scientifically justified and practically feasible to establish separate ambient water criteria for PCBs with degrees of chlorination $\leq$ 4 Cl/biphenyl (which represent 65% of current U.S. production) and for PCBs with degrees of chlorination $\geq$ 5 Cl/biphenyl (which are the homologs most persistent in the environment and potentially the most toxic).

We believe that separate criteria for the higher and lower PCBs would be in the public interest for three reasons.

- The development of Aroclor 1016 by Monsanto, and its subsequent use by capacitor manufacturers beginning in 1971, represented a major and technically successful effort by industry to reduce to a negligible level the most environmentally persistent components of the dielectric fluid used in capacitors. Failure of the proposed rules to give any

WATER_PCB-SD0000073866

recognition to the differences between the toxicity and persistence of different commercial grades of PCBs would certainly discourage other manufacturers from attempting to remove objectionable impurities from other products in the future.

o A regulation that attempts to discourage the use of one substance on the basis of a gross exaggeration of its toxicity increases the likelihood that it will be replaced by a substitute that may in fact be environmentally less desirable than the original substance.

o Although the proposed effluent standards apply only to manufacturers of PCBs, capacitors, and transformers, the ambient water criterion could be used as a basis for regulating other dischargers, such as paper mills, whose effluents contain Aroclor 1242 because they recycle paper containing that material. A water quality criterion that recognized the more benign nature of Aroclor 1242 compared to higher chlorinated PCBs, which were not used in paper products, would protect aquatic life and still enable the public to enjoy the environmental benefits of recycled paper.

GENP 009227

WATER_PCB-SD0000073867