IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEVADA

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

DISCOVERY DEPOSITION OF DAVID WOOD

On the part of the Plaintiff

April 1, 1993

Concannon & Jaeger
General Court Reporters
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St. Louis, Missouri 63101
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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEVADA

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

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 the Defendants, pursuant to Notice, under the provisions of Rule 26 of the Rules of Civil Procedure, taken on April 1, 1993, at the law offices of Messrs. Husch & Eppenberger, 100 N. Broadway, St. Louis, Missouri, 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, and Richard Hinckley, Vice-President/General Counsel, Nevada Power.

The Defendant, Monsanto, was represented by Attorney Bruce A. Featherstone of the law firm of Kirkland & Ellis, 1999 Broadway, Ste. 4000, Denver, Colorado 70202.

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A P P E A R A N C E S (:continuing)

The Defendant, Westinghouse, was represented by Attorney Laurie Basch of the law firm of Weil, Gotshal & Manges, 767 Fifth Avenue, New York, New York 10153.

Also present: Liz Gini, paralegal.

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DAVID WOOD,

of lawful age, being first duly sworn to tell the truth, the whole truth, and nothing but the truth, deposes and says on behalf of the Plaintiff, as follows:

DIRECT EXAMINATION

QUESTIONS BY MR. BRADLEY:

Q. Would you please state your name and spell your last for the record.

A. My name is David Wood, W-o-o-d.

Q. Mr. Wood, my name is Ralph Bradley. We introduced ourselves to one another just a few moments ago; is that true?

A. Yes.

Q. And you understand that I represent Nevada Power Company in this lawsuit they brought against Monsanto, General Electric, and Westinghouse; is that correct?

A. Yes.

Q. If during the course of the deposition I ask a question that you don't understand, will you tell me?

A. Yes.

Q. And if at any point during the deposition you want to take a break for whatever reason, just let us know and we'll accommodate you. All right?

A. Thank you.

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Q. Did you review any documents in preparation for today's deposition?

A. Yesterday I did look at one or two documents that we produced containing my name that had been transferred to you.

Q. Do you recall which documents those were?

A. No, not in detail.

Q. Do you recall the date of them, roughly?

A. They covered part of a period between 1966 and 1975-'76.

Q. And were they -- The documents that you reviewed, were those letters written by you?

A. Some of them were written by me and some of them were received by me.

Q. Other than letters written to you or by you, did you review any other materials in preparation for today's deposition?

A. The package of documents contained certain attachments that were attached to what had been sent to me.

Q. All right. Other than the letters and the attachments, did you review any documents to prepare for today's deposition?

A. I believe not.

Q. Okay. Have you had your deposition taken before?

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A. Yes, I have.

Q. When did you have your deposition taken before?

A. My deposition was taken in 1992, and in an earlier period which would probably have been in the period of 1986 or '87.

Q. What case was it in '92 that resulted in your having your deposition taken?

A. I don't recollect.

Q. Was your deposition taken here in St. Louis?

A. Yes, it was.

Q. What subject matters were covered in your deposition?

A. My understanding of the use of Aroclor, PCB-related dielectric fluids in electrical equipment.

Q. And can you be more specific about what the subject matter of your deposition was in '92? For example, what particular use of PCB-related dielectric fluids did you discuss in your deposition?

A. I really don't recall in 1992 the particular subject matter, or indeed the case in question.

Q. Do you remember what legal issue was involved?

A. In that particular case, no, I don't.

Q. Okay. Were you represented by an attorney in 1992 when you had your deposition taken?

A. Yes, I was.
Q. And who was that attorney?
A. I don't recall.
Q. Was your deposition transcribed?
A. Yes, it was.
Q. Did you sign it?
A. Yes, I did.
Q. Do you have a copy of it?
A. No, I don't.
Q. Who has a copy, do you know?
A. The -- I assume that the Monsanto counsel would have a copy of that.
Q. Are you represented by an attorney today?
A. Yes.
Q. Mr. Featherstone?
A. Yes.
Q. What was the subject matter of the deposition you had taken in 1986 or 1987?
A. That was a case that involved a transformer fire in San Francisco.
Q. Going back to the 1992 deposition, do you recall the names of any of the parties in that lawsuit?
A. My mind is a blank on the 1992 deposition.
Q. Does Stroh Die Casting sound familiar to you?
A. No.

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Q. Do you recall the names of any attorneys that were present during your 1992 deposition?

A. No.

Q. Do you know whether the case in which you gave a deposition in 1992 resulted in a trial?

A. It didn't.

Q. It did not result in a trial?

A. Correct.

Q. Did it settle?

A. I don't know. To the best of my recollection, the deposition I gave in 1992 did not involve chlorinated biphenyls.

Q. All right. What was the nature of the deposition you gave in 1986-'87?

A. There had been, in a large building in San Francisco, fume damage to the interior of the building resulting from the involvement in a volt transformer in the street outside the building, and the damage to the interior of the building had resulted in renovation of the interior of the building. The insurance company who had processed the claim for the damage to the interior of the building was seeking to recover certain of their damage from Monsanto and others.

Q. And did you testify in that deposition about the work you had done at Monsanto related to chlorinated

biphenyls?

A. Yes, I did.

Q. I now would like you to give me a summary of your educational history beginning with your first college attendance.

A. I attended Trinity College Cambridge, in England, and I have a degree in the Natural Sciences, and part two of the Law Tripos.

Q. Okay.

A. That gave me a Bachelor of Arts in Natural Science.

The degree system of an expert is different in England to the United States. When I left Cambridge University I joined Monsanto in Great Britain and have worked with Monsanto from that time to the present.

Q. Does the degree you received indicate you received a Bachelor's Degree?

A. I received a Bachelor's Degree, yes.

Q. All right. And in Great Britain is that the equivalent of some similar degree from American universities?

A. The degree system in Cambridge University says that I could, in a three-year period, which I spent at Cambridge University, gain the equivalent in American terms of a BSC in science, and have proceeded through a one-year

law course which would have exempted me from two years of chambers work had I chosen to pursue the law as an active legal profession.

Q. And you indicated that you studied Natural Sciences; is that correct?

A. That is correct.

Q. And when did you attend Trinity College?

A. 1957 to '59.

Q. How old were you when you began college?

A. Seventeen.

Q. As part of your study of natural sciences, did you study polychlorinated biphenyls?

A. No, I did not.

Q. You also indicated that you studied part two of the Law Tripos?

A. That is correct.

Q. What is the Law Tripos?

A. The Law Tripos is the three-year study of law, which is then followed by another two years of chamber work, which would have equipped me to practice law and be called to the bar in Great Britain.

In part two of the Law Tripos, I essentially covered the theoretical study of contract law, communal property, history of law. Those were the major areas of study.

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Q. When you began work with Monsanto, was that in their Great Britain office?

A. Yes, it was.

Q. What year did you begin work for Monsanto?

A. 1959.

Q. What job title did you have when you began work for Monsanto in 1959?

A. Sales trainee.

Q. What work did you do as a sales trainee?

A. I began to learn about Monsanto, Monsanto's line of products, the benefits that those products could bring to the British industry, and to learn how to sell those products to British industrial users of the chemicals that Monsanto produced.

Q. As a sales trainee, I take it you were receiving training from one person or several people?

A. I was receiving training from many people.

Q. And how long were you a sales trainee?

A. Approximately one year.

Q. During the one year you were a sales trainee, did you learn that Monsanto manufactured polychlorinated biphenyls?

A. No, I did not.

Q. What work -- Excuse me. What was your next job title?

A. The next job title was salesman in the United Kingdom.

Q. How long were you a salesman in the United Kingdom for Monsanto?

A. Approximately two to three years.

Q. Who was your supervisor when you were a salesman at Monsanto?

A. Dennis Hope.

Q. H-o-p-e?

A. Uh-huh.

Q. What work did you do as a salesman for Monsanto in the United Kingdom?

A. I was selling organic silicates, which were used in the precision casting of toughened metals for applications such as the rotating blades in jet aviation.

Q. During that two-to-three-year period when you were a salesman, did you sell products containing polychlorinated biphenyls?

A. No, I did not.

Q. What was your next job title?

A. I was a European-wide salesman.

Q. What was your job title?

A. Sales representative.

Q. And was it sales representative, period, or sales representative for Europe?

A. I don't believe we made that distinction.

Q. All right. But your job responsibilities involved sales throughout Europe?

A. At that point, yes, throughout Europe.

Q. And what year did you become a sales representative?

A. I don't recall.

Q. Would it have been in roughly 1962 or '63?

A. Given the time I joined Monsanto, it would have been likely to have been in that period.

Q. How long were you a sales representative for Monsanto?

A. Essentially through 1966 or '67.

Q. During the time you were a sales representative, were you involved in the sale of Monsanto products containing polychlorinated biphenyls?

A. Yes, I was.

Q. What information -- Well, let me ask this: What products were you selling as a sales representative that contained PCBs manufactured by Monsanto?

A. I was involved in sales of Aroclor capacitor fluids and Pyroclor transformer fluids.

Q. Were you involved in the sale of Pyranol transformer fluids, as well?

A. I should explain. That's when I sold

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Pyroclor. In Europe Monsanto sold PCB-containing transformer fluids under a trademark, Pyroclor. They were similar to the fluids which were sold in the United States under various other corporate, such as GE, Pyranol, Westinghouse -- Pyranol was a trademark of General Electric. Inerteen was a trademark of Westinghouse.

Q. During the 19 -- During the time you were a sales representative, did you sell products that contained the equivalent of Aroclor 1242?

A. Yes, I did.

Q. Under what brand name?

A. Pyroclor, probably.

Q. During the time you were a sales representative, how many formulations of Pyroclor were you selling?

A. Pyroclor was -- There were no more than two formulations that I recall of Pyroclor.

Q. What were the formulations that you recall selling while you were a sales representative?

A. One was a mixture of a higher chlorinated Aroclor, Aroclor 1260, with trichlorobenzene, with a small addition of tetra phenyl tin as a scavenger.

Q. Would you spell that for me?

A. T-e-t-r-a, tetra, phenyl, p-h-e-n-y-l, tin, t-i-n.

And the other was a mixture of higher

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chlorinated biphenyl, with trichlorobenzene, with PPO as a scavenger.

Q. Did the Pyroclors have specific names that you referred to them by?

A. Pyroclor.

Q. Did the different formulations nave specific names?

A. I don't recall.

Q. You had indicated earlier -- Let me ask it this way: Did the first formulation relate to the trademark of Inerteen or Pyranol?

A. I'm sorry. I'm not sure I understand your question.

Q. Did the first formulation resemble Inerteen or Pyranol?

A. The first formulation that I mentioned related to Pyranol, the second formulation related more closely to Inerteen.

Q. Who within Monsanto, if you know, was responsible for selling PCB products in Europe that were similar but not identical to Pyranol?

A. Are you asking me, were there other companies selling similar materials or who was responsible within Monsanto for those products?

Q. Within Monsanto.

MR. FEATHERSTONE: Well, you're obviously excluding Mr. Wood, who sold a Pyroclor that was similar to but not identical to Pyranol.

THE WITNESS: You're going to have to ask me the question again.

Q. (by Mr. Bradley) I'm interested in knowing who within Monsanto determined that for its European sales it would sell a product that was similar to but not identical to Pyranol, which was sold in the United States.

MR. FEATHERSTONE: Object to the form of the question.

Q. (by Mr. Bradley) The way the rules for depositions work, when an objection is made, you're still required to answer unless you're instructed not to. So go ahead and answer my question.

A. The formulation of transformer fluids that Monsanto sold in that period in Europe would be proposed by the business management in the United States, and at such time as they had recommended a formulation to be sold, we would conduct studies in Europe to make sure that material sale was compatible with responsible business practice in comparison to competitive materials sold by French, German and Italian producers of similar materials.

Q. Did you ever speak with anyone within the business group of Monsanto in the United States where they

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indicated to you the reason for the particular formulation of PCB that was sold throughout Europe by you when you were a sales representative?

A. Yes. I talked to Mr. Paul Benignus, B-e-n-i-g-n-u-s.

Q. Did you speak with Mr. Benignus during the time you were a sales rep?

A. Yes, I did.

Q. Was that in person or via the telephone or both?

A. Both.

Q. What did Mr. Benignus tell you was the reason that Monsanto was selling the particular formulations of PCBs in Europe during the time you were a sales representative?

MR. FEATHERSTONE: You're now talking about the Pyroclor?

MR. BRADLEY: Yes.

MR. FEATHERSTONE: Okay.

A. Mr. Benignus told me at that point in time that we in Monsanto were making materials that were related to formulations that had been invented by General Electric, and that, as such, the formulations that we were selling, if we were to use performance data which had been generated in the United States, the formulations had to be aligned

with the formulations that we made for General Electric in the States.

Q. (by Mr. Bradley) Did Mr. Benignus tell you why you would not be selling the specific formulation made by GE in the States?

MR. FEATHERSTONE: You have not established that. I object to the form of the question.

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

A. I'd like you to rephrase the question.

Q. As I understand it the formulation of Pyroclor that was sold was similar to but not identical to the formulation made by GE in the United States; is that correct?

A. Pyranol, as formulated by General Electric, itself had several formulation forms. They could vary depending on whether trichlorobenzene was used as an additive, whether a tritetra chlorobenzene was used as the additive, to the percentage ratio between the chlorinated benzene and the chlorinated biphenyl, and to the concentration of the scavenger that I had talked about, the tetra phenyl tin. We decided to standardize on one of the formulations for sale in Europe, which was an exact replication of one of the Pyranol grades sold by General Electric in the United States.

Q. Do you recall which of the Pyranol grades sold

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in the United States you sold in Europe?

A. No, I don't. But here we're talking small distinctions between these various grades of product.

Q. Was the other formulation that you sold while a sales representative identical to an Inerteen formulation that was manufactured and sold in the United States?

A. Yes. The basic difference between the two grades of Pyroclor was in the scavenger that was used. And essentially, the product that we sold in Europe was the same as Inerteen KA, I believe was the designation.

Q. Did you receive any training prior to becoming a sales representative regarding Pyroclor?

A. Once I had assumed responsibility for sales of Pyroclor, I received training.

Q. Where did you receive the training?

A. I received some training in Europe and I received some training in the United States.

Q. Was the training just for you, or were you part of a group that was being trained on Pyroclor?

A. In terms of sales of dielectric fluids in Europe, at that point in time I was the person responsible for selling dielectric fluids in Europe.

Q. And I take it, then, the training was directed just towards you when you received training regarding Pyroclor?

A. Yes --

Q. Who gave you --

A. -- at that time.

Q. And we're talking about during the time that you were a sales representative.

A. Uh-huh.

Q. In fact, until I ask you questions about your next job responsibility, I will assume that all of your answers relate to the work you did as a sales representative. Fair enough?

A. Yes.

Q. All right. Who gave you the training regarding Pyroclor?

A. In Europe I was trained by John Campbell, by Colin Coleman, C-o-l-e-m-a-n, and Richard Baxter.

Q. Okay.

A. In the United States I received training from Paul Benignus.

Q. What job title did John Campbell have when you received training from him?

A. Product supervisor, specialty chemicals.

Q. Was John Campbell a medical doctor?

A. No, he wasn't.

Q. Was he a toxicologist?

A. No.

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Q. Was he an epidemiologist?
A. No, he was not.
Q. Was he a businessman?
A. Yes, he was.
Q. Was his training in business?
A. His training was in science. He adopted a business career.
Q. Do you know whether John Campbell had received a doctorate degree when you received training from him?
A. John had received a Doctor of Science degree before he trained me.
Q. All right. And what job title did Colin Coleman have when you received training from him?
A. He was an MTS representative. MTS is a term in Monsanto used to mean Marketing Technical Services.
Q. I take it, then, Colin Coleman was not a medical doctor?
A. He was not a medical doctor. He was not a doctor.
Q. Nor was he a toxicologist?
A. No.
Q. Nor was he an epidemiologist?
A. He was not an epidemiologist.
Q. Do you know whether his educational background was in business?

A. His training was in science.

Q. And do you recall what science he received training in?

A. Chemistry and physics.

Q. And what job title did Richard Baxter have when you received training from him?

A. He was manager of research in our laboratory in North Whales, England.

Q. Was Richard Baxter a doctor?

A. Yes. He was a doctor of science.

Q. He was not a medical doctor, then?

A. He was not a medical doctor.

Q. Was he a toxicologist.

A. No, he was not a toxicologist.

Q. Was he an epidemiologist?

A. No.

Q. What was his specialty in science?

A. Chemistry.

Q. Do you know what area of chemistry he specialized in? If there was an area.

A. Chemical synthesis.

Q. What was Paul Benignus's job title when you received training from him?

A. Product manager, dielectras.

Q. Is Paul Benignus a doctor?

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A. No, he is not.
Q. Is he a toxicologist?
A. No, he is not.
Q. Is he an epidemiologist?
A. No, he is not.
Q. Do you know whether his educational background is in business?
A. Yes, it is.
Q. You indicated that you received training from Mr. Benignus in the United States; is that correct?
A. I want to revisit that question because you asked me to confine my comments to the time when I was a sales representative, and I don't believe I received training from Paul in the United States while I was a sales representative. I certainly met and was instructed by Paul in Europe during the time that I was a sales representative.
(Thereupon, a short recess was taken.)
Q. (by Mr. Bradley) All right. Did you receive any written materials as part of the training you received from John Campbell, Colin Coleman, Richard Baxter or Paul Benignus regarding Pyroclor?
A. I'm sure I did.
Q. Do you recall the nature of the written material that you received from those gentlemen?

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A. In the period that I was a sales representative I would have received and I would have reviewed with them such things as technical literature about the product at that time. I would have received the material related to the maintenance of equipment containing those fluids at that time. I would have received reports about the nature of the marketplace and use of these materials in the European community, including Great Britain. That would have included packaging and handling information surrounding the transportation and storage of these materials. I would have received industrial hygiene information as to how workers in our customers' plants were to use these materials.

Now, that list, I must have you understand at this later stage, is not exhaustive or complete. I probably received information on other subjects, but those specific areas, definitely I would have received and did receive information about.

Q. Do you recall the titles of any of the documents that you received while a sales rep as part of your training on Pyroclor?

A. I would have received the technical literature which I can recall at this date. It was a blue binder of material with a title, "Pyroclor," and I would have received copies of a document related to the servicing and

maintenance of equipment which was called an Askarel Maintenance Guide. Askarel, A-s-k-a-r-e-l.

Q. What was in the blue binder of material entitled "Pyroclor"?

A. Information about the areas in which fire-retardant transformers would be used. It would have contained information about compatible solid elastomeric materials that would be used in the construction of transformers in combination with chlorinated biphenyl liquid dielectrics.

Q. What do you mean when you refer to technical literature?

A. When I refer to technical literature, I refer to literature which will define the product in technical terms. It will define the area of application of such chemical products. It will define the relationship between that chemical material and other materials that will be combined with it in chemical application. It will define how the material should be stored and handled. It will include industrial hygiene practice related to the material. It will include disposal methodology for waste materials. It will include detailed technical specifications for the product, and it will probably include, in many cases, relevant codes and industry codes and standards which relate to the material, and it will often contain

charted material by the way of charts and graphs which will relate to the performance properties of the material.

In the case of something like Pyroclor, it would include such things as the dielectric strength, the variation of dielectric strength and temperature, the variation of dielectric strength with the frequency of the power which was being controlled by the transformer.

This is an overview of the types of things that a piece of technical literature related to a chemical insulating fluid would have to portray to the customer, a very wide range of information involving both the properties and the usage and handling of that material.

Q. Was the technical literature in the blue binder of material entitled "Pyroclor" primarily literature developed in-house by Monsanto?

A. There certainly was information that was solely generated by Monsanto, but equally, our Pyroclor literature would draw on information that had been generated by standards and code-setting committees in the United States, and it would give reference and credit to those particular data sources.

Q. Other than standard and code publications were there any other publications within the binder material entitled "Pyroclor" that were not in-house-generated documents by Monsanto?

MR. FEATHERSTONE: You mean specifically cited in the brochure? Because you have not established that he actually drafted the document.

MR. BRADLEY: I assumed that he didn't. He said that he was provided it.

MR. FEATHERSTONE: Right. But how would he know what material was looked at to develop this if he didn't draft it?

MR. BRADLEY: I didn't ask him what he -- what material was looked at to draft it. I asked him what was in the blue binder. At least that's what I thought I asked him.

MR. FEATHERSTONE: Okay. Then I make --

Q. (by Mr. Bradley) Okay. Let me ask the question again. Within the blue binder of material entitle "Pyroclor," was there any other technical literature generated outside Monsanto other than by code-setting groups?

A. I think the most direct way I can answer that question is that the Pyroclor literature in Europe was based on the dielectric fluid literature which had been generated by Monsanto in the United States, and that literature had been developed by Monsanto in combination with our customers in the United States.

Q. For example, in the blue binder of material

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entitled "Pyroclor," were there any copies of any studies done by individuals or groups of people other than Monsanto employees relating to the health and safety of people exposed to PCBs?

A. I don't recall.

Q. Do you recall there being any reference in the blue binder of material entitled "Pyroclor" to a 1937 round-table discussion that was reported in the Journal of Industrial Hygiene?

A. No, I don't.

Q. As I understand your testimony, you ceased being the sales representative around 1967?

A. It's not clear in my own mind. At a point in time I was not the sales representative for dielectric fluids. I essentially became the marketing manager for dielectric fluids, replacing John Campbell's role of the same period of time. Although I had European-wide responsibility, I was relocating from the United Kingdom to the Brussels headquarters during that period.

We moved the European headquarters from London to Brussels, and essentially I still maintained the same contact and relationship with the European electrical industry, but there had been a subtle shift in my responsibilities from that of purely the sales contact with the marketplace to rather establishing what our sales and

performance strategy for that particular product line was in Europe.

Q. And when you became marketing manager, did the blue binder of material entitle "Pyroclor" still exist?

A. Yes, it did.

Q. Did you use -- Let me rephrase the question. During the time that you were marketing manager did you maintain the blue binder of material entitle "Pyroclor"?

A. We maintained technical literature relative to the use and handling of Pyroclor. Whether it remained blue during that whole period, I really don't remember.

MR. BRADLEY: Could you read back that answer, please?

(Thereupon, the reporter read back the answer.)

Q. (by Mr. Bradley) Did you have files of literature on PCBs during the time that you were sales representative, other than materials contained in the blue binder entitled "Pyroclor"?

A. Would you repeat that question, please?

Q. Did you have materials on PCBs during the period of time you were sales representative, other than the material that was in the blue binder entitled "Pyroclor"?

A. We would have had equivalent literature which related to the use of the Aroclor family of products in

capacitors. We would have in certain situations made use of American literature.

Q. Okay.

A. And our market technical service group would prepare specific project reports on issues which were raised by specific customers relative to their individual use of our materials.

Q. And this was all material that you would have maintained but would not have been within the blue binder of material entitled "Pyroclor"?

A. This is true.

Q. And where was this literature or -- Excuse me. Where was this material kept?

A. Copies of this literature would be kept in our -- certainly it was maintained in our Brussels office. But in our regional sales offices, people would have access to sets of that data to send to both current and prospective customers.

MR. FEATHERSTONE: We're now switching between the time period that you were sales rep and the time period you were marketing manager, because you just now made reference to the Brussels office.

A. Uh-huh. I thought we had already made that bridge, anyway.

Q. (by Mr. Bradley) All right. So that I under-

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stand your answer, the period of time that you had the literature outside of the blue binder of material entitled "Pyroclor" was during the time you were marketing manager?

A. We had literature about our products throughout the period when I was sales representative and when I was marketing manager.

Q. And the separate set of documents that were in existence while you were sales rep were maintained where?

A. At that particular time when I was a sales rep, our European headquarter office was in London, and the main literature center was at that time in London. When we moved the European headquarters from London to Brussels, then our central literature source would be maintained in Brussels, not in London. But all sales offices would have access and would have a more limited storage of technical literature for product which they were selling in that particular region, and if their particular region contained customers of dielectric fluids, that regional office would have copies of the dielectric literature.

Q. Okay. While you were sales representative, did Monsanto have a medical department in its European operations?

A. Yes, we did.

Q. And where was it located?

A. In London.

Q. While you were sales representative, who was the head of the medical department in London for Monsanto?

A. We had a medical department which had a number of functions. One was that purely of having a medical office in a headquarters' building to look after strictly personnel medical affairs. We equally had associated with that department an individual who was responsible for product issues of a medical nature, but that latter function operated as an extension of the headquarters product safety groups in the United States.

Q. During the time you were sales representative, who was the person within Monsanto's medical department in London responsible for product issues of a medical nature?

A. Doug Hardy, H-a-r-d-y.

Q. At the time you were sales representative, do you know whether the Monsanto headquarters product safety group in the United States was run by a medical doctor?

MR. FEATHERSTONE: Sorry. May I hear the question again, please?

(Thereupon, the reporter read back the question.)

A. No, I don't.

Q. (by Mr. Bradley) While sales representative, do you know whether the Monsanto headquarters product safety group in the United States was run by a toxicologist?

A. No, I don't.

Q. Do you know whether the person in charge of the headquarters product safety group in the U.S., while you were sales rep, was an epidemiologist?

A. No, I don't.

Q. Do you know whether, while you were sales rep, the person in charge of the Monsanto headquarters product safety group in the United States had any training whatsoever in the medical and toxicological aspects of polychlorinated biphenyls?

A. No, I don't.

Q. While you were sales representative, did you ever hear the term "business group" in relation to the manufacture and sale of polychlorinated biphenyls?

A. Can you repeat that question?

MR. BRADLEY: Would you read it?

(Thereupon, the reporter read back the question.)

A. Yes.

Q. (by Mr. Bradley) Was the product safety group at Monsanto's headquarters in the United States part of the business group working with Monsanto products containing PCBs?

A. No.

Q. While you were sales rep, what persons by title or name were part of the business group working with

Monsanto products that contained PCBs?

A. Whilst I was a sales representative with Monsanto in Europe, my contact in the United States in the business group was Paul Benignus.

Q. Did Mr. Benignus indicate to you who else, if anyone, was part of the business group relating to Monsanto products containing PCBs?

A. To the extent that Paul Benignus himself reported to supervisory management within a broader business division than dielectric chlorinated biphenyls, there were people senior to Mr. Benignus who had management responsibility for a range of products, including the chlorinated biphenyl dielectras.

Specifically, since you asked me to be specific, we would be visited occasionally in Europe by Mr. George Buchanan, who was responsible for the specialty products area, or he may at that time have been called the function fluid business within the organic division, and within whose group Mr. Benignus worked.

Q. Did Mr. Benignus indicate to you that his supervisor was part of the business group for Monsanto products that contained PCBs?

A. Yes.

Q. Did Mr. Benignus indicate to you anyone else who was part of the business group for Monsanto products

containing PCBs?

A. In the United States?

Q. Yes.

A. Dr. Ralph Munch, M-u-n-c-h, was responsible for the technology, the applicational technology of the PCB fluids at that point in time.

Q. And Mr. Benignus indicated to you that Dr. Munch was part of the business group for Monsanto products that contained PCBs?

A. Yes.

Q. Who else, if anyone, did Mr. --

MR. FEATHERSTONE: Are you talking about dielectrics, David?

MR. BRADLEY: I'm talking about dielectrics.

MR. FEATHERSTONE: He's talking about products containing PCBs. So, Mr. Bradley, are you talking about dielectrics, or are you broadening this?

Q. (by Mr. Bradley) So that I understand your answer, your answer is related to dielectric products manufactured by Monsanto that contained PCBs; is that correct?

A. As was related to dielectric fluids.

Q. All right. Did Mr. Benignus indicate to you who else was a part of the business group working within Monsanto for dielectric products containing PCBs?

A. At the time that I was a sales representative the only two people I had contact with and that I was aware of as being members of the dielectrics business group for fluids including chlorinated biphenyls were Paul Benignus himself and Dr. Munch.

Q. Was there the business group -- Let me rephrase it. Was there a European business group for dielectric products manufactured by Monsanto that contained PCBs?

A. It was not referred to as a dielectric business group. I mean, the business in Europe was managed by -- At the time that I was sales representative, essentially, dielectric fluids in Europe in a commercial management sense were managed by John Campbell. I was the salesman, and Colin Coleman was the technical service representative.

Q. When you have -- Do you consider polychlorinated terphenyls to be part of the group of polychlorinated biphenyls?

A. I'd ask you to repeat that question, please.

Q. Do you consider polychlorinated terphenyls to be part of the group known as polychlorinated biphenyls?

A. No.

Q. Did Monsanto manufacture products sold throughout Europe while you were sales representative that contained polychlorinated terphenyls?

A. Monsanto manufactured a number of polychlorinated terphenyls, but they were part of the polychlorinated polyphenol family. There is no way that you can -- A polychlorinated biphenyl by definition cannot be a polychlorinated terphenyl, and vice versa.

Q. And you indicated that they're all part of the polychlorinated polybiphenyl family?

A. No. No.

Q. That's why I asked.

A. I said that, if you begin to link benzene rings together, at one point or juncture, one is a phenyl group, two is a biphenyl group, three is a terphenyl group, four is a quatraphenyl group. So, something which contains three rings can never be a biphenyl. Something that contains two rings cannot be a terphenyl. That terminology discretely defines the difference between the number of rings you have in the particular molecule. You can combine and cover the whole group by a descriptor which is not widely used which is a polyphenol.

Q. At the time that you were a sales rep, did the Monsanto corporate headquarters in the United States have a medical department?

A. I'm sorry?

Q. At the time that you were a sales representative, did the Monsanto corporate headquarters in the United

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States have a medical department?

A. I don't know.

Q. Does Monsanto still have a corporate headquarters in Brussels?

A. Monsanto has its European headquarters of its agricultural company and its chemical group in Brussels.

Q. Do you know whether the European headquarters for Monsanto in Brussels still maintains files of material it had on PCBs?

A. I do not know whether the company consolidated records about PCBs in Europe within Europe or whether we combined those records in our consolidated PCB records in St. Louis.

Q. And if they were consolidated within Europe, they would be at the headquarters in Brussels?

A. I don't know.

Q. Did you receive any additional training in Pyroclor when you became marketing manager for dielectric fluids?

A. The time that they changed my responsibilities from sales representative to that of marketing manager, I'm not conscious that I received any specific additional training.

The reason for my appointment to the marketing management role was essentially because of the experience

that I had gained in being the sales representative for those materials. And so, if education includes that period of osmosis of learning on the job, yes, I received more training.

Q. Do you recall whether you received any additional written material specifically directed towards Pyroclor when you became marketing manager for dielectric fluids?

A. As we developed and updated technical literature, I would receive new materials and new additional material to include in further additions of our technical literature.

A piece of technical literature is not static. As your knowledge evolves, so does -- you update your technical literature.

Q. Would the technical literature that was evolving include instruction manuals for customers purchasing Monsanto products containing PCBs?

A. Yes, it would.

Q. Did the European Monsanto instruction manuals differ from instruction manuals distributed by Monsanto to its customers within the United States?

MR. FEATHERSTONE: Object to the form of the question. It's vague and indefinite.

A. I'll answer it.

Our American literature was in the American form of the English language. Our European literal was in several languages, including British English.

Q. (by Mr. Bradley) Would the European instruction manual simply take the English versions developed by Monsanto's corporate headquarters in the United States and translate them into various languages?

MR. FEATHERSTONE: Object to the form of the question. Also vague.

A. Would you care to rephrase the question?

Q. (by Mr. Bradley) Yeah. When -- Do you know whether the instruction manuals that were sent to customers of Monsanto's European operations received instruction booklets that were identical to the instruction booklets distributed to Monsanto's customers in the United States, with the exception that they were simply written in another language?

A. By extension of the definition of "other language," you need to appreciate that technology is itself a language. So that, to the extent that some of our European customers were advanced enough to use a different system of measurement, the metric system, there was not just translation of language to language. Charts, graphs, tables would need to be changed from the duodecimal system operated in the United States to the more broadly used

metric systems.

In terms of standardization, where material standards in Europe differed from the ASTM standards exercised in the United States, then the relevant national standards, such as BIN in Germany or the British Standards Institute in Britain, would need to be checked, and we would need to change the material content so that it related to that particular national emphasis. Even then, Monsanto was strategizing globally and acting locally.

Q. So as I understand it, the differences were in -- involved conversion of the measuring system in the United States to the metric system. That was one change in the instruction booklet; is that correct?

A. Yes.

Q. And another change came about if there were different code-setting standards in different nations?

A. This is true.

Q. Were there any other changes?

A. Probably, yes.

Q. And what were they?

A. I don't recall minute by minute everything that happened twenty years ago. I'm sorry.

Q. Of course I don't expect you to recall everything in detail, but I'm interested in what you do recall.

Who would know -- Let me rephrase it. Who, if

anyone, was in charge within Monsanto's European operation for development of the instructions manuals that accompanied Monsanto products containing PCBs that were sold throughout Europe?

A. At that stage the procedure, as I -- Now, are we talking about -- am I a sales representative or am I a marketing manager?

Q. Sales rep.

A. Okay. When I am sales rep, then John Campbell, as the marketing manager, would be responsible for clearing any new literature before it was public and issued to our customer base. He would make sure that our technology as represented by Richard Baxter and Colin Coleman had signed off, that they agreed that the technical information contained therein was accurate and was expressed correctly in units. There would be a sign off by Doug Hardy in terms of saying that he agreed that the representation for material handling instructions were essentially suitable for understanding in Europe.

Q. And when you became marketing manager, did you have the role that previously Mr. Campbell had?

A. Dr. Campbell.

Q. Dr. Campbell.

A. Yes, I did.

Q. And when you undertook that responsibility as

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marketing manager, did you review any medical or toxicological information relating to PCBs?

A. Purely for clarification are we going to be jumping back and forth at this point between my marketing management role or my sales representative role, or -- In terms of my trying to openly answer your questions, it really would be helpful if I know what period I'm answering from, because my role changed, as I said, and I need to know what role I'm in if I'm going to be responsive to your questions.

Q. I apologize if my question wasn't clear. I thought my question started by when you were marketing manager, but if it didn't, that's what I intended.

So, while you were marketing manager, did you review any material relating to the medical or toxicological issues involving PCBs prior to your work with updating instruction manuals?

A. I was not qualified to comment on the handling and industrial hygiene materials. Personally, it was my responsibility to make sure that literature that we were going to be sending to the marketplace had received review in Europe from Doug Hardy as to his understanding that this was an appropriate representation of the safety of that product and the handling of that material. And if he required to ask questions of his contacts in the United

States, then he would so do.

Q. Do you know whether Doug Hardy was relying on information forgiven to him by Monsanto employees in the United States when he reviewed the proposed changes, if there were any, to instruction manuals?

A. Okay. Now, am I marketing manager?

Q. Yes.

A. Marketing manager. Okay. At that time I know that Doug Hardy would make his judgments about material in Europe based on his view of what he was receiving from his peers in the United States, and individual contacts that he would make within the Monsanto technical community as opposed to the commercial community, and outside of the Monsanto technical community in the European technical community.

Q. When you refer to "his peers," do you mean his peers within the Monsanto corporate headquarters in the United States?

A. Yes. Doug Hardy was seeking to find out how to -- what was the United States view of handling materials made by Monsanto. Protocol suggested he should elicit such information from his peers within Monsanto.

Q. Was Doug Hardy's role different at all during the period of time when you were sales rep versus when you were marketing manager regarding that one issue we've just

discussed?

A. Not considerably different.

MR. BRADLEY: If it's acceptable, this would be a good time for me to be taking a break. Ten minutes.

(Thereupon, a short recess was taken, after which the reporter read back the last question.)

A. Not considerably different.

Q. (by Mr. Bradley) I take it, during the time you were marketing manager, that you submitted changes in instruction manuals to Doug Hardy for his review for products containing PCBs?

A. Yes.

Q. Did you send a letter to Mr. Hardy requesting that he review those changes in the instruction manuals?

A. It would have been normal practice that, if a draft change of any sort had been suggested, proposed, that I would send a copy to Hardy's office and say, "Need your commentary on this suggested change."

Q. Okay. And would Doug Hardy then provide you with written comments regarding any suggested changes?

A. It would have been the appropriate action for him to take, yes.

Q. Do you recall whether he, whether Doug Hardy ever provided my written material to you regarding any of the proposed changes in instruction manuals for products

containing PCBs?

A. Specifically, no.

Q. What was your job title following your being marketing manager?

A. I became marketing manager, food and fine chemicals.

Q. When did you become marketing manager for food and fine chemicals?

A. 1970 slash '71.

Q. When you became marketing manager for food and fine chemicals, did you have any responsibility for dielectric fluids containing PCBs?

A. I did not.

Q. What fine chemicals were you responsible for when you became marketing manager for food and fine chemicals?

A. The major product area for which I had responsibility was for the marketing of aspirin.

Q. What was your next job title?

A. After the food-and-fine job?

Q. Yes.

A. My next job title was international sales manager, fluids.

Q. When did you become international sales manager, fluids?

A. 1974.

Q. As international sales manager for fluids, did you have any responsibility for dielectric fluids containing PCBs?

A. Yes, I did.

Q. What responsibilities did you have?

A. I had the responsibility to manage the sale of dielectric fluids containing PCBs in marketplaces outside of the United States, around the rest of the world, as part of a product range of functional fluids, which included aviation fluids, industrial heating fluids. So it was one product line component of a product line for which I had a responsibility for sales outside of North America.

Q. Okay.

A. And that job was based in America.

Q. As international sales manager for fluids, did you have any responsibility for selling transformers or capacitors containing PCBs? I mean -- Strike the question.

As International sales manager for fluids, did you have responsibility for selling any Monsanto products that were intended for use in electrical transformers or capacitors to be used by the electrical industry?

A. Yes, I did.

Q. What were you selling in that regard?

A. I was selling Pyroclor, I was selling

Inerteen, and I was selling Pyranol.

Q. Was the Inerteen that you were selling manufactured by Monsanto?

A. Yes, it was.

Q. Was it manufactured on -- in plants owned and operated by Monsanto?

A. Yes, it was.

Q. Was the Pyranol you were selling manufactured by Monsanto?

A. Yes, it was.

Q. And was it manufactured in plants owned and operated by Monsanto?

A. Yes, it was.

Q. And were those plants that manufactured Pyranol within the United States?

A. The plants that manufactured the Inerteen and Pyranol that I sold were in the United States. If I were selling Pyroclor, then it would have been manufactured in our British plant.

Q. As international sales manager for fluids, did you have any responsibilities regarding instruction manuals that accompanied products manufactured by Monsanto that contained PCBs and were dielectric fluids?

A. My responsibility as sales manager of fluids would be to insure that any customer or perspective

customer in my geographical area of responsibility had received a copy of our instruction manuals. It would not have had -- My job at that stage did not contain a responsibility for actually producing the instruction manuals.

Q. While you were international sales manager for fluids, who within Monsanto was responsibility for producing the instruction manuals for Monsanto dielectric fluids containing PCBs?

A. Paul Benignus.

Q. Do you know how long Mr. Benignus had that responsibility?

A. At the time that I was in the international salesman management job in 1974, Mr. Benignus had certainly been responsible for the dielectric fluid line for materials containing chlorinated biphenyls for at least ten years.

Q. And did those responsibilities that Mr. Benignus had include determining what would be contained within the instruction manuals accompanying Monsanto dielectric -- Monsanto products containing dielectric fluids with PCBs?

MR. FEATHERSTONE: Well, I think you had it right the first time, which was Monsanto dielectric fluids. You said Monsanto products containing dielectric fluids.

Q. (by Mr. Bradley) Let me re-ask the question. Did Mr. Benignus have responsibility during that ten-year period for determining what would be included in the instruction manuals for Monsanto dielectric fluids containing PCBs?

A. As product manager, he would have responsibility for issuing instruction manuals. He would be guided as to content of certain chapters of the instruction book by inputs from other disciplines within Monsanto.

Q. And after he received that guidance, the final decision, though, was his?

A. No. He could not -- If for example, our technology department insisted that certain dielectric performance data were included, he could not preclude them and say, "No, we're not going to include that." So he had responsibility for making sure that Monsanto had in its marketplaces technical support literature relative to our products. He would have to obtain clearance that such literature followed corporate guidelines beyond just his product authority relative to certain areas of contact.

Q. I want to take you back in time to 1970. Whatever your job title was doesn't matter to me.

A. Okay.

Q. In 1970 were there any European nations that had proposed elimination of PCBs?

MR. FEATHERSTONE: Object to the form of the question.

A. Could you ask the question --

Q. (by Mr. Bradley) I will re-ask it. In 1970 had any European nations outlawed the use of PCBs?

A. Not to my knowledge.

Q. In 1970 had any European nation proposed -- Let me rephrase it. In 1970 had there been proposed legislation in any European nation that would restrict or eliminate the use of PCBs?

A. No.

Q. In 1971 was there any European nation that had legislation restricting or eliminating the use of PCBs?

A. Not to my knowledge.

Q. Was there ever a time when any European nation enacted legislation restricting or eliminating the use of PCBs?

A. I am not aware of any point when my job within Monsanto contained responsibility for fluids associated with PCBs or through my general knowledge of anything that be happening whilst my job was not related to PCBs, of any European country that went as far as early, in terms of regulating PCBs, as the United States of America.

Q. Didn't Sweden take any regulatory action relating to PCBs during the 1970s?

A. I can't talk for the whole of the 1970s, because I was not involved with PCBs during the totality of the 1970s.

Q. When did you cease your involvement with PCBs during the period of the 1970s?

A. In 1977.

Q. By 1977 had Sweden taken any action to restrict or eliminate the use of PCBs?

A. Sweden may -- I do not specifically know. If there were anything going on in Sweden at that point in time, it was probably going to be regulating the use or restricting the use, but I am not specifically aware of Swedish regulations concerning the use of PCBs.

Q. So that I understand your answer -- I'm not so much interested in what your specific knowledge is of specific regulations in Sweden regarding the use of PCBs, but I am interested in knowing if you know when Sweden first enacted regulations, if it ever did, restricting or eliminating the use of PCBs.

A. I am not aware of any regulations issued by Swedish authorities reference the use of PCBs.

Q. And when I say "regulations," I include laws in that. Is that your understanding?

A. Yes.

Q. Okay. Prior to 1977 did Japan enact any laws

or regulations restricting or eliminating the use of PCBs?

A. For clarification may I ask whether we're talking about dielectric situations or generic uses of PCBs?

Q. Generic uses of PCBs.

A. I believe that Japan did issue regulations concerning the use of PCBs, excluding them from certain applications.

Q. And when do you believe that Japan took that action?

A. In the seventies.

Q. In the early, mid, or late seventies? If you know.

A. Early to mid.

Q. Do you know whether the restrictions imposed by Japan on PCBs included restrictions on PCBs in dielectric fluids?

A. I believe it did not.

Q. Did Great Britain prior to 1977 enact any laws or regulations restricting or eliminating the use of PCBs?

A. I am not aware of regulations in Great Britain restricting the use of PCBs generically or limiting the use of PCBs generically. At that point in time Monsanto was only involved in dielectric uses of PCBs.

There were regulations passed in a number of

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countries after the fact of Monsanto's withdrawal from certain nonelectrical applications. Again, I'm not sure of details because they were irrelevant to us, because, in the 1970s, essentially, Monsanto at a point in time was only involved with dielectric uses of PCBs.

Q. When did you cease being international sales manager for fluids?

A. Late 1974, early 1975.

Q. So you had that job for about a year?

A. About a year.

Q. What was your next job title?

A. I was manager of dielectric fluids.

Q. Did that job begin in 1975?

A. It was either November or December of 1974, or January of 1975; it was about the turn of the year.

Q. Did you receive any additional training regarding PCBs when you became manager of dielectric fluids?

A. Yes, I did.

Q. What training did you receive?

A. Informal training.

Q. From whom?

A. From Paul Benignus; from my immediate supervisor, Dr. Paton, P-a-t-o-n; from the research departments within Monsanto; and from people who were involved with Monsanto's positions relative to the use and application of

PCBs, such as Mr. Papageorge, P-a-p-a-g-e-o-r-g-e.

Q. Okay.

A. And again, that list is a list of significant people who talked to me at the time that I changed -- I made that transition. It is not exhaustive.

Q. What -- I want you to tell me as much as you can remember about the content of your discussions with Mr. Papageorge as part of your informal training when you became manager of dielectric fluids.

MR. FEATHERSTONE: That's the question?

MR. BRADLEY: Yes.

THE WITNESS: Can I talk to Chris a moment?

MR. BRADLEY: Yes.

(Thereupon, a short colloquy was had, after which the reporter propounded the previous question.)

A. The informal training essentially was a day-to-day process; there would be very few days that I would not be talking with Bill Papageorge.

The nature of the dielectrics business in the United States and beyond the United States was such at that point in time that we were routinely communicating with our customers, with the users of electric equipment, with regulators, with universities, and as such, very few days would go by that I would not have occasion to discuss emerging situations with Mr. Papageorge, and to the extent

that, in the course of those discussions I would learn things that I had not been knowledgeable of previously, it was part of my education.

Q. (by Mr. Bradley) So your informal training with Mr. Papageorge is what you learned primarily from your day-to-day contacts with him?

A. Yes, it was.

Q. You indicated that, because of the nature of the dielectric fluids during the period of time you were manager of dielectric fluids, that you would -- Excuse me -- that Monsanto would routinely have communications with customers; is that correct? Is that what you said?

MR. FEATHERSTONE: He said "Nature of the dielectrics business."

MR. BRADLEY: Whatever.

Is it true that, because of the nature of the dielectric business when you were manager of dielectric fluids, that Monsanto would be routinely communicating with customers?

A. We were routinely communicating with customers throughout the period that I was manager of dielectrics.

Q. (by Mr. Bradley) Did those customers include General Electric?

A. Yes.

Q. Did they include Westinghouse?

A. Yes.

Q. You also indicated that, because of the nature of the dielectric business while you were manager of the dielectric fluids, that Monsanto would have communications with users of dielectric equipment; is that correct?

A. Monsanto had communications with users of dielectric equipment. By virtue of our membership with certain industrial panels, and at the request of our direct customers, from time to time we would have communication sessions with their customers. And through processers and repairers of electrical equipment, we would have contact with our customers' customers. Through participation in EPA panels, we would have contact with our customers' customers.

There were many ways during the period that I was manager of dielectrics that Monsanto, myself, and more broadly, other people within Monsanto, were in contact and communicating with not only our direct customers, but their customers, and other people involved in PCB considerations.

Q. What industrial panels was Monsanto a member of that resulted in Monsanto communicating with users of dielectrical equipment?

A. There were groups such as the ANSI C107 committee, the EPRI, Electrical Power Research Institute, National Electrical Manufacturers Association, Edison

Institute.

Q. Is that Edison Electrical Institute, EEI?

A. Yes.

There were various conferences which were specifically summoned to relate to PCBs. There was an EPA-sponsored convention that related to these PCBs.

Q. Was that in Chicago in 1975?

A. Yes, it was. Widely attended by a broad representation of the electrical industry.

Q. What leads you to that conclusion, that it was broadly represented by the members of the electrical industry?

A. I was a speaker at the conference; I know what the attendance at the conference was.

Q. How do you know what the attendance was? By speaking with people who were also in attendance?

A. Yes.

Q. And how else do you know whether there were members of the electrical utility industry at the 1975 conference?

A. Because that convention was convened by the EPA to keep people aware of how the convention was being publicized and how it was being positioned, and I know that the EPA sought a strong attendance from the utility industry.

Q. Any other way that you know that members of the electrical utility industry were present at that 1975 conference?

A. I guess at the time of the convention and shortly thereafter we had some discussions regarding who had been there, and short of reviewing any sign-up list for the convention, I mean, I was aware that there had been a fairly broad representation of the utility industry.

Q. Did you personally review the sign-up list?

A. No, I did not.

Q. Who did you speak with at the conference who indicated to you they were a member of the electrical utility industry? If you recall.

A. I don't -- I talked to an enormous number of people at that convention.

Q. Well, do you recall whether any of them informed you that they were a customer of General Electric?

A. Nobody advised me specifically that they were a customer of General Electric. Many of them told me that they were members of various United States utility corporations and they bought electrical equipment containing PCBs, which was the subject of the conference.

Q. Were there written proceedings of the conference following its completion?

A. Yes, there were.

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Q. Do you know whether those were mailed to electrical utility industries that purchased dielectric fluids containing PCBs that were manufactured by Monsanto?

A. I know that we mailed copies of my papers -- my paper at that conference to a number of utility people who said that either they had been and had not managed to get a copy at the conference or had heard of the conference and requested a copy of the paper. In terms of saying, "Was there a Monsanto mailing of the proceedings of that conference to our customers' customers," no, there was not. It was not our conference; it was an EPA conference.

Q. Do you know whether -- Let me ask it this way: We know Monsanto didn't do the mass mailing. Do you know whether EPA did a mailing of the proceedings of that conference to your customers' customers?

A. I know that they had the proceedings available to those who requested it.

Q. You also indicated that you received informal training when you became manager of dielectric fluids from different research departments within Monsanto. Which research departments did you receive informal training from when you became manager of dielectric fluids?

A. I received -- Again, I routinely communicated with our dielectric technology group, headed by Ralph Hunch. I communicated with our analytical services depart-

ment, specifically with Jim Muir at that time, and, as I have said previously, I communicated routinely with Bill Papageorge, representing the outreach from my particular role into the toxicology and medical group of Monsanto.

Q. So Bill Papageorge, as I understand your last answer, was your connection to Monsanto's medical and toxicology departments while you were manager of dielectric fluids?

A. He was my major contact with those departments.

Q. Who was director of Monsanto's medical department when you were manager of dielectric fluids?

A. George Roush.

Q. Did you discuss anything with George Roush while you were manager of dielectric fluids regarding the medical or toxicological aspects of PCBs?

A. From time to time, yes.

Q. Tell me what you remember about those conversations.

MR. FEATHERSTONE: With Dr. Roush?

MR. BRADLEY: Yes.

A. I can't recall specific conversations. If occasions demanded that I reach out to the medical group, and if for some reason Papageorge was traveling or unavailable, there were occasions when I would contact

Roush. There would be few occasions when I would intentionally roach out rather than through Papageorge if Papageorge was available.

Q. (by Mr. Bradley) Do you recall any occasion were you reached out to Dr. Roush and discussed with him information regarding the medical or toxicological aspects of PCBs?

A. No.

Q. Have you ever spoken with anyone from Nevada Power Company?

A. To my recollection, no.

Q. Have you ever spoken with any salesmen who have sold the dielectric fluids manufactured by Monsanto to Nevada Power Company?

MR. FEATHERSTONE: Any salesman who has sold dielectric fluid manufactured by Monsanto to Nevada Power?

MR. BRADLEY: Yes.

A. No. Because at the point that I became the dielectric manager in 1975, at that particular point in time I believe we had already ceased selling dielectric fluids to anybody other than manufacturers of electrical equipment.

Q. (by Mr. Bradley) Have you spoken with anyone within Monsanto who claims that they have spoken with anyone from Nevada Power Company?

A. To my recollection, no.

Q. Do you know whether PCBs enter the body through the skin?

A. We, as a matter of course, for many years in our industrial hygiene made recommendations to users of PCBs, strongly recommended and advocated avoiding prolonged skin contact to preclude any potential entry of PCBs to the system through the skin. There is no question that PCBs have solvency action; we pointed that out. And to the extent that any solvent material can penetrate the skin, there was a potential of the PCBs to enter the body through the skin.

Q. Do you know whether PCBs enter the body through the skin?

MR. FEATHERSTONE: Object to the form of the question.

Q. (by Mr. Bradley) I'm not interested in what you told your customers. I'm interested in whether you know whether PCBs enter the body through the skin.

A. I don't know that they enter the body through the skin.

Q. Have you ever heard the term "furan"?

A. Yes.

Q. Do you know what a furan is?

A. Yes.

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Q. What is a furan?

A. It is a cyclable compound. It's an organic cyclable material.

Q. Have you ever heard the term polychlorinated dibenzofuran?

A. Yes.

Q. Do you know whether any of the dielectrical fluids manufactured by Monsanto contained any polychlorinated dibenzofurans?

A. The alleged presence of chlorinated dibenzofurans in chlorinated biphenyls was a claim that came fairly late in the discussions, regulation and control of PCBs.

At the time that Monsanto became aware of allegations surrounding chlorinated dibenzofurans, we again initiated test work within Monsanto to be able for us to verify whether, first, you have the presence, and the test work, and we concluded that prior to exiting the PCB dielectrics business, as I recall, confirmed only the potential of extremely extraordinary low levels of furans in higher chlorinated biphenyls that Monsanto had produced.

Q. What was your understanding about the levels of the furans in the dielectric fluids manufactured by Monsanto?

A. I thought I just answered that question.

Q. You did. You said there were extremely small levels. But what were the levels that were found, that you recall?

A. In Aroclor 1254, the one report that I saw of work handled in Muir's department, suggested that they may have identified presence in the parts-per-billion level.

Q. Have you ever heard the term "chloracne"?

A. Yes.

Q. What is it?

A. Chloracne is a condition which was really defined during the Second World War, which was a condition which carried symptoms of skin eruptions, a certain amount of skin darkening, a certain amount of rash, pustules, which was associated at that particular point in time with the use of chlorinated materials, in insulation of cables and certain power control systems in military equipment.

Q. Do you know whether there were any reported cases of chloracne prior to the Second World War?

A. At the time that people were developing data about the presence of PCBs in the environment and the potential impact of such presence, review was carried out of the previous medical literature concerning chloracne, and, as I recall, there were some earlier reported claims of similar symptoms in the thirties and forties, but which subsequent generation of medical information certainly did

not relate specifically to chlorinated biphenyls.

MR. BRADLEY: Read it back, please.

(Thereupon, the reporter propounded the previous question.)

Q. (by Mr. Bradley) When was the time period that people were developing data about the presence of PCBs in the environment and the potential impact of such presence that resulted in a review being made of prior cases of chloracne?

A. Considerations of the potential presence of PCB in the environment and the possible impact of such presence, if determined, of any lengthy duration, reached a peak in the period starting from about 1966 and continued until the present.

Q. So was there a review made of prior cases of chloracne shortly after 1966 regarding any alleged correlation between chloracne and PCBs?

A. I don't recall when the review of the earlier cases was done.

Q. When did you learn that there had been a review of the earlier cases?

A. In the 1974-'75 period.

Q. Who told you there had been a review of the prior cases of chloracne?

MR. FEATHERSTONE: You called it the prior

cases of chloracne. He called it the literature. Are you talking about the same thing, Mr. Bradley?

MR. BRADLEY: I have my question out there. It's based upon the notes I have of his testimony.

MR. FEATHERSTONE: I object to the form of the question.

Q. (by Mr. Bradley) Go ahead.

A. I think, given the objection of counsel, we better rephrase the question.

Q. Did you not understand the question?

A. I'm now confused.

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

(Thereupon, the reporter read back a portion of the testimony.)

Q. (by Mr. Bradley) Who told you that a review was made of previous medical literature regarding chloracne?

A. It was either Paul Benignus or Bill Papageorge.

Q. Did -- Whichever one of them gave you the information, did they indicate to you that a peer-reviewed study had been conducted that discounted the claims made in the 1930s and '40s regarding chloracne and its relationship to PCBs?

A. I am going to have to ask you to repeat that question, because there are a lot of elements in the question.

(Thereupon, the reporter propounded the previous question.)

A. Neither one of them claimed a peer review. The information was that a literature review had been carried out which suggested that the symptoms which had been perceived in certain people alleged to be suffering from chloracne earlier was probably related to exposure to chlorinated napthalenes or other materials other than PCBs.

Q. (by Mr. Bradley) Did either Bill Papageorge or Paul Benignus refer you to an article in the Journal of Industrial Hygiene and Toxicology, dated September, 1937, Volume 19, Number 7, by Cecil K. Drinker and others?

A. I don't recall.

Q. I'm going to show you Plaintiff's Exhibit 979 and ask you to review that for me.

MR. FEATHERSTONE: What do you want him to do?

MR. BRADLEY: I want him to review it to indicate to me whether he's ever seen it before and whetner he's familiar with the information in it. So he is going to have to read it.

MR. FEATHERSTONE: You want him to read this entire article?

MR. BRADLEY: Unless he's already seen it.

THE WITNESS: I don't know whether I've seen this article or not.

Q. (by Mr. Bradley) In your work at Monsanto have you ever reviewed any articles concerning PCBs that were published in the Journal of Industrial Hygiene and Toxicology?

A. I don't recall.

Q. Did either Paul Benignus or Bill Papageorge indicate to you that in 1937 a report was written regarding the effects from exposure to vapors of chlorinated diphenyl?

A. Either Bill Papageorge or Paul Benignus indicated that the appropriate people in Monsanto were continuously reviewing known hygiene effects of PCBs, as we did with all our products.

It was not part of my job. It was not required of me or appropriate for me to attempt to encompass the job of all expert functions within Monsanto that helped us to good decision making around the commercialization of the products that we sold.

MR. BRADLEY: I move to strike the answer as nonresponsive.

My question was whether Bill Papageorge or Paul Benignus indicated to you that in 1937 a study was

done regarding the effects of inhalation of vapors from chlorinated diphenyl.

A. I don't recall.

Q. Have you heard the term, "chlorinated diphenyl"?

A. Yes.

Q. Is that the same as chlorinated biphenyl?

A. Yes. Chlorinated diphenyl is the terminology used in Europe, or chlorinated biphenyl, or the other way around. I mean, there is a distinction across the Atlantic between the use of the terms biphenyl and diphenyl.

Q. And are both of them referred to also as PCBs?

A. Today, yes.

Q. Do you know whether in 1937 anyone used the term PCBs?

A. I have never seen the use of the term PCB at that point in history.

Q. When did you know PCB began to be used as a term?

A. Probably in the late sixties.

Q. And when it began being used as a term in the late sixties, it referred in part, did it not, to what had been referred to as chlorinated diphenyl?

A. That was probably not the case until the early seventies.

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Q. Did Bill Papageorge or Paul Benignus ever tell you that in 1937 the effects of ingestion of chlorinated diphenyls were studied?

MR. FEATHERSTONE: Object to the form.

A. I don't recall.

Q. (by Mr. Bradley) Are you familiar with the term "halowax"?

A. I know the term halowax.

Q. What was halowax in 1937? If you know.

MR. FEATHERSTONE: If you know.

A. Yeah. I know the term halowax was used in relationship to some chlorinated waxy type of products. Beyond that I cannot be more specific.

Q. (by Mr. Bradley) Do you know whether halowax was comprised in part of chlorinated diphenyl?

A. No, I don't.

Q. Do you know whether it was comprised in part of chlorinated naphthalene?

A. My recollection is that I associate halowax relative to chlorinated paraffins and chlorinated naphthalenes.

Q. Do you know whether Monsanto undertook any studies between 1930 and the completion of your work with PCB products at Monsanto regarding the health effects of a combination of chlorinated naphthalene and chlorinated

diphenyl?

A. I have no detailed knowledge of such work.

Q. Did Bill Papageorge ever discuss with you any studies that had looked at the effects of exposure to a combination of chlorinated naphthalene and chlorinated diphenyl?

A. I do not recall conversations relative to that specific procedure.

Q. Do you recall specific conversations relative to that topic with any Monsanto employee?

A. No.

Q. Did Bill Papageorge indicate to you that Monsanto knew as early as 1937 that eight or ten General Electric employees exposed to a combination of chlorinated naphthalene and chlorinated diphenyl as part of a halowax mixture were very severely afflicted, horrible specimens, as far as their skin condition was concerned?

MR. FEATHERSTONE: Object to the form.

A. As I have already stated, I did not discuss in detail with either Benignus or with Papageorge in any extensive detail work that was relative to the early thirties and forties.

Q. (by Mr. Bradley) Did anyone ever tell you that, if there were a sufficient concentration of PCBs on the skin to cause a skin condition or rash, systemic

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poisoning may occur in some people who are hypersensitive to PCBs?

A. Yes. And that would form the basis for the good industrial hygiene practice which Monsanto communicated, which was that, if people were working with PCBs and were seen to have any rash or allergic condition, that they should be withdrawn from work in a PCB environment.

MR. BRADLEY: I move to strike the answer following the word "Yes," as nonresponsive and self-serving.

Did Monsanto ever generate documents informing readers that exposure to PCBs may cause systemic poisoning?

MR. FEATHERSTONE: Object to the form of the question.

A. I don't recall exactly what the cautionary statements of industrial hygiene were in the booklet, the instruction manual. If you have one and want to show it to me, then I could comment to it.

Q. (by Mr. Bradley) With your degree in science and with your extensive work history at Monsanto, are you familiar with the phrase "systemic poisoning"?

MR. FEATHERSTONE: Can I have the question again, please?

(Thereupon, the reporter propounded the previous two questions.)

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MR. BRADLEY: Go ahead and answer.

THE WITNESS: I was waiting. Did my counsel want -- Other than listen to those questions, do you want to give me any advice, or --

MR. FEATHERSTONE: I've already objected to the form of the question. So, If you can answer it, go ahead. If you can't, tell him that.

A. I can't answer it.

Q. (by Mr. Bradley) Have you ever heard the term "systemic poisoning"?

A. Yes.

Q. When you've heard that term, what has it meant to you?

A. Systemic poisoning is a situation where an exposure at a part of the body does not necessarily create a symptom at that part of the body, but may affect or have an impact on a central system so that symptoms elsewhere in the body may then display further additional symptoms.

Q. What are the central systems in the body?

A. The heart -- Can I answer that question without it being -- as a generalized thing? I'm not saying that I'm associating in this answer in any way any of these things that might concern the central system where there is PCB activity.

Q. Yes.

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A. The heart is a central system, the lungs are a central system, the liver is a central system, the kidneys are a central system.

Q. Do you know whether any central systems have been shown to be poisoned by exposure to PCBs?

A. An exposure to PCBs has been shown to potentially lead to a buildup of PCBs in adipose tissue. Whether that, and when that would proceed to a point that could be defined as poisoning, that gets us into another definition and discussion.

Q. Other than the buildup of PCBs in adipose tissue, are you aware of any other central systems that are alleged to have been injured by exposure to PCBs?

A. No.

Q. Has anyone ever indicated to you that liver damage may result from exposure to PCBs?

A. The liver is an organ which contains substantial adipose tissue, and, therefore, buildup of PCBs in the liver area has been associated with PCBs. To the extent that a liver surrounded by adipose tissue containing PCBs may have a change in function, and that the change in function could be considered as damage, then, yes, there is damage.

Q. Did anyone ever tell you that before March 18th, 1970, Monsanto admitted that all customers using

dielectric fluids containing PCBs had not been officially notified about known effects, nor did Monsanto labels carry information about known effects?

MR. FEATHERSTONE: Object to the form.

A. Relative to what Monsanto is saying about the usage of PCBs, I have to ask you to divide that question that you just asked me, taking into account and asking me it in terms of, are you asking me about knowledge at the time I was in the sales representative job, or at the time that I was in the European marketing management job, are you asking --

MR. FEATHERSTONE: I think the question is narrower than that. I think the question is whether anybody has ever admitted to you, whatever the question, and then goes on to state. Why don't you ask to have the question repeated.

(Thereupon, the reporter propounded the previous question.)

A. No.

MR. BRADLEY: Off the record for just a moment.

(Thereupon, a luncheon recess was taken.)

Q. (by Mr. Bradley) During the period of time in the 1960s when you were working with dielectric fluids containing PCBs, did you relay any information to any

electrical utility industry group regarding the effects of exposure to PCBs?

A. At the time that I was involved with PCB dielectrics in the sixties, there would be occasions when I would talk to utilities that used the electrical equipment about the handling and maintenance of the equipment. I can recollect a few occasions when that sort of communication occurred during that period.

Q. During the 1960s did you talk with any electric utility companies within the United States regarding the effects of PCBs?

A. No, I did not.

Q. During the 1960s were you aware of any communications Monsanto Company made to electrical utility companies within the United States regarding the effects of exposure to PCBs?

A. Only to the extent that such communications were translated into instruction manuals that would be supplied to European users of our materials.

Q. What work did you do when you were no longer manager of dielectric fluids? What was your next job title?

A. Are we now in the late seventies period?

Q. That's my understanding.

A. Immediately after I was manager of

dielectrics, I was manager of heat transfer fluids.

Q. Over what period of time were you the manager of heat transfer fluids?

A. That was about a two-to-three-year period.

Q. Beginning when, roughly?

A. '76, '77.

Q. Okay. During your work as manager of heat transfer fluids, did you have any involvement with PCBs?

A. Yes, I did.

Q. And what was that involvement?

A. To the extent that there were residual correspondence questions, issues after we had stopped manufacturing and distributing and selling PCB-containing dielectric fluids, I was called upon occasionally to handle questions outside of Monsanto which pertained to the time that we had been in that business.

Q. Were those questions posed from electrical utility companies?

A. I believe I may have had a limited number of isolated questions from utility companies during that period of time.

Q. I take it, though, that the heat transfer fluids that you were managing did not contain PCBs?

A. They did not.

Q. What was your next job title?

A. Manager of raw material purchases.

Q. When did you begin that job and when did it end?

A. It began in the period of either 1979 or '80, and it would have ended in 1982.

Q. What was your next job title?

A. I became commercial director for Monsanto Chemical Company in Brazil.

Q. When did you begin and end that job?

A. End of March of 1982, and I finished it in September of 1988.

Q. What was your next job title?

A. I then became business director for plasticizers and specialty resins.

Q. When did that job begin?

A. That job began in September of 1988.

Q. When did it end?

A. Until sometime in 1989.

Q. What was your next job title?

A. Business director for polymer modifiers in the specialties division.

Q. Did that begin in 1989?

A. Yes.

Q. And when did it end?

A. That job ended in 1991.

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Q. What was your next job title?

A. Business director, Saflex Americas. S-a-f-l-e-x, Americas, with an S on the end.

Q. What is Saflex Americas?

Q. Saflex is a plastic sheet which is used to laminate glass in such applications as safety in automotive windshields. Every windshield in the western world contains a plastic laminate to protect passengers. It is all plastic, and Monsanto is the major world producer of that plastic sheet.

Q. Over what period of time were you director of Saflex Americas?

A. From 1991 until the present time. Americas implies that I have responsibility for that particular business in North and South America.

Q. Were you -- Let me ask it this way: Do you know whether Monsanto and its customers have entered into indemnification agreements regarding the customer sale of PCBs?

A. In the early 1970s, before I became responsible for the dielectric business in the Americas -- North America, Monsanto had entered into agreements with our customers who produced dielectric equipments in which they, to a certain extent, indemnified Monsanto against the consequences of their mishandling our PCBs.

Q. Do you know whether Monsanto's customers' customers were informed of the indemnification agreement that you just discussed?

A. No.

Q. Monsanto sold dielectric fluid beginning in the 1930s; is that -- Let me rephrase the question.

Monsanto sold dielectric fluid containing PCBs beginning in the 1930s; is that correct?

A. My recollection of the historical perspectives that I was given when I became involved with the business is that we entered that business sometime in the 1930s.

Q. Do you know whether Monsanto customers were ever informed regarding the 1930s studies that associated chloracne with exposure to chlorinated diphenyl?

MR. FEATHERSTONE: Object to the form.

A. At the time that I became involved with dielectric fluids containing PCBs, I know that our instruction manuals which were supplied to producers of electrical equipment containing such fluids certainly contained industrial hygiene recommendations which recognized that skin contact for a prolonged period was undesirable. Beyond that it would be pure speculation on my part.

Q. Do you know whether Monsanto ever informed its customers that chloracne was a condition known in the thirties to be caused by exposure to a mixture of

chlorinated naphthalene and chlorinated diphenyl?

A. I do not have specific knowledge about that.

Q. Do you know whether Monsanto ever informed its customers that pathologic changes in animals exposed to a commercially chlorinated diphenyl were reported as early as 1944?

A. No.

Q. Do you know whether Monsanto ever informed its customers that the toxicity of the vapors of Aroclor 1242 and 1254 were documented as early as 1956?

A. No.

Q. Do you know whether Monsanto ever reported to its customers that ninety-nine percent of all Americans reportedly have over five hundred parts per billion PCBs in their adipose tissue?

A. Could you repeat the question?

Q. Do you know whether Monsanto ever informed its customers that ninety-nine percent of all Americans reportedly have over five hundred parts per billion PCBs in there adipose tissue?

MR. FEATHERSTONE: Parts per billion? Is that what you said?

MR. BRADLEY: Yes.

A. I don't believe Monsanto ever carried out any work which would have caused us to make such an estimate

for us to communicate to our customers. There were allegations that PCBs were broadly present in the adipose tissue of the population of America, but, in that it was not for us to fuel nonscientific speculation by reporting every allegation that was made at that time, we probably did not report such.

Q. (by Mr. Bradley) Are you familiar with the term biomagnification?

A. Yes.

Q. What is it?

A. Biomagnification is the process by which a material can be assimilated by a species in the ecological chain, and as that particular species, as a natural food for a higher species, is consumed, then the presence of the material that may be in the adipose tissue of the consumed species is magnified in the tissue of the consuming species.

Q. Are you familiar with the phrase food chain?

A. Yes.

Q. Do PCBs biomagnify in the human food chain?

A. Yes, they can.

Q. Did Monsanto ever inform its customers that PCBs can biomagnify in the human food chain?

A. Yes, we did.

Q. And how did you do that?

A. As part of the notification to our customers of the need to avoid contaminating waters with PCBs. We used examples, as I recall, of biomagnification in the fish food chain.

Q. Where would that information have been?

MR. FEATHERSTONE: I'm sorry. Where would that information have been?

Q. (by Mr. Bradley) Is that in the instruction manual?

A. No.

Q. Where was it located?

MR. FEATHERSTONE: You mean, in what form was it communicated?

Q. (by Mr. Bradley) Thank you. In what form was it communicated?

A. As Monsanto over a period of time developed information about the fate of PCBs in the environment, we kept our customers aware on a continuing ongoing basis of various studies that were carried out which related to distribution of PCBs in the environment, and --

MR. FEATHERSTONE: I think he's asking you whether it was done in a written form or whether it was done in meetings. How was that information communicated?

Q. (by Mr. Bradley) Brochures, letters, instruction manuals?

A. Letters and discussions.

Q. Did you ever author a letter to a customer -- Before I -- Let me stop that question for a moment and ask to have the last question read back.

(Thereupon, the reporter propounded a portion of the testimony.)

Q. (by Mr. Bradley) Let me start a new question: Mr. Wood, did you author any letters to any Monsanto customers informing those customers that PCBs can biomagnify in the human food chain?

A. Almost certainly not.

Q. Did you ever review any letter authored by a Monsanto employee which informed Monsanto customers that PCBs can biomagnify in the human food chain?

A. I believe, yes.

Q. Who authored that -- Who were the authors, if there was more than one, of those letters, if there was more than one?

A. That type of communication would probably have been authored by Jim Muir, Bill Papageorge. These are the names that come to mind as people who would compose such letters.

Q. I'm interested in knowing whether you surmise that these gentlemen wrote those letters or whether you ever remember reviewing a letter written by anyone that

informed Monsanto customers that PCBs can biomagnify in the human food chain.

A. I know that there were questions from our customers about the issues of biomagnification, and, therefore, I know that individual letters would have been authored by such people in response to such questions. I am not aware of any general open customer letter communication that they authored.

Q. And going back for a moment, do you recall ever reviewing a letter written by a Monsanto employee to Monsanto customers that discusses PCB biomagnification in the human food chain?

A. I don't recall that.

Q. Did you have any discussions with any Monsanto customers where Monsanto informed the customers that PCBs can biomagnify in the human food chain?

A. Yes, I did.

Q. When did those occur?

A. Between 1975, January, and 1976, '77.

Q. With whom did you have those discussions?

A. At various points I would have had discussions around those subjects with every one of our U.S. customers.

Q. So you had those discussions with General Electric?

A. Yes.

Q. And you had those discussions with Westinghouse?

A. Yes, I did.

Q. Do you know whether anyone within Monsanto prior to 1975 informed its customers that PCBs can biomagnify in the human food chain?

A. I surmise that they must have done because biomagnification was not an alien term in discussions between Monsanto and its customers when I became involved in this business in 1975.

Q. Have you ever reviewed a letter written by any of Monsanto's customers to their customers that indicates that PCBs can biomagnify in the human food chain?

A. No.

Q. Have any of Monsanto's customers ever informed you that they have told their customers that PCBs can biomagnify in the human food chain?

MR. FEATHERSTONE: I think we're on Monsanto's customers to its customers. Is that right?

THE WITNESS: I thought we had just departed from that.

MR. FEATHERSTONE: Well, let's have the question back, then, to prevent any confusion on this.

(Thereupon, the reporter propounded the previous question.)

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A. Monsanto's customers advised me that they were communicating with their customers about the presence and impact of PCB in the environment. Whether they specifically in such communication dealt with biomagnification, I cannot with certainty say.

Q. (by Mr. Bradley) Do you know what the term "synergism" means?

A. Yes.

Q. What does synergism mean?

A. Synergism means that a particular activity related with two or more individual products can be magnified more than by purely the additive affect of those two activities when they are combined.

Q. Can PCBs work synergistically with other compounds impairing an immune system?

MR. FEATHERSTONE: Objection. Calls for speculation on this witness's part.

A. I have no knowledge.

Q. (by Mr. Bradley) Do you know whether Monsanto ever informed its customers that PCBs can work synergistically with other compounds by impairing the immune system?

A. No.

Q. No, you don't know, or no, Monsanto didn't relay that information to its customers?

A. You asked me if I knew if Monsanto had ever, and I said no.

Q. Did Westinghouse ever inform you that it knew as of 1938 that PCB contact with the skin can cause systemic effects, including injurious effects to the liver?

A. Westinghouse never told me this.

Q. Did General Electric ever tell you that it knew in 1938 that PCB contact with the skin can cause systemic effects, including injurious effects on the liver?

A. General Electric never told me this.

MR. FEATHERSTONE: Could I have that last question back?

(Thereupon, the reporter read back the question.)

A. In both cases, in answer to both of those questions, I was never told that by Westinghouse and I was never told that by General Electric.

Q. (by Mr. Bradley) Did Westinghouse ever tell you that it knew in 1947 that chronic poisoning may occur with repeated exposures to sufficient concentrations of PCB vapor?

A. No.

Q. Did General Electric ever inform you that in 1947 it knew that chronic poisoning may occur with repeated exposures to sufficient concentrations of PCB vapor?

A. No.

Q. Did Monsanto inform its customers prior to 1970 that chronic poisoning may occur with repeated exposures to sufficient concentrations of PCB vapor?

MR. FEATHERSTONE: I'm sorry. Let me hear the first part of that question back.

(Thereupon, the reporter propounded a part of the previous question.)

MR. FEATHERSTONE: All right. That's all I need.

(Thereupon, the reporter propounded the previous question in its entirety.)

MR. FEATHERSTONE: I object to the form of the question as calling for speculation on the part of the witness as to what may have happened at Monsanto prior to 1970. No foundation for him to answer the question on behalf of the entire company.

A. I certainly made no such disclosure to my customer base in Europe.

Q. (by Mr. Bradley) Were you ever provided any documents in the work that you did with Monsanto that indicated Monsanto knew in 1947 that chronic poisoning may occur with repeated exposures to sufficient concentrations of PCB vapor?

A. No.

Q. Were you ever informed during your work at

Monsanto that repeated exposures to PCB vapor may produce internal bodily injury which may be disabling or could be fatal?

A. Sorry. It's just the form -- the form of ingestion I didn't capture in that question.

MR. BRADLEY: Would you read the question back?

(Thereupon, the reporter read back the question.)

A. I was informed by Monsanto that exposure to vapors of PCBs at high levels at high temperatures should be avoided. This was never communicated to me in a sense that this was potentially fatal.

Q. (by Mr. Bradley) Did Monsanto ever inform its customers that periodic physical examinations should be conducted by medical personnel for workers exposed to PCBs?

MR. FEATHERSTONE: Object to the form of the question and to the absence of foundation for this witness to testify on behalf of Monsanto over a long period of time. Calls for speculation.

A. The standard industrial hygiene practice that was communicated in our instructional manuals to dielectric users did not include recommendation as to routine medical inspection.

Q. (by Mr. Bradley) And over what period of years are you familiar with those instruction manuals?

A. An initial period between 1965 and 1970, and a secondary phase between 1975 and 1978.

Q. Did you ever review instruction manuals prepared prior to 1965?

A. No, I did not.

Q. Have you ever heard of Congressman Ryan?

A. I recall the name. I can't recall in what context I know the name.

Q. Do you know whether Congressman Ryan in 1970 proposed legislation that would impact upon the sale of PCBs?

A. No.

Q. Do you know whether in 1955 Monsanto knew that production workers manufacturing PCBs experienced chloracne, gastric troubles, and liver troubles?

Let me rephrase the question. I'm not happy with that question. Do you know, during the period of time you were employed at Monsanto, whether it ever informed its customers that it was reported in 1955 that production workers manufacturing PCBs experienced chloracne, gastric troubles, and liver troubles?

MR. FEATHERSTONE: Object to the form of the question.

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

MR. FEATHERSTONE: It misstates the evidence.

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

A. I'm unable to respond to that question. I have no knowledge of such communications prior to my being involved, and certainly I was not involved whilst I was responsible with any such communication.

Q. You're familiar with the work of Professor Widmark?

A. Professor Widmark, to my knowledge, did very little work himself with any relevance to the subject we're talking about.

Q. Are you familiar with the work of Dr. Jensen?

A. Yes.

Q. Did he issue a published report in 1967 regarding PCBs in the environment?

A. No.

Q. When did he issue a report? If he did.

A. I believe his report, which he commented about the work earlier, but his report was issued no earlier than 1969.

Q. Was his report a published report?

A. Which one are we talking about?

Q. The one in '69, I guess.

A. I believe his work was finally presented in a published form sometime in the 1969 time frame.

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Q. Was it available in an unpublished form prior to '69?

A. It had been -- Commentary about the direction that his work was taking were released by Dr. Jensen and Dr. Widmark in the winter of 1966.

Q. What was Dr. Jensen reporting?

A. I don't believe Jensen was a doctor at that time, so that Dr. Jensen, he was not a doctor reporting anything at that point in time.

Q. What was Mr. Jensen reporting?

MR. FEATHERSTONE: Object to the form.

Q. (by Mr. Bradley) What was Mr. Jensen reporting in this unpublished study that came out in 1966?

MR. FEATHERSTONE: Wait a minute. The witness has talked about commentaries in the winter of 1966. Is that what you're talking about?

MR. BRADLEY: The witness has talked about a published study that appeared in '69 and commentaries that were are released in the winter of '66. That's what my notes show.

Were the commentaries written by Mr. Jensen or by others?

A. By others.

Q. (by Mr. Bradley) Were the commentaries comments on an unpublished study prepared by Mr. Jensen?

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A. The commentaries departed from an unpublished study of work in progress by Mr. Jensen and extended themselves into areas of speculation which were of some embarrassment to Mr. Jensen.

MR. BRADLEY: I move to strike the answer as nonresponsive.

Were the commentaries evaluations of an unpublished work that was being circulated by Mr. Jensen?

A. No. Certainly not.

Q. (by Mr. Bradley) All right. What were -- Were the commentaries on -- Well, let me ask it this way: What were the commentaries commenting on?

A. Commentaries in December of 1966, based on some analytical studies which Mr. Jensen was conducting but had not completed, were made essentially at the instigation of people who were manufacturing an analytical -- a piece of analytical equipment which they wished to promote at that particular time.

The press releases about the performance of that equipment related to the ability of such equipment to determine the presence of the environmental contaminants of a chlorinated nature in the environment. The commentary related to some things or the presence of some molecules other than BDT, which the particular study was involved with, and beyond that point, the rest of the commentary was

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speculative.

Q. Was there any discussion in the commentaries of PCBs?

A. No. There was a commentary at that point in time about some materials which were described by the commentators as chlorinated diphenols. And this created some major confusion as to what chlorinated species of industrial or agricultural product was Jensen really addressing in his analytical study.

Q. Was there a time when it was made clear that chlorinated diphenols were chlorinated diphenyls?

MR. FEATHERSTONE: Wait a minute. That doesn't follow. You mean that that's what he was talking about?

MR. BRADLEY: Yes. Chlorinated diphenols, and in fact, he was talking about chlorinated diphenyls.

Can you answer the question?

A. Sure.

MR. FEATHERSTONE: Then go ahead and answer it.

A. To my mind, the query as to what chlorinated species really were involved in Mr. Jensen's study, to my mind, was not scientifically resolved until about 1969 or even later.

Q. (by Mr. Bradley) When it was scientifically

resolved, what chlorinated compound was it that was involved in Mr. Jensen's study?

A. Highly chlorinated biphenyls. PCPs, as they became known.

MR. FEATHERSTONE: When you said "chlorinated diphenols," would you spell that for the reporter?

THE WITNESS: Yes. The original Swedish language articles commenting on Jensen talk about work related to a chemical material described as chlorinated diphenols, d-i-p-h-e-n-o-l-s.

MR. FEATHERSTONE: All right.

Q. (by Mr. Bradley) Okay. And how is that different from the spelling of chlorinated diphenyls?

A. A phenol radical is a benzene ring with a hydroxyl group associated with it.

Q. I'm just talking about the spelling? How does the spelling differ?

A. Diphenyl has a Y in place of the O, but they're very different chemical materials, and, therefore, whether my answer is self-serving or not, we have to be very precise on what we're talking about.

MR. BRADLEY: I move to strike as nonresponsive.

MR. FEATHERSTONE: Off the record.

(Thereupon, a short colloquy was had.)

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Q. (by Mr. Bradley) And at the time of the Jensen published report in 1969, was he a doctor?

A. I don't know. I don't know whether he received his doctorate or not.

Q. And following his report, do you know whether Monsanto increased or decreased its production of PCBs?

MR. FEATHERSTONE: Which report, now?

MR. BRADLEY: The 1969 published report.

A. Chronologically, Monsanto's reduction of its output of PCBs was after the publication of the Jensen report, but I must insist that that is purely that. I mean, chronologically we reduced production, in time, after the publication of Jensen's report.

Q. (by Mr. Bradley) Well, let me ask this question: Did you increase or decrease the production of PCBs in 1970 versus 1969?

A. On a worldwide basis, I do not have that knowledge.

Q. How about on the -- using the United States as a universe? Between 1969 and 1970, did Monsanto increase or decrease its United States production of PCBs?

A. I don't know.

Q. Between 1969 and 1971, did Monsanto increase or decrease its worldwide production of PCBs?

A. I don't know.

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Q. Can you tell me what year Monsanto first reduced its worldwide production of PCBs following issuance of the published report by Jensen in 1969?

MR. FEATHERSTONE: Object to the form of the question. Also calls for speculation on the part of the witness, since he's already told you for several of those years he doesn't know one way or the other.

Q. (by Mr. Bradley) Mr. Wood, if you don't know the answer, just tell me you don't know it; if you do know the answer, go ahead and answer it.

A. Because I was uninvolved with PCBs during that period, I don't know the answer to that question.

Q. All right. Do you know what it means to biodegrade?

A. Yes, I do.

Q. Do PCBs manufactured by Monsanto biodegrade?

A. Yes.

Q. What does biodegrade mean?

A. Biodegrade means that when a chemical is present in the environment in contact with other naturally-occurring species in the environment, that the material will gradually be broken down into smaller components.

Q. And if a compound breaks down into smaller components but does not completely disappear, does it still biodegrade?

A. Yes.

Q. And how is that expressed, as complete biodegradation, partial biodegradation, or some other phrase or term?

MR. FEATHERSTONE: Object to the form of the question.

Q. (by Mr. Bradley) What phrase is used to refer to a compound that breaks down into smaller components but does not completely disappear?

A. I would refer to it as a partially biodegradable mixture.

Q. Are the PCBs manufactured by Monsanto completely biodegradable or partially biodegradable?

A. Partially biodegradable.

Q. Are there any PCBs manufactured by Monsanto that are completely biodegradable? Excuse me. Let me rephrase that. During the period of time that you were working with Monsanto relative to the issue of PCBs, were any of the PCBs manufactured by Monsanto completely biodegradable?

MR. FEATHERSTONE: Are you talking about product mixtures, or are you talking about individual isomers?

MR. BRADLEY: I understand, you know, from the Tucker deposition that there is a difference. I want to

hear what his understanding is and explanation of it, so I'm just going to leave the question as it is.

MR. FEATHERSTONE: Object to the form of the question.

A. Polychlorinated biphenyls, as sold by Monsanto for various dielectric applications, were complex mixtures of isomers. The various isomers of chlorinated biphenyl have differing biodegradation rates, and those varying biodegradation rates will themselves vary depending on the environment within which the biodegradation is occurring, So discussion about complete or incomplete biodegradation can only be discussed relative to specific PCB mixtures and different specific environmental exposures.

Q. (by Mr. Bradley) During the time you were working with PCBs at Monsanto, were there any PCB mixtures that completely biodegraded?

A. Certain isomers of polychlorinated biphenyl in tests carried out by Monsanto were shown to biodegrade completely.

Q. Were any tests conducted by Monsanto outside of a laboratory situation which showed that -- Strike the question.

Would you read back his answer to me?

(Thereupon, the reporter propounded the previous answer.)

Q. (by Mr. Bradley) Did Monsanto perform any test to determine whether the isomers which were shown to biodegrade completely would biodegrade completely outside of the laboratory?

MR. FEATHERSTONE: Object to the form.

A. That would not have been a fruitful line of testing, so we did not.

Q. (by Mr. Bradley) I have shown you Plaintiff's Exhibit 424 just before we started up again following the lunch hour. Is that an exhibit you have ever seen before?

A. You said 424.

Q. Let me start the question again. I'm now showing you Plaintiff's Exhibit 422 which I asked you to review just before we started up again here following our lunch break. Is that an exhibit that you have seen prior to today?

A. No, I haven't.

Q. Okay. I'm going to show you Plaintiff's Exhibit 435 and ask you to review that for me, please.

A. Yes.

Q. Is this a letter written by you?

A. Yes, it is.

Q. All right. And it's to George Buchanan in St. Louis?

A. Yes, it is.

Q. And it's dated December 1, 1966?

A. Yes, it is.

Q. And attached to the letter is a copy of a letter received from Ola Palm in Stockholm?

A. The signature appears to be "Ola," and given my knowledge of the -- or remembrance of the organization, that would have been Ola Palm.

Q. And is this exhibit a true and accurate copy of the letter you authored December 1, 1966 to George Buchanan with the attachment?

MR. FEATHERSTONE: Are you excluding the handwriting that's on the second and third pages?

Q. (by Mr. Bradley) Let me first ask: Is that your handwriting on the letter from Ola Palm to you?

A. No.

MR. FEATHERSTONE: Let's go off the record.

(Thereupon, a discussion was had.)

Q. (by Mr. Bradley) Other than the handwriting on the first page of the letter written to you by Ola Palm, is this a true and accurate copy of the letter you wrote December 1, 1966 to George Buchanan attaching the letter directed to you from Ola Palm in Stockholm?

A. The copy of the letter from Rising & Strand is indeed a copy of the letter I received from them. The letter dated the 1st of December is my letter to George

Buchanan. Other than the handwritten notes on the Rising & Strand letter, there are some underlinings of emphasis on page two and some side-linings on page three which are not mine.

Q. Otherwise, it's a true and accurate copy?

A. Yes, it is.

Q. Did you write the letter to George Buchanan, December 1, 1966, shortly after you received the letter from Ola Palm in Stockholm?

A. Given the normal mail transmission time, the Rising & Strand letter you see is dated November 28th, and almost immediately I wrote to Mr. Buchanan.

Q. Is this a document that you maintained in your files at Monsanto as part of Monsanto's regularly-conducted business activity?

A. It would normally have been in my dielectric Sweden file.

Q. Okay.

MR. FEATHERSTONE: About that question, Mr. Bradley, you were intending to ask him about his copy of the letter without somebody else's handwritten marginal notes?

MR. BRADLEY: That's correct. Without the handwritten notes and without the underlinings and without the lines drawn beside two paragraphs on the last page from

Ola Palm.

MR. FEATHERSTONE: Okay.

Q. (by Mr. Bradley) Mr. Wood, I have shown you Plaintiff's Exhibit 358. Is that a memorandum that you wrote to Bill Papageorge on October 30th, 1975?

A. The heading would suggest so.

Q. All right. Is this a true and accurate copy of the letter that you wrote to Mr. Papageorge on that date?

A. I don't recall every letter I wrote in 1975. It does not seem to have been tampered with.

Q. And is this a document you wrote regarding an EPA letter received October 17, 1975?

A. That's what the reference to this memo suggests.

Q. Is this a document that you kept in your files at Monsanto as part of its regularly-conducted business?

A. Yes.

Q. I'm now going to show you Plaintiff's Exhibit 357 and ask you to review that document.

Let's go off the record for a moment.

(Thereupon, a short recess was taken.)

Q. (by Mr. Bradley) Mr. Wood, you have before you both Plaintiff's Exhibits 357 and 358?

A. Yes.

Q. Exhibit 358, which we have previously spoken about, indicates that it's a comment on an EPA letter received 10-17-1975. Is Plaintiff's Exhibit 357 the letter from the EPA that is referenced in Exhibit 358?

A. Yes.

Q. Is that a true and accurate copy of the letter that is referred to in Plaintiff's Exhibit 358, absent the markings and handwriting?

A. Are we on 358 or 357?

Q. Let me start all over again. On 357 there are some underlinings and there are some handwritten words.

A. Yes, there are.

Q. Did you write those handwritten words?

A. Yes.

Q. Did you underline those portions of Exhibit 357 that are underlined?

A. Yes.

Q. And did you put the markings next to certain paragraphs, the straight line up and down?

A. Yes.

Q. And is this a true and accurate copy of the letter that you received October 17, 1975 from the United States Environmental Protection Agency?

A. Yes.

Q. Is this a document that you maintained within

your files at Monsanto as part of Monsanto's regularly-conducted business?

A. Yes.

Q. Turning to 358, on the second page under item twelve, you have listed Q10, which I assume means question ten. It says, None, question mark; Yusho, question mark; Cloracne years ago, hyphen, Dangerous Question. What were you referring to when you indicated there was a dangerous question?

A. Question ten in the EPA letter requests a description of any adverse health or environmental effects which you know or believe speculate to have resulted from the introduction of PCB compounds.

It asked the correspondent to indicate specifically occasions of dates, times, locations, amounts and parties involved for which such effects are known, and, in making a comment on this question ten to Bill Papageorge, who would be responsible for Monsanto's response to the EPA, I was trying to express a concern that, in trying to succinctly and precisely to respond in an open fashion to question ten, that there were issues of judgment, and that we needed to be very clear and get consensus that this indeed did represent a corporate position in our responses.

I allude to Yusho because there had been an

awful lot of inaccurate reporting about exactly what was the Yusho incident, who was involved, what had been the effects.

Q. Well, let me ask this question: Number ten asks, as you indicated, for a description of any adverse health or environmental effects which you know or believe to have resulted from the introduction of PCBs compounds or mixtures into the environment, and then it asks for specific information, and on Exhibit 358 regarding that question you begin with none, question mark. Why did you put none, question mark?

A. Because this was at a time when there were allegations that perhaps PCBs were carcinogenic, and so, in answering any type of response of this sort, by putting those words with those question marks, I was saying there needs to be some discussion, some debate as to, is there any limit to the severity of affect. We need to -- Let's talk about it, Bill.

Q. And by putting "None," was that intended as an expression of prior corporate response to similar types of questions?

MR. FEATHERSTONE: Object to the form.

A. No. I don't believe that was so.

Q. (by Mr. Bradley) Aren't you basically saying here in Exhibit 358, "Geez, maybe we shouldn't tell them

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anything. Maybe we should tell them about Yusho. Maybe we should tell them about chloracne that happened years ago." That's a pretty dangerous question; isn't that basically what you're saying there?

A. No. I think that's your interpretation of what you think was in my mind. It's not what I've just stated was in my mind.

Q. Tell me -- I didn't understand your answer on why you would list "None" for a description of any adverse health or environmental effects. Did you believe that "None" would be an appropriate response to question ten?

A. I think that "None" could have been appropriate as a response to adverse human health effects.

Q. Well, the question says, "A description of any adverse health or environmental effects..." Now --

MR. FEATHERSTONE: Well, that's not what it says, so let's get it right. ".. which you know or believe to have resulted from the introduction of PCB compounds or mixtures into the environment."

MR. BRADLEY: That's the reason that I talked about environmental effects, Mr. Featherstone, is because he had talked about adverse human health effects. I was just trying to broaden it.

But in 1975 you were aware of the report by Mr. Jensen describing PCBs in the environment; is that

true?

A. I saw the report of Mr. Jensen which reported the presence of a previously unidentified chlorinated species in the environment. That's all he was reporting, the presence of a chlorinated species hitherto unidentified in the environment.

Q. Lets me ask you this question, then, Mr. Wood: By 1970 didn't you believe that PCBs were present in the environment and were having some adverse affect on the environment?

A. No. I believed the PCBs were in the environment. I would have been guilty of the worst sort of speculation had I tried, from my knowledge base at that point in time, to say what was the effect of those compounds in the environment.

Q. Did you ever believe that PCBs in the environment caused eggshells to thin?

A. I believe that chlorinated species in the environment could be connected with eggshell thinning. I did not -- I was not capable at any time prior to 1975 of really being able to satisfy myself intellectually that PCBs were directly involved in eggshell thinning.

Q. What did you mean when you wrote on Exhibit 358, "Chloracne years ago - Dangerous Question," with a hyphen in between there?

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A. The hyphen in between was not relating the dangerous question to chloracne. I was merely pointing out that, in terms of the adverse effects, or adverse health effects of PCB, chloracne had been raised as an adverse affect of PCBs. That had nothing to do with their presence in the environment in the sense that this question was being asked. I mean, that was their presence in the work-place which was leading to -- had been related to lead to chloracne years ago.

And the question said, "..that you know or believe to have resulted from the introduction of PCB compounds or mixtures into the environment." Chloracne was associated with its presence in the workplace, so it was purely an industrial hygiene question, and I wanted to know how Bill was going to handle that.

I then put a hyphen there, because I'm saying now, the dangerous-question comment in this item twelve, it relates to the whole of question ten in the EPA document. So I said this is a dangerous question because by 1975 we had already experienced as a corporation the ability of people to take an honest display of information by Monsanto and to extend that into speculation, conjecture, and to departures which the information did not support, and therefore, I'm saying that there is an issue here of danger in how we respond to that question.

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Q. By 1975 you've already indicated to us that either Mr. Benignus or Mr. Papageorge had made a review of the early studies regarding chloracne and determined that they did not relate to PCBs. Is that correct, or am I misunderstanding what you told us previously?

A. Yes, you are.

MR. FEATHERSTONE: Or misstating.

THE WITNESS: Well, certainly misstating, if not misunderstanding.

Q. (by Mr. Bradley) What was the prior review of -- Let me ask it this way: By 1975 had there been a review made of the previous medical literature of chloracne regarding similar symptoms in the thirties and forties, but which either Mr. Benignus or Mr. Papageorge determined did not relate specifically to PCBs?

A. Wow.

MR. FEATHERSTONE: Object to the form.

THE WITNESS: That is still a misstatement of what we talked about earlier today.

MR. FEATHERSTONE: Well, all right. But all he asked is did that happen, and if it's a misstatement, then the answer is no.

A. No.

Q. (by Mr. Bradley) Okay. Was there a review made of previous medical literature of chloracne by Mr.

Benignus or Mr. Papageorge prior to 1975?

A. No.

Q. Did Mr. Benignus or Mr. Papageorge ever make a review of any literature regarding chloracne?

MR. FEATHERSTONE: Objection. Calls for speculation.

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

A. I don't know. I do not believe that either Mr. Benignus or Mr. Papageorge personally reviewed the previous literature about chloracne, because neither of them was competent so to do.

Q. Did either Mr. Benignus or Mr. Papageorge inform you that a review had been made of previous medical literature on chloracne?

A. Mr. Benignus or Mr. Papageorge, as part of my education when I came on board, told me what their latest thinking was about chloracne and PCBs.

Q. Did they tell you --

A. The basis of that I do not know.

Q. Did they tell you that a review had been made of previous medical literature on chloracne?

A. I believe somebody told me that the information had been reviewed.

Q. Did somebody tell you that, as a result of the review, that they determined subsequent generation of

medical information indicated that those symptoms that were reported in the thirties and forties did not relate specifically to PCBs?

A. Yes.

Q. Why then, Mr. Wood, would you in Plaintiff's Exhibit 358, item twelve, regarding question ten of Exhibit 357, write, "Cloracne years ago" in relation to a question that asked for a description of any adverse health or environmental effects which you know or believe to have resulted from the introduction of PCB compounds or mixtures into the environment?

A. Irrespective of whether I believed chloracne was associated with the use of PCBs previously, there is no question that there was a record which stretched for years of people believing and people misstating causal connections between chloracne and PCBs. And it was clear to me that as we respond to this particular EPA questionnaire and as other people respond to this EPA questionnaire, that there was a potential for old mythology to renew itself.

Q. Part of the reason you described question ten as a dangerous question is because you believed it would require Monsanto to tell that it knew that there were problems associated with PCBs that it hadn't informed the public about; isn't that true?

A. No.

Q. Mr. Wood, I'm going to show you Plaintiff's Exhibit 1675. Have you -- Let me ask it this way: Are you familiar with a 1975 or 1977 report from NIOSH on PCBs?

A. I recall that there was a report from NIOSH in that sort of time frame on PCBs.

Q. Do you recall whether you reviewed the NIOSH report that was generated sometime around '75 to '77?

A. It would have been reviewed by the department within Monsanto that should review such data to give it their -- who were technically equipped to so review, and they would then -- normally they would either discuss with the business group or write to the business group telling us what they believed the -- was an appropriate executive summary of drawing our attention to what they felt were the critical public issues surrounding such a document.

Q. Perhaps my question wasn't clear. My question was, do you ever recall reviewing a -- Well, let me ask it this way: I'm now going to show you Plaintiff's Exhibit 1373 and ask you whether you have ever seen that document before.

A. No.

Q. Is this the report -- Well, would you know whether this is the report of NIOSH that you were referring to as being generated in the 1975-to-1977 time frame? And I refer you to the reference just above the date at the

bottom of the document.

A. I know that NIOSH published a report in that time frame. Whether this particular document that I'm looking at, which is a document which has an HEW cover but with a NIOSH subhead down here -- since I know that the NIOSH document published at that time related to exposure to PCBs, I surmise that this is the document to which that was referring.

Q. All right. Mr. Wood, I'm going to represent to you that Plaintiff's Exhibit 1675 is a copy of the reference section out of 1373. And if you would, for a moment, I'd like you to compare the pages to make sure that my representation is accurate.

MR. FEATHERSTONE: Well, do we need to do that, or can we just simply assume that your representation is accurate? Is that acceptable to you? It's acceptable to us.

MR. BRADLEY: Yes. That's fine.

Now, my question, Mr. Wood, is, which of the references listed on Plaintiff's Exhibit 1675 give you --

A. That's this reference?

Q. (by Mr. Bradley) Yes.

A. 1675?

Q. I'm going to start the question all over again. Which of the references listed on Plaintiff's

Exhibit 1675 relate to any adverse health or environmental affects which you know or believe to have resulted from the introduction of PCB compounds or mixtures into the environment --

MR. FEATHERSTONE: Object to the question.

Q. (by Mr. Bradley) -- that precedes October 17, 1975?

And I assume you object to that, as well.

MR. FEATHERSTONE: I do. I object to the form and object to the harassing nature of the question and object to the form of the question.

THE WITNESS: Anything else?

MR. FEATHERSTONE: Well, I'll think about it while you try to figure out how you'd ever answer a question like that.

THE WITNESS: Well, I can't answer a question like that.

Q. (by Mr. Bradley) Do you know whether any of the references listed on Plaintiff's Exhibit 1675 relate to adverse health or environmental effects alleged to have resulted from the introduction of PCB compounds or mixtures into the environment?

A. To answer that question we're going to have to go through this one by one, and if I can recall having seen the particular study, then I'll have to make a judgment as

to whether I have any comment about any potential hazard. If we're going to do that, we'd better get to it.

MR. FEATHERSTONE: Off the record.

(Thereupon, a discussion was had.)

Q. (by Mr. Bradley) Have you completed your review of the references on Plaintiff's Exhibit 1675?

A. Yes, I have.

Q. Would you answer my question now?

A. None of these references leads me to change my conclusion about the adverse health questions on human beings resulting from the introduction of PCB compounds or mixtures into the environment.

As a clarification of an earlier answer, I am -- that comment is restricted to adverse health effects resulting from the introduction of PCBs into the environment.

Q. And how -- Do any of the references on Exhibit 1675 -- Just a moment.

I'm going to stop that question and go back and ask you to read the question that he's responding to that I posted to him just before the break.

(Thereupon, the reporter read back the question.)

Q. (by Mr. Bradley) Mr. Wood, I appreciate the answer you have given me, and that partially answers my question. Are there any references on Plaintiff's Exhibit

1675 that relates to any adverse environmental effect which may have resulted from the introduction of PCB expounds or mixtures into the environment?

A. I have not reviewed this list of reference on 1675 from the total viewpoint of effect on the environment. Monsanto conceded very early on in our deliberations on PCB that PCB was present in the environment. I'm trying to wend my way through this one. If it's not responsive, then stop me.

MR. FEATHERSTONE: Let's go off the record for a second, and maybe we can come --

MR. BRADLEY: Okay.

(Thereupon, a short colloquy was had.)

Q. (by Mr. Bradley) Back on the record. Let me ask it this way, Mr. Wood: In October, 1975 were there adverse environmental effects which you knew or believed to have resulted from the introduction of PCB compounds or mixtures into the environment?

A. There was the adverse affect of there being present in the environment unbiodegraded synthetic material which was capable of biomagnification in food chains. I consider that an adverse affect.

Q. Any other adverse effects, adverse environmental effects?

MR. FEATHERSTONE: That the witness knew

about?

Q. (by Mr. Bradley) That you knew or believed to have resulted from the introduction of PCB compounds or mixtures into the environment in 1975.

A. At that stage my knowledge of the adverse environmental effects was presence and the biorefractory nature of the material that was present.

Q. Do you now have in front of you Plaintiff's Exhibit 1475?

A. Yes. Is that an exhibit that you have seen before?

A. Yes, it is.

Q. Is this a letter from Douglas Hardy to you, among others, dated January 12, 1967?

A. Yes.

Q. Is the subject matter "Aroclor - Sweden"?

A. Yes.

Q. Is this a true and accurate copy of the letter written to you and others by Douglas Hardy on that date?

A. Yes.

Q. Is this a document that you maintained in your files at Monsanto as part of Monsanto's regularly-conducted business?

A. Yes.

Q. Is that the Monsanto letterhead in the top

left-hand portion of that exhibit?

A. Yes.

Q. Would you now put in front of you Plaintiff's Exhibit 1498?

A. Yes.

Q. Is your name listed on the top right-hand corner as someone who received a carbon copy of this?

A. It is.

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

A. Yes.

Q. And is this a memo written by R. A. Baxter to R. E. Keller dated August 19th, 1975?

A. Yes, it is.

Q. And is this a true and accurate copy of the letter that you received a copy of from R. A Baxter to R. E. Keller dated August 19th, 1975?

A. It is, except I was not previously privy to the comment on this particular copy H. S. Bergen made.

Q. Pardon me?

A. I had not previously seen the additional hand-written comment that was made by somebody who received this copy other than myself.

Q. You mention the name H. S. Bergen. Does it appear to be his handwriting?

A. I can't tell whether that is Howard's copy or

whether this is somebody else's? I can't make out the signature or the initialing of the comment.

Q. Can you make out what the comment is?

A. No.

Q. Does it appear to you to say European something?

A. Again, speculating, I read it as "European trip," but --

Q. Okay. And is this a memo that you maintained in your files at Monsanto as part of Monsanto's regularly-conducted business?

A. Yes.

Q. And this also has the Monsanto letterhead in the top left-hand corner?

A. Yes, it does.

Q. Would you now examine Exhibit 1425?

A. Yes.

Q. Is this a copy of a memo you wrote to W. B. Papageorge on August 29, 1975, regarding an August 29, '75 telephone call?

A. Yes, it is.

Q. Did you write this memorandum shortly after you received the telephone call?

A. Yes, I did.

Q. Is this a true and accurate copy of the memo

you sent to W. B. Papageorge dated August 29, 1975?

A. Yes, it is.

Q. Did you maintain a copy of this exhibit in your files at Monsanto as part of its regularly-conducted business?

A. Yes, I did.

Q. Would you now look at Exhibit 1117?

A. I have it.

Q. On the top right-hand portion of that it indicates you received a carbon copy of this; is that correct?

A. That is correct.

Q. And this is a letter from R. E. Keller to R. Baxter dated August 15th, 1975 on the subject of chlorinated dibenzofurans?

A. Yes.

Q. What does the LLW hyphen 5045 indicate under R. Baxter's name?

A. At that stage, our European Technical Laboratory had moved from Ruabon in North Wales, England, to Louvain-La-Neuve, Belgium, and the mail zone relative to that location was 5045.

Q. There's also some handwriting on it which appears to say "European trip file folder, pls," which I assume means "please."

A. That's my assumption. It's not my handwrit-

ing.

Q. All right. And other than the handwriting, is this a true and accurate copy of the letter that you received a copy of, dated August 15, '75, from R. E. Keller to R. Baxter?

A. Yes.

Q. And is this a document that you maintained in your files at Monsanto as part of Monsanto's regularly-conducted business?

A. Yes.

Q. Does this also have Monsanto's letterhead on the top left-hand portion of the exhibit?

A. Yes, it does.

Q. I now ask you to look at Plaintiff's Exhibit 1242.

A. Okay.

Q. This document indicates that you were a recipient of this exhibit with an attachment from G. to you and a variety of others; is that correct?

A. Yes.

Q. And it's dated February 10, 1975?

A. Yes, it is.

Q. Subject matter is "Westinghouse"?

A. Yes, it is.

Q. It says, "Attached is a xerox copy of the

Westinghouse Codicil No. 1 which is part of the contract"?

A. Yes, it does.

Q. Who is G.?

A. I think this is related to Gladys Burgos in the New York offices who is the "from" in this particular memo.

Q. And is this a true and accurate copy of the letter she sent to you and others dated February 10, 1975?

A. I believe so.

Q. Okay. Is this a document you maintained in your the files at Monsanto as part of its regularly-conducted business?

A. C. Paton is asterisked, receiving the original copy; Ray Ford received an original carbon copy; and the way that the contract files were maintained, certainly those files would have been maintained. I'm not sure that I would have kept my copy of this particular document on file because it would have been part of the corporate contract file.

Q. But Monsanto would have retained a copy?

A. Yes.

Q. Okay. And I'll ask you to look at Plaintiff's Exhibit 1419. Have you reviewed it?

A. Yes.

Q. Is this a copy of a letter from you to Mike

Modan dated November 7, 1975?

MR. FEATHERSTONE: Minor point: This letter has a bunch of attachments to it which aren't here. Are you just asking him to verify that this is a copy of the cover letter?

MR. BRADLEY: Yeah. I'll just get to that. That is not a minor point; it's a major point.

This doesn't have the attachments referred to in the letter; is that correct?

A. This is correct.

MR. FEATHERSTONE: All right. When I said my minor and major, it was not about the significance of the attachments, just in responding to the question, I want it made clear that this is a true and correct copy of the cover letter that went with all these attachments. We will stipulate that there were attachments with it.

MR. BRADLEY: We'll stipulate that the attachments are not part of the exhibit. Is that correct?

MR. FEATHERSTONE: Yes. I also stipulate that the attachments went to Modan, too.

MR. BRADLEY: Off the record.

(Thereupon, a short colloquy was had.)

Q. (by Mr. Bradley) And is this letter a cover letter that had attached to it the references that are referred to in the exhibit?

A. Yes, it is.

Q. And the exhibit itself doesn't have the attachments, correct?

A. It does not.

Q. And is this a true and accurate copy of the letter written by you November 7, 1975 to Michael Modan absent the exhibits?

A. I presume it is, but just as a matter of reference, this is the first copy I've seen so far where we have such a striking difference between pages of the copy. There is a very distinct difference in page one and page two, but this would seem to be a representative copy of the memo at November 7th, 1975.

Q. Is this a document that you maintained in your files at Monsanto as part of Monsanto regularly-conducted business?

A. A cover letter, yes.

Q. Okay. Would you now look at Exhibit 1510?

A. Yes.

Q. At page 317 of Plaintiff's Exhibit 1510 is there a paper authored by you entitled "Chlorinated Biphenyl Dielectrics - Their Utility and Potential Substitutes"?

A. There is.

Q. And does that continue on through page 324 of

WATER_PCB-SD0000056567

that exhibit?

A. Yes, it does.

Q. Is that a true and accurate copy of a report that you prepared?

A. Yes, it is.

Q. Did you maintain a copy of this report in your files at Monsanto as part of Monsanto's regularly-conducted business?

A. Yes, I did.

Q. The beginning of Plaintiff's Exhibit 1510 refers to "Session V, Economics and Substitutes." Turn to the first page of the exhibit.

A. Uh-huh.

Q. Did you present this paper at a conference?

A. I presented this paper at a conference at the Pitt Hotel in Chicago in November of 1975.

Q. And that was as part of the National Conference on Polychlorinated Biphenyls, November 19 to 21?

A. Yes, it was.

Q. And I'd asked you to refer to Plaintiff's Exhibit 1509. Does Plaintiff's Exhibit 1509 also contain the report that is referenced in 1510 beginning at page 317 and ending at 324?

A. Yes, it does.

MR. FEATHERSTONE: Are you going to attach

WATER_PCB-SD0000056568

1509 to the transcript?

MR. BRADLEY: I was not intending to.

MR. FEATHERSTONE: Would you just describe on the record what 1509 is?

MR. BRADLEY: I'd be happy to do that. 1509, the top right-hand, it says U.S. Department of Commerce, National Technical Information Service, PB-253 248, and it's entitled "National Conference on Polychlorinated Biphenyls," November 19 to 21, 1975, Chicago, Illinois.

It begins with Bates number 774190 and ends at Bates number 774667.

MR. FEATHERSTONE: That's the Nevada Power Bates number?

MR. BRADLEY: Yes.

Why did you write Plaintiff's Exhibit 358 -- Let me rephrase the question. I take it the letter referenced at Plaintiff's Exhibit 357 came to you in October of 1975.

A. No.

Q. (by Mr. Bradley) To whom did it go? If you know.

A. I believe that this would have gone to Mr. Papageorge.

Q. And did Mr. Papageorge send it to you?

A. I believe he would have done that.

Q. Why would he have done that?

A. Because Mr. Papageorge and I and our technology community would discuss how Monsanto should openly and responsively respond to such a letter.

Q. In October of '75, were you manager of dielectric fluids?

A. Yes, I was.

Q. In October of '75, what title did Bill Papageorge have?

A. I'm not sure what his title was at that point in time. His function was that of product stewardship.

Q. Is -- Do you know why Mr. Papageorge was the person who was chosen to respond to the October 17, 1975 letter from the United States Environmental Protection Agency, versus you, for example, who was manager of dielectric fluids?

A. Because most of Monsanto's relationships with the Environmental Protective Agency were conducted by people who had, as part of their role, the routine -- Sorry. None of this was routine -- people who had the responsibility to coordinate Monsanto's product safety moves with the EPA.

Q. And that was Mr. Papageorge?

A. That was Mr. Papageorge.

MR. BRADLEY: I have nothing further.

MR. FEATHERSTONE: Great. No questions.

DAVID WOOD

Subscribed and sworn to before me this 10th day of June, A. D., 1993.

MY COMMISSION EXPIRES 3/19/95.

Suzanne H. Thompson
Notary Public, within and for the State of Missouri

SUZANNE H. THOMPSON
NOTARY PUBLIC STATE OF MISSOURI
ST. CHARLES COUNTY
MY COMMISSION EXP. MAR.19,1995

WATER_PCB-SD0000056571

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, 100 N. Broadway, in the City of St. Louis, State of Missouri, by Ralph A. Bradley and Richard Hinckley, attorneys for the Plaintiff; by Bruce A. Featherstone, attorney for the Defendant, Monsanto; by Laurie Basch, attorney for the Defendant, Westinghouse; and by DAVID WOOD, the witness, in said office on April 1, 1993.

The said witness, DAVID WOOD, 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 and caused to be transcribed into typewriting, and that the foregoing pages correctly

set out the testimony of the aforementioned witness, DAVID WOOD, 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.

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

May 3, 1993

David Wood
Saflex Business Director-Americas
Monsanto Chemical Company
800 North Lindbergh Boulevard
St. Louis, Missouri 63167

Re: Nevada Power Vs. Monsanto

Dear Mr. Wood:

This letter, incorporated as the last page of your deposition, taken on April 1, 1993, will serve as notice to you that your testimony is now ready for your reading and signing of same.

I would appreciate your contacting my office by calling (314) 421-1000 within the next thirty days so that arrangements can be made to accomplish this before your deposition must be filed in Court.

Thank you for your cooperation in this regard.

Sincerely,

MARK D. CONCANNON

MDC:mk

WATER_PCB-SD0000056574

DAVID WOOD

- DEPOSITION CORRECTION SHEET -

In Re: NEVADA POWER Vs. MONSANTO

Upon reading his deposition transcript and before subscribing thereto, the deponent indicated the following:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

DAVID WOOD

WATER_PCB-SD0000056575

DAVID WOOD

- DEPOSITION CORRECTION SHEET -

In Re: NEVADA POWER Vs. MONSANTO

Upon reading his deposition transcript and before subscribing thereto, the deponent indicated the following:

Page 8 Line 17 should read: vault not volt.

Reason assigned for change:

Page 22 Line 8 should read: Wales not Whales!

Reason assigned for change:

Page 37 Line 3/9 should read: Polyphenyl not Polyphenal.

Reason assigned for change:

Page 41 Line 5 should read: DIN not BIN

Reason assigned for change:

Page 64 Line 23 should read: Cyclic not Cyclable

Reason assigned for change:

Page 95 Line 24 should read: DDT not BDT.

Reason assigned for change:

Page 97 Line 3 should read: PCBs not PCP's

Reason assigned for change:

Page Line should read:

Reason assigned for change:

Page Line should read:

DAVID WOOD

WATER_PCB-SD0000056576

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OCT 17 1975

OFFICE OF ENFORCEMENT

Monsanto Industrial Chemicals Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166

OCT 22 1975

Gentlemen:

Recent governmental sampling data indicate the presence of Polychlorinated Biphenyls (PCBs) and comparable chemical substances in the air, in water bodies, and in fish in several areas of the country. In order to determine the nature and extent of the possible adverse effects resulting from the presence of PCB compounds in the environment, the Environmental Protection Agency (EPA), in cooperation with other federal and State agencies, is attempting to determine the sources and amounts of PCBs entering the environment. It is important that this effort be carried out without delay.

It is our understanding that your company handles PCB compounds or mixtures or comparable chemical substances in its operations. I am therefore requesting, pursuant to the authority provided by Section 308 of the Federal Water Pollution Control Act, as amended, 33 U.S.C. 1318, and Section 114 of the Clean Air Act, as amended, 42 U.S.C. 1857c-9, that your company furnish EPA with information pertaining to your use and handling of PCBs and comparable chemical substances. In addition to a general description, which should include information as to sources, quantities, uses, and ultimate disposition, you should respond in detail to the enclosed questions. If any question is not applicable to your company or operations, please so indicate by responding "not applicable."

The information requested herein must be provided notwithstanding its possible characterization as confidential information or trade secrets. Should you so request, however, any information (other than effluent or emission data) which the Administrator of this Agency determines to constitute methods or processes entitled to protection as trade secrets will be maintained as confidential, pursuant to procedures specified in 40 CFR Part 2.

PLAINTIFF'S EXHIBIT 357

E001281

ADM 006290

Within 14 days of receipt of this letter, your company must provide all information concerning your current status and activities and covering the twelve month period immediately preceding receipt of this letter.

Within 30 days following receipt of this letter, your company must provide all information for all of the prior years indicated.

The information required herein should be sent directly to the address indicated below. If you have any questions you may call the person indicated below or Mr. Blake A. Biles of our office at (202) 755-8731.

We appreciate your prompt cooperation in this matter.

Sincerely yours,

Stanley W. Legro
Assistant Administrator
for Enforcement

Enclosure

Regional Contact:
Mr. Earl J. Stephenson
Director, Enforcement Division
Environmental Protection Agency
1735 Baltimore
Kansas City, Missouri 64108
Telephone: (816) 374-2576

F001282

ADM 006291

WATER_PCB-SD0000056578

POLYCHLORINATED BIPHENYL (PCB) COMPOUNDS OR MIXTURES

Within 14 days of receipt of this letter, your company must provide all information concerning your current status and activities and covering the twelve-month period immediately preceding receipt of this letter.

Within 30 days following receipt of this letter, your company must provide all information for all of the prior years indicated.

FOR PURPOSES OF THIS LETTER, THE PHRASE "PCB COMPOUND OR MIXTURE" INCLUDES ALL CHEMICAL SUBSTANCES KNOWN OR BELIEVED BY YOU TO BE PCB COMPOUNDS OR MIXTURES OR OF A SIMILAR CHEMICAL NATURE, IRRESPECTIVE OF TRADE NAME, AND SPECIFICALLY INCLUDING CHLORINATED TERPHENYLS.

Different??

1. For each PCB compound or mixture produced or imported by your company, for each company facility, during each year of 1971, 1972, 1973, 1974, and the first two quarters of 1975:

   a. The total amount of each PCB compound or mixture produced or imported.

   b. The name and address of each of your company's facilities which handle PCB compounds or mixtures (including production facilities and wholesale and retail outlets), and the amount of each PCB compound or mixture distributed through each facility.

   c. The name and address of each customer of each PCB compound or mixture, the amount of each PCB compound or mixture obtained by each customer from each facility, and each customer's delivery point(s) for the receipt of each PCB compound or mixture.

2. For each PCB compound or mixture incorporated by your company into its products, for each company facility, during each year of 1971, 1972, 1973, 1974, and the first two quarters of 1975:

   a. A description of each product.

   b. For each product the total amount incorporated of each PCB compound or mixture.

WATER_PCB-SD0000056579

2. (continued)

c. For each product the name and address of each source from which your company obtained each PCB compound or mixture, and the amount of each PCB compound or mixture obtained from each source.

d. The name and address of each of your company's facilities which handle such products (including production facilities and wholesale and retail outlets), and the amount of each product distributed through each facility.

e. The name and address of each customer of each product, and the amount of each product obtained by each customer from each facility. For consumer products list only the total production of each product at each facility and the total number of customers. Do not provide the name and address of each customer of consumer products.

3. For each PCB compound or mixture used by your company in its operations other than for incorporation into its products, for each company facility, during each year of 1971, 1972, 1973, 1974, and the first two quarters of 1975:

a. A description of each use.

b. For each use the total amount of each PCB compound or mixture.

No mobile

c. For each use the name and address of each source from which your company obtained each PCB compound or mixture, and the amount of each PCB compound or mixture obtained from each source.

4. For each PCB compound or mixture reclaimed by your company, for each company facility, during each year of 1971, 1972, 1973, 1974, and the first two quarters of 1975:

a. A description of each method of reclamation.

b. For each method of reclamation, the total amount of each PCB compound or mixture reclaimed.

c. The total amount of each PCB compound or mixture reclaimed.

1001284

ADM 006293

WATER_PCB-SD0000056580

d. The name and address of each source from which your company obtained PCB compounds or mixtures, and the amount of each PCB compound or mixture obtained from each source.

e. For each method of reclamation, the location of every reclamation site, the name and address of each party involved in the reclamation of each PCB compound or mixture, and the amount of each PCB compound or mixture reclaimed by each party.

5. For each PCB compound or mixture disposed of by your company (with or without the involvement of other parties), for each company facility, during each year of 1971, 1972, 1973, 1974, and the first two quarters of 1975:

Koenig Records

a. A description of each method of disposal.

b. For each method of disposal the total amount of each PCB compound or mixture disposed.

c. The total amount of each PCB compound or mixture disposed.

d. The name and address of each source from which your company obtained PCB compounds or mixtures, and the amount of each PCB compound or mixture obtained from each source.

Difficult

e. For each method of disposal, the location of every disposal site, the name and address of each party involved in the disposal of each PCB compound or mixture, and the amount of each PCB compound or mixture disposed of by each party.

6. The composition by chemical name and percent by weight of each PCB compound or mixture produced, imported, sold, reclaimed, used, and/or disposed of by your company since January 1, 1971.

7. The results of any and all sampling and analysis performed by your company, its agents or contractors since January 1, 1971, concerning the following:

a. Concentrations of PCB compounds or mixtures in the effluent of any discharges by the company (into waters of the United States or Publicly Owned Treatment Works) or in the emissions of the company into the air.

F001285
ADM 006294

b. The flow and/or composition of any discharges or emissions by the company (into waters of the United States or Publicly Owned Treatment Works, or into the air) which contain PCB compounds or mixtures.

c. Concentrations of PCB compounds or mixtures in receiving waters (both upstream and downstream) of any discharges by the company which contain PCB compounds or mixtures and concentrations of PCB compounds or mixtures in the air in the area of the company.

8. The methods by which PCB compounds or mixtures are transported to, by, and/or from your company, including:

a. A description of each method of transportation, and the form in which PCB compounds or mixtures are transported by each method. Where different methods of transportation are used at different facilities specify which transportation method is used at each facility.

b. The names and addresses of all known transportors of PCB compounds or mixtures.

9. All occasions (including spills) of which you are aware on which PCB compounds or mixtures have or may have been introduced into the environment. In particular, describe such occasions insofar as they involved PCB compounds or mixtures in their liquid state, as incorporated into closed systems, or as incorporated into open systems. For each occasion, indicate name and address of party involved; dates, time, and location of the discharge or spill; and the amounts involved.

10. A description of any adverse health or environmental effects which you know or believe to have resulted from the introduction of PCB compounds or mixtures into the environment. Indicate any specific occasions including dates, times, locations, amounts, and parties involved for which such effects are known.

11. Any and all other information which you possess concerning:

a. The production, importation, reclamation, use, distribution, and disposal of PCB compounds or mixtures.

b. The discharge of PCB compounds or mixtures into the environment.

In addition to the above, EPA would appreciate receiving any other information which you possess concerning the distribution and discharge of PCB compounds or mixtures by sources other than your company, including your company's customers and sources.

E001287

ADM 006296

WATER_PCB-SD0000056583

Monsanto

FROM (NAME & LOCATION): David Wood-St. Louis-B2SD

DATE : October 30, 1975 cc: f-EPA

SUBJECT : EPA

REFERENCE : COMMENTS ON EPA LETTER REC'D 10-17

TO : W. B. Papageorge
B2SK

1. Bill, this seems to be a new version.

2. Page 1. C1. Terphenyls specifically mentioned.

3.a) Production records answer 1(a).
b) Remember we warehoused PCBs for short period 1974 ahead of labor contract renewal.
c) Question 1c raises a problem that has been at back of my mind. #2 report is supposed to show "ship to" address, but if this is case, why do 3rd party W/GE shipments appear under "bill to" locations.

4. Q2 a) No problem
b) No problem
c) No problem
d) No problem
e) Policy - Hanley level?

5. Q3-No problem except 71/72

6. Q4-No reclamation.

7. Q5-a) No problem
b) Difficult. Can split Dielec/HT/Pydraul
But some returns mixtures of oil/PCB, etc.
c) Can do.
d) Difficult
e) Difficult

8. Q6 - Available

9. Q7 - a) Guess we have
b) Guess we have
c) Guess we have

10. Q8 - a) Bulk Rail
Bulk R - 3 accounts
Drum - Specify drum construction
b) E. M. Potter

ADM 006288

E001288

PLAINTIFF'S EXHIBIT 358

IN - 10 REV. 1/72

WATER_PCB-SD0000056584

11. Q9 - Should answer from our activity?

12. Q10 - None? Yusho? Cloracne years ago - Dangerous Question.

13. Q11 - a) Might get HUB again?

b) Should write this one very carefully - can make some positive points in this section.

David Wood

/deb

ADM 006289

E001289

WATER_PCB-SD0000056585

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

84144

WATER_PCB-SD0000056586

XIII. Probability of Success

XIV. Cost of Program

$220,000 and bio with max. at $20-25M

XV. Future

STR 021939

WATER_PCB-SD0000056587

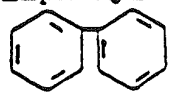
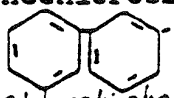
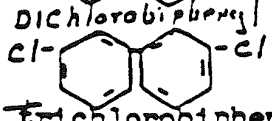
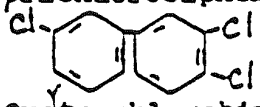
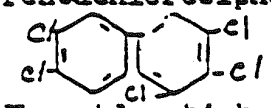
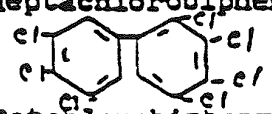
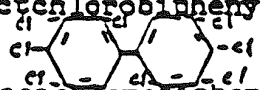
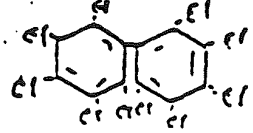
PCB ENVIRONMENTAL POLLUTION ABATEMENT PLAN

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.

WATER_PCB-SD0000056588

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

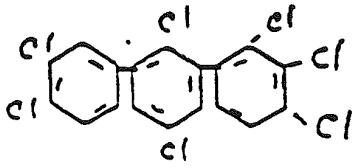
WATER_PCB-SD0000056589

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.

WATER_PCB-SD0000056590

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 car further concentrate PCB to possible harmful effects. Specifically in birds PCB can affect the calcium metabolism leading to egg shel 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-SD0000056591

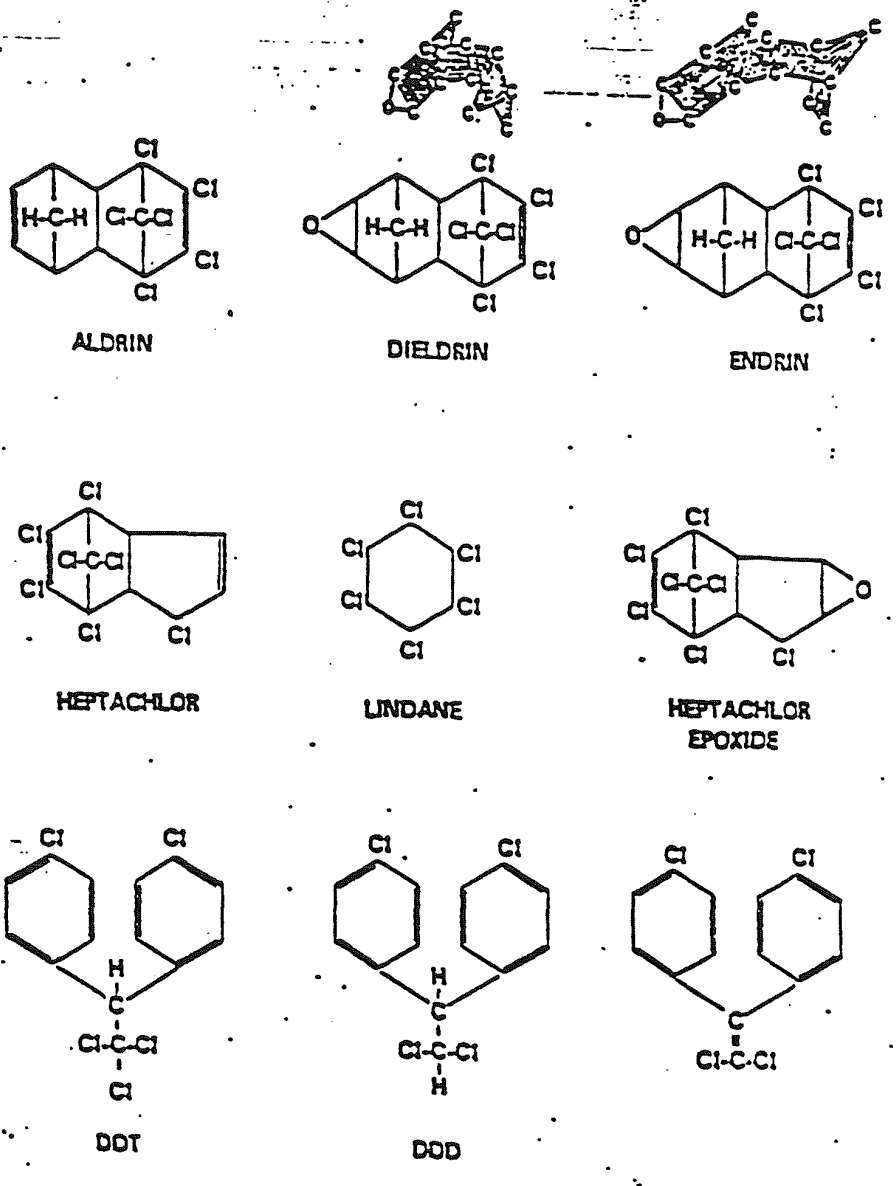
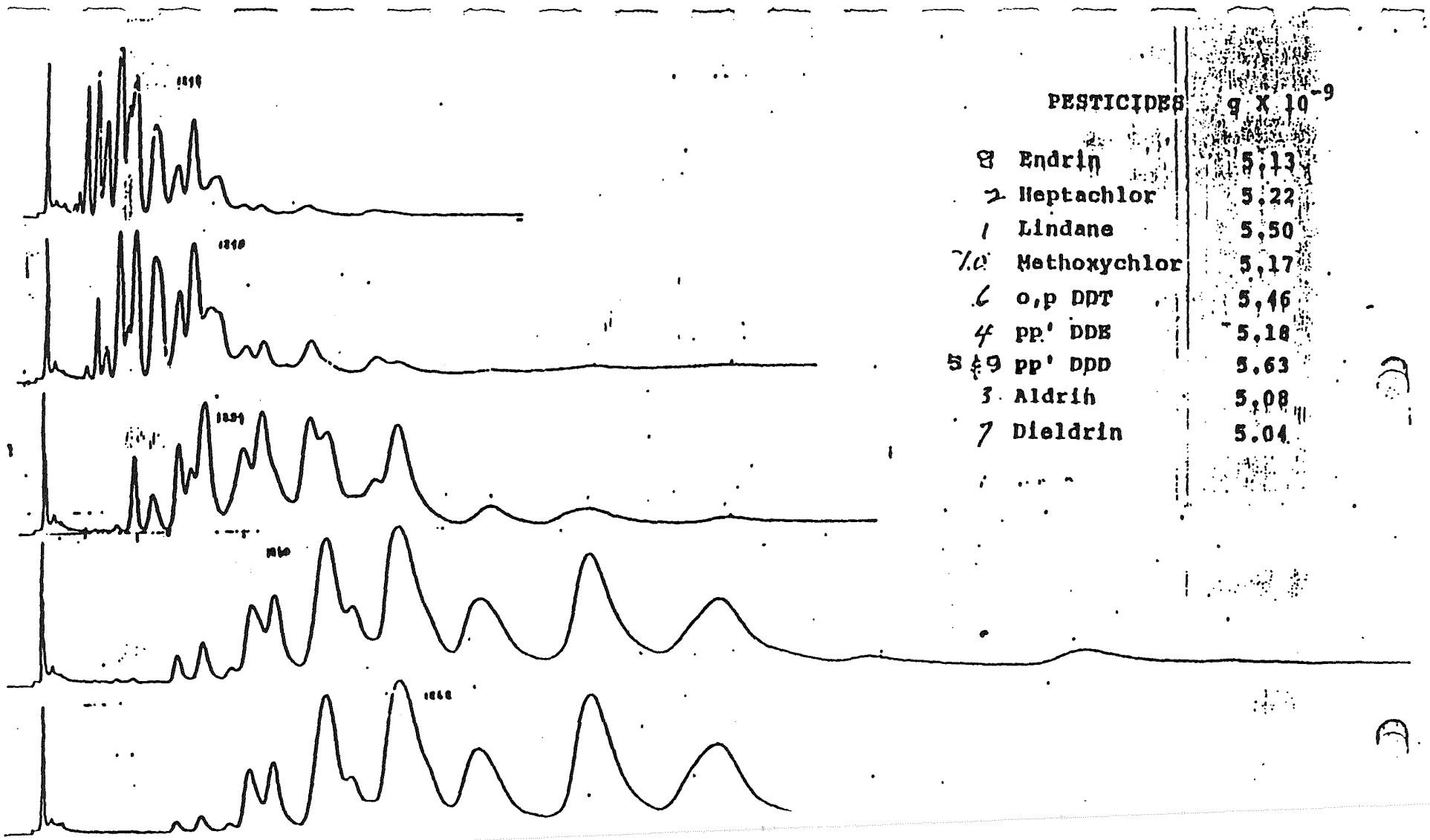


Fig 1 Structural Formulae of Nine Chlorinated Hydrocarbon P

STR 021944

WATER_PCB-SD0000056592



	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-SD0000056593

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 c 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 cert 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-SD0000056594

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 worker.

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. contaminati 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 o

WATER_PCB-SD0000056595

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 o their mobility. They also may be the least serious because the 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 a "dedusting agent" which inadvertently found its way back to the stream.

STR 021948

WATER_PCB-SD0000056596

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 op 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 a 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

Printing 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 t past because we are dealing with that quantity of material in th

WATER_PCB-SD0000056597

environment today which was deposited over the past forty years. We mustmust 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 t low chlorinated ones have not been identified present in nature.

1. Electrical - The large customers have established collect systems a 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 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-SD0000056598

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 contract 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 asse-ciated 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-SD0000056599

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.

WATER_PCB-SD0000056600

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 actior 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 notif: cation 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 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-SD0000056601

5. Emphasize better control over other Aroclor 1254 & 1260 uses.

5. Investigate with manufacturers 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.

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 acti that will not unduely alarm the market but reduce the exposure in terms of liability. Coordinate recommendations with Marketi

WATER_PCB-SD0000056602

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

STR 021955

WATER_PCB-SD0000056603

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

STR 021956

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XIV. Cost of Program

Neither the program nor the costs have been clearly defined at this ti
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 i
very difficult if not impossible to develop a reasonable cost figure b
one point is clear it will be larger than the normal research budget c
handle. For this reason, assuming the approach is acceptable, we shal
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 altho
we do not feel this is a likely possibility.

WATER_PCB-SD0000056605

ROFIT AND LIABILITY VS. TI

CTION

DO NOTHING

DOLLARS

70 71 72 73

Time

DISCONTINUE MANUFACTURE OF PCB

DOLLARS

70 71 72 73

Time

RESPONSIBLE APPROACH

DOLLARS

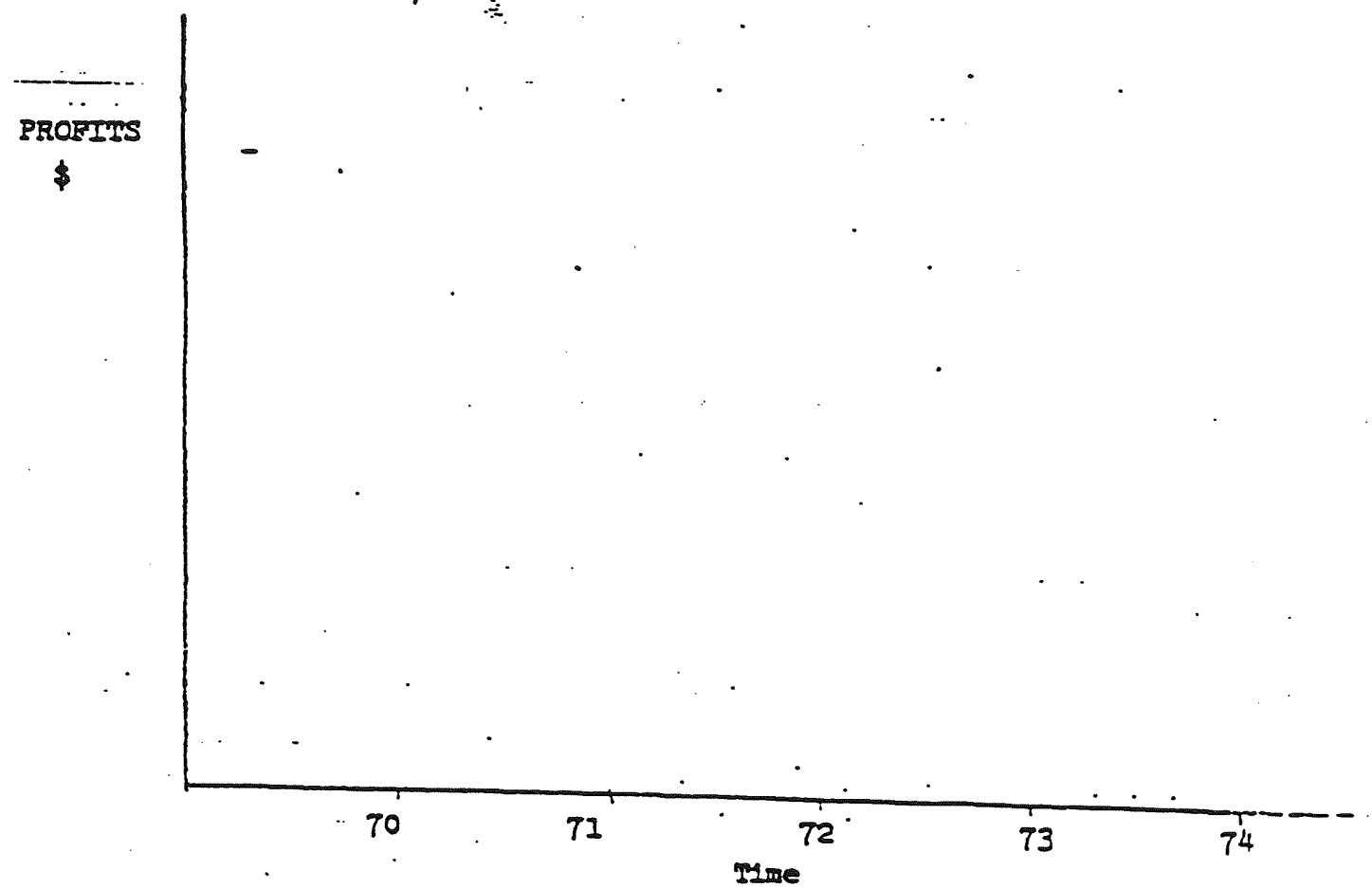
STR 021958

70 71 72 73

Time

WATER_PCB-SD0000056606

PROBABILITY OF SUCCESS



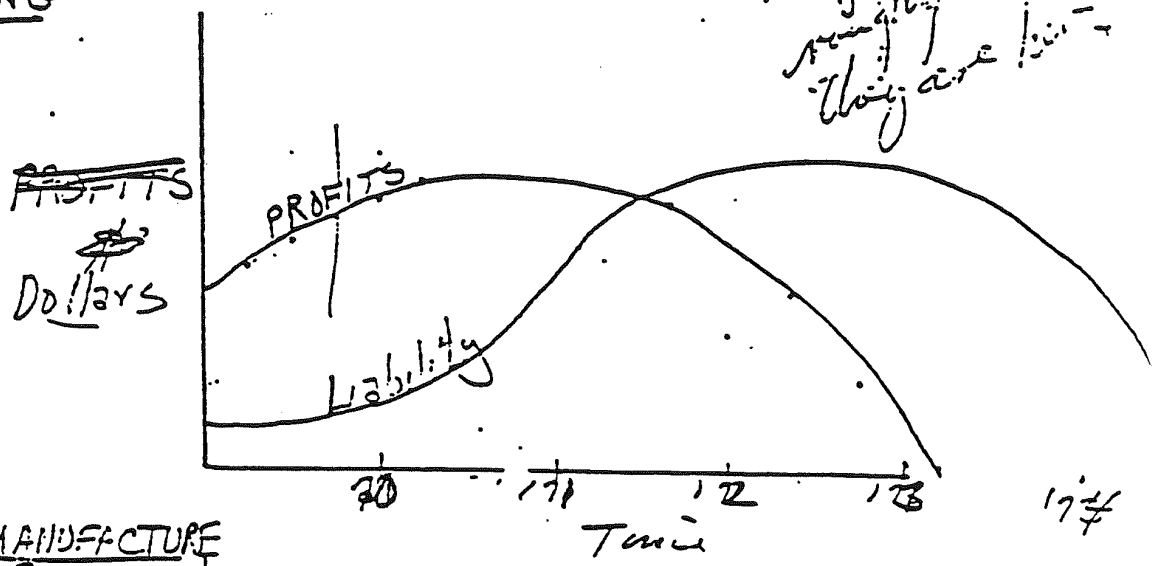
STR 021959

WATER_PCB-SD0000056607

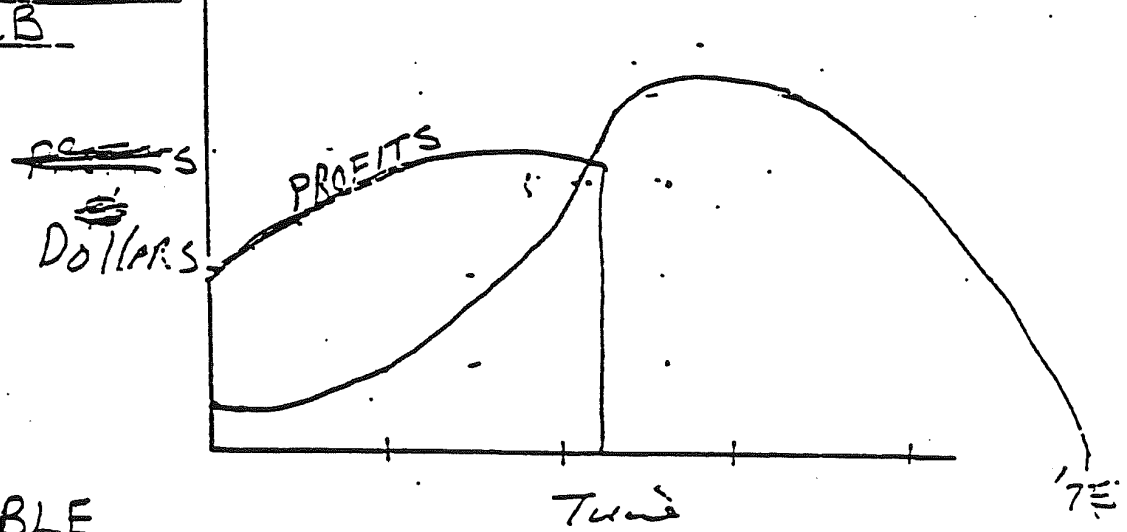
PROFIT AND LIABILITY VS TIME

ACTION

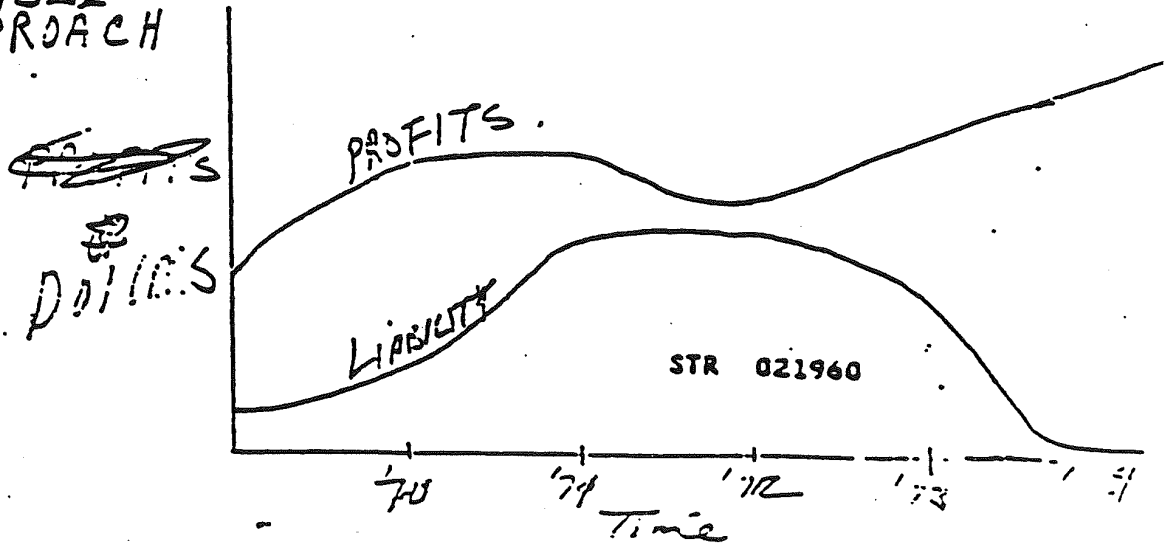
DO NOTHING



DISCONTINUE MANUFACTURE of PCB



RESPONSIBLE APPROACH



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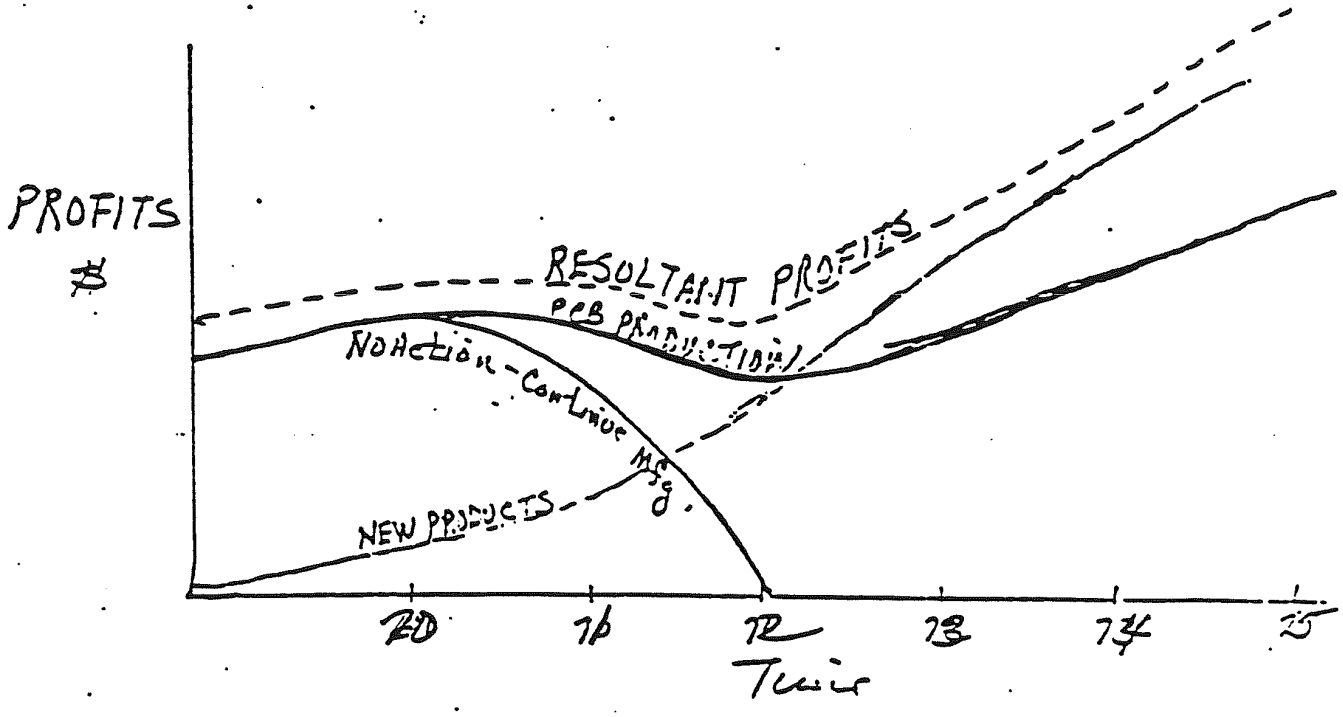
PROBABILITY OF SUCCESS



STR 021961

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

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 Bi da

Question evidence a u

Question shrimp toxi especially other t 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 than lower chlorine compounds.

84174

Therefore we will have to restrict uses and clean-up as much as we can, starting immediately.

↑ to what level?

Which ones?

PLAINTIFF'S EXHIBIT 424

PLAINTIFF'S EXHIBIT 4575A

EV 071 MON 0209

WATER_PCB-SD0000056610

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 transfe

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.

WATER_PCB-SD0000056611

F. Fluids	Possible Pollution by Customers Plant Operation	Possible 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.

MON 0211

WATER_PCB-SD0000056612

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 Therminol 55. Therminol 66.

MON 0212

WATER_PCB-SD0000056613

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.

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.

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 fo a time.

Recommend replacemen future Aroclor busin 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)

WATER_PCB-SD0000056614

Transformers	Transformer Plant can operate in a clean, efficient manner with recycle of off-grade Aroclor.	Product transfor can remain clos no exposure for
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 clea 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.

WATER_PCB-SD0000056615

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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Brussels, Belgium

1st December, 1966

Aroclor Sweden

Hugh

G. R. Buchanan & St. Louis

THIS COPY FOR

A. Arpino - Brussels
Dr. Emmet Kelly - St. Louis
D.V.H. Hardy - London
R.A. Stenroot - St. Louis

Dear George,

I attach a copy of a letter received from Ola Palm in Stockholm. I have sent copies of this letter also to the appropriate departments within our own organisation. In consideration of the importance we are placing on development of the Swedish market for Aroclor over the next five years, we would be grateful if you could arrange for this information to be considered by the appropriate departments in St. Louis and their comments transmitted to us as soon as possible.

Based on the recommendations made by our medical departments we shall have to decide whether to arrange for publication of data in Sweden or not.

In relation to the specific problem mentioned of disposal of used materials, we would be interested to learn how this problem is handled in America. In the U.K. many companies have been burying material in drums, material in the drums having been absorbed into vermiculite or some similar porous material. Has any entirely safe method been developed for the disposal of waste Aroclor ?

Best wishes.

GB.

per D. Wood.

P.S. Thinking of the total quantities of Aroclor used in Sweden compared with the much larger volumes of Pentachlorophenol and Sodium Pentachlorophenate, for water treatment in the paper industry and sapstain control in the timber industry. Is it likely that the chlorinated phenols show similar chromatographic traces to the chlorinated bi-phenols?

PLAINTIFF'S EXHIBIT 435

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Ex 10

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cc: Mr. D.S. Cameron - ME

RISING & STRAND

AKTIEBOLAG

OP/BO

TELEFON: 34 61 33 TELEGRAM: HENRIK TELEX: 1624
POSTGIRO: 3 44 43 BANKGIRO: 73-0448

STOCKHOLM VA
SVEAVÄGEN 67

November 28, 1966

Monsanto Europe
BRUSSELS 3
Belgium

For the attention of Mr. D. WOOD

Dear David,

re: AROCLORS

As mentioned, there has been some publicity in Sweden concerning investigations made at the Institution of Analytical Chemistry at the Stockholm University. These have revealed that a group of products called Polychlorinated Bi-Phenols - PCB for short - accumulated in certain organs of animals. They are said to be related to DDT and equally poisonous.

The findings were discussed at a meeting of scientists at the Wenner-Gren Centre in Stockholm on November 22. Below please find a translation of an article in the Swedish daily paper "Dagens Nyheter":-

"It is found in salmon and in pike. It is found in sea eagle living on fish. It is found on the surface of the needles of the fir trees, that is in the air. It is found in the hair of a five months baby...

The scientists working with biocides have for a long time seen this something as unknown "peeks" on their gas chromatographs and at a meeting at the Wenner-Gren Center, Research Assistant Sören Jensen of the Institution for Analytical Chemistry at the Stockholm University could reveal the identity of these peeks. It has been found that they consist of a group of poisons, Polychlorinated Biphenols (for short PCB) which are closely related to, and equally poisonous as, DDT.

PCB is broken down considerably slower than DDT and gives rise to damage of liver and skin. PCB is not

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used as a herbicide. It is not manufactured in Sweden but is supposed to used by the industry to quite some extent. No special industry can so far be accused of being the source of contamination.

Research Asst. S. Jensen has tested 200 fishes and a number of birds. He has taken several samples of air and has reached the conclusion that PCB is equally common in Nature as chlorinated hydrocarbons of the type of DDT, DDE, and Lindane. Even fish in Laddjojaure in Lapland contain PCB. Mr. Jensen has also found that PCB does not appear in animals living on a vegetarian diet, such as the elk.

In the course of his work, Mr. Jensen has not found anything indicating that the source of contamination comes from agricultural additives. It is, however, obvious already now that PCB is most frequently found in organisms living in water or feeding from water animals. In all examined pikes PCB was found. In a sea eagle found dead outside Stockholm it was found that the liver contained 30 mg of mercury per kilo, 76 mg DDT and considerably more PCB. The exact figure has not yet been determined.

PCB is found in water and in air, and not only in the Swedish air, but also in e.g. London air. Mr. Jensen has not yet been in London for sampling but could identify the poison by studying a gas chromatogram of air published in a British technical journal.

Mr. Jensen har also examined the hair of his family and himself and has found PCB on all samples. Most PCB was found in the hair of his wife but most sensational was that the girl aged 5 months had more PCB in her hair than her brothers and sisters of 3 and 6 years. Probably the girl had got the poison via the mother's milk.

In the State Museum Mr. Jensen has examined the whole collection of sea eagles dating back to 1880. By testing it could be established that PCB was present only in birds from 1944 and thereafter while birds collected before 1944 were quite free from PCB.

The use of PCB in Sweden is not established in detail. According to American sources these types of products are used in the manufacture of a variety of heat-resistant materials. They are used for electrical insulation, for fire-proof heat transport in hydraulic oils, in lubricating oils used at high

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temperature and pressure, in paints and as pigments in various plastics. PCB is not imported only as such. It is also part of several finished products. Nothing is known as to the way in which it reaches the water and the air. According to Mr. Jensen, products containing PCB should have this openly declared.

PCB is equally harmful whether absorbed via the skin, through the food, or by inhalation. In contact with the skin it can cause oedema. For DDT the highest permissible concentration in the air has been set at 0.5 - 1 mg/cu.metre. For PCB it has been mentioned to be 0.5 mg/cu.metre. Mr. Jensen will now try to get more complete analytical material. He hopes eventually to be able to disclose the source of the contamination and will also increase his cooperation with toxocologists and geneologists."

Another daily paper, Svenska Dagbladet, has a similar article. Here it is mentioned that Mr. Jensen, working under Laborator (Professor) Gunnar Widmark, has disclosed facts which will have far-reaching importance since the findings have proved a new source of pollution of the nature.

One of the participants at the meeting was Dr. A.V. Holden of Scotland, scientific contact man between the twelve O.E.C.D. countries, who has established coordinated analysis of chemicals used and found in nature.

I suppose there is no doubt that what has been termed Polychlorinated Biphenyls is equal to Aroclor. There is also no doubt that the published facts will cause considerable unrest in several quarters. We probably will have to have Aroclor registered with the Swedish Board of Poisonous Substances and the industry will have to be particularly careful in handling the material. The problem in some cases of course may be the disposal of used material. I understand that there hardly exists a convenient method of destroying Aroclor and that possibly burying unuseable material may be the only answer.

We shall be glad to hear from you soon.

Yours sincerely,

RISING & STRAND ...DLAG
HENRY STRAND

STR 017393

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THE JOURNAL OF
INDUSTRIAL HYGIENE
AND TOXICOLOGY

VOLUME 19 SEPTEMBER, 1937 NUMBER 7

THE PROBLEM OF POSSIBLE SYSTEMIC EFFECTS FROM CERTAIN CHLORINATED HYDROCARBONS*

CECIL K. DRINKER, MADELEINE FIELD WARREN AND GRANVILLE A. BENNETT

Department of Physiology, Harvard School of Public Health and Department of Pathology, Harvard Medical School, Boston, Mass.

THE use of chlorinated naphthalenes and compounds of allied pharmacological possibilities is extremely wide, and with the steady growth of the use of electricity is certain to expand much farther. For years it has been known that many of these compounds cause a troublesome acne, and there is a large literature upon this phase of the subject. Our investigations have not been concerned with chloracne but with the possibility of systemic effects following ingestion or inhalation of such products. In the spring of 1936, the Halowax Corporation, a division of the Bakelite Corporation, called our attention to three fatal cases of jaundice in workmen using chlorinated naphthalenes and chlorinated diphenyl, and requested that the subject be investigated as rapidly and thoroughly as possible.† In brief these cases were as follows:

Patient 1. Male, age 21. The previous medical history of this man was in no way significant except for the fact that he had an attack of jaundice about 6 weeks prior to his fatal illness. Late in December, 1936, he became badly constipated and had much abdominal pain and distention. When admitted to the hospital he was slightly jaundiced and was evidently very ill. He was somewhat anemic and his skin, particularly upon the arms, face, chest and back, showed many pustules. He died after a brief period in the hospital, and at autopsy was found to

* Received for publication June 30, 1937.

† The Halowax Company makes many products besides chlorinated naphthalenes, and it has come to our knowledge that all of these products are indiscriminately called "halowaxes" by purchasers and users, and are lumped together as possible causers of acne and even of systemic disease. Since "halowax" is merely a trade designation, care should be taken to describe compounds by their chemical names and thus avoid condemnations which are both troublesome and misleading.

EXHIBIT
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have a cirrhosis of the liver with acute yellow atrophy superimposed upon it. This man had been exposed to low concentrations of vapors arising from a mixture of tetra and pentachlornaphthalenes, together with approximately 10 per cent of a refined chlorinated diphenyl. While both he and others engaged in the same work had chloracne, there were no other disturbances of health in fellow workmen, nor was there any precipitating cause for the acute yellow atrophy such as treatment with arsphenamine or exposure to dangerous concentrations of carbon tetrachloride.

Patient 2. This was a young man who died in February, 1936, after an acute illness characterized by jaundice. He had been exposed to fumes arising from a mixture of penta and hexachlornaphthalenes. There is no record of chloracne. The patient worked with a large number of other people of whom but one (Patient 3), a close friend, had significant illness.

Patient 3. Another young man employed with Patient 2. He became jaundiced in March, 1936, and died after an illness of 2 weeks. A careful autopsy resulted in a diagnosis of acute yellow atrophy of the liver Here again no history could be obtained as to a precipitating cause, and there was no record of preceding attacks of jaundice.

In addition to these three very recent fatalities, we have learned of four other possible cases, none of them fatal. All of these have had jaundice and the entire group consists of isolated individuals who have been picked out of large groups having the same exposure. In but one instance, Patient 1, is there record of antecedent disturbance of health, and the general health of fellow workers has been good.

Such cases have not been reported in the medical literature and only occasionally can one find reference to systemic effects of any sort. For example, Courtois-Suffit (1934) reports on work done by Touraine and his associates (1934) who examined 60 workers who had been exposed to trichlornaphthalene. Of these 13 were found to have mild digestive complaints, anorexia, nausea and vertigo, but Courtois-Suffit remarks finally, "Absorption is certainly possible and we have for proof of it some of the digestive and general complaints which have been due to it. But they appear to be of little consequence considering the mildness of the digestive troubles and the absence of respiratory phenomena."

In Touraine's cases the exposure was to a trichlornaphthalene, whereas the American cases of acute yellow atrophy were exposed to compounds of higher chlorination. Our own experiments indicate that trichlornaphthalenes require enormous dosage, far beyond anything encountered in industry, in order to produce liver damage. Teleky (1927) reported a number of cases of chloracne in persons exposed to chlorinated naphthalenes with a chlorine content ranging from 14 to 53 per cent. He found that the lower the chlorine content the less the acne. Mittelstädt (1935) examined a number of cases of chloracne due to trichlornaphthalene and reported a number of vague general complaints but nothing in the nature of serious disease. Regarding his animal experimentation, Lehmann (1919) reported that animals fed chlorinated naphthalenes refused to eat after a time and that, whether poisoned by inhalation or by feeding, at death showed "peculiar" lesions in the liver. Flinn and Jarvik (1936) gave subcutaneous injections of enormous doses of chlorinated naphthalenes dissolved in paraffin oil to rabbits. The compounds used were as follows:

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   naphthalene.
2. A mixture of
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1. A mixture of tri and tetrachlornaphthalene.
2. A mixture of tetra and pentachlornaphthalene.
3. A mixture of penta and hexachlornaphthalene.

In addition, sublimates from (2) and (3) were collected in oil and injected subcutaneously.

None of the animals receiving (1) or the sublimate from (2) died, and even after 2 months were quite normal when autopsied. The first death in the animals receiving (3) occurred on the 12th day and the last died on the 26th day. Those receiving the sublimate from (3) were even more severely affected. Autopsy in these animals revealed striking changes in the liver, not, as described, entirely characteristic of acute yellow atrophy but sufficiently suggestive to cause the authors to conclude that "certain chlorinated naphthalenes or impurities contained in them are capable of producing yellow atrophy of the liver in the rabbit."

At the beginning of their paper, Flinn and Jarvik (1936) mention the fact that there have been three cases of acute yellow atrophy of the liver in men working with chlorinated naphthalenes but give no details in regard to them. These cases are undoubtedly the same as those described in the beginning of this paper.

One may summarize the meagre literature upon systemic effects from these substances as follows:

1. With the exception of the mention of acute yellow atrophy by Flinn and Jarvik (1936) there are no reports or even suggestions of serious effects upon human beings.

2. There is evidence (Teleky, 1927) that the degree of chlorination is significant in relation to the production of acne. In the work of Flinn and Jarvik (1936) the compounds producing serious liver injury were the most highly chlorinated of those tested, though the chlorine contents as given by analysis vary surprisingly little.

3. There are no published figures upon the amounts of various chlorinated naphthalenes in the air which will produce injury of any sort, and while the work of Lehmann (1919) and of Flinn and Jarvik (1936) point to the liver as a possible site of injury this indication rests upon such extreme dosage as to fail to apply directly to human exposure.

Experimental Work

In appraising the possible toxicity of any substance met in industry it is first necessary to determine the principal route of absorption. In the case of the compounds under consideration there can be no doubt that inhalation is their chief means of entering the body. They are used hot in a great variety of operations and volatilize in varied degree. They are often applied in solution in such volatile solvents as carbon tetrachloride and toluene. The amounts reaching the air under such circumstances are hardly detectable. It will however be shown that carbon tetrachloride adds to the toxicity of the chlorinated naphthalenes and allied compounds, and if there is possibility of inhaling these compounds in other parts of the factory then inhalation of carbon tetrachloride adds a decided hazard. Under such circumstances solvents such as toluene should be used.

Observation in a number of plants causes us to feel that even though

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workmen may be extremely dirty and careless, comparatively little of these waxes is eaten. They are tenacious substances, insoluble in water, and if they get on the hands they stick there and are not transferred to the food.

Skin absorption is the third possible means of entering the body. It may occur but at best must be slight when compared to the steady inhalation of finely divided or gaseous material in the air.

tion. They thrive upon a diet very similar to man, and in the case of these chlorinated compounds it is possible that diet may be very significant. Finally, their normal characteristics have been described so well as to make the detection of abnormalities both easy and certain.

Method of exposure.—The inhalation experiments were carried out in four large air-tight wooden boxes, each capable of holding ten rat cages, size

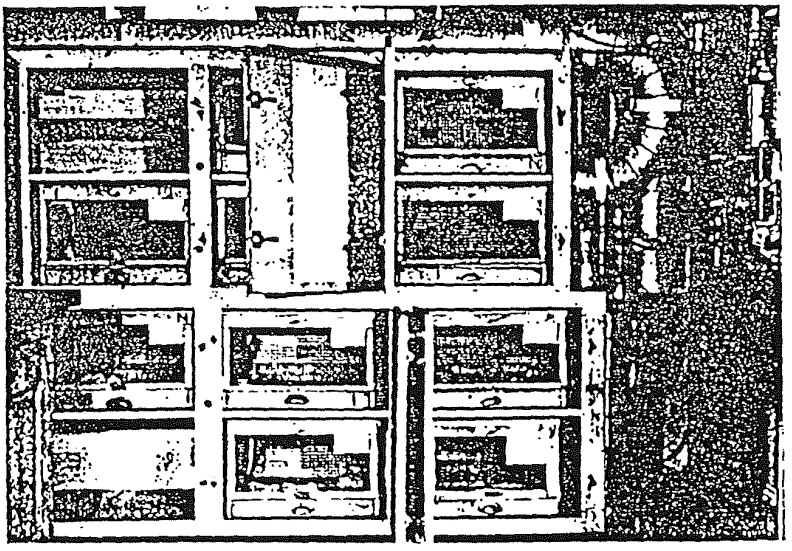

FIG. 1. Front view and inflow end of two boxes with rat cages in place and doors open.

Inhalation experiments are then the most important sources of information, but to them we have added a certain number of observations upon ingestion and subcutaneous injection of various compounds.

Inhalation Experiments

Animals. White rats have been employed throughout. They permit the use of a large number of animals in a relatively small inhalation installa-

22" x 22" x 14", in two tiers of five cages each. When the experiment was not in progress the doors were opened wide and the cages kept in place (figure 1).

At the center of one end of each box the inflow end air was introduced through a pipe 7 inches in diameter (figure 2). Each box was equipped with an individual variable-speed electric blower which blew the air through several feet of 7-inch pipe before enter-

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ing the end of the box. An orifice meter was placed in the pipe line, and the flow of air in cubic feet per minute could be adjusted and read off directly from a calibration curve. A vane deflector placed at the entrance of the pipe into the box was adjusted to assure a uniform distribution of the stream of air to the two tiers of cages.

At the opposite end of the box—the outflow end—the air from each box was exhausted through a 7-inch pipe fitted with a damper and connected to a large central exhaust fan (figure 3).

About 4 inches from the entrance of the 7-inch pipe into the box, the fumes of the substances listed were introduced into the inflowing air. Specially designed pyrex glass flasks (figure 4), $7\frac{3}{4}$ inches long and with a diameter of $1\frac{1}{2}$ inches, were used to hold the heated waxes. These flasks were made with a side arm and tube that extended to the bottom. The top of the flask was ground, and into this fitted a short tube $1\frac{1}{2}$ inches in length. This short tube was inserted into a large rubber stopper that fitted tightly into a hole cut out of the 7-inch pipe on the under side (figure 2). The flask in turn was placed in an electric heater made to cover it completely below the side arm and ground glass top. Rubber tubing connected the side arm with a compressed air reservoir and a gentle stream of air blown through the melted wax kept it in motion and assured uniform heating. Into each flask was inserted a long stem centigrade thermometer which was kept in place and could be read at any time above the 7-inch pipe through which it passed (figure 2).

Approximately 30 gm. of pulverized chlorinated naphthalenes or 20 gm. of chlorinated diphenyl were placed in the bottom of each flask and melted in the electric heater. Fresh samples were used every other day, but it was often found necessary to add 20 gm. of new material even after one run since so much had sublimed. Whatever the case, the collected sublimate was always removed from the upper part of the flask and a clean top used each day. No sample was ever used for more than two runs.

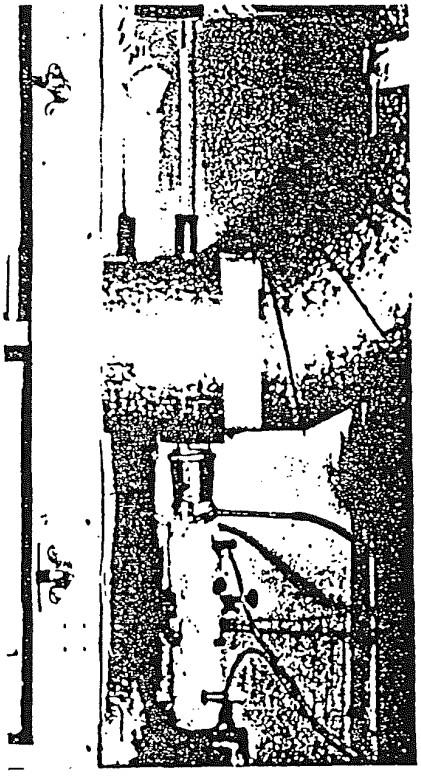

FIG. 2. Electric heater for maintaining chlorinated compounds at a constant temperature in place at inflow end of box.

The flask plus the contents was carefully weighed at the beginning of the run and at the end, and the loss in weight used to calculate the average

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amount in a cubic meter of air per minute as determined by a series of flowmeter readings. The figures obtained were not absolute because of slight variations in the air flowing through the boxes and because of deposition of material on the thermometers and on the inside surfaces of the box, but they checked well with direct determinations through air samples.

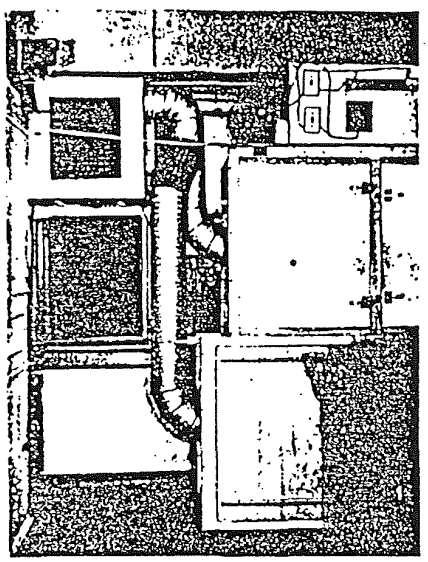

FIG. 3. Outflow end of two boxes showing connections to exhaust system.

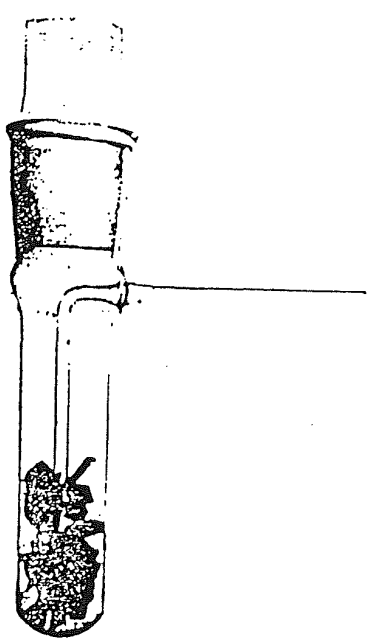

FIG. 4. Pyrex glass flask

Approximately 1 hour was allowed for the wax in the flasks to melt and come to a constant temperature. At that time the box doors were tightly closed, air bubbled through the flasks, and the blowers turned on. This was the beginning of the exposure period. By means of rheostats on the fans and dampers in the outflow pipes, the amount of air flowing through the boxes was adjusted and an attempt was made to keep the four boxes as uniform as possible—usually between 165 and 175 c.f.m.

In the first group of experiments the following substances were tested:

1. A mixture of trichlornaphthalenes plus a trace of tetrachlornapthalene. Chlorine content 49.9 per cent.
2. A mixture of penta and hexachlornaphthalenes. Chlorine content 62.6 per cent.
3. A mixture of 90 per cent penta and hexachlornaphthalenes plus 10 per cent refined chlorinated diphenyl. Chlorine content 63.0 per cent.
4. Chlorinated diphenyl. Chlorine content 65.0 per cent.

The compounds were selected as representing a certain range in chlorination and also because of their industrial imp[illegible]e. In each instance 80 animal[illegible]xposed, 10 rats being placed in e[illegible]e. They were fed Purina

Dog Chow supplemented by lettuce, eggs, milk and cod liver oil.

This first group of experiments was begun on July 1, 1936 and the last exposure to number 2 (penta and hexachlornaphthalenes) was on November 16th. The exposure to the other three compounds ceased upon November 18th. On October 15th representative animals were taken out of exposure from groups 1, 2, and 4 and were killed after 2 months on December 15th, in order to see whether this clear period would bring about recovery in the affected livers. Animals from group 3 were similarly removed from exposure on October 4th and killed for examination on December 4th.

The average length of exposure was 16 hours daily for 6 days a week. Each morning at about 9:00 exposure ceased, and between this time and 4:00 p.m. the rats were cleaned, fed, weighed, etc. In order to secure uniformity of exposure the cages were shifted on a regular schedule, since wax concentrations were somewhat higher at the inflow end of the boxes. Preliminary runs showed that once properly adjusted, wax concentrations in the air remained very uniform from day to day, but to insure absolute safety readings of temperature, airflow, etc. were made every night between 10:00 and 12:00 p.m. as well as on starting and stopping. At different times during the course of the experiment tests for free chloride were made but were uniformly negative and showed that under the temperatures used no decomposition occurred.

TABLE 1

CONDITIONS MAINTAINED IN INHALATION EXPERIMENT FROM JULY 1 TO NOVEMBER 16 AND 18

MATERIAL	CHLORINE CONTENT	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AV. DAILY EXPOSURE
	%	°C.	mg./cu. m.	range	hours	hours
Trichlornaphthalenes plus traces of tetrachlornaphthalene	49.9	150–160	1.31	High 2.60 Low 0.10	1896	16
Penta and hexachlornaphthalenes	62.6	160–170	1.16	High 2.19 Low 0.51	1864	16
85% penta and hexachlornaphthalenes plus 10% chlorinated diphenyl	63.0	165–175	1.37	High 3.17 Low 0.64	1896	16
Chlorinated diphenyl	65.0	165–175	0.57	High 1.19 Low 0.23	1896	16

Table 1 shows the temperatures at which the various substances were held, the average concentrations per cubic meter of air, and the average exposures from July 1 to November 16 and 18.

The concentration of chlorinated naphthalenes and chlorinated diphenyl in the air of workrooms.—Table 1 shows that animals have been exposed to varied concentrations of the substances under

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test. The concentrations employed may be regarded as fairly representative of industrial experience. Prior to the initiation of inhalation experiments a number of estimates of chlorinated hydrocarbons in the air of different factories were made and the

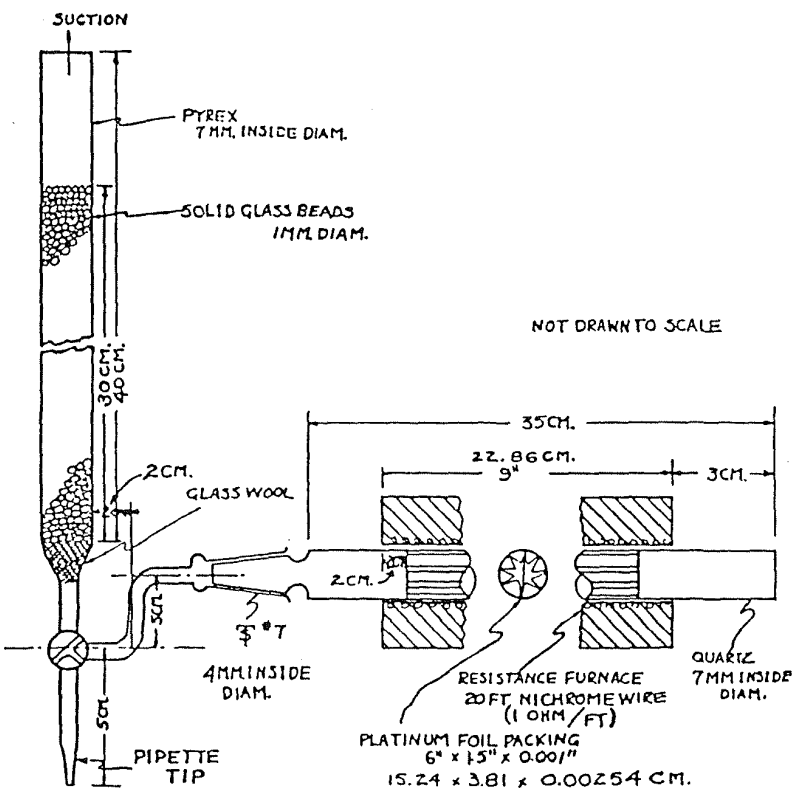

FIG. 5. Dimensioned sketch of combustion tube and absorption apparatus.

concentrations chosen for inhalation experiments depended on these examinations. The technic of analysis and the apparatus employed were the work of Frederick R. Millhiser and William F. Hemperly.

The method and apparatus used for determining concentrations of chlorinated hydrocarbons in air were adapted from well-known procedures. The air in question is passed over heated platinum in an electrically heated quartz tube and the effluent gas scrubbed in a column of glass beads moistened with sodium carbonate containing a trace of sodium sulfite. The beads are then washed down and the chloride determined nephelometrically as silver chloride.

Tebbens (1937) has recently described a method and apparatus which should be equally satisfactory for this work. In figure 5 we show a dimensioned sketch of the combustion tube and absorption apparatus as used by us in both our laboratory and field problems. The absorption tube is

somewhat easier to wash down than is Tebbens's but the essentials of the two devices are the same.*

In both cases conversion of the chlorinated hydrocarbons to hydrochloric acid and subsequent absorption as sodium carbonate should be complete. In our case concentrations in air are apt to be very low—the objective is less than 1 mgm. per cu. m. Consequently the amount of silver chloride actually formed in the final reaction is so small that it can not be determined either gravimetrically or by titration. For this reason we have been forced to use the nephelometric procedure which is sensitive to concentrations as low as 0.1 mgm. per cu. m. of air.

It is doubtful if the sampling rate should exceed 1 liter per minute as conversion of the chlorinated compound to hydrochloric acid and its subsequent absorption are not efficient unless the velocity of the gas stream is low. Another precaution to be noted is that the method is not selective—any chlorinated substance will be determined. Furthermore it does not distinguish between solid particles and gases but determines them all alike and the results must, of course, be computed in terms of total chlorine.

At the present time we possess information as to the amounts of chlorinated naphthalenes in the air of 30 different plants, and in a number of instances the measurements have been repeated several times. Frequently the amounts have been greater than those used in our experiments, but it must be remembered that the rats have been exposed for 16 hours to an atmosphere constantly impregnated with the substance under test, whereas human exposure is usually a variable quantity, intense for a short time and then negligible. It is our opinion at the present time that the concentrations of chlorinated hydrocarbons used in our experiments would be dangerous for workers in the case of compounds above trichlornaphthalene in chlorination. Fortunately it is easy to ventilate processes of manufacture which require these substances and to reduce air contamination practically to the vanishing point. Such treatment of the problem at once removes both the possibility of systemic poisoning and the annoyances that arise from cases of acne.

Results of Inhalation Experiments.

1. Animals exposed to a mixture of trichlornaphthalenes plus small amounts of tetrachlornapthalene. Living animals were apparently entirely normal. Autopsies performed near the end of exposure seemed to show slight swelling of the liver, and microscopic examination occasionally showed swollen and hypergranular liver cells. The changes were, however, never more than slight.

2. Animals exposed to a mixture of penta and hexachlornaphthalenes. No abnormalities were observed in the living animals. Rats were killed and autopsied every 6 weeks. In the first animals sacrificed liver changes were observed. These were swelling of cells, slight granulation and hyalinization. In September and October these conditions were somewhat more advanced, and in November the process became stationary. There were highly

* The combustion and absorption apparatus suited to field sampling is now made by Willson Products, Inc., Reading, Pa. The equipment includes flowmeter and suction pump with a carrying case.

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granular cells, hyaline inclusions and mitotic figures, but no more than 2 months previously.

3. Animals exposed to a mixture of 90 per cent penta and hexachlornaphthalenes plus 10 per cent refined chlorinated diphenyl. No abnormalities were seen in the living animals. After 6 weeks the livers showed changes similar to those in the animals exposed to penta and hexachlornaphthalenes. These advanced in grade during August and September and then became stationary.

4. Animals exposed to chlorinated diphenyl. No abnormalities were seen in the living rats. After 6 weeks' exposure there was slight liver damage which advanced during the next 2 months. The changes consisted in slight to moderate swelling of the liver cells, an increased granularity and many mitotic figures. Hyalinization was always present as a result of inhalation of chlorinated diphenyl.

Summary of the first inhalation experiment.—In these experiments careful observation of appearance, body weight, activity, blood, and urine showed no abnormalities of any sort. Yet after 6 weeks' exposure all the compounds with chlorination above trichlornaphthalene caused minor degrees of liver damage, and no changes whatsoever in other organs. There was no acute yellow atrophy or anything suggesting it except that a slight degree of liver damage was always present and was quite clear in the liver sections examined microscopically. This damage had no detectable effect on the health of the animals. They held their weight, ate and behaved normally, being in every respect similar to the many people who have been exposed to these compounds without illness of any sort.

The functional appraisal of the liver damage caused by certain chlorinated naphthalenes and by chlorinated diphenyl.—There are no tests of liver function useful in such minor degrees of liver damage as were produced in these experiments. Indeed the animals resisted the injury so perfectly as to display no abnormalities except upon histological examination of the liver. The situation was perhaps similar to that met in industry, where, barring acne, the health of workers in these compounds has been good with the exception of the fact that in isolated instances jaundice has occurred which upon at least three occasions has gone on to acute yellow atrophy.

During recent years this disease has been seen following administration of carbon tetrachloride, arsphenamine and cinchophen. In the case of carbon tetrachloride it is known that a low calcium diet and alcohol favor the production of liver damage. For the acute yellow atrophy that occasionally complicates use of the other two drugs no cause can be assigned. One cannot produce acute yellow atrophy with arsphenamine, but somehow or other this now and then does happen to patients under antisyphilitic treatment.

It occurred to us that something of the same sort might be involved in this problem. The human cases have been scattered and few. They have been isolated instances out of large groups of healthy employees who have had equal degrees of exposure. It was our idea that perhaps many of these people got liver changes such as existed in our rats, changes not recognizable through

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any means other than autopsy examination. If, upon the substratum of such changes, they got an acute liver disturbance, acute catarrhal jaundice, not a very common disease but one which any of us may experience, would this relatively innocuous disease go over to acute yellow atrophy?

Knowing that our inhalation rats had liver changes, but changes too slight to cause recognizable symptoms, we decided to test their resistance to substances known to cause liver destruction. Carbon tetrachloride and alcohol were selected. Having information that 1.0 cc. of carbon tetrachloride plus 1.0 cc. of ethyl alcohol per kilogram would kill 14 per cent of normal white rats, we reduced the dose to 0.75 cc. carbon tetrachloride and 0.75 cc. of ethyl alcohol.

This mixture was given by stomach tube to the following groups of animals and with the results found in the following tabulation.

Rats fed 0.75 cc. per kgm. each of carbon tetrachloride and ethyl alcohol by stomach tube

1. *Trichlornaphthalene plus trace of tetrachlornaphthalene.* Fed at 9:00 a.m., Nov. 10, 1936. 10 rats. No deaths.

2. *Penta and hexachlornaphthalenes.* Fed at 9:30 a.m., Nov. 10, 1936. 10 rats.
   - 3 died Nov. 11th between 4:30 and 10:30 p.m.
   - 1 died Nov. 12th at 3:20 p.m.
   - 1 died Nov. 12th at 4:30 p.m.
   - 1 died Nov. 13th between 9:30 and 11:30 a.m.
   - 1 died Nov. 15th between night of Nov. 14th and 12:30 p.m. Nov. 15th. 2 died Nov. 16th between 10:15 p.m. Nov. 15th and 9:00 a.m. Nov. 16th (stiff).

3. *90 per cent penta and hexachlornaphthalenes and 10 per cent chlorinated diphenyl.* Fed at 10:00 a.m., Nov. 10, 1936. 10 rats.
   - 1 died Nov. 10th between 5:00 and 10:30 p.m.
   - 5 died Nov. 11th between 4:30 and 10:30 p.m.
   - 1 died Nov. 11th between 4:30 p.m. and 9:00 a.m. Nov. 12th.
   - 2 died Nov. 12th about 1:00 a.m.
   - 1 died Nov. 13th between 5:00 and 10:00 p.m.

4. *Chlorinated diphenyl.* Fed at 10:00 a.m., Nov. 10, 1936. 10 rats.
   - 1 killed Nov. 10th at 10:30 p.m. (almost dead).
   - 2 died Nov. 11th between 4:30 and 10:30 p.m.
   - 1 died Nov. 12th before 8:30 a.m. (stiff).
   - 1 died Nov. 13th between 9:30 and 11:00 a.m.
   - 1 died Nov. 16th between 10:15 p.m. Nov. 15th and 9:00 a.m. Nov. 16th (stiff).

Controls: Fed at 9:30 a.m., Nov. 12, 1936. 10 rats. 1 killed Nov. 13th for normal liver.

This tabulation summarizes into the facts that:

1. No normal rats were killed by carbon tetrachloride and ethyl alcohol.

2. No trichlornaphthalene exposed rats were killed, and this finding agrees with our inability to find lesions of moment in the livers of the animals that inhaled this substance.

3. The penta and hexachlorinated naphthalene, the mixture of these with 10 per cent chlorinated diphenyl, and finally the latter substance alone seem to have produced conditions lowering the resistance to an agent capable of producing serious liver disease.

4. The sole lesion produced by this test of liver function was acute yellow atrophy usually accompanied by jaundice.

This test of liver function was accomplished with a substance which itself is an organic chloride and curiously enough it is the only substance we were able to find that was effective.

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In animals with the minor degree of liver injury which has been described we were unable to produce acute yellow atrophy or any variety of liver effect with arsphenamine, cinchophen, butyl chloride, ethylene chloride and tetrachlorethylene, but carbon tetrachloride was uniformly effective in disclosing the existence of liver damage.

Recovery from liver damage following removal from exposure.—Animals exposed to trichlornaphthalenes plus traces of tetrachlornaphthalene being practically normal on removal from exposure need no consideration. In the case of the penta and hexachlor-

signs of liver injury will be many months in returning to normal.

The effect of high concentrations of trichlornaphthalenes with traces of tetrachlornaphthalene.—The first group of inhalation experiments showed that this material in concentrations averaging 1.31 mgm. per cu. m. of air was relatively innocuous, judged both by direct observation and by the carbon tetrachloride test. This is an interesting fact since such compounds cause acne, though less potently than substances of higher chlorination. In order to explore the matter further one of the inhalation boxes was arranged

TABLE 2

CONDITIONS MAINTAINED DURING INHALATION OF HIGH CONCENTRATIONS OF TRICHLORNAPHTHALENES PLUS TETRACHLORNAPHTHALENE

MATERIAL	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AV. DAILY EXPOSURE
	°C.	mg./cu. m.	range	hours	hours
Trichlornaphthalenes plus traces of tetrachlornaphthalene	137–200	10.97	High 16.49 Low 5.78	1232	16

naphthalene, rats after 2 months' removal from exposure still showed swollen liver cells, increased granularity, hyalinization and mitotic figures. The condition was not advanced as compared with rats killed at the time of removal from exposure but on the other hand 2 months were insufficient for recovery.

The same findings were true of the mixture of penta and hexachlorinated naphthalenes and chlorinated diphenyl and for chlorinated diphenyl alone.

Apparently the changes induced in the liver cells by these substances are exceedingly persistent and one must expect that an individual showing any

so that fumes from four glass containers were delivered to the air line instead of one. This resulted in the conditions shown in table 2. The animals subjected to these conditions showed no clinical effects of any sort. After 1 month the liver cells were slightly swollen and over-granular and there were occasional mitotic figures. These changes were similar to the early effects of more highly chlorinated compounds, and progressed only slightly during the third and fourth months. When rats in this condition were given carbon tetrachloride and alcohol, in some instances their livers showed massive central necrosis and

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In others this did not develop. Fifty rats were used in this experiment and one may conclude that while the trichlornaphthalenes are in no degree as toxic as those of higher chlorination they are not entirely free from effects upon the liver if high enough concentrations are inhaled over long periods.

The effects of high concentrations of penta and hexachlornaphthalenes.—There can be no doubt as to the damage done the liver by these compounds but in the concentrations so far reported no symptoms were caused that could be recognized clinically and nothing approaching acute yellow atrophy occurred except through the use of the carbon tetrachloride test. On December 1, 1936, 80 rats were subjected to the conditions summarized in table 3. This experment was terminated on January 21. All of the animals lost weight and appetite and deaths began after 8 days of exposure. Fifty-five rats died, most of them heavily jaundiced, 8 were killed for microscopic examination, 9 were killed by the carbon tetrachloride test and 8 lived through the period of exposure. The livers of the animals killed for examination showed marked fatty degeneration, central in type with necrosis of liver cells. Surviving animals showed pronounced changes in the liver after 35 days of freedom from inhalation. It is thus evident that penta and hexachlornaphthalenes are markedly toxic compounds and that recovery from their effects is extremely slow.

The effects of penta and hexachlornaphthalenes, the mixture of these with 10 per cent chlorinated diphenyl, and of chlorinated diphenyl alone, when inhaled in low concentrations through an 8-hour day instead of a 16-hour day as in the first experiment.—Since steady human exposure to any of the compounds tested would invariably be for 8 hours rather than 16-hour periods, a further inhalation experiment was arranged under the conditions shown in table 4 which are quite comparable to those in table 1 except for the shorter inhalation periods. Eighty rats were used for each of the three compounds tested. None at any time showed the slightest evidence of illness. Microscopic examination beginning after 6 weeks' exposure showed swollen liver cells, excess granulation, hyaline inclusions and occasional mitotic figures. These changes did not progress and were very similar to those in the animals exposed for 16 hours under the conditions set forth in table 1. The carbon tetrachloride test was uniformly fatal to them and one must conclude that con-

TABLE 3

CONDITIONS MAINTAINED DURING INHALATION OF HIGH CONCENTRATIONS OF PENTA AND HEXACHLORNAPHTHALENES

MATERIAL	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AV. DAILY EXPOSURE
	°C.	mg./cu. m.	range	hours	hours
Penta and hexachlornaphthalenes	137–195	8.88	High 14.0 Low 5.75	608	16

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centrations of these compounds such as were employed cause a certain degree of liver damage even if inhaled for but 8 hours daily. This injury is resisted successfully by the rats just as was the 16-hour injury but it is none the less there and destroys the ability of the animal to resist the carbon tetrachloride test.

Summary of inhalation experiments. The findings that have been described briefly will be amplified upon the pathological side in a further paper by Dr. G. A. Bennett. What has been given is, however, sufficient to indicate that compounds more highly chlorinated than trichlornaphthalene are capable of causing liver injury when inhaled steadily in quite low concentrations. It is an extraordinary thing that even the most searching examination fails to show injury in any other region. It is not easy to grade the toxicity of the different compounds tested, but the chlorinated diphenyl is certainly capable of doing harm in very low concentrations and is probably the most dangerous. Industrial experience combined with these experiments make it appear probable that workmen never inhale enough of any of these substances to get acute yellow atrophy. They may, however, acquire a substratum of liver damage upon which acute yellow atrophy may develop. Experience in a number of plants has shown how easy it is to reduce concentrations of these compounds practically to the vanishing point, and every effort should be made to attain such conditions.

TABLE 4

CONDITIONS MAINTAINED DURING INHALATION OF LOW CONCENTRATIONS OF THREE COMPOUNDS DURING 8-HOUR INSTEAD OF 16-HOUR PERIODS

MATERIAL	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AV. DAILY EXPOSURE
	°C.	mg./cu. m.	range	hours	hours
Penta and hexachlornaphthalenes.....	149–193	1.44	High 2.58 Low 0.42	920	8
90% penta and hexachlornaphthalenes plus 10% chlorinated diphenyl.....	150–197	1.66	High 3.30 Low 0.56	912	8
Chlorinated diphenyl.....	153–174	0.93	High 3.23 Low 0.03	920	8

Gross Feeding Experiments

The various compounds used were ground as finely as possible and mixed with a standard balanced ration for the white rat. The food was placed in a single container, at which the 10 animals in a cage had an equal chance, the amount of the compounds added being reduced as the number of rats lessened during the feeding period. The experiments were designed to give an idea as to the possible toxicity of the compounds selected and, if toxicity was observed, some idea as to the site or sites of damage.

The experiments were successful in both respects, and indeed one may anticipate that future appraisals of the possible toxicity of chlorinated hydro-

carbons may often be made by simple feeding and do not require the elaborate apparatus and the expense necessary for inhalation experiments. The essential reason for this opinion resides in the identity of the lesions produced by both methods, and the fact that the different compounds so far studied seem to arrange themselves identically so far as toxicity is concerned whichever way they are administered.

Trichlornaphthalene plus traces of tetrachlornaphthalene.—Feeding began on May 4, 1936 and continued until November 2, 1936. In the beginning 3 gm. of this mixture were added to the food for 10 rats each day, and this concentration was maintained throughout the experiment. All the animals were killed except the last which died on Nov. 2. There was no loss of weight and no appearance of wasting illness of any sort. The single death was due to some variety of respiratory infection which had no relation to the material inhaled.

Histological examination showed slight changes in the liver but nothing of great significance.

Tetra and pentachlornaphthalenes.—Feeding began on June 29, 1936. A dosage of 0.5 gm. daily was employed. All the animals sickened gradually and were either killed or died by August 28, 1936.

At autopsy both grossly and histologically the liver was the single organ affected. The liver cells showed swelling, hypergranulation, hyaline inclusions and vacuolation. Here and there necrotic cells were found. There was a tremendous accumulation of fat.

Penta and hexachlornaphthalenes.—Feeding began May 4, 1936, a 3 gm. dosage being used. By June 6, nine rats had died. The last one was obviously ill and was killed for autopsy examination. All animals lost weight from the beginning and were ill. At autopsy the liver alone was affected, the lesions observed being similar to those that have been described for tetra and pentachlornaphthalenes but worse.

90 per cent penta and hexachlornaphthalenes and 10 per cent chlorinated diphenyl.—Feeding began May 4, 1936 on a 3 gm. dosage. On May 16th feeding was stopped but all the animals went on to death, the last dying on June 8th. An autopsy the liver lesions were extremely severe and of the usual type.

On account of the high toxicity of the 3 gm. dosage, four rats were given a 0.5 gm. dose every other day. Feeding began June 24, 1936 and the last animal was killed Sept. 11th. There were no deaths but all the animals lost weight. At autopsy the liver as usual was the single organ affected, the lesions being characteristic and extensive.

Chlorinated diphenyl.—Feeding began May 4, 1936 on a 3 gm. dosage and was discontinued on May 10th. Seven of the 10 rats were dead by May 12th. The three remaining rats gained in weight but were sacrificed for autopsy purposes on July 8th. The liver changes began at once. There were no changes in other organs.

A second group of 10 rats was fed a much smaller dose - 0.5 gm. every other day. Feeding began May 20, 1936. The first rat died on May 29th and four more before June 21th. The remaining were sacrificed. Those rats that died showed losses in weight, while those sacrificed had recovered

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their initial loss in weight and were gaining. The liver lesions were similar to those found in rats fed penta and hexachlornaphthalenes plus 10 per cent chlorinated diphenyl but not so marked.

Summary of gross feeding experiments.—Of the various materials fed rats in large doses trichlornaphthalene plus traces of tetrachlornaphthalene was quite innocuous. Tetra and pentachlornaphthalene showed definite liver damage. Penta and hexachlornaphthalenes caused a similar grade of injury. The addition of chlorinated diphenyl to penta and hexachlornaphthalenes increased the toxicity. Chlorinated diphenyl alone produced liver lesions but in the dosage used was less effective than when mixed with highly chlorinated naphthalenes. In no case did the compounds used produce acute yellow atrophy but the lesions observed indicate this might be possible if one found a dosage which could act for the proper period of time.

Feeding Precise Doses by Stomach Tube

The compounds employed were suspended in gum acacia. In figuring the dosage the total amount a man of 50 kg. would inhale in an 8-hour day assuming an air concentration of 20 mgm. per cu. m. was first calculated and reduced to milligrams per kilogram. The rats and rabbits received this dose each day. The compounds used were those employed in the gross feeding experiments and the results were essentially similar though the lesions were less severe.

Subcutaneous Injections

The same gum acacia suspensions were injected subcutaneously into rats and rabbits, the dosage being calculated on the basis of 4 mgm. per cu. m. of air. Again similar results were obtained. In all such experiments there must of necessity be differences in the degree of effect but invariably the liver was the sole organ affected and the lesions were those already described many times.

Discussion

These experiments leave no doubt as to the possibility of systemic effects from the chlorinated naphthalenes and chlorinated diphenyl. As in the case of the effects upon the skin, the degree of chlorination seems to determine the systemic toxicity, and it is a striking thing that when trichlornaphthalene is reached systemic effects are never marked and are produced with the greatest difficulty. It is most remarkable, too, that all the compounds tested attack the liver and the liver alone. During the past few months we have determined the organically combined chloride in the livers of animals very severely poisoned by penta and hexachlornaphthalenes but have found no increase over normal figures, though the livers, as determined histologically, were very severely affected. At the present time we are conducting inhalation experiments on a chlorinated diphenyl containing 55 per cent of chlorine instead of 64 per cent as in the case of the experiments reported in this paper and on a compound with a chlorine content between tri and tetrachlornaphthalene. We are also determining the degree to which the diet may increase or decrease toxicity, this being suggested by similar work upon carbon tetrachloride.

In the basis of these experiments

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and on many field determinations of different compounds in the air of workrooms, it appears safe and it is certainly easily attained, to ventilate so that the air breathed does not contain more than 0.5 mgm. per cu. m. of any of these compounds above trichlornaphthalene. In the case of the latter compound concentrations of 10.0 mgm. are permissible. We know from many examinations in many different plants that such concentrations have been greatly exceeded during the past 20 years, and we are conscious of the fact that our rat exposures have been inexorably constant whereas human exposure is never so ordered. Time and careful observation may change these opinions as to standards, but today we are convinced they are safe. Impregnating tanks and other arrangements utilizing the chlorinated hydrocarbons are easy to hood and to safeguard. Compared with benzene, and tetraethyl and many other compounds, these substances are very little toxic and operations employing them can easily be safeguarded. It may be argued that where possible trichlornaphthalene should be used, but this compound will cause acne and if employed very carelessly might do more. Furthermore, higher chlorination is often essential for highly practical reasons. The solution consists in thoroughly adequate ventilation plus good housekeeping around all wax containers.

A final word of caution bears upon the use of carbon tetrachloride as a wax solvent. Obviously this compound adds readily to the toxicity of the highly chlorinated waxes. If carbon tetrachloride is used, ventilation should be excellent, but in our opinion it would be better to dispense with carbon tetrachloride and depend on other solvents, especially upon those containing no chlorine.

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Discussion

Dr. Cecil K. Drinker: We have had quite a long morning, but since Dr. von Oettingen has to leave, I am going to ask him to say a word.

Dr. W. F. von Oettingen (Director, Haskell Laboratory of Industrial Toxicology, Wilmington, Delaware): I wish to congratulate Dr. Drinker and his group on the very interesting and excellent work on the subject. I also wish to congratulate the Halowax Corporation on the fact that they didn't spare any effort to elucidate the problem so that the dangers which apparently are connected with the use of this material can be controlled.

I personally believe that there is no toxic material which cannot be used safely if it is handled properly. In order to handle such materials properly during the different operations it is absolutely essential to be familiar with the toxicity and especially with the mechanism of the action. Since there is no animal which corresponds in all its physiological characteristics to the human being it is important that such compounds be studied with different species of animals so that one can get a cross-section of the potential dangers.

In addition, this fact illustrates the importance of the pre-employment and periodical examination of workers in such work. As was pointed out by Dr. Drinker, there are individuals who are apparently more susceptible to certain toxic agents than others. On the other hand, we have to try to detect the very first signs of incipient poisoning in order to prevent more serious damage. In the present instance it is very difficult to find these very first symptoms because there are no adequate methods, but I trust that in time the scientific profession will supply the medical profession with adequate methods which will allow the physician to determine incipient damage of the organ before serious clinical symptoms become manifest.

Thank you.

Afternoon Session

Dr. Cecil K. Drinker: In this discussion I will call on one or two individuals and I shall expect others to speak as their notes incline them to. First of all I shall ask Dr. Sayers if he will open the discussion for us.

Dr. R. R. Sayers (Chief, Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service, Washington, D. C.): Dr. Drinker, Ladies and Gentlemen: It gave me a great deal of pleasure to have the opportunity to listen to the excellent and interesting discussion and presentations made this morning. Dr. Drinker, and I might add, the members of the Halowax Corporation, have discussed this matter with us, as well as the manufacturers of the diphenyls.

We have been doing some work but not nearly as extensive as that carried on here. The work that we have been doing seems to confirm the work that Dr. Drinker has carried on. I think there are certain parts of it that we can very well keep in mind.

We are dealing with toxic substances, but we are dealing with toxic substances each and every day in industry—harmful substances, hazardous substances. That these can be controlled is well known, no matter what they are, and that we can use them and use them in a safe manner. Dr. Drinker has called your attention to the fact that this apparently has been done and can be done in any of the plants where halowax is used. I have information from one or two of the other men who are in the audience that in plants where damage has been done—skin damage and apparently liver damage to some of the workers—the manufacturers have since corrected the conditions and apparently have adequate engineering control supplemented with adequate medical control.

After all, the proof of the pudding is in the eating. If the man does not get the disease your engineering control is successful. If he does get the disease, no matter what you have done in the way of engineering, you haven't been successful. We must go hand in hand. Neither profession alone can be successful. We have got to work together whether we like it or not. I happen to like it.

There is one other thing. As far as materials are concerned I think we ought to be

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smart enough to use every one of them successfully. If this material is particularly adapted for a certain purpose we should use it. Another material that was used previous to this for insulation purposes, which was flammable, caused a disaster in which approximately 167 men lost their lives. I say approximately 167 because they were never just sure whether it was 167 or 168. It might have been one or two more but they were quite sure that 167 lost their lives. It happened when they had insulated a cable with this material. They had an armored electric cable. It was covered with lead armor on the outside. It was 1200 feet long and was being lowered into a mine shaft approximately 3000 feet deep. It was lashed to a steel rope. It slipped and fell to the bottom of the shaft. When the foreman was inspecting it he set it on fire with his carbide cap-lamp. The carbon monoxide from the fire killed those men that were in that mine. Many of course escaped.

Here we have one hazard, a fire hazard. Now we have another one, a health hazard due to the toxic materials. We have to evaluate them. Certain of these materials, I am informed, are also flammable. I am not just sure how flammable they are but flammability probably decreases as your chlorination increases. But your toxicity also increases as your chlorination increases, according to Dr. Drinker, and I think that checks with other findings. We have these hazards to balance but we can control them. I feel quite confident that we can.

Perhaps we can find other substances that are better even than this material. At the present time I am advised that we have no better. I am advised that in ships, such as submarines, it is quite important to have a non-flammable substance for the insulation of their electrical wire.

DR. CECIL K. DRINKER: Dr. Gray, would you care to say a word?

DR. ALBERT S. GRAY (Director, Bureau of Occupational Diseases, State of Connecticut Department of Health, Hartford, Conn.): Dr. Drinker, I don't think there is anything that I can say except that we used this material in Connecticut and we had a number of so-called cases. All I can say is a confession of ignorance on our part at that time and I was very glad to see that your digging into the literature as thoroughly as you have hasn't elicited any further information than we were able to get, basically. About all we could find was about the two cats that our friend, Lehmann, experimented with. We got in touch with him and he confessed that the amount that he had given the cats and his method of determining it were probably subject to very serious scientific criticism, and we agreed with him on that point.

We felt, and I am very glad that it is what you feel as a result of your experiments, that if we put in an efficient ventilation system sufficient to prevent the dermatitis, we probably wouldn't have liver damage. That is what we did entirely empirically.

I think that is about all I have to say. I have been delighted to be here and to have as many members of my staff here as I could jack out of the office. We have been delighted to listen to the discussion.

DR. CECIL K. DRINKER: May we now make the discussion general and those who have questions please volunteer.

MR. MANFRED BOWDITCH (Director, Division of Occupational Hygiene, Massachusetts Department of Labor and Industries, Boston, Mass.): I would like to second very strongly what Dr. Sayers has said with regard to the approach to this problem in proper control rather than by prohibition, which seems to me wholly unnecessary not only in this case but in the case of other toxic substances with which we have to deal. The problem of proper ventilation seems to me relatively simple from what I have heard of the situation thus far. The problem of maintaining that ventilation properly does not seem to me quite so simple. I think it is going to be quite necessary that there should be a very adequate inspection of the plants using the materials and I can assure you that that will be the case here in Massachusetts.

When this trouble first broke in this state a little over a year ago we issued a quite strongly worded warning letter to all plants using these substances and it has all along

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been my plan to follow that up with a further letter bringing the situation as we now know it, as a result of Dr. Drinker's work, to the attention of users in this state. In that letter we shall unquestionably advocate the concentrations that Dr. Drinker has suggested this morning.

One point that I think is worth commenting on in that connection is the question of identification of the substances. It is extremely important from the state administrative point of view that employers using these substances should know what they are using. They are identified at present only by numbers. If we list those numbers in a warning letter which we send out there are likely to be changes in those numbers. The Halowax Corporation is a progressive concern and it is going to be putting out bigger and better halowaxes all the time. The company's coöperation in this present investigation has been such that I feel assured that they will take the proper steps to see that we in the state offices and also the users of the products will know what we are using.

I wonder whether Mr. Brown would care to say anything about that.

MR. SANDFORD BROWN (President, Halowax Corporation, New York, N. Y.): There are some aspects of this situation on which I think I can enlighten the medical and state and civic authorities, with respect to the commercial and practical aspects. If you go into the research laboratories of any large chemical manufacturing company today you will find anything from one to a thousand different new chemical products which have not yet been put on the market. Some of those may or may not be toxic. The problem so far as the chemical manufacturer is concerned is a question of timing. You have heard this excellent presentation given this morning by the Drinker brothers as to the work that they have done here. Should you take a product of which you have developed, say, 5 or 10 gm. and spend $50,000 on research to determine whether or not it is toxic or should you wait until you have determined whether you have a market for it?

If you are producing only one hundred substances a year you can see that that would run into boxcar numbers in the way of dollars and cents before you ever sold any. That is the problem we have had in this case. It has been on the market for 25 years. Until within the past 4 or 5 years there has never been any intimation that it would cause any systemic effects. Thousands and thousands of workmen have dealt with millions and millions of pounds of certain of these materials, particularly the tri-chlornaphthalenes. Then we come to the higher stages, combined with chlorinated diphenyl and other products, and suddenly this problem is presented to us.

We had asked various authorities interested in public health, going back over a period of 15 to 20 years, to investigate it but there wasn't much enthusiasm for it. Mr. Bowditch suggested that we take it up with the Drinker brothers at this institution, which we did. You know the results of that work.

Now so far as these changes are concerned, they are beyond our control to a certain extent. We will manufacture a product—let's call it 1234. It has certain chemical and physical characteristics. It is supplied to a cable manufacturer. It is composed of certain constituents. There may be some tetrachlornaphthalene, trichlornaphthalene, paraffin, a little pitch or bitumen, and possibly some chlorinated diphenyl. It does a certain job but he wants it to a little more plastic or he wants its viscosity or the specific gravity changed. Possibly by a change in those constituents of only 1 per cent we can get that particular property. We can't sell it to him as the same product so we put a new number on it. Basically, however, if the variation in the chlorinated naphthalene or the chlorinated diphenyl constituent hasn't changed, the toxic property of that will not change.

When it comes to a question of coöperating with the state authorities in that connection, if there were some major change made in a product we would have no hesitancy in advising them and we would also advise our customers. Virtually every consumer of these materials at some time or another has been given their technical or chemical designation along with their various properties, whether they be physical or chemical.

Those are some of the practical problems

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with which all manufacturers of chemicals are confronted today, particularly in the synthetic organic field where the development is so rapid that our sales departments can't even keep up with the research departments sometimes, in knowing what they are doing.

MR. F. R. KAIMER (Assistant to Manager, York Wireworks, General Electric Co., York, Pa.): I am certainly pleased to have this opportunity to say a few words with reference to the experience we have had at our York plant. I perhaps should say that again in this case experience alone has been the best teacher. I have lived with the problem at York with the men who went through the experience from its beginning.

It is only 1½ years ago that we had in the neighborhood of 50 to 60 men afflicted with various degrees of this acne about which you all know. Eight or ten of them were very severely afflicted—horrible specimens as far as their skin condition was concerned. One man died and the diagnosis may have attributed his death to exposure to halowax vapors but we are not sure of that. There was an atrophied condition found as a result of the autopsy but we are not definitely sure that it was or was not connected with his work. Knowing the man as I did when he was employed, with the superficial examination that he had, he appeared to me very thin, pallid in his appearance, and I would not say from my poor knowledge of the physical make-up of the human being that he presented a healthy appearance. However, it was only for a 6 months' period from the time of his employment that he complained of this constipated condition and we advised that he see his home physician. It rapidly developed to the point where he was in the hospital and in a very short time he died.

More serious than that perhaps is the fact that we had 50 other men in very bad condition as far as the acne was concerned. The first reaction that several of our executives had was to throw it out—get it out of our plant. They didn't want anything like that for treating wire. But that was easily said but not so easily done. We might just as well have thrown our business to the four winds and said, "We'll close up," because there was no substitute and there is none today in spite of all the efforts we have made through our own research laboratories to find one.

But we did develop—and I was most closely associated with it—and set up a routine for bringing these men back to normal health conditions. A number of them were sent to Dr. John H. Stokes and to Dr. O. H. Perry Pepper of the University of Pennsylvania Hospital, and the others to Dr. Isaac R. Pels at Johns Hopkins. Through their recommendations and studies we employed a trained nurse and two local physicians and you might say established a small hospital and its facilities at the plant. Through the application of quartz light, x-ray, mechanical removal of comedones and the treatment of pustules that developed in later stages, an utterly strict routine where the worst cases were administered to each day for a period of 15 to 20 minutes, another group who were less serious three times a week, and still another group once a week, we have in this year and a half brought each and every man back to a normal skin condition. Those who were very seriously afflicted do show scars, but otherwise their skin is as healthy in appearance as my own. I tell you we are very proud of the fact that they are still all employed and the amount of halowax that we are using today is even greater in quantity and in types than we were using a year and a half ago.

With the adequate ventilation system we have installed, with the routine for change of clothing from street clothing to work clothing when they come to work and the roverse of that process, with the assurance that a shower will be taken before the street clothing is again put on, we have found no recurrence of this skin trouble. Each and every man working with halowax products, either from solution, from solid compounds or handling the wire insulated and treated with it, is examined twice yearly with a complete physical examination, including blood analysis and efforts to determine any liver damage.

However, there is the point which was very definitely brought out this morning. We do not know as yet when this thing starts. I believe it would be of great help

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to us all in industry if some very fundamental work was done on humans, as Dr. Jones mentioned before we came into this meeting, some control in fundamental work to determine some method whereby we may determine the inception of any liver disorder.

We have had our men examined in groups three times since the trouble developed and nothing has shown up in any one man. We have learned and appreciate the fact that we must handle hazardous materials, but we have learned how to handle them. It has been a very great experience for us and for myself, and again the best teacher.

DR. CECIL K. DRINKER: Can you recollect the air concentration that you are maintaining now with your present ventilating equipment?

MR. F. R. KAIMER: We have had two examinations made of the air by Mr. William F. Hemperly and they average from 0.2 to 0.6 mgm. per cu. m. We recently discovered one condition which was found as the cause of a high reading in one of the examinations. The compound is one that is not manufactured by the Halowax Corporation that is used rather infrequently, perhaps not more than 50 gallons of it in a 6 month period. It is in the form of a paste, reduced with solvent to a paste form, and it was not known that it contained a chlorinated solvent in certain percentage. We discovered it only recently through the analysis of a sample and we found that that was the cause of throwing the results off to a high value. It was then about 8 mgm. per cu. m., I believe. That is going to be eliminated now. That is a combination of toluene and carbon tetrachloride solvent. When that compound is exposed to the air the chlorinated solvent odor is completely masked by the toluene. It is lost. I was able to detect it only by removing the head of the drum and immediately smelling the odor of carbon tetrachloride. As soon as that head was removed for a period of 10 seconds the toluene predominated and we had no knowledge of the other being in there.

MR. ARTHUR G. BEYER (Research Engineer, United American Bosch Corporation, Springfield, Mass.): Do I understand you to say that those men who were afflicted are back on the same job?

MR. F. R. KAIMER: They all returned to normal skin health, as I say, and are working on the same job.

DR. CECIL K. DRINKER: Dr. Schwartz, you have seen a good deal of this general subject.

DR. LOUIS SCHWARTZ (Medical Director, Dermatoses Investigations, United States Public Health Service, New York, N. Y.): I am primarily interested in dermatitis and it was only because of my researches in that field that I happened to come across information given to me by Dr. Gray that there were some cases of yellow atrophy of the liver attributed to halowax. I can only talk from personal experience about the skin cases. I know from what I have seen and from what I have heard from doctors who have been treating these cases that if they are treated like an ordinary acne vulgaris and kept away from further large exposure they all get well, with the same results as acne vulgaris. Those who have large pustules may have scars resulting and those who have superficial pustules or only comedones won't have any scars.

As far as prevention goes, I felt even before this investigation was undertaken that this substance, like any other poisonous substance, can be handled and used in industry provided proper safety precautions are taken, and I so advocated at the meeting in Pennsylvania when this was discussed.

About ventilation and safety precautions, I think that while we cannot, with our present knowledge, detect by any chemical tests the early symptoms of intoxication from this substance, the skin offers an easy way of proving whether your method of ventilation is efficient or not. If there are any cases of acne or of this dermatitis occurring in a plant where halowax or the chlorinated naphthalene or chlorinated diphenyls are used, then that shows that there is sufficient concentration of these substances in the air to cause plugging of the follicles and to cause a skin condition. If there is sufficient concentration to do that there may be

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sufficient concentration to cause systemic poisoning in the few people who are hypersensitive to the action of these hydrocarbons. Everybody is not hypersensitive to them. If they were, of the thousands of people who have been handling these substances, more would have contracted this disease and it would have been reported very much earlier. This material was used in Germany as early as 1914 or 1915.

While I cannot add anything to the methods outlined here for safety in the way of ventilation and so forth, I can say that if you go into a plant and find that there is any acne present among the workers with this material you will know that there is sufficient of the substance in the air to cause acne and consequently sufficient perhaps to be dangerous to the few people who are hypersensitive to its action.

DR. CECIL K. DRINKER: There is a practical point in regard to the question of determining these substances in air. My brother pointed out this morning that there are several pieces of apparatus for doing this. It has seemed desirable to a number of the men who are here that during the next couple of years, while we are in a position of learning, that we endeavor, if we can, to confine our analyses to one piece of apparatus, so that at least our results will be as comparable as we can make them from place to place.

I don't know much about this phase of the subject: perhaps, Mr. Cook, you have an idea or two about that.

MR. WARREN A. COOK (Chief Industrial Hygienist, Bureau of Occupational Diseases, State of Connecticut Department of Health, Hartford, Conn.). On the determination of the halowax I wonder if it wouldn't be preferable to have Mr. Hemperly discuss the method he has been using throughout the country for the determination of chlorinated naphthalenes.

DR. CECIL K. DRINKER: I think so far as that is concerned it is best to leave that to discussions with Mr. Hemperly and Dr. Brandt afterward. But the question of determining some uniformity of technic for a while at least is, I think, a matter of general interest to us.

MR. WARREN A. COOK: I am not quite sure that I have in mind exactly what you want in that regard. In connection with sampling?

DR. CECIL K. DRINKER: Yes, In connection with the whole technic of determining the material in air, length of sampling, type of apparatus, and so forth. It has been suggested that we endeavor to agree upon some uniform procedure for that and as figures begin to come in, as they will in the course of the next couple of years, we will at least have them on a comparable basis.

MR. WARREN A. COOK: In that regard there is no question but what the determinations and results of analyses of the concentration of injurious materials in air, correlated with pathological findings or freedom from pathological findings, are real factors in further substantiating toxic limits which are originally given us from animal experimentation. In order to obtain data which are of value along that line it is desirable to know to what extent, in terms of milligrams per cubic meter, workers are exposed to in breathing any potentially injurious material.

It seems to me that one of the things that should be done, which many of the plants and many of the organizations equipped to make determinations of injurious materials in air should do, is to make an effort to develop one group and series of results which will represent average exposures of workers to chlorinated naphthalenes. In getting that figure I think that it is of great importance that we should consider average daily exposure. There is a tendency very often in taking samples of air to determine maximum exposures, to get the exposure over a 15 or 20 minute period when the worker may be actually tending a pot where the material is being used, whereas during the subsequent half hour he may be 40 or 50 feet away from that particular location. Therefore, for one thing, it seems to me it would be extremely desirable to obtain information in as many plants and as many locations as possible of the average exposure, taking into consideration not only the worker's maximum exposure while actually

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at work with these materials but also his much smaller exposure and possibly even lack of exposure as he may go to other parts of the room or even to other departments during the course of the day.

Another type of determination which seems to be extremely desirable to have is concentrations of the chlorinated naphthalenes at certain reference points. I believe that Mr. Hemperly very carefully duplicated these reference points in each of the plants where he took his determinations. He took the samples, I believe, at breathing level and a certain measured distance from the pots where the chlorinated naphthalenes were being handled, so that next year he could go back to those same locations or others could take determinations at those same locations, which are definitely fixed and recorded, and learn whether, due perhaps to clogged pipe lines or to fans which might become loaded with the condensed chlorinated naphthalene, there might be poorer ventilation than originally designed and higher concentrations of the chlorinated naphthalene than originally determined.

It seems to me that it would be an extremely desirable thing to have made available for all of us who are making these determinations these reference points so that in Massachusetts and in Connecticut, at one plant or at another, a considerable group of workers could be taking samples at this one particular point with reference to the source of generation of the vapor. Such results would permit a comparison of knowledge between plants.

In that regard it happens that there is a committee of the American Public Health Association which is charged with the development of chemical methods for determination of atmospheric contamination such as that now under consideration. It seems to me that it might be a very desirable project for that committee to consult with the investigator of the Halowax Corporation and suggest to all of those who are doing work of this type, after some discussion, what reference points could be adopted and also what should be done in connection with getting these average exposures. As a matter of fact our committee will discuss that very feature and possibly include it in our report before the A. P. H. A. in October as one of the projects which we shall carry out at that time.

As I have not given this consideration, I am afraid my discussion is not as connected as I might wish it to be. We have a real problem here and one that deserves some study.

DR. CECIL K. DRINKER: Would it be of service to the American Public Health Association Committee if a sub-committee from this meeting, collected perhaps by my brother and those of you involved with these problems, were to make a recommendation to the A. P. H. A. as to the things you have brought up and as to suitable apparatus, and let the final statement come from the Association after they have considered that material?

MR. WARREN A. COOK: I think that would be a splendid idea because we have a bulk of information on this particular material. A number of individuals have given much thought to the development of apparatus, both the combustion method which we have here and also the continuous record type of apparatus which Professor Drinker mentioned this morning. I think that it is a sufficiently important project that a sub-committee made up from this group could give that committee a very definite steer.

[Personnel of the Sub-committee: W. A. Cook, chairman, A. L. Coleman, H. B. Elkins, W. B. Fulton, S. W. Gurney, E. R. Hayhurst, W. F. Hemperly, F. W. Sehl, and A. N. Setterlind.]

MR. HERVEY B. ELKINS (Chemist, Division of Occupational Hygiene, Massachusetts State Department of Labor and Industries, Boston, Mass.): In connection with what Dr. Schwartz has said, I am not sure that I am in complete agreement as regards the use of skin lesions as warning agents. It is my understanding that in insulated wire plants the chlorinated diphenyls are very commonly compounded with the chlorinated naphthalenes. It is also my understanding that these are more likely to cause a severe skin irritation than the straight chlorinated naphthalenes. On the other

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based, from Dr. Drinker's work one would judge that the straight chlorinated naphthalene was nearly as toxic at least as the mixture of it with a small amount of chlorinated diphenyl.

In the condenser factory where we had our cases there is no chlorinated diphenyl used and no acne of the type described in the reports on the insulated wire factories.

DR. R. EMMETT KELLY (Monsanto Chemical Co., St. Louis, Mo.): I can't contribute anything to the laboratory studies but there has been quite a little human experimentation in the last several years, especially at our plants where we have been manufacturing this chlorinated diphenyl. It has been our observation that although on one occasion we did have a more or less extensive series of skin eruptions which we were never able to attribute as to cause, whether it was impurity in the benzene we were using or to the chlorinated diphenyl, we have never had any systemic reactions at all in our men. We have examined them very closely both from what laboratory tests we thought might help us and from the clinical viewpoint. Also from chlorinated diphenyl there have been no cases of systemic poisoning reported.

I don't believe that we can transpose the laboratory results into the actual humans without paying considerable attention to the volatility of different substances and the way they are being used.

DR. JOHN A. HOOKEY (Consulting Dermatologist, Halowax Corporation, Detroit, Mich.): I have had considerable experience with the dermatological angle of this problem. The experience at the Halowax plant at Wyandotte definitely was that the dermatosis did increase when compounds were used rather than the straight chlorinated naphthalenes.

From the discussion we have heard today I think the observation Dr. Drinker made that the chances are that dermatological problems will disappear along with the other is probably true. However, I think that certain precautions, certain insurance measures, you might say, should be taken in hiring men who are going to work with these products, even though we are going to attempt to get the concentrations low. We saw this morning that the effect of these products was on the liver and that if some one working in these products developed liver damage from some other source the chances of his having serious trouble was increased. Therefore, inasmuch as there is no test to tell whether a person has had liver disease, certainly in the preliminary medical examination of applicants for work the history at least should be gone into very carefully for a history of previous liver diseases.

There are other things that should be taken into consideration also. One is the history of syphilis, because syphilis does have an effect on the liver. If there is any history of syphilis I don't think that that man should be hired. A Kahn test should be taken and I think that it would be a good plan to take Kahn tests on men at stated intervals, because they might develop syphilis after they are hired.

I think those things should be done even though we feel that if the concentration of these vapors in the air is kept as low as was recommended this morning, the chances of having toxic effects are very small.

MR. F. R. KAIMER: I would like to clarify a point of Dr. Hookey's.

You mentioned at the beginning of your talk that your experience in acne condition was more pronounced from the compounds of various materials with chloronaphthalene than with the straight chloronaphthalenes. Did you mean by that, that the acne condition actually was more pronounced with the compounds than with the straight chloronaphthalene or was that due to the fact that you were in a plant operated in a different fashion? In other words, you handled your numerous wire compounds in more of a batch operation. That is my understanding from Mr. Brown.

Is it a fact that the straight chloronaphthalenes are less harmful in so far as acne is concerned or is it because of the handling of batch compounds?

DR. JOHN A. HOOKEY: That is a question that would be difficult to answer. I based my statement on the fact that in taking a general survey of these cases after I started working with them the men in the plant said

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that they developed acne more often and more severely after they started making compounds. It may be that it was in the method of the handling.

MR. F. R. KAIMER: You say that the condition increases with the increased chlorine content and we are attributing the acne primarily to the chlorine radical. If that is true, what are we to associate insofar as these various other constituents are concerned, such as various plasticizing agents? How much do we know about those insofar as development of acne is concerned? Some of these compounds have a half dozen constituents in them other than chlorodiphenyl and chloronaphthalene. We are at the present time considering the chloronaphthalene as the basic element responsible for the acne condition which we have. We know very little about what the other materials may or may not do.

DR. JOHN A. HOOKEY: I don't know about these other materials. Perhaps Dr. Schwartz would know something more about them.

DR. LOUIS SCHWARTZ: It is well known in industry that there are many compounds that cause acne. For instance, paraffin acnes and oil acnes have been known for a long time. Paraffin acnes, wax acnes, are simply a mechanical plugging of the follicles of the skin by the minute particles of wax that fall on the skin. I think that the acne caused by these chlorinated naphthalenes and diphenyls, because it is caused by both—I was down at the Swan Chemical Company where they make chlorinated diphenyls and they have acne there just the same as over at Wyandotte where they make the chlorinated naphthalenes—I believe that that is caused by the same thing, a blocking up of the follicles of the skin, the formation of the comedone and then the comedone becomes infected and forms a pustule. They don't all pustulate because they don't all become infected. Many of these men never have any pustules. They just have little white elevations on their skin.

In those people who are in the acne age, the youngsters of 18, 20, 22 and 23, acne vulgaris is most apt to occur. The sebaceous glands are most active and they seem to have it much more than the older people in whom the sebaceous glands are not as active.

We keep a clipping of all articles relating to industrial dermatitis in my office and I recently read an article in a German magazine in which they report in Germany a similar acne condition from chlorinated phenols and chlorinated benzenes and solid waxes. It seems that this acne-like condition is not peculiar to halowax or chlorinated naphthalenes or diphenyls but can occur with any condition that blocks up the sebaceous follicles of the skin.

DR. ROYAL MEEKER (Special Agent, State of Connecticut Department of Labor, Hartford, Conn.): I am full of questions. As a statistician I am a little bit suspicious of averages, so I should think that we should take maxima as well as averages in getting at the threshold dose or the dangerous impregnation of the atmosphere with these poisonous compounds. I just wanted to drop that as a hint for this committee to consider in its work.

In spite of what you said at luncheon, Dr. Drinker, I still think it is rather important to determine how the plugging of the pores actually does occur, whether they are plugged as Dr. Schwartz has suggested, from the particles falling on the outside of the skin or whether they are plugged, as so many doctors have informed me, from inside as it were. The fumes are breathed, the substance gets into the blood stream. It is thrown off through the pores of the skin and the pores are plugged. I think it is rather important to determine that because it seems to me, from the slight knowledge that I have of the industrial application of halowax compounds in insulating wires, that the plugging of the skin, if it is just an outside plugging, may take place either from handling a solid substance or from the coating on the wire after it becomes cold.

I haven't heard anybody say anything about those Massachusetts cases of very severe dermatitis and I am not so sure but what there was some question of liver damage there. Nobody has said anything about them at all. There is no question there

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that the condition, whatever the complications might have been, came from handling gold wire, in a confined area of course. I think this needs a great deal more study, Dr. Drinker, than you and your associates have been able to give it as yet. All I am serious about is the way we can administer the protective labor laws in order to protect both the employer and the employee.

I listened with very great interest to the expositions of suggested pots for the application of halowax, chlorinated naphthalene and diphenyl. It seemed to me that they left very much to be desired. I don't see why the application of the halowax compound, if it is necessary, as I assume it is, to use this rather dangerous substance, can't be done in a practically closed pot. If you please, Dr. Drinker, I wish you would ask Mr. Reeves of the Rockbestos Products Corporation to tell how they have handled it. If I am any judge of equipment and safety devices they have come as near to eliminating entirely from the atmosphere all contamination from fumigated or evaporated halowax as anyone. All of the application of halowax, either in the melting pots or where it is applied to the wire, is done under hooding and with ventilating apparatus, and it seems to be entirely adequate.

Mr. B. H. Reeves (Vice-president and General Manager, Rockbestos Products Corporation, New Haven, Conn.): I will be very glad to tell of our experience if it will help the picture along. Our experience has been more or less parallel with Mr. Kaimer's in as much as we manufacture the same type of wire. We have avoided the serious picture that he ran into, probably due to the fact that shortly after 1923 we were using benzene as a solvent for asphaltic materials. We got into anemia difficulties with benzene fumes and had to install a complete ventilating system to remove all those fumes from the machines that applied the compounds to the wire. Following the installation of that equipment we were able to get a substitute for benzene, so we got it out of the picture.

We are still in the same fix as every one else is as far as finding a substitute for halowax. There is none that we know of. Consequently when we went to the use of halowax we had a head start as far as the ventilating system was concerned, since ours was already installed and adaptable to a compound with a benzene solvent rather than a melted halowax compound. In order to keep the fumes of a highly volatile solvent under control we did develop a practically complete enclosure for the container in which the compound was placed and exhausted that container in order to prevent any escape of the fumes from it. When we changed to the halowax compounds we followed the same scheme of applying the compounds and used a completely enclosed pot. There is a hole in one side for the wire to go in and one on the other side for the wire to come out. There is enough exhaust suction on the enclosure to prevent any fumes from getting out of the openings where the wire enters and leaves. Of course periodically it is necessary to open the pot to replenish the compound or make adjustments. In that case we have the ventilating system interlocked with the door that the operator opens so that when he opens it he increases the amount of air travel about ten-fold.

Dr. Royal Meeker: What is the velocity when the door is open?

Mr. B. H. Reeves: With the door wide open, at breathing level the velocity is 200 feet. That is the linear velocity. We check that every week on every opening at every machine with a velometer, a small instrument which is easy enough to operate and reads directly. Whenever the velocity falls below that figure the pipe connecting that machine is taken down and cleaned, because there will be condensation inside the pipe to cut down the air flow and reduce the ventilation efficiency.

Dr. Royal Meeker: What do you think of that trap device shown?

Mr. B. H. Reeves: I don't know what to think of that. I don't know whether it would be practical or not. I was going to ask Dr. Drinker whether in passing the air laden with halowax fumes through the boxes of rats there was any deposit of halowax in the enclosure.

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DR. CECIL K. DRINKER: Yes. It is detectable readily through the outflow pipe.

MR. B. H. REEVES: Those in the far end probably didn't get the concentration.

DR. CECIL K. DRINKER: We change the position of the boxes each day. The ones furthest away move into the nearest position, so that over a period of weeks all are exposed equally.

DR. EMERY R. HAYHURST (Consultant in Industrial Hygiene, State Department of Health, Columbus, Ohio): I would like to ask if it wouldn't be possible to put a cold water line around that trap and deposit it all before the air escapes from the trap.

MR. B. H. REEVES: We have tried cooling the surface of the exhaust pipes in order to concentrate the deposit in one place and make it unnecessary to remove long lengths of the ventilating system. While we have found a slight advantage in doing so it hasn't at all paid for the expense. It is much easier to take the piping down. Consequently I doubt the possibility of removing it all by cooling the surfaces of the trap. It might be possible, by building a labyrinth of refrigerating coils, to collect it. But then you would have the problem of removing it from the coils after you had collected it and it would involve rather complicated procedure.

DR. B. L. VOSBURGH (Medical Director, General Electric Company, Schenectady, New York): We have heard about the possibility of preventing liver damage and skin trouble among manufacturers of wires and cables and so forth, but like the old rhyme, every dog has fleas and the fleas have fleas, we also have customers who use wires and cables in tunnels, in enclosed spaces, splicing them together and doing all sorts of things. I am not at all certain that we know what the concentration of these chlorinated hydrocarbons is under those conditions.

About the time we were having so much trouble at our York factory some of our customers began complaining. We thought we were having a hysteria of halowax mania throughout the country. Some of their complaints were bona fide. We had no difficulty in handling cold wire and the men had no skin trouble. Yet when they did the same thing with possibly the application of heat in tunnels, ships and so forth, they actually did develop trouble.

We have used, of course, the icterus index in following some carbon tetrachloride cases and I wondered what you have to say about that. Is that of no value at all in the case of liver damage in this material?

DR. CECIL K. DRINKER: I don't think so until it gets so extreme that we know it any way.

DR. B. L. VOSBURGH: I did write down a few questions that came to mind. Some of them have been answered and some are foolish but I shall ask them anyhow.

It occurred to me that if trichlornaphthalene has been proved to be practically innocuous, isn't it a problem of research largely for the Halowax Corporation to use only that one material adopted with other known chlorinated compounds to meet the requirements of customers? That is one of the foolish ones probably, but I shall just ask it.

Furthermore, how long is it reasonable to expect the liver to recover after it has been pretty well damaged. I talked to you and you said you hadn't worked that out with the animals as yet.

DR. CECIL K. DRINKER: In that case we set aside a certain number of animals to recover, after knowing that a certain amount of damage had been done. Then we started to kill them but we invariably ran out of rats before they ran out of lesions. We don't know how long it lasts.

DR. B. L. VOSBURGH: Have you given them calcium and glucose as you would with carbon tetrachloride?

DR. CECIL K. DRINKER: Not yet, but we are doing an experiment now with one group on a very high calcium diet and another group on a calcium free diet. The whole question of calcium in the diet, of giving milk daily to these people may be worth while.

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DR. B. L. VOSBURGH: I just had those questions in mind. I would like to hear what Mr. Brown would say as to the possibility of using only this one innocuous chlorinated naphthalene.

MR. SANDFORD BROWN: That would simplify our problem exceedingly, not only from the commercial standpoint but from the toxicity standpoint. But if we did so I think that Mr. Kaimer would be the first to object because he wouldn't be able to get the technical effects he desires in the cable. The same thing applies throughout all the industry where we are using these higher chlorinated products.

The problem as we see it, and it is one which we intend to study further (we have our program for this continuous work that will be done under the direction of the Drinker brothers), is to try to find a line of demarcation and whether or not within this complicated chemical structure there is some one thing that causes the trouble. If we could take hexachlornaphthalene and remove 1 per cent of some unknown constituent with which we are not now familiar and eliminate the toxicity, that would be a lovely solution. Whether we will ever be able to attain that I don't know. That is one of the things we have in mind.

As I said before, that is one of the things with which all manufacturers of these synthetic organic products are confronted at some stage, either in their laboratories or in commercial developments. It is largely a question of timing as to when you should do the work, how much you should do, and whether you know how to do it. You have to learn that first.

DR. CECIL K. DRINKER: Unless there is some other important matter I will declare the meeting adjourned.

DR. R. R. SAYERS: May I say a word more with regard to what Dr. Hookey stated on syphilis? If you are going to eliminate all your workers who happen to develop syphilis during the time they are working for you, you are probably going to lose some very important employees. It would seem that it would be worth while to give serious consideration to seeing that conditions are proper and suitable for them to continue working for you and that they have proper treatment. In other words, I don't believe that is a good or sufficient reason for discharging those employees who do develop syphilis. We have not found that to be true in other places and I question whether this is one of the places. I may be in error.

MR. SANDFORD BROWN: I want to take this occasion to express on behalf of the Halowax Corporation my thanks for the excellent cooperation we have received from various state authorities and our customers as well in this investigation. I believe you have all formed the opinion, based on what you have heard this morning, that our whole motive here is to conduct this on an ethical, scientific and constructive basis.

In collaboration with the Monsanto Chemical Company we have a much more comprehensive program in view to carry on. Therefore we want to continue that same type of cooperation.

There is one thing that I want to bring up in that connection, which will have to be observed by the state authorities, when they go out to make these inspections. That is the necessity of not creating mob hysteria on the part of the workmen in the plants where these inspections are made. Mr. Hemperly has run into some very interesting situations in the various examinations he has made. I know that he would be glad to relate them and give the benefit of his experience to the heads of any of these state departments who will have the direction of this work. Otherwise I can see where we will be unable to get the full coöperation of not only the individual workmen but the plant foremen and the management, and we must have that if we are to get the results that we are shooting for over the next several months or years. This thing may continue, probably will continue for years.

904341

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Monsanto INDUSTRIAL CHEMICALS CO.

FROM (NAME & LOCATION): R. E. Keller - T1B - St. Louis

DATE: August 15, 1975

SUBJECT: CHLORINATED DIBENZOFURANS

REFERENCE:

TO: R. Baxter
LLN - 5045

cc: H. S. Bergen - B2SL
R. A. Liggett - LLN - 5045
J. P. Mieure - T2F
R. H. Munch - T1B
W. B. Papageorge - B2SK
W. R. Richard - T3A
D. Wood - B2SD

Dick,

In June this year a plan was developed with Bill Papageorge and others to learn more about chlorinated dibenzofurans in our Aroclor products. As a part of this plan it was decided that furans standards should be prepared and analytical methodology developed for the detection of at least 0.1 ppm for each furan homolog. Laboratory mixtures of monochloro- through hexachlorodibenzofurans have been prepared and characterization for homolog distribution is underway. Also, we have about one-man continuous effort on the method development work.

As part of the plan it was decided that we should determine if Bayer has carried out "in-house" work of this type. The attached June 16 memo from Dave Wood to J. N. Haggart covers a request for this information. We have had no reply to this correspondence to our knowledge. Any information or assistance you can provide on this point will be appreciated.

During the past week a publication has appeared in the literature entitled "Identification of Chlorinated Dibenzofurans in American Polychlorinated Biphenyls" by R. W. Risebrough et al. of the University of California. A copy of this paper is attached. It shows the identification of chlorinated dibenzofurans in our Aroclor products except Aroclor 1016. We are now anxious to develop our own data for comparison with this publication.

Regards,

Bob K

R. E. Keller

ss
Attachments(2)

NEV 021408

PLAINTIFF'S EXHIBIT 1117

729463

WATER_PCB-SD0000056651

Monsanto

Gladys Burgos - N. Y. O.

February 10, 1975

WESTINGHOUSE

TO :

C. R. Field
H. R. Ford*
T. L. Gossage
C. Jordan
M. L. Marcum
D. L. Mellon
C. Paton**
M. A. Petrilli
D. A. Rutherford
P. L. Slayton
D. Wood

Attached is a xerox copy of the Westinghouse Codicil No. 1 which is part of the contract. Please attach this to your copy of the contract.

Thanks.

G.

* Original carbon copy.
** Original copy.

PLAINTIFF'S EXHIBIT 1242

NEV 006406

705642

WATER_PCB-SD0000056652

Monsanto

MONSANTO INDUSTRIAL CHEMICALS CO.
1114 Avenue of the Americas
New York, New York 10036
Phone: (212) 764-5000

CODICIL NO. 1

February 3, 1975

Westinghouse Electric Corporation
Box 920 - Highway 58 West
South Boston, Virginia 24592

Gentlemen:

This letter is codicil to contract on Inerteen 54201 CM dated January 6, 1975, and should be considered a part of it.

It is understood that the products sold hereunder contain polychlorinated biphenyls, which some studies have shown may be an environmental contaminant. Buyer agrees to use its best efforts to prevent such products from entering into the environment through spills, leakage, use, disposal, vaporization, or otherwise. In the event Seller determines that, in order to prevent an unreasonable threat to health or the environment, it is necessary to discontinue the sale to Buyer of polychlorinated biphenyls for the applications contemplated by Buyer, Seller may terminate the Agreement at any time by giving Buyer at least ninety (90) days' prior written notice.

Because of potential toxicological and/or ecological consequences, Inerteen 54201 CM should not be used or purposely contaminated with other materials such as chlorinated naphthalenes or chlorinated alkyl naphthalenes or chlorinated alkyl biphenyls. In the event of any such use or contamination, this contract may be terminated by Seller within thirty (30) days' notice. (Does not apply to trichlorobenzene as commercially used in transformer fluids.)

ACCEPTED BY:

WESTINGHOUSE ELECTRIC CORPORATION

MONSANTO COMPANY

P. L. Slayton
Regional Sales Manager

NEV 006407

705643

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criteria for a recommended standard....

OCCUPATIONAL EXPOSURE TO POLYCHLORINATED BIPHENYLS (PCBs)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health

SEPTEMBER 1977

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

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PLAINTIFF'S EXHIBIT 1373

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PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. The National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices, to provide relevant data from which valid criteria for effective standards can be derived. Recommended standards for occupational exposure, which are the result of this work, are based on the health effects of exposure. The Secretary of Labor will weigh these recommendations along with other considerations such as feasibility and means of implementation in developing regulatory standards.

It is intended to present successive reports as research and epidemiologic studies are completed and as sampling and analytical methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on polychlorinated biphenyls by members of the NIOSH staff and the valuable, constructive comments by the Review Consultants on polychlorinated biphenyls, by the ad hoc committees of the Society for Occupational and Environmental Health and the American Occupational Medical Association, and

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by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies that reviewed this criteria document on polychlorinated biphenyls. A list of Review Consultants appears on page vi.

John F. Finklea, M.D.
Director, National Institute for
Occupational Safety and Health

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The Division of Criteria Documentation and Standards Development (DCDSD), National Institute for Occupational Safety and Health, had primary responsibility for the development of the criteria and recommended standard for polychlorinated biphenyls. From DCDSD, John M. Fajen served as criteria manager and developed the basic information with the assistance of John A. Wass, Ph.D. Personnel from other NIOSH Divisions that assisted in the development of this document were Robert H. Hill Jr., Ph.D., Alan K. Gudeman, and Dennis M. O'Brien (Division of Physical Sciences and Engineering); Mark W. Jones (Division of Surveillance, Hazard Evaluations and Field Studies); and Trent R. Lewis, Ph.D. (Division of Biomedical and Behavioral Science).

The DCDSD review of this document was provided by Richard A. Rhoden, Ph.D., Chairman; J. Henry Wills, Ph.D.; and Howard L. McMartin, M.D., with A. Blair Smith, M.D. (Division of Surveillance, Hazard Evaluations and Field Studies), and James H. Sterner, M.D.

The views expressed in this document, the conclusions reached, and the recommendations for a standard are those of NIOSH after review of the evidence and consideration of the comments of reviewers. These views and conclusions are not necessarily those of the consultants, other federal agencies, and professional societies that reviewed the document.

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CRITERIA DOCUMENT: RECOMMENDATIONS FOR AN OCCUPATIONAL EXPOSURE STANDARD FOR POLYCHLORINATED BIPHENYLS

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I. RECOMMENDATIONS FOR A POLYCHLORINATED BIPHENYLS (PCBs) STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to polychlorinated biphenyls (PCBs) in the workplace be controlled by adherence to the following sections. The standard is designed to protect the health and provide for the safety of employees for up to a 10-hour workday, 40-hour workweek, over a normal working lifetime. The standard is measurable by techniques that are valid, reproducible, and available to industry and governmental agencies. Compliance with the standard should substantially reduce any risk of reproductive or tumorigenic effects of PCBs and prevent other adverse effects of exposure in the workplace. Employees should regard the recommended workplace environmental limit as the upper boundary for exposure and make every effort to keep exposure as low as possible.

Evidence indicates adverse reproductive and tumorigenic effects in experimental animals exposed to certain commercial PCB preparations. Currently available information is not adequate to demonstrate that other commercial PCB preparations do not have these effects. Should sufficient information become available to indicate that the standard offers greater or lesser protection from some chlorobiphenyl isomers or commercial preparations than is needed, it will be considered for revision.

The Toxic Substances Control Act of 1976 (Public Law 94-469) required the US Environmental Protection Agency (EPA) to prescribe marking and disposal regulations for PCBs by July 1, 1977 (Federal Register 42:26563-77, May 24, 1977). By this Act, the manufacture, processing, distribution

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in commerce, or use of PCBs in any but totally enclosed systems is to be banned, effective 1 year after the date of its enactment, October 11, 1976. Two years after the enactment date PCB manufacture is to be banned, and processing and distribution in commerce are to be banned 2.5 years from that date. However, the Act allows the Administrator of EPA to rule otherwise if he finds that manufacture, processing, distribution in commerce, or use in other than totally enclosed systems will not present an unreasonable risk of injury to health or to the environment. The Act does not affect use of equipment already containing PCBs in totally enclosed systems, so that a potential for occupational exposure to PCBs will continue to exist for many years as a consequence of their transportation, installation, use, and disposal. The part of the Act specific for PCBs is presented in Figure I-1.

"PCBs" are defined for this recommended standard as commercial preparations of chlorinated biphenyl compounds, including those preparations which may be described as single isomers or classes of isomers, such as Decachlorodiphenyl. Biphenyl and its monochlorinated derivatives occurring in commercial preparations of PCBs shall be measured along with the polychlorinated derivatives, and shall be treated in this standard as the polychlorinated components of the preparations. "Occupational exposure to PCBs," is defined as working with PCBs or with equipment containing PCBs that can become airborne or that can spill or splash on the skin or into the eyes, or the handling of any solid products that may result in exposure to PCBs by skin contact or by inhalation. The term "PCB work area" is defined as an area where there is occupational exposure to PCBs. In areas where no occupational exposure to PCBs occurs,

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but where PCBs are present in equipment in the workplace, adherence is required only to Section 8(a).

Section 1 - Environmental (Workplace Air)

(a) Concentration

Occupational exposure to polychlorinated biphenyls (PCBs) shall be controlled so that no worker is exposed to PCBs at a concentration greater than 1.0 microgram total PCBs per cubic meter of air (1.0 µg/cu m), determined as a time-weighted average (TWA) concentration, for up to a 10-hour workday, 40-hour workweek.

(b) Sampling and Analysis

The recommended TWA occupational exposure limit for PCBs has been determined to be the lowest reliably detectable limit by the sampling and analytical methods recommended in this document. Environmental samples shall be collected and analyzed as described in Appendices I and II, or by any methods shown to be at least equivalent in accuracy, precision, and sensitivity to the methods specified.

Section 2 - Medical

Medical surveillance shall be made available to all employees subject to occupational exposure to PCBs.

(a) Preplacement or initial medical examinations for workers shall include:

(1) Comprehensive medical and work histories with special emphasis on hepatic function, skin condition, and reproductive history.

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(2) Comprehensive physical examination with particular attention to the skin and to hepatic function including determinations of serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamic-pyruvic transaminase (SGPT) activities. The responsible physician may also wish to obtain measurements of serum triglyceride concentrations or of other indices of fat metabolism.

(3) A judgment of the employee's ability to use positive pressure respirators.

(b) During examinations, applicants or employees having medical conditions that could be directly or indirectly aggravated by exposure to polychlorinated biphenyls or formulations containing polychlorinated biphenyls shall be counseled on the increased risk of impairment of their health that might result from working with these substances.

(c) Women in the work force who are of child-bearing age shall be advised of the potential adverse effects of PCBs on the unborn child. Those who bear children while working with PCBs shall be counseled concerning the advisability of nursing their babies.

(d) Initial medical examinations shall be made available to all workers as soon as practicable after promulgation of a standard based on these recommendations.

(e) Periodic examinations shall be made available at least annually and include: (1) interim medical and work histories, and (2) physical examinations as outlined in paragraphs (a)(1) and (a)(2) of this section.

(f) If evidence of adverse effects of exposure to PCBs is suspected or confirmed, appropriate medical care shall be made available to the affected worker(s).

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(g) Pertinent medical records shall be maintained for all employees exposed to PCBs in the workplace. Such medical records shall be maintained for the period of employment plus 30 years. These records shall be made available to the designated medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, of the employer, and of the employee or former employee.

Section 3 - Labeling and Posting

All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Illiterate workers and workers reading languages other than those used on labels and posted signs shall be otherwise informed regarding hazardous areas and shall be informed of the instructions printed on labels and signs.

(a) Labeling

The following warning label shall be affixed in a readily visible location on PCB-processing or other equipment, and on PCB-storage tanks or containers:

POLYCHLORINATED BIPHENYLS
(PCBs)

DANGER! CONTAINS POLYCHLORINATED BIPHENYLS
CANCER SUSPECT AGENT

Use only with adequate ventilation.
Do not get in eyes, or on skin or clothing.

First Aid: In case of skin or eye contact, flush with running water.

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(b) Posting

Warning placards shall be affixed in readily visible locations in or near PCB work areas. The information contained thereon shall be arranged as in the following example.

POLYCHLORINATED BIPHENYLS
(PCBs)

DANGER!

CANCER SUSPECT AGENT

AUTHORIZED PERSONNEL ONLY

Do not enter unless area is adequately ventilated.
Do not get in eyes, or on skin or clothing.

First Aid: In case of skin or eye contact, flush with running water.

Section 4 - Personal Protective Equipment and Clothing

(a) Protective Clothing

In any operation where workers may come into direct contact with PCBs, protective clothing impervious to PCBs shall be worn. Gloves, boots, overshoes, and bib-type aprons that cover boot tops shall be provided when necessary. Protective apparel shall be made of materials which most effectively prevent skin contact with PCBs where it is most likely to occur. Employers shall ensure that all personal protective clothing is inspected regularly for defects and that it is in a clean and satisfactory condition.

(b) Eye Protection

Chemical safety goggles, face shields (8-inch minimum) with goggles, or safety glasses with side shields shall be provided by employers and shall be worn during any operation in which PCBs are present. If liquid or

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solid PCBs contact the eyes, the eyes shall be irrigated immediately with large quantities of water and then examined by a physician or other responsible medical personnel. (A drop of vegetable oil on the eye has been found to reduce the resultant irritation.) Eye protection shall be in accordance with 29 CFR 1910.133 and ANSI Z 87.1-1968.

(c) Respiratory Protection

(1) Engineering controls shall be used when needed to keep concentrations of airborne PCBs at or below the recommended TWA occupational exposure limit. The only conditions under which compliance with the permissible exposure limit may be achieved by the use of respirators are:

(A) During the time necessary to install or test the required engineering controls.

(B) For nonroutine maintenance or repair activities.

(C) During emergencies when concentrations of airborne PCBs may exceed the permissible limit.

(2) When the use of respirators is permitted by paragraph c(1) of this section, respirators shall be selected and used in accordance with the following requirements:

(A) The employer shall establish and enforce a respiratory protection program meeting the requirements of 29 CFR 1910.134.

(B) The employer shall provide respirators in accordance with Table I-1 and shall ensure that employees properly use the respirators provided. The respirators shall be those approved by NIOSH or the Mining Enforcement and Safety Administration. The standard for approval is specified in 30 CFR 11. The employer shall ensure that

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respirators are properly cleaned, maintained, and stored when not in use.

TABLE I-1

RESPIRATOR SELECTION GUIDE

Concentration of PCBs	Respirator Type Approved under Provisions of 30 CFR 11
Greater than 1.0 µg/cu m or Emergency (entry into area of unknown concentration)	(1) Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode. (2) Combination Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure mode and an auxiliary self-contained breathing apparatus operated in pressure demand or other positive pressure mode.

Section 5 - Informing Employees of Hazards from PCBs

(a) All new and present employees in any area in which PCBs are used shall be informed of the hazards, relevant symptoms, and effects of overexposure to PCBs, and the precautions to be observed for safe use and handling of these materials.

(b) All employees involved with the manufacture, use, transport, or storage of PCBs shall be informed that PCBs have been found to induce tumors in experimental animals after repeated oral ingestion and that because of these findings it is concluded that PCBs are potential human carcinogens; employees shall also be informed that adverse reproductive

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effects may result from occupational exposure to PCBs.

(c) The employer shall institute a continuing education program, conducted by instructors qualified by experience or training, to ensure that all employees occupationally exposed to PCBs have current knowledge of job hazards, proper maintenance and cleanup methods, and proper use of protective clothing and equipment, including respirators. The instructions shall include a general description of the medical surveillance program and of the advantages to the employee of participation. Special attention shall be given to women in the workplace. They shall be made aware of the potential adverse effects of PCBs on the unborn child, and of the known transport of PCBs to breast milk. Elements of the program shall also include:

Emergency procedures and drills;
Instruction in handling spills and leaks;
Decontamination procedures;
Firefighting equipment location and use;
First-aid procedures, equipment location, and use;
Rescue procedures;
Confined space entry procedures;
Low warning (odor) properties of PCBs.

(d) The information explaining the hazards of working with PCBs shall be kept on file and be readily accessible to workers at all places of employment where PCBs are manufactured, used, stored, or transported. Required information shall be recorded on the "Material Safety Data Sheet" shown in Appendix III, or similar form approved by the Occupational Safety and Health Administration, US Department of Labor.

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Section 6 - Work Practices and Engineering Controls

(a) Regulated Areas

Access to PCB work areas shall be regulated and limited to authorized persons. A daily roster shall be kept of persons entering such areas.

(b) Handling of PCBs and General Work Practices

(1) Operating instructions shall be formulated and posted where PCBs are handled or used.

(2) Transportation and use of PCBs shall comply with all applicable local, state, and federal regulations.

(3) PCBs shall be stored in tightly closed containers in well-ventilated areas.

(4) When PCB storage containers are being moved, or when they are not in use and are disconnected, valve protection covers shall be in place. Containers shall be moved only with the proper equipment and shall be secured to prevent dropping or loss of control during transport.

(5) Storage facilities shall be designed to contain spills completely within surrounding dikes and to prevent contamination of workroom air.

(6) Ventilation switches and emergency respiratory equipment shall be located outside storage areas in readily accessible locations which will remain minimally contaminated with PCBs in an emergency.

(7) Process valves and pumps shall be readily accessible and shall not be located in pits or congested areas.

(8) Containers and systems shall be handled and opened with care. Approved protective clothing as specified in Section 4 shall be worn

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by employees engaged in opening, connecting, and disconnecting PCB containers and systems. Adequate ventilation shall be provided to minimize exposures of such employees to airborne PCBs.

(9) PCB-operating and storage equipment and systems shall be inspected daily for signs of leaks. All equipment, including valves, fittings, and connections shall be checked for leaks immediately after PCBs are introduced therein.

(10) When a leak is found, it shall be repaired or otherwise corrected immediately. Work shall resume normally only after necessary repair or replacement has been completed, the area has been ventilated, and the concentration of PCBs has been determined by monitoring to be at or below the recommended TWA concentration limit.

(c) Control of Airborne PCBs

(1) Suitable engineering controls, designed to maintain exposure to airborne PCBs at or below the limit prescribed in Section 1(a), shall be used. Complete enclosure of processes is the recommended method for control of PCB exposure. Local exhaust ventilation may also be effective, used alone or in combination with process enclosure. When a local exhaust ventilation system is used, it shall be so designed and operated as to prevent accumulation or recirculation of airborne PCBs in the workplace environment and to effectively remove PCBs from the breathing zones of employees. Exhaust ventilation systems discharging to outside air must conform to applicable local, state, and federal regulations and must not constitute a hazard to employees or to the general population. Before maintenance work on control equipment begins, the generation of airborne PCBs shall be eliminated to the extent feasible.

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Enclosures, exhaust hoods, and ductwork shall be kept in good repair so that designed airflows are maintained. Airflow at each hood shall be measured at least semiannually and preferably monthly. Continuous airflow indicators are recommended, such as water or oil manometers properly mounted at the juncture of fume hood and duct throat (marked to indicate acceptable airflow). A log shall be kept showing design airflow and the results of semiannual airflow measurements.

(2) Forced-draft ventilation systems shall be equipped with remote manual controls and shall be designed to shut off automatically in the event of a fire in the PCB work area.

(d) Special Work Areas

(1) PCB Hazard Areas

A hazard area shall be considered as any space having physical characteristics and containing sources of PCBs, such as transformers, that could result in PCB concentrations in excess of the recommended airborne PCB exposure limit. Exits shall be plainly marked, conveniently located, and open outwardly into areas which will remain minimally contaminated in an emergency.

(2) Confined or Enclosed Spaces

Entry into confined or enclosed spaces, such as tanks, pits, process vessels, and tank cars where there is limited egress, shall be controlled by a permit system. Permits shall be signed by an authorized representative of the employer and shall certify that appropriate measures have been taken to prevent adverse effects on the worker's health as a result of his or her entry into such space.

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Confined or enclosed spaces which have contained PCBs shall be thoroughly ventilated to assure an adequate supply of oxygen, tested for PCBs and other contaminants, and inspected for compliance with these requirements prior to each entry. Adequate ventilation shall be maintained while workers are in such spaces. Leakage of PCBs into such confined or enclosed spaces while work is in progress shall be prevented by disconnecting and blanking the PCB supply lines. Each individual entering such confined or enclosed space shall be furnished with appropriate personal protective equipment and clothing and be connected by a lifeline harness to a standby worker stationed outside of the space. The standby worker shall also be equipped for entry with approved personal protective equipment and clothing and have contact with a third person. The standby person shall maintain communication (visual, voice, signal line, telephone, radio, or other suitable means) with the employee inside the confined or enclosed space.

(e) Emergency Procedures

For all PCB work areas where there is a potential for the occurrence of emergencies, employers shall take all necessary steps to ensure that employees are instructed in, and follow, the procedures specified below as well as any others appropriate to the specific operation or process.

(1) If PCBs leak or are spilled, the following steps shall be taken:

(A) All nonessential personnel shall be evacuated from the leak or spill area.

(B) The area of the leak of spill shall be adequately ventilated to prevent the accumulation of vapors.

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(C) If the PCBs are in liquid form, they shall be collected for reclamation or sorbed in vermiculite, dry sand, earth, or similar nonreactive material.

(2) Personnel entering the spill or leak area shall be furnished with appropriate personal protective equipment and clothing. All other personnel shall be prohibited from entering the area.

(3) Only personnel trained in the emergency procedures and protected against the attendant hazards shall shut off sources of PCBs, clean up spills, control and repair leaks, and fight fires, in areas where PCBs are used.

(4) All wastes and residues containing PCBs shall be collected in PCB-resistant containers and appropriately disposed of (Federal Register 42:26563-77, May 24, 1977).

(5) Safety showers, eyewash fountains, and washroom facilities shall be provided, maintained in working condition, and located so as to be readily accessible to workers in all areas where the occurrence of skin or eye contact with PCBs is likely. If liquid or solid PCBs are splashed or spilled on an employee, contaminated clothing shall be removed promptly and the skin washed thoroughly with soap and water for at least 15 minutes. Eyes shall be irrigated immediately with copious quantities of running water for at least 15 minutes if liquid or solid PCBs get into them. A drop of vegetable oil may be applied to the eye to relieve the irritating effect of PCBs.

Section 7 - Sanitation Practices

(a) Employees occupationally exposed to PCBs shall be provided

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with separate lockers or other storage facilities for street clothes and for work clothes.

(b) Employees occupationally exposed to PCBs shall not wear work clothing away from their place of employment.

(c) Employees occupationally exposed to PCBs shall be provided clean work clothing daily, and cleaning establishments shall be informed as to the hazards of handling PCBs and proper disposal procedures for PCB-contaminated waste water.

(d) Facilities for shower baths shall be provided for employees occupationally exposed to PCBs. Workers should shower before changing into street clothes.

(e) Employees exposed to PCBs shall be advised to wash their hands and exposed skin before eating, drinking, smoking or using toilet facilities during the work shift.

(f) Food, drink, or smoking materials shall not be permitted in areas where PCBs are handled, processed, or stored.

Section 8 - Monitoring and Recordkeeping Requirements

(a) Monitoring

(1). As soon as practicable after the promulgation of a standard based on these recommendations, each employer who manufactures, processes, handles, stores or otherwise uses PCBs shall determine by an industrial hygiene survey whether occupational exposure to PCBs may occur. Surveys shall be repeated at least once every year and within 30 days of any process change likely to result in occupational exposure to PCBs. Records of these surveys, including the basis for any conclusion that there

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may be no occupational exposure to PCBs, shall be retained until the next survey has been completed.

(2) If occupational exposure to PCBs is determined to be possible, a program of personal monitoring shall be instituted to measure or permit calculation of the exposures of all employees.

(A) In all personal monitoring, samples representative of the employees' breathing zones shall be collected.

(B) For each TWA concentration determination, a sufficient number of samples shall be taken to characterize each employee's exposure during each work shift. Variations in work and production schedules and in employees' locations and job functions shall be considered in choosing sampling times, locations, and frequencies.

(C) Each operation in each work area shall be sampled at least once every 3 months.

(3) If an employee is found to be exposed to PCBs in excess of the recommended TWA concentration limit, control measures shall be initiated, the employee shall be notified of the exposure and of the control measures being implemented to correct the situation, and the employee shall be monitored every 30 days. Such monitoring shall continue until two such consecutive determinations indicate that the employee's exposure no longer exceeds the recommended TWA concentration limit. Routine monitoring may then be resumed.

(b) Recordkeeping

Environmental monitoring records shall be maintained for at least 30 years after the employee's last occupational exposure to PCBs. These records shall include the dates and times of measurements, job function and

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location of employees within the worksite, methods of sampling and analysis used, types of respiratory protection in use at the time of sampling, TWA concentrations found, and identification of exposed employees. Each employee shall be able to obtain information on his or her own environmental exposures. Daily rosters of authorized persons who enter regulated areas shall be retained for 30 years. Environmental monitoring records and entry rosters shall be made available to designated representatives of the Secretary of Labor and of the Secretary of Health, Education, and Welfare.

Pertinent medical records for each employee shall be retained for 30 years after the employee's last occupational exposure to PCBs. Records of environmental exposures applicable to an employee should be included in that employee's medical records. These medical records shall be made available to the designated medical representatives of the Secretary of Labor, of the Secretary of Health, Education, and Welfare, of the employer, and of the employee or former employee.

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(e) POLYCHLORINATED BIPHENYLS.—(1) Within six months after the effective date of this Act the Administrator shall promulgate rules to— Rules.

(A) prescribe methods for the disposal of polychlorinated biphenyls, and

(B) require polychlorinated biphenyls to be marked with clear and adequate warnings, and instructions with respect to their processing, distribution in commerce, use, or disposal or with respect to any combination of such activities.

Requirements prescribed by rules under this paragraph shall be consistent with the requirements of paragraphs (2) and (3).

(2)(A) Except as provided under subparagraph (B), effective one year after the effective date of this Act no person may manufacture, process, or distribute in commerce or use any polychlorinated biphenyl in any manner other than in a totally enclosed manner.

(B) The Administrator may by rule authorize the manufacture, processing, distribution in commerce or use (or any combination of such activities) of any polychlorinated biphenyl in a manner other than in a totally enclosed manner if the Administrator finds that such manufacture, processing, distribution in commerce, or use (or combination of such activities) will not present an unreasonable risk of injury to health or the environment.

(C) For the purposes of this paragraph, the term "totally enclosed manner" means any manner which will ensure that any exposure of human beings or the environment to a polychlorinated biphenyl will be insignificant as determined by the Administrator by rule. "Totally enclosed manner."

(3)(A) Except as provided in subparagraphs (B) and (C)—

(i) no person may manufacture any polychlorinated biphenyl after two years after the effective date of this Act, and

(ii) no person may process or distribute in commerce any polychlorinated biphenyl after two and one-half years after such date.

(B) Any person may petition the Administrator for an exemption from the requirements of subparagraph (A), and the Administrator may grant by rule such an exemption if the Administrator finds that— Petition for exemption.

(i) an unreasonable risk of injury to health or environment would not result, and

(ii) good faith efforts have been made to develop a chemical substance which does not present an unreasonable risk of injury to health or the environment and which may be substituted for such polychlorinated biphenyl.

An exemption granted under this subparagraph shall be subject to such terms and conditions as the Administrator may prescribe and shall be in effect for such period (but not more than one year from the date it is granted) as the Administrator may prescribe. Terms and conditions.

(C) Subparagraph (A) shall not apply to the distribution in commerce of any polychlorinated biphenyl if such polychlorinated biphenyl was sold for purposes other than resale before two and one half years after the date of enactment of this Act.

(4) Any rule under paragraph (1), (2)(B), or (3)(B) shall be promulgated in accordance with paragraphs (2), (3), and (4) of subsection (c).

(5) This subsection does not limit the authority of the Administrator, under any other provision of this Act or any other Federal law, to take action respecting any polychlorinated biphenyl.

FIGURE I-1. SECTION 6(e) OF THE TOXIC SUBSTANCES CONTROL ACT

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This report presents the criteria and the recommended standard based thereon which were prepared to meet the need for preventing occupational disease and injury arising from workplace exposure to PCBs. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare, under Section 20(a)(3) of the Occupational Safety and Health Act of 1970, to "...develop criteria dealing with toxic materials and harmful physical agents and substances which will describe...exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of his work experience."

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultations with others, formalized a system for the development of criteria upon which standards can be established to protect the health and to provide for the safety of employees exposed to hazardous chemical and physical agents. Criteria and recommended standards should enable management and labor to develop better engineering controls resulting in more healthful work environments. Mere compliance with the recommended standard should not be used as a final goal.

These criteria for a standard for PCBs are part of a continuing series of criteria developed by NIOSH. The recommended standard applies to the processing, manufacture, and handling of PCBs as applicable under the Occupational Safety and Health Act of 1970. The standard was not designed for the population-at-large, and any application to situations other than occupational exposures is not warranted. It is intended to (1) protect

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against acute and chronic PCB poisoning, (2) be measurable by techniques that are available to industry and official agencies, and (3) be attainable with existing technology.

The standard is designed to substantially reduce the risk of development of carcinogenic, adverse reproductive, hepatotoxic, and dermatologic effects. Since 1970, PCBs have been one of the more thoroughly investigated environmental and occupational hazards. Nevertheless, there are important gaps in the knowledge of chronic exposure effects in man at low concentrations of PCBs. Important research needs include studies on the reproductive histories of women who have been exposed to PCBs, and quantitation of the dermal and respiratory absorption of different mixtures of PCBs. A better understanding is needed of the contaminants in commercial PCB preparations, particularly studies to determine the extent to which any chlorinated dibenzofurans in tissues of PCB-exposed American workers result from direct absorption or are derived from PCBs in the body. Another need is for an assessment of the hazards associated with the mobilization, during fasting or in other abnormal physiologic states, of PCBs stored in the body.

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Extent of Exposure

Biphenyl (C 12H 10), diagrammed in Figure III-1, can be chlorinated by replacing any or all of its hydrogen atoms with chlorine [1].

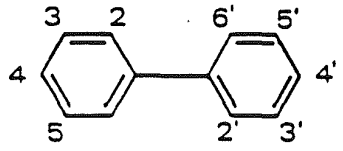
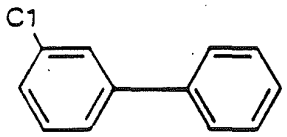
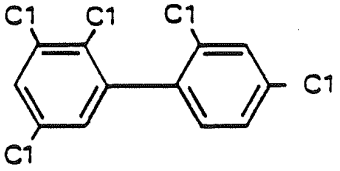


Figure III-1. BIPHENYL MOLECULE AND RING NUMBERING SYSTEM

Specific chlorobiphenyl molecules are designated by reference to the positions of the chlorine atoms according to the numbering scheme depicted in Figure III-1. The lowest possible numbers are assigned, and the phenyl moiety with the fewest chlorine atoms is assigned prime numbers [1,2]. Examples of the nomenclature used here are shown in Figure III-2.



3-chlorobiphenyl



2,2',3,4',5-pentachlorobiphenyl

Figure III-2. EXAMPLES OF NOMENCLATURE SYSTEM OF CHLOROBIPHENYL COMPOUNDS

There are three monochlorobiphenyl compounds, 2-, 3-, and 4-chlorobiphenyl. The 5- and 6-monochlorobiphenyls are identical to 3- and 2-monochlorobiphenyl, respectively. There are 18 dichlorobiphenyl

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compounds. The number of possible chlorobiphenyl isomers and the corresponding weight-percents of chlorine are presented in Table III-1.

TABLE III-1

NUMBER OF ISOMERS AND PERCENT CHLORINE
FOR THE 10 CHLOROBIPHENYL (PCB) CLASSES

Chlorobiphenyl	Empirical Formula	No. of Isomers	Weight % Cl
mono	C 12H9C1	3	18.79
di	C 12H8C1 2	12	31.77
tri	C 12H7C1 3	24	41.30
tetra	C 12H6C1 4	42	48.56
penta	C 12H5C1 5	46	54.30
hexa	C 12H4C1 6	42	58.93
hepta	C 12H3C1 7	24	62.77
octa	C 12H2C1 8	12	65.98
nona	C 12HC1 9	3	68.73
deca	C 10C1 10	1	71.18

Adapted from reference 1

In the commercial synthesis of chlorobiphenyls, biphenyl is catalytically chlorinated with anhydrous chlorine; either iron filings or ferric chloride may be used as the catalyst [1]. The commercial preparations, commonly referred to as "PCBs," are isomeric mixtures. The weight-percent chlorine in commercial mixtures has generally varied between 21 and 68% and has been used to designate grades of commercial products. Commercial PCB products manufactured in the US, Great Britain, and Japan have been marketed under the trade name "Aroclor" [1-3]. Several grades of Aroclor have been designated by numbers such as 1221, 1242, 1254, and 1260, where the last two digits represent the percent by weight of chlorine in

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dibenzofurans [17-23] and naphthalenes [18,19]. Concentrations of chlorinated dibenzofurans in various commercial PCB products are presented in Table III-2.

TABLE III-2

CHLORODIBENZOFURAN TYPES AND CONCENTRATIONS (μg/g) IN COMMERICAL PCB PREPARATIONS

Mixture*	Chlorodibenzofurans di	tri	tetra	penta	hexa	hepta	Total	Ref.
(1) 1016	0.5						0.5	**
(1) 1016			<0.001	<0.001	<0.001			21
(1) 1248			0.5	1.2	0.3		2.0	21
(1) 1254			0.1	0.2	1.4		1.7	21
(1) 1254			0.2	0.4	0.9		1.5	21
(1) 1260			0.1	0.4	0.5		1.0	21
(1) 1260			0.2	0.3	0.3		0.8	21
(2) A-60			1.4	5.0	2.2		8.4	21
(3) DP-6			0.7	10.0	2.9		13.6	21
(4) K300			(a)	(a)			1-1.5	20
(4) K400	(c)***	(e)	(e)	(c)			17-18	20
(4) K500				(a)	(c)	(a)	2.5-4	20
(4) K600			(a)	(a)	(b)	(b)	3-5	20

*(1) Aroclor, (2) Clophen, (3) Phenoclor, (4) Kanechlor
**(I Pomerantz, written communication, January 1977)
*** (a), (b), (c), (d), (e) represent relative amounts in increasing order

Some commercial preparations that were marketed under the trade name Aroclor contained chlorinated terphenyls in addition to chlorinated biphenyls. Aroclors 2565 and 4465 contained 75% and 60% chlorinated biphenyl compounds and 25% and 40% chlorinated terphenyl compounds, respectively. Both mixtures contained 65% chlorine [1].

A broad class of nonflammable synthetic chlorinated hydrocarbon insulating liquids used in electrical capacitors, transformers, nuclear

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the mixtures. Another grade of Aroclor, 1016, made primarily of tri- and tetrachlorobiphenyl compounds and containing 41% chlorine by weight, was introduced in 1971 to replace Aroclor 1242 [2,4,5]. Other PCB products manufactured in Japan were marketed as "Santotherm" [1], and "Kanechlors" 300, 400, 500, and 600, containing approximately 42%, 48%, 54%, and 60% chlorine, respectively [6]. In Germany, products marketed as "Clophens" A50 and A60 contained 54 and 60% chlorine, respectively [7]. In France, PCBs were marketed as "Phenoclors" and "Pyralenes;" Phenoclor DP6 contains 60% chlorine [8]. Other countries reported to have produced PCBs are Italy, Spain, Czechoslovakia, Poland, Argentina, Brazil, the USSR, and India [1,9,10].

The chlorobiphenyl constituents of several commercial PCB products have been studied [6-8,11-16]. Some data, both qualitative and quantitative, are presented in Table XII-2. About half the 209 possible chlorobiphenyls do not occur in any of the commercial preparations. Among those compounds which do not occur, or which occur in trace amounts only, are 3-chlorobiphenyl, all of the tri- to pentachloro compounds that are chlorinated in only one ring, the penta-, hexa-, and heptachloro compounds that are completely chlorinated in one ring, and the penta- and hexachloro compounds that are chlorinated in four positions in one ring.

Commercial PCBs are insoluble in water, but are soluble in oil and many organic solvents. Some other physical and chemical properties of certain Aroclor products are presented in Table XII-1 [1].

In addition to chlorinated biphenyls, the commercial mixtures with 20-40% chlorine contained biphenyl from about 11% to traces, respectively, by weight. Many commercial PCB products also contain chlorinated

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reactors, and accessory equipment is designated by the generic term "askarel" [4,5,24,25]. PCBs have been major components of most askarels used in the US since 1932. Two general classes of PCB-containing askarels are "capacitor"-grade and "transformer"-grade [4,5]. Aroclor 1242 was the major capacitor impregnant in the US before 1971; subsequently, Aroclor 1016 has been used mainly for this purpose [4]. Transformer-grade askarels manufactured in the US include those marketed under trade names including "Asbestol," "Chlorextol," "Inerteen," "No-Flamol," "Pyranol," and "Saf-T-Kuhl" [4]. Transformer-grade askarels are usually mixtures of trichlorobenzene and more highly chlorinated (42-60%) biphenyls [5,24]. Some typical compositions are: 100% Aroclor 1242; 70% Aroclor 1254 and 30% trichlorobenzene; 60% hexachlorobiphenyl and 40% trichlorobenzene; 45% hexachlorobiphenyl and 55% trichlorobenzene; and 70% pentachlorobiphenyl and 30% trichlorobenzene. Another type of transformer-grade askarel contains 45% polychlorinated biphenyl (54% chlorine) and 55% of a mixture of tri- and tetrachlorobenzenes. Transformer-grade askarels also contain stabilizers such as glycidyl phenyl ether and 3,4-epoxycyclohexylmethyl-3, 4-epoxycyclohexane carboxylate [24].

Exposure to commercial preparations of PCBs in the work environment may involve many different chlorinated biphenyl compounds, and also substantial amounts of biphenyl, tri- and tetrachlorobenzenes, and small amounts of many different chlorinated dibenzofurans, chlorinated naphthalenes and in special uses, chlorinated terphenyls.

Commercial production of PCBs in the US began in 1929 and reached 85 million pounds in 1970 when the major producer began selling PCBs only for use in "closed" systems. Since 1972, only those Aroclors designated 1016,

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1221, 1242, and 1254 have been produced in the US, and total annual production has been around 40 million pounds [26].

Imported PCBs amounted to about a half-million pounds in 1972 and 1973 [26,27]. A decachlorobiphenyl produced in Italy and imported by one company for use in investment casting waxes accounted for 80-90% of the total PCB imports [26]. The other 10-20% was imported from France for use in semiclosed heat transfer applications [27]. Occupational exposure to decachlorobiphenyl could occur in the manufacture of the investment casting waxes as well as in the preparation of the investment casting molds in the 25 US foundries which use the decachlorobiphenyl wax [26].

Most of the PCBs produced in the US since 1971 have been used in electrical capacitors (70%) and transformers (30%). About 95% of the 100 million capacitors produced annually in the US contain PCBs [27]. There is potential occupational exposure to PCBs in the plants of the 17 reported companies that manufacture capacitors in the US. Capacitors are generally classified into two categories for disposal purposes. "Small" capacitors contain less than 2 pounds of PCBs; those incorporated into electrical equipment such as television sets, home air conditioners, and light fixtures contain 2-340 ml of PCBs and have service lives of at least 10 years [26,28]. "Large" capacitors may contain about 25 liters of PCBs [26] and have a service life of 15-20 years [26,27]. Potential occupational exposures exist in the servicing of appliances and in the disposal of used capacitors or equipment.

Transformers that contain PCBs are used mainly in or near inhabited buildings where fire hazards from cheaper oil-filled transformers are greatest. The estimated 135,000 PCB-containing transformers represent

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about 5% of all transformers in the US [27]. Occupational exposure to various askarels used for transformers may occur in their manufacture, servicing, and transportation, or as a result of leaks [29].

Other potential occupational exposures to PCBs exist through losses in storage [30], shipment [29], manufacture and use of heat exchange units [27,31], and in use of previously manufactured items which contain PCBs, such as hydraulic systems, vacuum pumps, and gas transmission turbines [30,31]. The past use of PCBs in carbonless copying papers may result in exposure of workers currently engaged in paper reclamation [30]. Workers in plants that previously used PCBs may have current exposure in their working environments because PCBs have been shown to remain in the workplace air and on surfaces for years after PCB use has been discontinued [32,33]. Several occupations that may have involved exposure to PCBs were tabulated in a 1966 publication [34]. NIOSH estimates that 12,000 workers have potential occupational exposure as a result of current uses of PCBs in their working environments [35].

In addition to their occupational exposures, PCB workers may be exposed to PCBs carried into their homes from the workplace [36], from general contamination of the ambient air [26,37,38] and water [26,37], and to PCBs and their metabolites in their diets [39-46].

Metabolism and Mechanism of Action

A study of the metabolism of 4-chlorobiphenyl was reported in 1959 by Block and Cornish [47]. In this experiment, 1 gram of 4-chlorobiphenyl was fed to rabbits in a single dose and 4'-chloro-4-biphenylol and its

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glucuroniside were recovered from the urine in amounts that accounted for 24 and 50%, respectively, of the administered dose.

Subsequently, a substantial number of metabolic studies of individual chlorobiphenyl compounds [41-43,48-84], mixtures [85,86], and metabolites [48,49,87] were reported, and a comprehensive review was published in 1976 [88]. These reports collectively demonstrate through many study methods that some aspects of metabolism are of special significance to the toxicity of PCBs and that some isomers are more toxic, or have different effects, than others [89-94].

Chlorinated biphenyl compounds are readily absorbed from the digestive tract, regardless of the degree or pattern of chlorine substitution [50,51,95,96]. It seems likely that similar absorptive characteristics apply to the respiratory system since chlorobiphenyl mixtures in air are rapidly absorbed [97], as is decachlorobiphenyl [98,99]. Varying amounts of chlorobiphenyls, depending on degree and pattern of chlorination, are excreted in the feces [42,50,53-56,100], milk [41-44,51,101], and hair [102] of animals, but no more than trace amounts are excreted in the urine [42,51-55,57-62,103-105].

Metabolites of chlorobiphenyl compounds have been found in the urine of mammals including mice [52], rats [48,53-56,58-60,63,64,66,71,85], rabbits [65,67-69], monkeys [51,61,74,75], swine [72], goats [73], and cows [41,73], as well as in feces [48,50-54,56,58-65,76-80], and milk [41]. The metabolites excreted in urine [53,54,58,59,61,63,64,66,67], bile [50,51,53,81], feces [52-54,58,63,76], and milk [41] are, to varying degrees, conjugated with glucuronic or sulfuric acids. Differences in metabolism of PCBs among the aforementioned species are more quantitative

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than qualitative [51,73]; however, metabolism in birds and fish may differ qualitatively from that in mammals [55,77]. Among mammals there are also quantitative differences in PCB metabolism and in effects related to age and sex [50,93,106]. Metabolites identified in mammals include mono- to polyhydroxylated derivatives [41,48,49,51-56,58-81,85], and methoxy [59,60], hydroxymethoxy [64,65,68,70,76,87], dihydrodihydroxy [51,53,54,69,74,75,81], hydroxydihydrodihydroxy [51,74], and dechlorinated derivatives [48,65,70,77].

The lower-chlorinated biphenyl compounds are more readily metabolized than are the more highly chlorinated ones [41,50,51,55,61-64,66,82-84,96,107-109], with no metabolism having been demonstrated for decachlorobiphenyl [66]. As a consequence, some of the more highly chlorinated compounds persist in the tissues for years after intake has been discontinued [51,83,103,110].

The presence of at least two adjacent, unsubstituted hydrogen atoms, particularly in positions 3, 4, and 5, or 3', 4', and 5', is required for rapid metabolism of chlorobiphenyls [79,83,84]. All mono- di-, and trichlorobiphenyls, and all tetrachlorobiphenyls except 3,3',5,5'-tetrachlorobiphenyl meet this requirement. The latter compound, 3,3',5,5'-tetrachlorobiphenyl, was found to be particularly toxic to monkeys, and it was suggested that the chlorinated dibenzofuran derivative may have been involved [94]. While dibenzofuran derivatives have not been demonstrated to exist as mammalian metabolites, they may have been identified as PCB metabolites in chickens [111] and Curley et al [22] reported the excretion of dibenzofurans in urine of rats. In the latter case, however, dibenzofurans were also identified in the administered PCB [22].

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Dibenzofurans are of concern because they may be many times more toxic than PCBs [19,112].

Metabolites found in urine [48,51,53,56,60,61,64,66-74,85], bile [81], feces [51-53,56,58,60,61,64,66,76,79,80,113], and milk [41] include hydroxy derivatives. Such compounds have been demonstrated to be more toxic than their respective parent chlorobiphenyl [41,114] and their presence in milk [41] is of special concern.

Hydroxylation may be direct through hydroxylating enzyme systems, or through formation of arene oxide intermediates [48,51,53,68,75,81,87,115]. This latter process is of particular concern because of potential carcinogenesis and mutagenesis as a result of covalent binding of arene oxides to nuclear components of the cell [51,68,74,82,86,116]. Such binding has been demonstrated both in vivo [51,86] and in vitro [51,82,86,116,117]. Additional evidence of hydroxylation through arene oxide intermediates included findings of metabolites in which chlorine, dueterium, or tritium were at different molecular locations than in the administered compound [68,115,116,118], and transdihydrodiols as mammalian metabolites [51,69,74,75,81].

Although adjacent unsubstituted hydrogen atoms are necessary for rapid metabolism of chlorinated biphenyls, it has been demonstrated that 2,2',4,4',5,5'-hexachlorobiphenyl, which does not have this characteristic, can be hydroxylated [70,79], and oxidatively dechlorinated [65,70]. It has been proposed that the metabolism of this compound may also involve arene oxide formation [65], and chronic exposure to potential carcinogenic activity of resulting arene oxides [86] may result from the metabolism of this and similar compounds [75].

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Historical Reports

Smyth [119], in a paper read October 28, 1930, presented the results of his studies with biphenyl, 2- and 4-chlorobiphenyl, and two unidentified polychlorobiphenyl mixtures. He reported the oral minimum lethal doses for rabbits and guinea pigs as 4+, 2.5, 3.5, 4+, and 4+ g/kg, respectively.

Health problems associated with the manufacture of PCBs were the subject of a report by Jones and Alden [120] in 1936. The case history was presented of a man whose employment, from April 1930 to the end of 1933, involved the distillation of chlorobiphenyl. In May 1933 he developed chloracne, a specific type of acne known to be caused by some chlorinated hydrocarbon compounds [121,122]. Jones and Alden [120] stated that the manufacturing process was not enclosed, that a different source of benzene (a starting ingredient) had been used from the summer of 1932 through October 1933, and that from March to October 1933, the dielectric qualities of the PCBs produced had been substandard. Of 24 men working in the manufacturing process during the period beginning in the summer of 1932, 23 developed chloracne. The first indication of chloracne in the workers appeared in January 1933. Following another change in the source of benzene, enclosure of the distillation apparatus and installation of ventilation fans, a gradual improvement in the acneiform eruptions was noted.

In 1936, Schwartz [123] reported digestive disturbances, burning of the eyes, and impotence in men working with chlorobiphenyls. He also noted that nonachlorobiphenyl was used as an insulator for automobile electric wires, in capacitors, and as a delusterer of rayon.

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An early use of PCBs was for incorporation along with chloronaphthalenes into synthetic waxes [124-128]. These waxes contained 10-20% PCBs [124-126] and were used to insulate electrical wire and cable. There were several reports that chloracne [125-128] developed in workers involved in the manufacture and use of these waxes, which were associated with at least one fatality in 1936 [125,127].

The fatal case was described by Drinker et al [125] in 1937. The patient, who had been exposed to low concentrations of tetra- and pentachloronaphthalenes (90%) and chlorinated biphenyls (10%) developed chloracne, followed by jaundice. He was hospitalized with abdominal pain and distention. At autopsy, cirrhosis of the liver with superimposed acute yellow atrophy was found. Two other fatal cases were described where the exposures had been to mixtures of penta- and hexachloronaphthalenes [125]. According to the authors, no similar cases had been reported in the literature. As a result of these fatalities, estimates of the airborne concentrations of chlorinated hydrocarbons in 30 different factories were made and animal experiments were performed to study the effects of exposure at such concentrations.

Rats were exposed 16 hours/day, 6 days/week to trichloronaphthalenes at 1.31 mg/cu m, to a mixture of penta- and hexachloronaphthalenes at 1.16 mg/cu m, to a mixture of penta- and hexachloronaphthalenes (90%) and chlorinated biphenyls (10%) at 1.37 mg/cu m, and to a chlorinated biphenyl mixture containing 64% chlorine at 0.57 mg/cu m. The authors [125] stated that higher concentrations had frequently been found in the factories, and that except for trichloronaphthalenes, they did not consider that it would be safe to expose workers to any of the mixtures at the concentrations

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studied [125]. Further details of the animal experiment were reported by Bennett et al [129] in 1938. These investigators [129] found morphologic changes in the livers of two groups of rats exposed at the 0.57-mg/cu m concentration and also at 0.93 mg/cu m for 8 hours/day. These animal experiments reported by Drinker et al [125] and by Bennett et al [129] have continued to be erroneously cited [130,131] even though Drinker [132] reported in 1939 that the "chlorinated biphenyl" was actually a mixture of chlorinated biphenyls and chlorinated terphenyls. Drinker [132] stated that a followup inhalation experiment with chlorinated biphenyls containing 68% chlorine showed them to be of low toxicity and he recommended permissible limits for workroom air of 0.5 mg/cu m for mixtures of chlorinated biphenyls and terphenyls and 10 mg/cu m for chlorinated biphenyls.

The first indication in the literature that PCBs might be embryotoxic or have teratogenic effects was the report by McLaughlin et al [133] in 1963, 5 years prior to the recognition of PCBs as an environmental pollutant. The authors evaluated the toxicity of Aroclor 1242 by injecting it into the yolk sac of fertilized eggs prior to incubation, and then observing the effects on embryonic development. None of the eggs hatched after injection with 25 mg of PCBs/egg; with injection of 10 mg/egg, one chick hatched out of 20 injected eggs, but it died 2 days later. Some of the embryos examined showed beak deformities, edema, and retarded growth.

Effects on Humans

(a) Effects from General Environmental Contamination

In the United States, PCBs are present in ambient air [26,37,38],

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water [26,37], and in many foods [39,45,46]. A common dietary intake of 10-20 μg/day has been estimated for teenage males in the US [46]. PCBs frequently have been found in various tissues and body fluids of the US population, eg, at ppm concentrations in adipose tissue [7,36,134-136], ppb concentrations in blood [137,138,140,141], and in milk [143,144] at ppm or ppb concentrations in the milk fat or whole milk, respectively.

The Environmental Protection Agency's Human Monitoring Survey has analyzed human adipose tissue samples collected since late 1968 for PCB content [134]. According to this 1972 report, 637 samples had been analyzed, and 198 of these contained more than 1 ppm of PCBs. Positive findings were made in tissues from each of the 18 participating states.

A detailed analysis of two samples collected in the Human Monitoring Survey was made by gas-liquid chromatography (GLC) and mass spectrometry (MS) and reported by Biros et al [135] in 1970. The samples contained at least 14 isomers ranging from penta- to decachlorobiphenyls. Price and Welch [36] stated that of more than 4,000 human adipose tissue samples examined by the Michigan State Department of Health Pesticides, none had chromatograms that exactly matched those of standard Aroclor solutions. Their data show relative accumulation in adipose tissue of the more highly chlorinated compounds, and relative dilution or absence of the less highly chlorinated compounds originally present in Aroclors 1254 and 1260. They [36] described the analyses of tissue samples at autopsy of a 77-year-old man in which PCB concentrations of 100-250 ppm (fat basis) were found The highest PCB concentration was in the liver. The authors [36] found about 55% of adipose tissue samples in the general population contained PCBs at <1.0 ppm, about 36% at 1-2 ppm, and the remainder at more than 2 ppm.

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During July 1972 through June 1974, 2,324 fat samples were analyzed by the Human Monitoring Survey, 1,277 in the first year and 1,047 in the second [136]. In the 2 years, respectively, PCBs were not detected in 24.5 and 9.1%, were present at <1 ppm in 40.2 and 50.6%, were present at >2 ppm in 5.5 and 4.9%, and were present at 1-2 ppm in the remainder of the samples. Penta-, hexa-, and heptachlorobiphenyl were the PCBs most frequently present.

A complete analysis of PCB compounds in a composite sample of adipose tissues from patients at the University Hospital in Lund, Sweden, was reported by Jensen and Sundstrom [7] in 1974. Forty-five compounds, accounting for the total PCB content of the adipose tissues, were found and identified by comparison with known PCB isomers. The biphenyl compounds included three tetrachloro isomers, many penta-, hexa-, hepta-, octa-, and nonachloro isomers, and decachlorobiphenyl. By comparison with Clophens A50 and A60, which had compositions similar to Aroclors 1254 and 1260, respectively, the authors [7] found the relative concentration of several compounds with chlorine substitution in the 4,4' positions of the biphenyl ring to have occurred, as did many compounds without vicinal, unsubstituted positions. Most of the compounds which underwent relative dilution to the greatest extent had either vicinal, unsubstituted 3,4-positions or two pairs of vicinal, unsubstituted positions.

Blood sera of 616 residents of urban and rural areas of South Carolina were analyzed for PCBs and the results were presented by Finklea et al [137] in 1972. Analysis was accomplished by GLC with a Ni-63 electron capture detector after basic dehydrochlorination. The amounts of PCBs present were estimated by integration of five peak areas associated

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with Aroclors 1254 and 1260. PCBs were not present in samples from all individuals in quantities measurable by the technique used (Table III-3). Analysis of the data indicated that measurable serum PCB concentrations were not related to the age (<5 to >60 years) or sex (305 females, 311 males) of the donor, but that the concentrations associated with race and residence (Table III-3) were statistically different.

TABLE III-3

PCB CONCENTRATIONS IN BLOOD SERUM BY RACE AND RESIDENCE

Race and Residence	No. in Sample	PCBs Measureable In		PCB Concentrations	
		No.	%	Ave* ppb	Max ppb
Rural black	107	5	4.67	9.45	20.6
Urban black	151	57	37.75	5.22	29.0
Rural white	192	119	61.98	5.12	16.6
Urban white	166	89	53.61	4.38	22.0

*Average of measureable concentrations

Adapted from reference 137

Maternal and cord blood samples collected in Tokyo, Japan from December 1973 through February 1974 were reported in 1975 by Akiyama et al [138] to contain PCBs at mean concentrations of 2.8 and 1.1 ppb, respectively (on a whole blood basis). The maximum concentrations found were 7.6 ppb in maternal blood and 3.3 ppb in cord blood. Quantitatively, significant correlations of PCB concentrations in 21 pairs of maternal and cord blood samples were not found. Qualitatively, pairs of maternal and cord bloods had identical PCB patterns resembling those of Kanechlors 500

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and 600. The data suggested nonselective in utero transfer of PCB compounds from mother to fetus. Concentrations of PCBs in human embryonic and fetal tissues were reported by Shiota et al [139] in 1973 to not exceed those found in postnatal individuals who died accidentally. The concentrations, found in 19 embryos 5-8 weeks old, were reported as <2 ppb. The concentrations found in 5 second trimester and 2 third trimester fetuses are presented in Table III-4, expressed on the bases of both whole tissue and on the fat content of the tissue.

TABLE III-4

CONCENTRATIONS (ppb) OF PCBs IN TISSUES OF HUMAN FETUSES

Age of Placental Contents	Basis	Tissue Analyzed			
		Cerebrum	Liver	Kidney	Skin
2nd trimester	Whole	2-23	2-33	6-20	17-83
	Fat	150-60	230-800	60-1,900	550-1,300
3rd trimester	Whole	2*	25-90	6-10	48-769
	Fat	270*	1,000-1,300	420-470	880-1,400

*One sample

Adapted from reference 139

PCB concentrations in the venous blood of nine patients hospitalized with severe wasting diseases were reported by Hesselberg and Scherr [140] in 1974. The investigators were concerned with the release of stored organo-halide pesticides and PCBs during mobilization of body fat. They were unable to detect any PCBs in the blood of 15 apparently healthy

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control subjects. PCB concentrations found in the patients' blood (uncorrected for efficiency of recovery) ranged from 10 to 100 ppb. Information was not presented on the patients' occupations etc prior to their having become ill.

PCB concentrations in blood plasma and in adipose tissue samples obtained from 28 people during routine abdominal sections had a correlation coefficient of 0.74 according to Inoue et al [141]. The average concentration of PCBs was 6.1±3.52 ppb in blood plasma, and in the adipose tissue (fat basis) it was 2.6±1.9 ppm. These investigators [141] also evaluated the effect of emaciation on PCB concentrations in blood plasma of these and other patients; they found an average of 8.4±4.26 ppb in 19 emaciated patients and 4.7±2.17 ppb in 30 unemaciated patients.

Hair samples collected from a college barber shop were reported by Matthews et al [102] in 1976 to contain PCBs at 0.34-0.76 ppm. The samples were composites from five or more individuals collected on two occasions, 4 months apart. Hair was collected from the barber shop aprons, and care was taken to avoid possible contamination. Five commercial preparations of hair sprays, shampoos, and hair clipper lubricating oil were negative for PCBs. Blood samples were not collected for comparison.

PCBs were reported in 1966 to have been found in hair samples from three members of a Swedish family [142], but no concentration data were given. It was speculated that one of the family members, a 5-year-old girl, had acquired PCBs from her mother's milk.

A correlation was found between the quantities and compositions of PCBs in samples of adipose tissue collected from four women during Caesarean deliveries and in milk samples collected 3-5 days later [143].

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There were differences in chromatographic patterns between individuals, but for each individual the chromatographic patterns for the adipose tissue and the milk were qualitatively the same. PCBs in all samples contained principally 4-8 chlorine substitutions. Although the basis (fat or whole milk) for expressing the concentration of PCBs in the milk was not stated, comparisons with PCB concentrations found in adipose tissue and milk by other investigators indicate that the whole milk basis was used [136,144] (EP Savage, written communication, February 1977). Concentration data are summarized in Table III-5.

TABLE III-5

PCBS IN MILK AND ADIPOSE TISSUE OF FOUR WOMEN

Subject	PCB Concentrations, ppm	
	Adipose Tissue	Milk
a	0.62	0.008
b	0.75	0.015
c	1.6	0.032
d	3.1	0.036

Adapted from reference 143

Concentrations of PCBs measured in milk samples from 39 women living in two small cities in Colorado were presented by Savage et al [144] in 1973. Two samples contained PCBs at concentrations of 0.05 and 0.1 ppm. Six other samples contained PCBs at 0.04 ppm, the lower limit of detection for the analytical method, or less. The time postpartum at which the samples were collected and the basis (fat or whole milk) for expressing the concentrations were not mentioned. (Comparison with data in the following

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paragraph suggests that the whole milk basis was used.)

Results of analyses of 384 human milk samples from 40 states for PCBs were presented in a written communication by EP Savage in February 1977. All positive samples that contained PCBs at less than 50 ppb on a whole milk basis were recorded as a "trace." Samples with 50 ppb or more of PCBs were reported as ppm in milk fat on the basis of 2.8% milk fat. Only five samples were not positive for PCBs, and 112 samples from 27 states contained measurable amounts (up to 12.6 ppm on a fat basis). Of the total number of samples, 141 were analyzed during December 1976 and January 1977. The time postpartum when the samples were collected was not stated.

While no adverse effects have been associated with PCBs at the concentrations found in adipose tissue, blood, or milk of individuals whose only known exposures were from general environmental contamination [7,36,102,136-144], knowledge of these concentrations is important to the evaluation of reports on occupational exposures. That is, the data provide a basis for evaluating body burdens of PCBs added by occupational exposure and indicate that workers may have substantial body burdens before the added insult of occupational exposure.

(b) Effects from Consuming PCB Contaminated Rice Bran Oil

An episode of poisoning associated with PCB ingestion occurred in Japan in 1968, and was the subject of a special issue of the journal Fukuoka Acta Medica in June 1969 [145-159]. These reports dealt primarily with the situation in Fukuoka prefecture where 325 poisoning cases had been identified through January 20, 1969. The episode resulted from consumption of a particular brand of rice bran oil [160] and ultimately involved persons in 22 prefectures [161]. About equal numbers of cases

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(approximately 450 each) were registered in Fukuoka and Nagasaki prefectures as of September 1973 [161]. In the prefectures of Hiroshima, Kochi, and Yamaguchi, there were 80, 45, and 40 cases, respectively, at that time. In each of the other 17 prefectures there were 1-25 registered cases. The total number of cases registered by March 1970 was 1,015; by September 1973, the number had increased to 1,200, and by May 1975 to 1,291 [161,162]. The disease became known as "Yusho," or rice oil disease [145,163]. The outstanding signs of the poisoning were acneiform eruptions and eye discharges (a peculiar secretion from the meibomian glands) [146]. Chloracne was suspected [164]. Hyperpigmentation of the skin, nails, and mucous membranes, swelling of the upper eyelids, and hyperemia of the conjunctivae were other common signs [146,165].

Studies of the rice oils consumed by the patients indicated that the oil associated with Yusho was produced mainly during February 1968 [147,148]. The source of the contamination was determined to be a heat exchange unit containing PCBs that leaked through tiny holes when rice bran oil was heated at low pressure to remove odorous constituents [163,165]. By intensive chemical analyses, including infrared spectrophotometry and GLC, the major contaminant in the rice bran oil was found to be Kanechlor 400 [147]. PCB concentrations in the oil varied, depending on the date of production or shipment. The highest concentration of PCBs, based on the chlorine content of the oil, was about 3,000 ppm which was found in canned oil shipped on February 5. GLC data were not quantitated. In oils shipped thereafter, PCB concentrations decreased rapidly, and only traces were found in oils produced after February 19, 1968 [147,148]. Minor contaminants in the rice oil included polychlorinated dibenzofurans at

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about 1/200 of the PCB concentration [20,160], traces of chlorinated naphthalenes, and bromine at about 2% of the chlorine content [147]. Recent analyses of some of the oil samples indicate that there may have been other chlorinated organic contaminants (F Cordle, written communication, November 1976).

In one study [148], the contaminated rice bran oil was found to have been used largely for frying food (which may have altered the constituents). The oil was consumed for various periods during the spring through October 1968 [148]; the first reported clinical examination of a Yusho patient had occurred on June 7, 1968 [163]. Studies through January 1969 of patients in Fukuoka prefecture indicated that onsets of Yusho began as early as February and as late as December 1968, and first involved the eyes [146]. Onset occurred in most patients in June, July, and August [146].

Some attempts were made to estimate the amounts of rice oil and PCBs consumed by the patients [166,167]. Maximum consumption of oil was estimated at 4.4 liters [166]. Isono and Fujiwara [167] estimated that two Yusho cases may have resulted from the ingestion of PCBs at a daily rate of 67 μg/kg body weight for 3 months. For 146 Yusho patients who lived in homes known to have used oil shipped on February 5-6, the estimated average total oil consumption was 800 ml, a volume that contained an estimated 2 g of PCBs [166]. It was estimated that the maximum volume of oil consumed by an individual was 2.7 liters. Of 21 patients who had consumed more than 1,400 ml (3-4 g of PCBs), 18 were considered to have had major signs of Yusho. Among 80 patients estimated to have consumed less than 720 ml of the oil, 31 were thought to have had major signs of Yusho. From the same

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data, the minimum PCB ingestion among the 146 patients was estimated at 0.5 g [165]. Estimates of the amount of contaminated oil consumed by 13 pregnant women during the ingestion period ranged from 300 to 2,600 mg [167], but estimates of their PCB consumption were not made. Of the 13 babies born to these women, 8 had jaundice, 3 had marked dermal chromopexy, and 9 had excess secretion of tears [167].

Several studies of PCBs in the tissues and body fluids of Yusho patients were made at various intervals after ingestion of the contaminated oil [146,147]. The samples taken closest to the time of ingestion were collected in October and November 1968 [146,147]. Samples from discharges of the acneiform eruptions of two patients contained PCBs at 32 and 45 ppm, and samples of subcutaneous fat from the face and abdomen of an 18-year-old man contained PCBs at about 75 and 13 ppm, respectively. PCBs with GLC patterns similar to those of the contaminated oil were found in these samples as well as in placental and fetal tissues [147]. Preserved tissues from a baby that had been stillborn in October 1968 were later analyzed and PCB concentrations of 1.8, 1.2, and 0.1 ppm in fat were found in the liver, skin, and fat, respectively [168]. The baby's mother had been classified as a severe case of Yusho with onset about mid-June, but the amount of oil consumed, the period of pregnancy during which it was consumed, and the body burden of the mother were not reported [149]. PCBs were found in all sputum samples from 13 patients collected between December 1969 and May 1970 [169,170]. PCB concentrations were highest in December and detection was less common by May.

Other data on concentrations of PCBs were obtained from body fat and other tissues taken from five Yusho patients at autopsy [168,171]. The

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dates of death were between July 1969 and May 1972. Cause of death was heart failure in four cases and a ruptured liver in another case [171]. Estimates of contaminated oil consumed by two of the dead patients were about 0.3 g and 1.6 g, respectively [171]. One PCB, probably a hexa- or heptachlorobiphenyl from the contaminated oil, was especially concentrated in the tissues. The peaks associated with tetrachlorobiphenyls were very low by comparison, suggesting that total PCBs in the body had been substantially decreased within a year after the end of exposure. The mesenteric fat contained PCBs at 0.9-15.1 ppm, and the liver contained 1.3-10.4 ppm in its fat. PCB concentrations in fatty tissues obtained during 11 control autopsies averaged 2.6 ppm. Of the organs examined (liver, heart, kidney, brain, and skin), the liver and heart usually contained the highest concentrations of PCBs [168,171].

In an additional case, the subcutaneous fat obtained on autopsy of a woman who died in September 1972 (about 2 years after consuming contaminated oil) contained PCBs at 2.9 ppm [168].

Polychlorinated dibenzofurans (PCDFs), mainly penta- and hexachloro compounds, were found in tissues obtained on autopsy of two Yusho patients who died in 1969 and of one who died in 1972 [160]. No chlorinated dibenzofurans were found in tissues obtained on autopsy of two controls, although PCB concentrations of about 1-1.5 ppm were found in adipose tissue and liver fat. The findings from the Yusho patients are summarized in Table III-6.

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TABLE III-6

PCBs AND PCDFs (ppm) IN FAT FROM THREE YUSHO PATIENTS AT AUTOPSY

Year of Death	PCBs		PCDFs	
	Adipose	Liver	Adipose	Liver
1969	3.4	4.7	0.03	2.3
1969	8.5	5.6	0.04	1.1
1972	2.1	3.5	0.01	0.3

Adapted from reference 160

The ratio of PCBs to PCDFs in the rice bran oil was about 200, as in the adipose tissues obtained at autopsy. However, in the liver, ratios of 2, 5, and 12 indicate that considerable concentration of PCDFs had occurred.

Information on PCBs [146,147,168,171] and PCDFs [160] in tissues indicates some shifts in concentrations during the 3 years after ingestion of the contaminated oil was discontinued. Masuda et al [168] reported that a year after ingestion stopped, the concentrations of tetrachlorobiphenyl components had decreased and were near those found in persons who had not ingested the contaminated oil. The more highly chlorinated PCB compounds were still retained in the fatty tissue 4 years after ingestion had stopped [168].

Blood from Yusho patients was first examined for PCBs 5 years after ingestion of the contaminated oil ceased. Three distinct GLC patterns were found among blood samples from 49 patients [172-175]. Two patterns (A and B) were peculiar to the Yusho patients, and the third pattern (C) was

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similar to that of controls. Patterns A and B were characterized by peaks corresponding to those of certain penta- and hexachlorobiphenyl compounds that were present in the contaminated rice bran oil. Patterns A and B differed, however, as to the relative amounts of these compounds [172,173]. These patterns became diagnostic for Yusho [161]. The average concentrations of PCBs in the blood serum were 9, 4, and 2 ppb for patients with patterns A, B, and C, respectively, and 3 ppb for 27 control subjects [173]. The maximum blood serum PCB concentration found among 72 Yusho patients examined between April 1973 and March 1974 was 26 ppb [174]. Of these patients, 43 had pattern A, 26 had pattern B, and 3 had pattern C.

Similar patterns were reported in 1975 by Abe et al [176] in a 1974 study of 18 female Yusho patients and their 30 children. Concentrations of PCBs in blood samples from mothers ranged from 3 to 33 ppb during 1974; PCBs in samples from their children ranged from 1 to 20 ppb, and in samples from 14 control children, from 1 to 8 ppb. PCB concentrations tended to be higher in the blood samples from children nursed by Yusho mothers. A sample of milk from a Yusho mother was reported in 1974 to contain PCBs with a GLC pattern similar to those in samples of fatty tissue from other Yusho patients [168]. Concentrations of PCBs in the mother's milk were 0.06 ppm on postpartum days 0-2, 0.04 ppm on days 3 and 4, and 0.03 ppm on day 5. The respective concentrations in the milk fat were 4.5, 3.0, and 2.6 ppm.

In addition to the skin and eye conditions manifested by most people who consumed the contaminated rice bran oil [146,151-153,162], there was pigmentation of the nails [146] and of the oral mucosa [154]. A substantial array of clinical and laboratory findings were published on

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patients with Yusho [150,152,155,156,177-180], including slight increases in activity of serum alkaline phosphatase, reduced serum iron concentrations [155], changes in the microanatomy of liver cells that were considered indicative of microsomal enzyme stimulation [156], symptomatic and functional changes indicative of neuropathy [150,177], respiratory involvement [170,178], a decreased concentration of bilirubin in the serum [179], and, in many patients, an elevation of the concentration of triglycerides in the serum [155,157,158,175,179-181].

Babies born to women with Yusho, both during and after the period of ingestion of the contaminated rice bran oil, were the subject of several investigations [149,159,176,182,183]. Babies of mothers who had ingested the contaminated oil became known as "black" or "cola" babies because of the abnormal skin pigmentation that tended to persist for several months after their birth [176,182,183]. Infants born up to 5 years after their mothers' last ingestion of contaminated rice oil were still affected to some extent [182]. In one study of four babies, other clinical and anatomical abnormalities (retarded intrauterine growth in three, edematous face and exophthalmic eyes in three, dentition in two, calcification on skull and wide, open sagital suture of skull in three) were seen at birth [183]. These were not permanent, and postnatal body and mental development appeared normal in these and other Yusho children [160,176,183]. In at least one case, an investigator concluded that a baby had developed Yusho from nursing [182].

The period of ingestion of contaminated rice bran oil was only a few months, but the effects have persisted for several years [160,161,174,175,179,180,184,185]. The skin lesions and hypersecretion

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from meibomian glands remained unchanged for long periods in many patients [174,184,185]; their magnitudes in 1974 appeared to be related to blood PCB concentrations [174]. In addition, complaints of generalized fatigue, and symptoms referable to the peripheral nervous system and to the respiratory system became more prominent. In 1974 these complaints and symptoms were established as part of the diagnostic criteria for Yusho [161]. These additional symptoms were not related to the PCB concentrations in the blood [174].

Elevated serum triglyceride concentrations were found to be related to the concentration of PCBs in the blood serum [175], and inversely related to the bilirubin concentrations in the serum [179]. The average serum triglyceride concentrations measured annually in 14 Yusho males from 1969 through 1974 ranged from 159 mg/100 ml in 1969, to 174 mg/100 ml in 1972, to 160 mg/100 ml in 1974 without any significant changes from year to year. In 29 Yusho females, the concentrations initially (1964) averaged 153-161 mg/100 ml, but decreased in 1973 and 1974 to 129 and 111 mg/100 ml, respectively [180].

The Yusho population of about 1,300 persons has been followed closely and records indicate that as of May 1975, 29 of them had died [162]. Deaths have been due to a variety of causes such as accidents, suicides, cardiac problems, and cancers. Malignant neoplasms were found in at least nine cases [161], from which Kuratsune et al [160] concluded that there was a suggestion of excess deaths but that no more could be said because information essential for analysis was not available.

The relevance of the Yusho episode to occupational PCB exposure is compromised because: (1) the oil was ingested; and (2) it contained large

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concentrations of dibenzofurans compared with those in the PCBs to which workers generally have been exposed in their occupations. Its relevance is further compromised because the effects observed from daily ingestion of 1-15 mg of PCBs [165,167] were peculiar and excessive compared to those observed in workers exposed by inhalation to PCBs at 1-5 mg/cu m [120,125], notwithstanding that the amounts absorbed may have been similar.

Nevertheless, information obtained from the Yusho episode is relevant to the study of PCB toxicology and occupational exposure. The information establishes that PCBs can be transmitted from mother to fetus, and, in the milk, from mother to child. It also establishes that some PCB compounds are eliminated from the body relatively rapidly, and that others may require years for elimination.

(c) Occupational Exposures

Chloracne was among the earliest reported effects associated with worker exposure to PCBs [125-128]. It was not clear in some early reports that PCBs were contributing to the chloracne because PCBs usually constituted 10-20% of mixtures containing 80-90% chloronaphthalenes, a previously known cause of chloracne [121,122]. An early report that associated chloracne with PCBs in the absence of chloronaphthalenes was that of Jones and Alden [120] in 1936. The manufacturing process was largely an open one and the workers were also exposed to benzene, biphenyl, and other compounds incidental to PCB manufacture. Over the years, cases of chloracne associated with occupational exposure to PCBs have continued to appear [186-196].

Other effects associated with PCBs in early reports included digestive disturbances, eye irritation, liver injury, and impotence

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[123,125]. Elkins [130] reported in 1950 that the average concentrations of PCBs in the workroom air of several plants in Massachusetts ranged from 0.1 to 5.8 mg/cu m. Maximum concentrations ranged from 0.2 to 10.5 mg/cu m. No evidence of immediate toxic effects was observed except at PCB concentrations approaching 10 mg/cu m, which the workers found to be unbearably irritating.

Three cases of severe chloracne were described by Puccinelli [186] in 1954. The affected employees worked in a factory that produced capacitors impregnated with Aroclor 1254. The workroom was 24 x 9 x 5 meters. Capacitors were heated to about 100 C in a 3-cu m autoclave to remove moisture, and then impregnated with the Aroclor while in the autoclave. The temperature in the autoclave was reduced about 12 hours later. When the autoclave was opened, the temperature of the Aroclor was 70-80 C. The capacitors were removed and carried to another location for finishing. Originally, one autoclave was used, but eventually eight were in operation, and PCB emissions to the workroom air occurred almost continuously. Concentrations of PCBs in 500-liter samples of air were found to vary from 5.2 mg/cu m in the center of the room, to 6.4 mg/cu m around the finishing operation, to 6.8 mg/cu m near the autoclave during removal of the capacitors. The three chloracne cases were in men, 18-24 years of age. They had worked in the factory for 2-4 years, and developed the first signs of chloracne 4-8 months after their exposures began. Other than chloracne, the men appeared healthy, and all findings, including liver function tests were reported as normal.

Eight other cases of chloracne associated with PCB exposure during the manufacture of radio capacitors were described by Hofmann and Meneghini

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[187] in 1962. In the process, PCB vapors were generated by heat. The cases included one man and seven women, 20-37 years of age, who were exposed to PCBs 2.5-4 months before onset of signs of chloracne. The face was involved in six cases; other involved areas varied, but included the arms, neck, upper torso, pubes, buttocks, and thighs. The case of a 21-year-old woman was described in detail. The first signs of chloracne appeared on her face 4 months after she began work, and she was observed by the authors [187] 4 months later. On the face, a dirty brown coloring appeared. A hyperpigmented spot with shaded areas was present on the forehead. Subsequently, her buttocks and pubes became involved. Exposure concentrations were not mentioned.

Severe chloracne was described by Birmingham [188] in 1964 in 13 of 15 workers exposed to an Aroclor which was a mixture of bi- and terphenyls (65% chlorine content). An enamel containing the Aroclor was painted onto glass and then baked in an oven. Faulty ventilation caused contamination by chlorinated hydrocarbon vapors. Exposure concentrations and duration of exposure were not given.

An additional case history published in 1969 involved a 43-year-old man exposed to PCBs in an electrical component factory [189]. He developed chloracne on the forehead, face, arms, and thighs within 3 months after beginning work handling racks of electrical parts that had been dipped in hot PCBs. Exposure concentrations and actual durations of exposure were not stated, but it was reported that the man had put his hands in the mixture without skin protection for a long time, and that his clothes often became impregnated with the PCBs. On examination 8 months after transfer to another job in the same room, papules, comedones, and pustules were

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found on his forehead, scalp, face, and arms. Although the man had been removed from direct exposure to PCBs, their odor was present in the man's new work area. It was reported that this was the first case of chloracne in the plant, where more than 100 workers had been engaged in the process for more than 20 years.

A company that used PCBs at two manufacturing facilities provided testimony on employee health in 1975 (In the Matter of General Electric Company, File No. 2833, New York State Department of Environmental Conservation). Examination of records submitted as testimony indicated that exposures were to an askarel [25] containing, by weight, about 60% of Aroclor 1254, 40% trichlorobenzene, and 0.0115-0.135% diepoxide scavengers. From the records submitted, it was not possible to determine the precise numbers of male and female workers. The exact occupations of the workers could not be determined either but a substantial number of "crimpers" was indicated.

The records showed that employees had reported to the dispensary complaining of skin rashes and dermatitis on 49 occasions during the previous 15 years. Only the fingers and hands were involved in 21 complaints, only the arms and hands in 5, and only the face and legs in 1. In 7 other complaints the face, neck, and legs were mentioned in 4, 2, and 1 cases, respectively, in addition to the upper extremities. Associated with the complaints of skin rashes and dermatitis were some complaints of itching of the face (2), neck (1), eyes (1), arms (2), and hands (1). A generalized skin rash was the basis of 14 additional complaints. One worker developed the generalized rash on exposed parts of his body after only 2 days of working with the askarel.

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The company physicians attributed the rashes to allergic or contact dermatitis caused by exposure to the askarel. Treatment included the use of creams, and temporary or permanent removal from exposure. Of the 49 complaints, 22 were second episodes, and in these cases the workers were removed permanently from exposure to askarels. One female employee who had dermatitis of the fingers was removed from exposure for 12 days. Within 2 days of reexposure she again reacted to the askarel and was permanently removed from such work.

Over the same 15 years, other kinds of complaints were made by the workers on 16 occasions. These complaints included burning sensations of the eyes (7), nose (1), and face (1); dry throat (1); asthmatic bronchitis (3); nausea (1); dizziness (1); and aggravation of acne (1). In most of these cases, the company physicians recommended permanent removal from exposure.

The health status of eight laboratory workers who routinely analyzed dielectric fluids containing PCBs was reported by Levy et al [197] in 1977. The men were 25-49 years of age and had been employed 2.5-18 years. Breathing zone, point source, and general work area air samples were collected on magnesium silicate at 50 ml/minute over the workday on three occasions. The breathing zone samples contained PCBs at 0.014-0.073 mg/cu m. Samples taken near an oven contained 0.042-0.264 mg/cu m, and general room area samples contained PCBs at 0.013-0.15 mg/cu m. The blood PCB concentrations in the workers were 36-286 ppb. The most common complaint of the workers (6 of 8) was dry or sore throat. Other complaints were skin rash (3 of 8), gastrointestinal disturbances (3 of 8), eye irritation and headache (each, 2 of 8). Findings on examination of the eight workers were

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skin rash (1), nasal irritation (2), rales (1), and elevated blood pressure (4). No liver, spleen or neurologic abnormalities were found by physical examination. There were no cases of chloracne. Serum alkaline phosphatase, SGOT, SGPT, and total bilirubin, measured in seven subjects, were all within normal limits. In addition, medical records of 40 other exposed employees were examined, revealing two cases of slightly increased SGOT, two elevated serum triglycerides, and one case each of increased serum alkaline phosphatase (SAP) activity, total serum bilirubin, and serum uric acid.

Epidemiologic Studies

An outbreak of dermatitis among workers in a Connnecticut chemical plant was described in 1954 by Meigs et al [190]. PCBs had been substituted for molten salt in a heat exchange unit without modification of the system. There were slight, but obvious, vapor leaks under certain conditions, and the concentration of PCBs in the workers' breathing zones was determined to be 0.1 mg/cu m. No employee worked regularly at points of leakage, and the operations, as described, continued for 19 months.

Mild to moderate chloracne on the face, forehead, and ears developed in 7 of 14 exposed workers; the mastoid region of one worker also was affected. The duration of exposure before the initial signs occurred ranged upward from 5 months and averaged 14 months. The average length of exposure was 11 months for those who did not develop chloracne, with one worker showing no signs after 19 months. Liver function tests were performed on the seven workers who had developed chloracne. Clinical tests included direct and total serum bilirubins, 24- and 48-hour cephalin

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flocculations, thymol turbidity, and SAP activity. Findings were normal in six workers, and borderline increases in cephalin flocculation and thymol turbidity were found in the seventh worker with chloracne. Thirteen months later, the thymol turbidity test had improved, but cephalin flocculation had not changed. All cases of chloracne were stated to have cleared up after an unspecified treatment. Control of vapor emissions by welding all joints in the heat exchange unit prevented recurrence [190].

Exposures of workers to PCBs in six industrial plants were discussed by Hasegawa et al [191] in 1972. The concentrations of PCBs found are summarized in Table III-7.

TABLE III-7

RANGE OF PCB CONCENTRATIONS (μg/cu m) IN WORKROOM AIR

Factory	Function	No. Samples	PCB Concentrations Vapors	Particulates
A	PCB manufacture	6	26-163	19-37
B	Capacitor manufacture	3	120-350	20-125
C	Biphenyl recovery	2	13-15	4*
D	Capacitor manufacture	2	350-540	48-6,270**
E	"	3	95-965	73-650

*1 sample
**6,270 due to spillage

Adapted from reference 191

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PCBs were manufactured in one plant and used in manufacturing capacitors in four plants (one had discontinued use of PCBs 1 month earlier). Biphenyl, not chlorobiphenyls, was present in the sixth plant [191]. Air samples were collected in two fractions. A fraction associated with particles >0.1μ was collected on filter paper, and a fraction containing vapors and particles <0.1μ in diameter was collected in two serially-connected midget impingers containing n-hexane. Samples were collected only from places where high concentrations of PCBs were expected and not from the factory where PCB use had been discontinued.

The vapor concentration exceeded the particulate concentration in all except the sample taken after spillage. Particulate matter was characterized by GLC as containing the same chlorobiphenyl composition as the PCB product used in the plant, whereas the vaporized material contained one less chlorine atom/molecule than the PCB used in the plant.

PCBs were measured in the blood of the employees of six plants, including 99 exposed workers and 32 controls [191]. Concentrations of PCBs in the blood sera of exposed workers averaged 370 ppb, whereas those of the controls averaged 20 ppb. The workers exposed to PCBs in the plant that had discontinued PCB use had serum PCB concentrations of 90 to 730 ppb (average 460 ppb). Based on data from three of the plants, no relationship was found between duration of exposure (from <1 to 20 years) and concentration of PCBs in the blood [191].

Complaints of dermal ailments seemed to be unrelated to the blood PCB concentrations and were considered to be due more to direct contact of the skin with PCBs than to generalized intoxication. The principal dermal findings included brown chromodermatosis of the dorsal joints of the hands

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and fingers and of the nail bed, and acneiform exanthema. The latter also involved the jaw, back, and theighs in several cases. The investigators [191] considered that there was a definite effect of PCBs on fat metabolism, as shown by decreases in the concentrations of total, free, and esterified cholesterols in the blood, and by trends in the same direction for neutral fats, total glycerides, phospholipids, and beta-lipoprotein in the blood. There was evidence of mild disturbances of liver function manifested by increased SGOT, SGPT, and SAP activities and decreased activity of serum cholinesterase. These enzyme activity changes were not considered to be clinically significant.

Studies of 38 current and 80 former employees of a capacitor factory in which Kanechlor 500 had been used from 1954 to about 1960 and Kanechlor 300 had been used from about 1960 to 1972, with PCB use having been discontinued in April 1972, were reported by Hara et al in 1973 [192] and again in 1974 [193]. (Presumably, this factory was the one stated by Hasegawa et al [191] to have discontinued use of PCBs.) Current workers included 17 who were engaged in the capacitor immersion process; the remaining 21 workers were engaged in finishing and assembling operations. The study concentrated on the 17 immersion process workers. During exposure to PCBs in March 1972, the concentrations of PCBs in the whole blood of the immersion workers ranged from about 7 to 300 ppb, and were closely related to years of exposure. One year later, blood PCB concentrations had all decreased, but by varying amounts. For example, one of two workers who initially had PCB concentrations in their blood of about 180 ppb had a concentration of <10 ppb 1 year later, while the other one had a concentration >100 ppb. The average PCB blood concentration for the

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17 workers decreased to about 75% of the original value. Based on blood samples collected about 6 and 12 months after use of PCBs was discontinued, the blood PCB half-lives for the immersion workers were calculated. It was found that the greater the duration of exposure, the greater the PCB half-life (1 year of exposure, 3 months half-life; 10-15 years of exposure, 30 months half-life). This indicated to the investigators that blood served as a PCB carrier, whereas fat served as a depot tissue [192].

While working with PCBs, many of the total group of employees had dermal complaints (blackheads, 45%; acneiform eruptions, 37%; skin irritations, 13%) [192]. A year after discontinuance of exposure to PCBs, these conditions had improved noticeably and only one or two blackheads remained. No correlation was apparent when concentrations of PCBs and triglycerides in the sera of a large number of workers were compared graphically. The workers were also studied about 18, 24, and 36 months after use of PCBs had been discontinued [193]. During this period, blood PCB concentrations decreased to about 10-20 ppb in all but two workers who had been exposed to PCBs for 9 and 15 years. The skin disturbances were reduced to vestigial markings on a few individuals. Comparisons with the concentrations of triglycerides and PCBs in the sera of these workers indicated that the proportion of workers with significant increases in triglyceride concentrations increased as the concentrations of PCBs increased. Of nine workers with blood PCB concentrations >50 ppb, five had elevated triglyceride concentrations.

Examinations of 13 workers from an electrical capacitor manufacturing plant for clinical manifestations of PCB toxicity were reported by Kitamura et al [194] in 1973. Examinations were performed when the company

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discontinued the use of PCBs in June 1972, and were performed twice subsequently at 3-month intervals. The average length of worker exposure to PCBs had been about 2.5 years. Immediately after discontinuance of PCB use, the average PCB concentration in the blood of workers was 820 ppb, ranging from 320 to 2,100 ppb [194]. The mean concentration fell to 310 ppb after 3 months, and to 200 ppb after 6 months. From these observations, Kitamura et al [194] estimated the biological half-life of the PCBs in the blood immediately following the cessation of exposure to be about 90 days. No consistent correlation could be found between the concentration of PCBs in the blood and the duration of exposure to PCBs. Nail, hair, and gum color and color of the mucous membranes of the oral cavity all were normal. Ten of the workers had varying degrees of skin disorders on different parts of their bodies. The skin disorders included seborrhea adiposa, acne vulgaris, and follicular papules on parts of the body where direct contact with the PCBs normally did not occur. The authors [194] concluded that PCBs probably had been an important factor in the etiology of the skin disorders and that results of blood tests, hepatic function tests, and urinalyses were normal. Serum triglycerides were not determined.

A study by Inoue et al [195] of the health of workers in family-owned silk-thread glossing factories in which PCBs were used was published in 1975. The study was initiated because PCB concentrations exceeding 100 ppb had been found in the blood of a 73-year-old man who had undergone surgery. His family operated a household thread-glossing factory. The family members and the hired helper were studied. Serum concentrations of PCBs resembling Kanechlor 500 ranged from 130 to 520 ppb. There was a close

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correlation between the PCB concentration in the blood and the degree of involvement in the glossing work. The head of the household had skin lesions and comedones on the face, back, and ears and had blood PCB concentrations of 190-210 ppb. The rest of the people had practically no skin abnormalities, and other findings (not described) were, in general, considered of minor significance. A study of PCB contamination of the premises and the air of the same factory was reported by Fujiwara et al [33]. At the time the samples were taken, use of PCBs had been discontinued. However, PCBs were found in air at 0.25 mg/cu m, in floor boards at 80-130 ppm, in the dirt under the machinery at 10-900 ppm, and in the dust on steel frame beams at 110-180 ppm. The PCBs were similar to those in Kanechlor 500.

Subsequent to the above study, Inoue et al [195] reported on the PCB concentrations in samples of blood obtained from 54 other similarly employed people. PCB concentrations of over 100 ppb, 50-99 ppb, 10-50 ppb, and 0-9 ppb were found in 2, 5, 19, and 28 persons, respectively. Correlative comparisons with the various functions performed in the factories showed that those workers who had direct contact with the glossing machines, those who maintained and repaired the machines, and those who had over 20 years of work experience had the highest concentrations of PCBs in their blood. Skin abnormalities and other findings in these 54 persons were described as relatively mild. One of the persons studied, a woman in her 10th month of pregnancy, had a serum PCB concentration of 24 ppb. Following birth, the mother and daughter were described as healthy with no evidence of abnormalities. The concentration of PCBs in the mothers's milk was found to be 0.25 ppm, and after

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consultation, she stopped nursing her baby [195].

In 1974, Sato and Hasegawa [32] discussed their findings on PCB residues in the workers and in the air of pressure-sensitive ("carbonless") copying paper manufacturing plants 2 years after PCB use had been discontinued. A PCB product comparable to Kanechlor 300 was still detected in the workroom air of four of five factories at concentrations ranging from 0.13 to 4.4 μg/cu m; in one factory PCBs comparable to a mixture of Kanechlors 300, 400, and 500 were found at concentrations ranging from 0.15 to 1.2 μg/cu m. Concentrations of PCBs in the blood sera of these workers, as measured by GLC, ranged up to 73 ppb, compared to a maximum of about 20 ppb in controls. The authors [32] concluded that the blood PCB concentrations in the workers were still elevated.

PCB concentrations in the blood of three groups of employees with different PCB exposure histories were presented in 1972 by Karppanen and Kolho [198]. The first group of four men and five women had no known occupational exposure to PCBs. The six women of the second group had been exposed while handling PCBs in an analytical laboratory. The third group of eight men and four women had worked, since 1968, in a plant where Aroclor 1242 was impregnated into capacitors. The authors [198] stated that the workroom air of the capacitor factory met internationally accepted limits (presumably <1 mg/cu m), and that protection of the skin had been given special attention. PCB measurements were made by GLC, using electron capture detection. The unexposed group had blood PCB concentrations of 5.6-12 ppb, the analytical laboratory workers had concentrations of 36-63 ppb, and the capacitor plant workers had concentrations of 74-1,900 ppb. Subcutaneous adipose tissue samples from two of the unexposed workers

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contained PCBs at 1.5 and 2.3 ppm; PCBs in their blood expressed as concentrations in fat of the blood were 6.6 and 9.9 ppm, respectively. In three capacitor plant workers, adipose tissue samples contained PCBs at 160, 285, and 635 ppm; PCBs in their blood, expressed as concentrations in their blood fat, were 400, 305, and 700 ppm, respectively. All persons examined were in good health. The capacitor plant workers had been under special medical observation but the investigators were unable to detect any biologic effect from the PCBs.

An epidemiologic investigation of 37 refuse workers who were potentially exposed to PCBs emitted from incinerated waste was described by Bumgarner et al [199] in 1973. The control group consisted of 36 workers from a lumber yard. Paired samples of scalp hair and blood were collected. PCB residues in the hair and blood plasma were extracted and analyzed by GLC with electron capture (EC) detection; rough quantitation was by evaluation of five peaks associated with Aroclors 1254 and 1260. The lower limit of detection was 1 ppb. Hematocrit, blood cholesterol, and blood pressure also were determined. PCB residues in the blood plasmas of the controls were detected in four workers and the maximum concentration was 4.2 ppb. Measurable concentrations of PCBs were found in the blood samples of 32 of the 37 refuse workers; the average and maximum concentrations were about 4 and 14 ppb, respectively. The concentrations of PCBs in plasma were not related to duration of exposure, age, or race. PCBs were not detected in hair samples (limit of detection, 1 ppb). Hematocrit, blood cholesterol, and blood pressure values did not change at different PCB concentrations.

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A survey of the health of 34 workers exposed to Aroclor 1242 during manufacture of capacitors was discussed by Ouw et al [196] in 1976. The Aroclor was an electrical-grade material that contained "no impurities." Breathing zone samples were collected in impingers containing isopropanol. It is not clear if all samples were collected from the breathing zones. Nineteen workers were assigned to fill capacitors with Aroclor 1242 heated to 70 C. These workers were exposed to PCBs at 1.08-1.44 mg/cu m. The other 15 workers, located in a different room, were assigned to assemble Aroclor-dipped capacitor components. These workers were exposed to PCBs at 0.32 mg/cu m. None of the 34 workers used protective clothing.

PCBs in the blood were separated by GLC and identified by their retention times relative to aldrin. PCBs were not detected in the blood of 30 control subjects. For the two groups of PCB-exposed workers, averages of measurable blood PCB concentrations are presented in Table III-8.

TABLE III-8

AVERAGE OF DETECTABLE BLOOD PCB CONCENTRATIONS (ppb)
OF TWO GROUPS OF WORKERS

Exposure Group	No. Workers	PCB Retention Time Relative to Aldrin 0.69	1.31	1.47	1.96
Fillers	19	602(19)*	314(17)	391(13)	475(4)
Assemblers	15	140(14)	100(14)	899(5)	(0)

*Numbers in parentheses are the numbers of workers in whom more than a trace of the PCB peak was detected.

Adapted from reference 196

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Distribution of PCBs in the blood of workers exposed while filling the capacitors differed from that of workers who assembled the components. The higher boiling components were present more frequently and to a greater extent in the fillers.

Twelve of the workers (5 of 19, and 7 of 15) complained of mild burning and irritation of the face, eyes, and skin, and 5 of these had eczematous rashes on the hands and legs. One filler had chloracne. Although individual abnormalities were found in SGPT, SAP, and bilirubin, the average values for the exposed workers were within normal limits. Bromsulphothalein retention tests were found to be elevated in four of the seven fillers whose blood PCB concentrations were >500 ppb. The investigators [196] reported no evidence of significant adverse responses to PCB exposure in the workers with blood PCB concentrations below 200 ppb.

Subsequently, "more efficient" exhaust ventilation was installed and the workers were advised to wear "suitable impervious gloves" [196]. Air measurements, made after the ventilation change, indicated that the fillers were being exposed to PCBs at 0.18-0.75 mg/cu m and the assemblers at 0.08 mg/cu m. These were substantial reductions. However, blood PCB concentrations that were found in 15 workers reexamined 2 months after the ventilation change did not show any substantial reductions. The investigators [196] speculated that this might have been because the workers did not strictly follow the recommendation to wear protective clothing.

Based on a search of chart records, Bahn (HA Sinclaire, written communication, June 1976) reported a preliminary study of the incidence of cancer in a group of 51 research and development employees and 41 refinery

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plant employees at a New Jersey petrochemical facility who were considered likely to have been exposed to Aroclor 1254 for various periods between 1949 and 1957. The eight cancers observed in the study population through December 31, 1975 were not significantly more than would be expected (5.7) in a similar sample of the US population [200]. However of the eight cancers, the three melanomas and the two cancers of the pancreas were significantly different from calculated expectations. Some findings of this preliminary investigation were described in a letter from Bahn et al [201] to the editor of the New England Journal of Medicine.

In this preliminary study, PCB exposure histories were based on recollections of two company employees. Exposures to other chemicals could not be ascertained. The expected cancer rates were based on US population data rather than on a rate for the locality of the petrochemical facility. To correct these deficiencies in the preliminary study, a more intensive investigation is being conducted (BN Kightlinger, written communication, November 1976). A substantial change has occurred in the cohort since release of the preliminary report by Bahn and her coworkers, and it seems likely that the findings on this new cohort will differ significantly from those of the preliminary study. The final report is not yet available.

In a study of current and former employees engaged in the manufacture of PCBs, no cases of malignant melanoma or pancreatic cancer were found from a review of the case histories of more than 300 employees (G Roush, written communication, September 1976). Seven cases of lung cancer were found from the death certificates of 50 former employees compared to an expected number of 2.7. The data are preliminary and were not corrected for age or smoking habits. The final report is not yet available.

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Animal Toxicity

Although there have been a few reports of dermal and inhalation experiments with animals, most of the information on animal toxicity has involved ingestion of PCBs in the diet or by intubation. Several animal experiments have involved oral administration of PCBs for the lifetime of the animal. These studies have demonstrated chronic changes in the microscopic anatomy of the liver and other organs, effects on reproduction, embryonic and fetal toxicity, effects on offspring from nursing, and carcinogenic and teratogenic responses.

(a) Inhalation and Dermal Application Studies of PCB Mixtures

Absorption and distribution of inhaled PCBs were studied by Benthe et al [97] in 1972. Groups of 4-6 male Wistar rats were exposed to aerosols of a commercial PCB mixture containing 42% chlorine, Pydraul A 200, commonly used in hydraulic fluids. Absorption and distribution of the PCBs were studied through the measurement of PCB concentrations in liver, brain, and adipose tissue. The aerosols were produced in an aerosol generator at 180 C. The aerosols were cooled, the larger particles were separated out, and the airborne PCBs were introduced into a chamber at a concentration of 30.4 ± 3.4 g/cu m. Groups of the rats were exposed for varying periods up to 2 hours. It was found that 15 minutes of exposure was sufficient to attain more than 50% of the PCB concentration of 69.7 μg/g liver wet weight that could be attained with 2 hours of exposure. Consequently, the investigators used an exposure time of 30 minutes to study distribution of PCBs to the tissues.

Immediately after 30 minutes of exposure, PCB concentrations were maximal, at about 52 μg/g liver tissue, whereas they were at low

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concentrations in the other tissues at 14 μg/g in adipose tissue, and 9 μg/g in brain tissue. After 24 hours the PCB level in the brain attained a maximum value of about 18 μg/g and within 36 hours the PCB concentration in the adipose tissue attained a maximum of about 250 μg/g. By 48 hours the concentrations of PCBs in the liver were reduced to about 3 μg/g and in the brain to about 5 μg/g, whereas the adipose tissue concentrations remained above 200 μg/g.

Experiments were reported by Rozanova [202] in 1943 in which rats were exposed to a technical mixture of "tetrachlorodiphenyl" and "pentachlorodiphenyl." The mixture, known as Solvol, was a transparent, colorless, oily, very viscous liquid used for filling capacitors. The "tetrachlorodiphenyl" component of the mixture had a distillation range of 220 to 245 C and the "pentachlorodiphenyl" component had a distillation range of 242 to 260 C. The animals were exposed in a 22-liter chamber through which air was drawn continually at a rate of 1-1.5 liters/minute, after first passing through a glass gooseneck containing the liquid PCBs. Air samples were taken from the chamber from time to time to determine the PCB concentrations. The analytical method was not reported.

Four rats exposed for 3 hours at about 10 mg/liter became uncoordinated and comatose and died within a day [202]. Autopsy findings included liver necrosis and fatty degeneration, cloudy swelling of the epithelial cells of the renal tubules, congestion in the heart and spleen, and necrotic signs in the spleen. Three rats were exposed repeatedly to vapors of Solvol at 0.5 mg/liter. One rat died after eight exposures, and the other two were killed after 11 exposures. Five other rats were repeatedly exposed at 0.25 mg/liter; one was killed after 16 exposures, and

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the others, which appeared to be in satisfactory condition, were killed after 69 exposures. In these chronically exposed rats, gross and microscopic findings were similar to, but less marked than, those found in the acutely exposed animals. In addition, hyperplasia of the Kupffer cells was found in the liver.

Treon et al [203] exposed groups of animals each comprised of 10 rats, 10 mice, 6 guinea pigs, 4 rabbits, and a cat to Aroclor 1242 or Aroclor 1254 vapors 7 hours/day, 5 days/week for up to 31 weeks. Aroclor 1242 exposures at concentrations of 8.6 μg/liter (0.83 ppm) for 3 weeks, 6.83 μg/liter (0.66 ppm) for 17 weeks, or 1.9 μg/liter (0.18 ppm) for 31 weeks. Exposures to Aroclor 1254 were at 1.5 μg/liter (0.11 ppm) for 31 weeks or at 5.40 μg/liter (0.41 ppm) for 17 weeks. No consistent changes in mortality, growth, pathology, organ size, liver function, or hematologic parameters were found in animals exposed to Aroclor 1242. The animals exposed to Aroclor 1254 vapors showed no changes in growth or mortality but microscopic evidence of apparently reversible hepatic cellular injury was found in all species except the cat at both exposure levels. Enlarged livers were found in the animals exposed at 5.40 μg/liter. An appreciable incidence of pneumonia was found among the exposed and control animals, a fact which could have confounded some of the results, but it is important to note that liver changes, including fatty degeneration, were found in exposed animals that were free of pneumonia.

Inhalation experiments with the commercial PCB product "Decachlorodiphenyl" were reported by Berczy et al [98,99] in 1974. The oral toxicity of this PCB product was investigated by Hunter et al [204], who administered it in the diet to Sprague-Dawley rats at 1,000, 2,000,

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5,000, and 10,000 ppm for 4 weeks. All animals fed Decachlorodiphenyl gained more weight than the controls and had greater liver to body weight ratios. Other effects observed at 10,000 ppm included increased spleen, thyroid, and kidney weights relative to body weights, reduced hemoglobin concentrations, and in males reduced rbc counts and hematocrits.

In one inhalation experiment [98], five male and five female rats were exposed for 6 hours to particles of the PCB product at an average concentration of 2.54 mg/liter. Seventy-eight percent of the particles were in the range of 1-5 μm in diameter, 17% in the range of 5-15 μm, and the remaining 5% were >15 μm. During exposure there were repeated episodes of blinking and sneezing. Signs of irritation disappeared after cessation of exposure. During the subsequent 14-day observation period, food and water consumption and growth of the rats were considered by the authors to have been similar to those of the controls. No gross pathological changes were seen when the rats were killed 14 days after removal from exposure [98].

Subsequently [99], three groups of rats, each consisting of 8 males and 8 females, were exposed 6 hours/day, 5 days/week for 4 weeks at average concentrations of 4, 80, and 777 μg/liter. A similar group of rats was used as a control. In this experiment, where 85-90% of the particles were in the 1-5 μm range and 1-3% were >15 μm, no signs of irritation were seen during the exposures at the lower concentrations and growth rates were normal compared to controls. At the highest concentrations, frequent blinking and sneezing were noted during the exposures, and the growth rate of the males was slightly retarded (final body weights of 395 g vs 435 g for controls). The liver weights, relative to body weight, were increased

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in males exposed at the highest concentration, and in females exposed at the medium and high concentrations. Microscopic findings in the livers of the rats exposed at the high concentration included occasional focal aggregations of mononuclear cells with either parenchymal or periportal distribution, and minimal degrees of periportal hepatocytic vacuolation, and decreased centrilobular or periportal glycogen. These findings were not considered by the authors [99] to be of toxicologic significance. A statistically significant decrease in packed cell and mean cell volumes was found in male rats exposed at the high concentration. In this group there was also a low white cell count due to a decrease in the number of lymphocytes, and increased thrombocyte activity. Blood glucose, SGOT, and serum sodium concentrations were decreased.

Von Wedel et al [205] described in 1942 the results of an experiment performed to determine the systemic effects of exposure of mice, guinea pigs, and rabbits, by inhalation, ingestion, and dermal application to an unspecified Aroclor. Concentrations and durations of exposure were not specified for the inhalation and ingestion experiments. However, 0.5, 1.0, or 1.5 ml of solutions containing 0.5 g Aroclor/ml were used for the dermal applications. Within 5 days after the dermal applications, small papules and blisters formed on the exposed skin areas and the external epidermal layers became desquamated. In addition, subacute yellow atrophy of the liver with some fatty infiltration was observed. Similar liver lesions were produced in the inhalation experiment.

In 1944, Miller [206] administered Aroclor 1242 to rats, rabbits, and guinea pigs by subcutaneous (sc) injection, by oral intubation, and by dermal and corneal application. The PCB doses ranged from single doses of

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69 mg to small drops (approximately 17 mg) applied daily to the cornea of rats for 25 days, to 1,380 mg injected daily into rabbits for 10 days. Fatty degeneration and atrophy of the centrilobular cells of the liver were the characteristic signs of toxicity. The greatest amounts of liver damage were seen in guinea pigs, less was seen in rabbits, and the least amount in rats, regardless of the dose, duration of exposure, or route of administration. Necrotic lesions were also seen in the skin of animals that received sc injections; signs of dermal irritation were seen after applications to the skin. The conjunctival tissue presented no gross changes when examined under magnification in the living animals. Since the pathologic changes in internal organs were similar regardless of method of administration, this experiment indirectly demonstrated that PCBs could be absorbed through the skin and the eye.

The effects of Solvol applied to the ears of rabbits were reported by Paribok [207] in 1954. Solvol was applied for 6 hours daily in doses of 0.7 to 3.76 g. A single application caused edema and inflammation of the ear, and one rabbit died 7 days after the application. With multiple doses, the animals died after 6-17 days. The dead animals, including the one that died after the single application, had fatty degeneration of the livers.

Vos and Beems [208] reported in 1971 on the dermal toxicity of PCBs in adult female New Zealand rabbits. Three commercial preparations of PCBs were used: Clophen A60, Phenoclor DP6, and Aroclor 1260. Twenty-seven 1-ml (118 mg) applications of each of these products (in isopropanol), 5 times/week over 38 days, to the clipped and shaved backs of the rabbits resulted in various manifestations of toxicity.

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In general, the toxic signs were most pronounced in the Clophen-treated animals and least pronounced with Aroclor 1260. Dermal findings included thickening of the skin due to hyperplasia and hyperkeratosis of the epidermal epithelium, and dilation and plugging of hair follicles with keratinous material. Microscopic study of liver sections showed a considerable diversity of lesions, including centrilobular degeneration, focal hydropic degeneration, focal necrosis, atrophy of centrilobular parenchymal cells, cytoplasmic hyaline degeneration, pigmentation of Kupffer cells, and, to a lesser extent, pigmentation of parenchymal cells. Renal damage was found in all PCB-treated animals. The most common findings were hydropic degeneration of the convoluted tubules, with nuclear pyknosis, and bursting and lysis of the tubular epithelial cells [208]. Dilation of the renal tubules, filled with casts of necrotic epithelial cells, was found in half the rabbits. These findings indicate that the dermal application of PCB mixtures causes systemic lesions of the liver and kidneys besides the direct effect on the skin. However, in other studies [19,21,23], it was determined that Clophen A60, Phenoclor DP6, and Aroclors 1248 and 1254 were contaminated, to varying degrees [21], with highly toxic tetra- and pentachlorodibenzofurans.

(b) General Effects of Oral Administration of PCB Mixtures

Single-dose oral LD50's of several PCBs reported in rats (JW Cook, written communication, June 1970) generally indicated that as the degree of chlorination increased, the acute toxicity decreased. The more highly chlorinated products (Aroclors 1248-1268) were of approximately equal toxicity (LD50's of about 10 g/kg), whereas the LD50's of the less highly chlorinated products (Aroclors 1221-1242) ranged from about 4 to 9 g/kg.

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The minimum lethal doses of these PCBs applied to the skin of rabbits were generally in the range of 1-2 g except for 1221 which was in the range of 2-3 g and 1268 which was >2.5 g.

The immunosuppressive activity of Aroclor 1260 was described in 1972 by Vos and de Roij [209] who fed three groups of 12 4-week-old female albino guinea pigs the PCB at 0, 10, or 50 ppm in their diets for 8 weeks. Aroclor 1260 was analyzed and found to be free of contamination with chlorinated dibenzofurans, although it appeared to contain a minor acnegenic impurity. In each group, six animals received sc injections of aluminum phosphate-adsorbed tetanus toxoid to stimulate the lymphoid system (antitoxin production). The other six animals in each group served as positive or negative controls. Cellulose acetate electrophoresis was used to determine serum proteins, including gamma-globulins. The gamma-globulin-containing cells in the popliteal lymph nodes were significantly reduced in the stimulated animals fed PCBs. Serum gamma-globulin levels were significantly decreased in the guinea pigs stimulated with tetanus toxoid and fed 10 ppm of Aroclor 1260 in their diet. Increased serum alpha-globulin levels were found in the stimulated guinea pigs fed either 10 or 50 ppm of the PCB, and significantly increased concentrations of albumin were found in the sera of both the stimulated and the unstimulated guinea pigs fed the PCB at 10 ppm. Also, both the absolute and relative weights of the cervical lymph nodes in the unstimulated group fed 10 ppm of Aroclor 1260 were significantly reduced whereas those of the mesenteric lymph nodes in the stimulated guinea pigs fed 10 and 50 ppm of PCB were significantly increased. These findings indicate that some immunosuppressive effect was produced by the feeding of PCBs. However, the

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decreases of the gamma-globulin levels were not found to be dose-related. No evidence of any PCB-induced change was observed in microscopically examined stained sections of liver, kidneys, adrenals, and skin.

Vos and Van Driel-Grootenhuis [210] reported their studies of the effects of PCBs on the humoral and cell-mediated immunities of guinea pigs in 1972. Three experiments were performed with different protocols. In the first experiment, the authors investigated the humoral immune response of guinea pigs fed 0, 10, 50, or 250 ppm of Clophen A60 in their diets and stimulated with a single sc injection of tetanus toxoid 3 weeks after the feeding regimen began. Suppression of humoral immunity was observed at the 50-ppm level. Microscopic examination of the livers revealed centrilobular degeneration, cellular atrophy, cellular necrosis, and nuclear enlargement. At the 250-ppm level, no antitoxin production was observed.

The diets of guinea pigs in a second experiment [210] contained 0, 10, or 50 ppm of Clophen A60 or 50 ppm of Aroclor 1260. Primary and secondary antigenic stimulations with tetanus toxoid were given after 3 and 5 weeks. The experiment lasted 6 weeks. Suppression of the humoral immune response was observed in groups fed 50 ppm of either PCB product. Decreases in the weights of the thymuses and increases in liver weights were observed at the 50-ppm Clophen A60 level and, to a lesser degree, at the 50-ppm Aroclor 1260 level. The residual liver concentrations of PCBs increased as the dose level and the duration of exposure increased.

In their third experiment, Vos and Van Driel-Grootenhuis [210] fed 30 guinea pigs diets containing Clophen A60 at 0, 50, or 250 ppm. After 3 weeks, the animals were challenged with 0.05 ml of Freund's complete adjuvant followed in 47 days by an injection of 0.1 ml of avian tuberculin

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antigen. The animals were killed 2 days later. All animals of the 250-ppm group died during the experiment, exhibiting retarded growth, atrophy and depletion of the lymphoid system, and liver damage. Significantly decreased thymus weights and increased liver weights also were observed, and total white blood cell counts were reduced significantly.

Bruckner et al [211] administered Aroclor 1242 to rats by oral intubation to determine its acute and subacute effects. Two groups of six rats each were given single doses of either 2.5 or 6.0 g/kg of Aroclor 1242. The initial effects observed at both dosages were the same for the first 4 hours, ie, diarrhea, decreased spontaneous activity and muscle tone, decreased response to pain stimuli and mild chromodacryorrhea. However, during the next 24 hours the group receiving 6.0 g/kg had profuse diarrhea, adipsia, oliguria, anorexia, erythema of the limbs, lack of response to pain stimuli, and general weakness. Eventually, ataxia, coma, and death followed. The condition of the rats receiving the lower dosage gradually improved after the first 24 hours and was normal at the end of 72 hours.

Another group of rats [211] that received single oral doses of 4 g Aroclor 1242/kg showed weight loss, elevated packed red cell volumes, increased serum polymorphonuclear leukocytes, crenated red blood cells, and increased SGOT activities. All organs appeared normal except the livers and kidneys. The livers exhibited foci of sudanophilic vacuolation. The kidneys showed widely scattered foci of vacuolated tubular epithelial cells.

In the subacute studies conducted by Bruckner et al [211], six rats were given 100 mg of Aroclor 1242/kg orally every other day for 3 weeks;

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three control rats received 100 mg/kg of peanut oil on the same schedule. Changes observed in the treated rats included increased liver weights, decreased packed red blood cell volumes, increased SGOT activities and marked increases in liver microsomal hydroxylating and N-demethylating enzyme activities. Microscopic examinations of the livers and kidneys revealed greater increases in generalized lipid vacuoles than had been found with the acute doses. When single ip doses of 100 mg Aroclor 1242/kg were given to rats, increased N-demethylase and aniline hydroxylase activities were observed after only 24 hours [211].

The effects of lower dietary levels of Aroclor 1242 on rats were reported by Bruckner et al [212], who fed it to groups of six male Sprague-Dawley rats at concentrations of 0, 5, or 25 ppm for 2, 4, or 6 months. Small reductions in hematocrit and hemoglobin levels similar to those found in other studies by Bruckner et al [211,213] were seen. Urinary excretion of coproporphyrin was significantly increased and dose-dependent increases in liver microsomal hydroxylase activity were measured at the time of each sampling. Similar dose-dependent relationships were found in other experiments [213,214]. Proliferation of the hepatic endoplasmic reticulum was seen after 2 months of ingesting a diet containing 25 ppm of Aroclor 1242; after 4-6 months of such ingestion, lipid vacuolization of the liver was evident.

In 1974, Bruckner et al [213] reported reduced weight gain, hepatic and renal damage, and an increase in urinary coproporphyrin excretion in rats injected ip with a total of 1.6 g/kg of Aroclor 1242 during a 10-week period. The hydroxylating and N-demethylating activities of the liver were significantly elevated 24 hours after a single ip injection of 100 mg/kg of

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Aroclor 1242, with hydroxylating activity showing the greater increase. Cytochromes P-450 and b5 and NADPH-cytochrome reductase activities of the liver all were significantly increased 3 days after dosing. A single dose of 50 mg/kg gave similar but less marked effects, whereas 25 mg/kg produced significant increases in only hydroxylating and N-demethylating activities.

Kimbrough et al [215] described in 1972 some effects of chlorobiphenyl mixtures on the livers of rats. Groups of 3- to 4-week-old male and female Sherman strain rats were given Aroclors 1254 and 1260 at 0, 20, 100, 500, and 1,000 ppm in their diets. Each group consisted of 10 males and 10 females. Food consumption was measured periodically. The animals were fed the PCBs for 8 months.

One female fed 100 ppm of Aroclor 1260 died after 6 months and two females fed 500 ppm died after 1 and 2 months. Eight females fed the 1,000 ppm diet died in 2-6 months. The rats fed 500 and 1,000 ppm gained less weight than did the controls. At autopsy, livers of the male rats fed Aroclor 1260 weighed significantly more than did livers of control male rats. Livers of the females were larger than normal but the weight differences were not statistically significant, although at 500 ppm the fractions of body weight represented by the livers increased significantly as a result of the reduced body weight gain. Microscopic findings in the livers included hepatocytic hypertrophy, inclusions in the cytoplasm, brown pigment in the Kupffer cells, lipid accumulations, and, at the higher dietary levels, adenofibrosis. The nodular greyish-white areas that represented extensive foci of adenofibrosis consisted of fibroblasts and collagen that surrounded rosettes of epithelial cells [215].

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Aroclor 1254 produced similar results [215]. One female and two male rats died at 500 ppm, but none died at the lower dietary levels, and the rats fed 500 ppm gained less weight than did controls. Ultrastructural changes in the livers of exposed animals consisted of proliferation of the smooth endoplasmic reticulum (SER) and atypical mitrochondria. Similar changes have been observed in other experiments with PCBs [131,212,216-218]. A major difference between the effects of the two products was the much higher incidence of hepatic adenofibrosis at a lower dietary level of Aroclor 1254 (100 ppm). In general, the effects of Aroclor 1254 on the liver were more pronounced than those of Aroclor 1260.

In 1973, Kimbrough et al [219] reported the results of a study conducted to determine whether morphologic changes produced in the liver would regress after ingestion of PCBs was stopped. Fifty male SPF Sherman strain rats were given Aroclor 1254 at 500 ppm in their diets for 6 months, and then were returned to normal diets. Groups of five rats were killed 0, 1, 2, 3, 4, 6, 8, and 10 months after ingestion of PCBs had been discontinued. The livers and adipose tissues of the 10-month group were analyzed for PCBs. Control animals were used in all evaluations and were fed only laboratory chow.

The livers of exposed animals killed when exposure to Aroclor 1254 was discontinued were enlarged and most of the 40 livers studied microscopically showed enlarged hepatocytes, increased lipid contents, and adenofibrosis. A brown pigment was seen in the Kupffer cells and in other macrophages of 15 livers. Small adenofibrotic lesions consisting of glandular epithelial cells that formed ducts surrounded by slight amounts of fibrotic tissue were seen; larger lesions had more extensive fibrosis

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and contained collagen. Similar findings had been reported earlier by Kimbrough et al [215] and both in the areas of adenofibrosis and in othewise normal hepatic tissue, Kimbrough [220] later reported finding small clusters of glandular type cells, resembling those of pancreatic tissue in general appearance and staining characteristics, in 15 of 36 rat livers with adenofibrosis. The cells stained red with the stain used for esterase, and developed a blue granular appearance with the stain used for protein bound tryptophan. These staining reactions were suggestive of those of salivary gland tissue to the author. The cells may have been derived from either ductal or vascular epithelium, but there is no evidence to substantiate either suggestion [220].

Signs of regression of the adenofibrotic lesions were not noted except for the disappearances of epithelial cells from the centers of the lesions [219]. Liver weights did regress to normal after 10 months without PCB exposure, but the lipid accumulation and the hypertrophy of the hepatic cells remained unchanged. Analysis of adipose tissues from the final group of rats killed showed that the PCB levels ranged from 924 to 1688 ppm (mean, 1192 ppm). Liver PCB levels ranged from 17.3 ppm to 26.2 ppm (mean, 22.7 ppm). The PCB concentrations in the adipose tissue and livers of the control animals were less than 1.0 ppm. The authors [219] were unable to decide whether contamination of Aroclor 1254 with dibenzofuran was responsible for the observed liver lesions [219].

Kimbrough and Linder [221] reported in 1974 the results of a PCB-feeding experiment which they undertook to induce adenofibrotic lesions in the livers of BALB/cJ inbred male mice, ie, lesions similar to those previously observed in rats fed Aroclors 1254 and 1260. Two hundred mice,

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5-6 weeks old, were distributed randomly into 4 groups of 50 each. Two groups were fed a ground diet containing 300 ppm of Aroclor 1254. At the end of 6 months, one of these exposed groups was placed on a PCB-free diet while the other exposed group continued on the test diet for another 5 months. The other two groups served as controls and were fed the plain ground laboratory diet for the entire 11 months. The average PCB intake was 49.8 mg/kg/day in the mice fed the PCB diet for the entire 11-month period.

Livers of 45 of the 58 surviving control mice were found to be normal. The other 13 had focal round-cell infiltrates and sometimes small areas of necrosis and fibrosis. Skin abscesses, usually near the groin, were identified in all 13 control mice with hepatic round-cell infiltrates. These skin lesions were thought to be abscesses of the preputial glands. In comparison, 10 hepatomas were identified in 9 of the 22 survivors in the group fed the PCB diet for 11 months. These tumors consisted of well-differentiated hepatocytes, relatively uniform in size but usually smaller than the surrounding liver cells. They were well circumscribed and surrounded by compressed hepatic parenchymal cells or strands of fibrous tissue. In the larger tumors, there were areas in which the sinuses were dilated and filled with a pink-staining amorphous material. No metastases were seen on gross inspection of the organs, although no detailed screening, such as serial sectioning of the lungs, was undertaken. Only one small hepatoma, composed of well-differentiated hepatocytes, was identified among the 24 survivors fed the PCB diet for only 6 months. The authors [221] noted that the mouse strain used in this study rarely develops hepatomas spontaneously.

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Adenofibrosis was identified in the livers of the mice subjected to the 11-month PCB diet. These lesions, according to the authors [221], may or may not be precursors of malignant lesions. They were seen in several areas of each liver as fibrosis and as glandular formations of proliferated epithelial cells replacing parenchymal cells. They formed ducts which produced mucus and which were surrounded by connective tissue of varying abundance.

Allen and Abrahamson [216] reported on morphologic and biochemical changes in the livers of rats given Aroclors 1248, 1254, and 1260 at 1,000 ppm in their diets for 6 weeks. A control group was fed unsupplemented chow. Each group contained 24 rats. Four rats were killed after 1,3,7,14,21, 28, and 42 days of exposure. White blood cells, hemoglobin (Hb), hematocrit (Hct), differential white cell count, total serum proteins, and blood urea nitrogen (BUN) were measured at each interval. Selected tissues were prepared for microscopic examination and the livers were homogenized and analyzed for cytoplasmic protein, DNA, and RNA. Liver microsomes were examined for aryl hydrocarbon hydroxylase, nitroreductase, N-demethylase, and nitrophenylacetate hydroxylase activities, and for cholesterol content.

All of the PCB-dosed rats failed to gain weight. The most severe effects were noted with Aroclor 1248, followed by Aroclors 1254 and 1262. All blood samples showed increases in Hb and Hct, with no changes in the white blood cell counts. Neutrophils were increased in the sera of all treatment groups. There were no changes in BUN or in total serum protein levels. Organ weights in all of the experimental rats constituted higher percentages of total body weights than in controls; the livers showed four-

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fold increases in weight in all PCB-dosed groups. The increased liver weights were discernible after only 1 day of exposure. Liver hypertrophy was attributed to proliferation of SER, development of large concentric arrays of membranes, and increases in lipid droplets within the cytoplasms of the affected cells. Aroclor 1248 was the most, and 1262 the least, toxic PCB product as judged by changes in liver histology. Liver homogenates contained increased concentrations of protein and RNA, and decreased concentrations of DNA. These changes were seen within 2 weeks after initiation of feeding Aroclors 1248 and 1254; the protein and nucleic acid concentrations then either leveled off or decreased after 4-6 weeks. Aroclor 1262, however, did not induce these effects until 4 weeks after the beginning of feeding; the initial changes were followed by reversals [216].

Liver microsomal fractions had increased protein and phospholipid concentrations. These changes occurred earlier in the rats fed Aroclor 1248 and 1254 than in the Aroclor 1262-fed animals. Microsomal nitroreductase activity, expressed on the basis of microsomal protein, was variable in the animals fed Aroclors 1248 and 1254; however, all animals fed Aroclor 1262 had progressive increases in nitroreductase activity. N-demethylase activity increased early in the experimental period and increased progressively in all treatment groups as the exposures continued. Aryl hydrocarbon hydroxylase, glucose-6-phosphatase, and other esterase activities increased initially, followed by continuous declines in activity in the groups fed Aroclors 1248 and 1254. The rats fed Aroclor 1262 had similar, but less marked, changes. When enzyme activities were expressed as activity per total liver, all showed marked increases. After 6 weeks, other degenerative changes in the liver occurred, such as dissolution of

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the concentric arrays of membranes, vesiculation of the endoplasmic reticulum, and accumulation within the cytoplasm of lipid droplets that had developed during the hypertrophic phase of the intoxication [216].

Allen et al [222] administered PCBs (Aroclor 1248) and polychlorinated terphenyls (Aroclor 5460) to rhesus monkeys. Sixteen male monkeys were distributed into three groups. Group 1 consisted of six animals and was fed a basal diet supplemented with 300 ppm of Aroclor 1248. Group 2 consisted of six animals fed a basal diet containing 5,000 ppm of Aroclor 5460. The remaining four monkeys constituted the control group and were fed the standard colony diet. Each animal had access to 400 g of diet daily. The physical status of the animals was evaluated daily and "complete" blood studies were performed biweekly. Approximately 10 g of liver tissue were removed from each animal during the 6th week (via laparotomy) and during the 12th week (at necropsy) for biochemical and microscopic evaluation.

Animals fed Aroclor 1248 lost an average of 26% of body weight; those receiving Aroclor 5460 lost an average of 19% of body weight. Gross changes seen in the animals fed Aroclor 1248 included loss of hair from head, neck, and back, puffy faces, edematous lips, and swollen eyelids with purulent exudates around the eyes. These changes were seen within 1 month; similar, but less marked changes were seen in the animals fed Aroclor 5460 [222].

Hematologic changes developed gradually. After 3 months, hemoglobins had decreased by about 2 g/100 ml, and hematocrits had diminished from about 40% to 33%. Total white blood cell counts did not change; however,

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there was a shift to the left in the differential count. Total serum proteins decreased by about 1.5-2 g/100 ml, and there was a gradual shift in the albumin/globulin ratio of the serum protein. No changes were seen in SGOT or BUN. Both experimental groups had similar patterns of changes [222].

At necropsy, both groups of animals showed extensive alopecia, acneiform lesions of the skin, subcutaneous edema, liver hypertrophy with fatty infiltration, and gastric mucosal hypertrophy and hyperplasia. Liver hypertrophy was attributed mainly to proliferation of the hepatocytic SER. Gastric hypertrophy was characterized by thickened gastric mucosa, numerous large cystic areas filled with mucin, and hyperplasia. Ulceration was seen, as was invasion of the underlying mucosa by glandular-type epithelial cells [222].

The authors [222] noted that, biochemically, the decreases observed in the DNA concentrations of the livers of both experimental groups reflected the hypertrophic cells observed microscopically, and the increases in protein and RNA were said to be compatible with the proliferated SER. Levels of microsomal protein per gram of protein were not markedly altered, but decreases in the specific activities of esterase, aniline hydroxylase, nitroreductase, and glucose-6-phosphatase became apparent within 6 weeks, and persisted. N-demethylase activity was increased at each examination.

The results of a toxicity study conducted on four young male rhesus monkeys fed Aroclor 1242 at concentrations of 3, 10, 30, or 100 ppm were reported by Bell [223], McNulty [94], and in a communication written in

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March 1977 by WP McNulty. All four monkeys on these diets died within 9 months. The monkeys had facial swelling, red and swollen eyelids, conversion of all secretory-type cells of the stomach to mucous cells, growth of mucous glands into the muscular walls of the stomach, multiple ulcers in the stomach, atrophy of the thymus gland, and either disappearance of sebaceous glands or conversion of these glands to keratin cysts, particularly in the eyelids.

Allen et al [104] and Allen and Norback [224] found gastric hypertrophy and hyperplasia and focal ulceration of the stomach lining in adult male rhesus monkeys fed single doses of 1.5 or 3.0 g of Aroclor 1248.

(c) Studies Involving Individual PCB Isomers

In 1972, Vos and Notenboom-Ram [225] discussed the comparative toxicities of dermally applied 120-mg doses of 2,2',4,4',5,5'-hexachlorobiphenyl and Aroclor 1260. The PCBs, dissolved in isopropanol, were applied 20 times to the clipped and shaved backs of three groups of four rabbits each, 5 times/week for 4 weeks. The control group received only isopropanol. The Aroclor 1260 sample was found to be "free" of chlorinated dibenzofurans (limit of detection, 1 ppm), and because of the nature of the chemical reactions utilized in the synthesis of 2,2',4,4',5,5'-hexachlorobiphenyl. Dermal applications of these PCBs resulted in early macroscopic skin lesions and morbid liver changes similar to those found by Vos and Beems [208]. These liver lesions included centrilobular degeneration and liver cell atrophy, focal cytoplasmic hyaline degeneration of the hepatocytes, enlarged nuclei, loss of glycogen and proliferation of SER. The authors [225] concluded that, although the

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major acnegenic action of crude PCB mixtures results from the presence of chlorinated dibenzofurans, PCBs have acnegenic actions of their own.

Hansell and Ecobichon [217] described the effects of a series of chemically pure chlorobiphenyls on rat liver morphology. Biphenyl and a series of isomerically pure mono-, di-, tetra-, hexa-, and octachlorobiphenyls of known composition were administered intraperitoneal (ip) injections in daily doses of 50 mg/kg to groups of seven young male Woodlyn strain Wistar rats for 3 consecutive days. The rats were killed 4 days after the final injections had been made and sleeping times after phenobarbital administration had been determined. The major microscopic alterations observed were proliferation of the hepatocytic SER, changes in the rough endoplasmic reticulum, and increased numbers of lipid droplets and microbodies. However, in the rats administered isomerically pure hexa- and octachlorobiphenyls, there were additional changes in hepatic morphology, including large numbers of hepatocytes with cytoplasmic vacuoles and small foci of necrosis involving five or six cells. Biphenyl and 2,2'-dichlorobiphenyl appeared not to induce extensive proliferation of the SER, but with the other compounds the SER proliferation appeared to be related to the degree of chlorination, especially to the presence of a chlorine in the 4 and/or 4' positions.

The investigators [217] also injected groups of seven rats ip with daily doses of 100 mg/kg of either 4-mono-, 4,4'-di-, or 2,5,2',5'-tetrachlorobiphenyl for 7 days; all rats from each group were killed 24 hours after the last injections. This regimen caused more pronounced alterations in hepatocytic ultrastructure than those observed after the 3-day experiments. Marked proliferation of SER and increased numbers of

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microbodies and lipid droplets were noted, as were a large number of necrotic foci, centrilobular necrosis, and proliferation of biliary ductules. The most severe lesions were seen in the group receiving 4,4'-dichlorobiphenyl. There was not the increase in hepatic weight and cell size noted by other authors [219,226]. Hansell and Ecobichon [217] observed that this apparent anomaly may have been due to the duration of PCB administration, only 3-7 days, and to the relatively low dosages.

Allen et al [226], in a series of experiments, studied the toxicity of 2,2',5,5'-tetrachlorobiphenyl in rats and rhesus monkeys. In the first experiment, 5-week-old rats were separated into five groups consisting of five males and five females each. After being fasted overnight, each of these groups was administered by gavage a single dose of one of the following amounts of the compound dissolved in corn oil: 0, 0.5, 1.0, 1.5, or 2.0 g/kg. Each dose had a total volume of 1 ml. After the dose had been given, blood was taken for complete blood counts. Eighteen of the 40 PCB-dosed rats died within 3 days. The dead animals included all those given 2.0 g/kg, 7 rats from the group given 1.5 g/kg, and 1 rat from the 1.0 g/kg group. The rats were observed for 21 days after which complete blood counts were performed and the surviving animals were killed and necropsied. The major pathologic changes observed in the animals that died were marked regressions of lymphocytes in the spleen and lymph nodes and of cortical thymocytes. With the exception of hemorrhage and atrophy of the thymus, which were related to the decrease in the cortical thymocytes, and enlargement of the liver and kidneys, all tissue samples were normal when compared with those from the nonexposed group.

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The second experiment was conducted to determine the effects of hepatic microsomal enzyme activity on the responses of male Sprague-Dawley rats to 2,2',5,5'-tetrachlorobiphenyl [226]. The rats were separated into 6 groups of 10 animals each. Group 1 was a positive control given four ip injections of 75 mg/kg of the microsomal enzyme inhibitor, SKF 525A, at 8-hour intervals. Group 2 was given four daily sc injections of 75 mg/kg of phenobarbital. Group 3 was the general control. Groups 4, 5, and 6 received 1.25 g/kg of the chlorobiphenyl in 1 ml of corn oil by gastric intubation; group 5 was dosed with the chlorobiphenyl 24 hours after 4 days with daily sc doses of 75 mg/kg of phenobarbital. Group 6 received 75 mg/kg of SKF 525A ip 2 hours prior to administration of 2,2',5,5'-tetrachlorobiphenyl, and every 8 hours thereafter for 24 hours. Within 4 days, all the rats in group 5 and 50% in group 4 had died whereas none had died in group 5, which was pretreated with phenobarbital. The findings that pretreatment with phenobarbital allowed complete survival of rats after an LD50 dose of the PCB, whereas pretreatment with SKF 525A caused 100% mortality, indicated to the investigators that metabolic transformation by endoplasmic reticulum enzymes resulted in deterification [226].

The third experiment was performed to compare the differences between the responses of rats to 2,2',5,5'-tetrachlorobiphenyl and Aroclor 1248 [226]. Twelve male rats were placed in three groups of four animals each; group 1 was fed 100 ppm of Aroclor 1248 in its diet, group 2 was given 100 ppm of the 2,2',5,5' isomer in its diet, and group 3 (control) was fed the staple ground meal diet. After 4 weeks of these feeding regimens, the rats were fasted for 24 hours, killed, and necropsied; blood was also collected

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at this time. There were no detectable differences in general appearance, food consumption, activity, growth rate, or blood chemistries between the two experimental groups and the control group. The only significant difference at autopsy was an increase in liver weight as a percentage of body weight of the animals fed Aroclor 1248: 4.46 ± 0.11%, compared with 3.38 ± 0.13% for those fed 2,2',5,5'-tetrachlorobiphenyl and 3.0 ± 0.12% for the controls. Proliferation of the endoplasmic reticulum within the hepatic cells was observed in the Aroclor 1248-fed animals. The N-demethylase activity and the cytochrome P-450 content of the microsomal fraction of homogenized liver from the Aroclor 1248-fed rats were increased whereas the activity of aniline hydroxylase and glucose-6-phosphatase in this fraction had decreased. There were increases in the concentrations of protein and RNA and a decrease in the DNA content of the liver homogenates from the Aroclor-fed animals. The livers of rats fed the isomer had similar but less marked changes in concentrations of protein, RNA, and DNA. The mean concentration of microsomal protein in liver was identical with that of the controls but was more variable. A significant increase in the mean activity of N-demethylase was found.

The fourth experiment [226] was performed to determine the effects of 2,2',5,5'-tetrachlorobiphenyl on non-human primates. Seven adult male rhesus monkeys were given 18 mg/kg of the PCB isomer dissolved in 2.5 ml of corn oil and three controls were given 2.5 ml of corn oil, all by gavage after a 24-hour fast. Complete blood counts had been done on each animal prior to intubation. Immediately after treatment, the animals were placed in metabolism cages and their urine and feces analyzed for 2,2',5,5'-

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tetrachlorobiphenyl by GLC. On the 14th day of the experiment the animals were fasted for 24 hours, killed, and necropsied. Tissues were taken for light and electron microscopy and GLC. No overt clinical effects were seen in the treated monkeys. Over 12% of the PCB was recovered unmodified in the feces but only minute amounts were present in the urine. Only the adipose tissue and adrenals had high PCB assays, and microscopically, except for a moderate proliferation of hepatocytic SER, all tissues were normal. DNA was slightly decreased in liver homogenates of exposed animals and hepatic microsomal cytochrome P-450 was increased.

Torok [227], in 1976, reported a study of pregnancy in NMRI mice treated with 2,2'-dichlorobiphenyl. The mice were separated into three groups, with group 1 (37 mice) serving as the control; group 2 (18 mice) received the PCB in oral doses of 375 mg/kg/day on days 1-3 of gestation, and group 3 (37 mice) received 750 mg/kg/day on the same schedule. Administration of the PCB at either level resulted in longer intervals from breeding to parturition: 18.2 days for controls, 19.4 days for mice treated with the PCB at 375 mg/kg/day, and 21.8 days in mice treated at 750 mg/kg/day. There also were reductions in the numbers of dams with litters and in the mean litter size. Reductions were greatest in group 3. The authors [227] concluded that the effects were due to delayed implantation.

(d) Reproductive and Teratogenic Effects of PCB Mixtures

Curley et al [101] studied the transplacental movement of PCBs in rats. Three groups of 90-day-old female rats were paired with male rats of the same age. All were fed standard laboratory chow by the authors, who designated the day of insemination as day 0. Aroclor 1254 was given in

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doses of 0, 10, and 50 mg/kg in peanut oil (presumably by oral intubation) once a day on days 7 through 15 of pregnancy to groups 1, 2, and 3, respectively.

On the 20th day after insemination, fetuses were taken by Caesarean section from three rats of each PCB-exposed group and from two control rats. The fetuses from each experimental group were divided into two lots and analyzed as duplicate samples for PCBs. Ten rats from each of the three experimental groups were allowed to deliver spontaneously. When the offspring were 5 days old, six mothers from each exposed group and two from the control group were separated from their litters for several hours and then returned for 1 hour of nursing. The contents (milk) of the pups' stomachs were analyzed for PCBs. Litters from three rats in each experimental group were allowed to survive until weaning at 21 days of age. These baby rats then were killed and their tissues analyzed for PCBs by GLC with EC detection [101].

The rats subjected to Caesarean section had normal fetal complements, in both size and number, and in the rats allowed to deliver spontaneously there were no significant differences in average litter size and weight among the three groups. However, the three groups, with 0, 10, or 50-mg/kg doses of Aroclor 1254, had 0, 1, and 4 stillbirths on the average, respectively [101].

Analyses of the tissues of the Caesarean-delivered pups showed measurable levels of PCB-derived components in the exposed groups only. The mean PCB concentrations were <0.12, 0.63 ± 0.06, and 1.38 ± 0.06 μg/g, respectively, for groups 1, 2, and 3. Although the PCB dose for group 3 was five times that of group 2 (50 vs 10 mg/kg Aroclor 1254), the average

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amount of PCB-derived components measured in the fetuses from these two groups differed by only two-fold. The authors suggested that the PCB distribution between the mothers and their fetuses may not have been uniform and that a partial (unspecified) barrier may have existed [101].

Livers were increased in size and had enlarged hepatocytes in 15 of 21, and 15 of 20 weanling rats from groups 2 and 3, respectively. Some rats from group 3 showed vacuolization of the hepatocytic cytoplasm (10 of 20), and 5 of 20 exhibited bile duct proliferation. Morphologic changes in the liver were more pronounced at the higher dose [101].

PCB-derived components were detected in litter-pooled milk at mean concentrations of <0.75, 20.60 ± 1.59, and 66.34 ± 8.36 μg/g in groups 1, 2, and 3, respectively. The authors [101] concluded that the morphologic changes identified in the livers of exposed weanling rats were probably caused by PCBs transmitted to the pups in the milk from the dams [101].

Reproductive effects of feeding Aroclors 1254 and 1260 to Sherman strain rats for two generations were reported by Linder et al [228] in 1974. In preliminary experiments, the two mixtures were fed to groups of 10 females at 100 and 500 ppm in the diet. Two similar groups served as controls. The diets, fed for 67 days before the first mating, were continued through gestation and lactation. After weaning of the first litters, the parents continued to be fed the diets. After being fed PCBs for a total of 186 days, they were again mated and the diets fed through the second gestation and lactation. Feeding Aroclor 1254 at 500 ppm resulted in only 4 first litters being born (2 alive), with no survivors to weaning. Consequently, feeding Aroclor 1254 at 500 ppm was discontinued. With Aroclor 1254 at 100 ppm, there was little indication from either the

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first or second mating of reduced fertility, or increased death in utero or during the nursing period. Aroclor 1260 fed at 100 ppm for 67 days had no apparent effect on reproduction, litter size, or survival of the first litters; however after being fed for 186 days, only 5 second litters were born from 9 mated females, compared to 9 out of 10 in the controls. At 500 ppm, Aroclor 1260 resulted in more pups dead at birth in first litters, reduced second litter size, and fewer litters being weaned (3 of 8 first litters; 2 of 6 second litters).

Subsequently, Linder et al [228] fed groups of 20 female Sherman rats Aroclor 1254 at 1, 5, 20, and 100 ppm and Aroclor 1260 at 5, 20, and 100 ppm. Appropriate control groups with similar numbers of rats were used. The experimental plan was similar to that described above except that the F1 generation pups continued to be fed the F2 generation diet until they reproduced the F2 generation. The first matings of the F1 generation were after they were exposed to PCBs in utero, in milk, and in the diet for 125-129 days. The F1 generation rats fed Aroclor 1254 at 20 and 100 ppm were mated a second time after a total of 274 days of PCB exposure.

Rats exposed to Aroclor 1254 at dietary levels of 20 ppm or more had fewer pups in their litters than the controls [228]. There were also fewer F2 generation pups than controls. Second litters born from rats fed 100 ppm of Aroclor 1254 had increased mortality and markedly decreased mating performance. 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 1 ppm of Aroclor 1254 and in either sex of F1 and F2 weanlings at 5 ppm or higher of both Aroclors 1254 and 1260.

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Villeneuve et al [229], in 1971, wrote about fetotoxic effects of Aroclors 1221 and 1254 in rabbits. Twenty-four mature female rabbits were divided into six groups each comprised of two control and four experimental does. Experimental animals were given the Aroclors orally at 1.0 and 10 mg/kg/day beginning after mating and continuing through gestation.z They were killed 28 days after mating. Neither Aroclor had a fetotoxic effect at either dose level. Liver weights expressed as percentages of body weight were significantly heavier in the does fed 10 mg/kg Aroclor 1254 than in controls (4.29 vs 2.79%). Liver weights of the other experimental does and of all fetuses were not significantly different from controls.

In another experiment reported by Villeneuve et al [230], 16 mature female rabbits were separated into four groups and, after mating, were dosed orally with 0, 12.5, 25, or 50 mg/kg of Aroclor 1254 daily for the first 28 days of gestation. The 50-mg/kg group had three pregnancies.z One pregnant female died on the 11th day and contained nine fetuses. A second one died on the 17th day and contained six resorption sites. The third female aborted three dead fetuses on the 28th day. Two rabbits in the 25-mg/kg group had normal fetuses. A third rabbit aborted her litter on the 28th day and died. The four animals in this group showed an average weight loss of 26 g and liver weights found at autopsy 29 days after mating averaged 5.11% of their body weights. Autopsies were performed on the fetuses of the two rabbits which had conceived in the 12.5-mg/kg group; the first rabbit had two normal fetuses, with six resorption sites, while the second aborted two fetuses on the 27th day and was found on autopsy to contain one partially resorbed and two dead fetuses. The two dead fetuses obtained on autopsy showed subcutaneous cephalic hemorrhages and had

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asymmetric skulls. Average weight gain of the females during pregnancy was 265 g, and their liver weights averaged 6.03% of their body weights. Controls gained 654 g during pregnancy, and their livers averaged 2.66% of their body weights.

In their third experiment, Villeneuve et al [230] gave each animal in three groups of six female rabbits 25 mg/kg Aroclor 1254 in corn oil (orally). Controls received corn oil alone. A control group and one exposure group were dosed from day 1 through day 28, and another control and an exposure group were dosed from day 7 through day 28. Administration of Aroclor 1254 at 25 mg/kg/day from day 1 through day 28 resulted in abortions in two of four rabbits. Their average weight gain was 245 g and liver weights averaged 6.03% of their body weights (controls, 531 g weight gain; liver weights, 2.65% of body weight). In the second group administered PCBs, one of four rabbits aborted. Average weight gain was 156 g and the liver weights averaged 4.82% of the body weights.

PCB concentrations in various tissues of six rabbits and their fetuses, chosen at random from the above groups, were determined by Grant et al [231]. Concentrations of PCBs were higher in the livers of the fetuses than in their mothers: 5.4 vs 2.1 ppm at a dose of 1 mg/kg; 78.1 vs 69.5 ppm at 12.5 mg/kg; and 375.3 vs 124.2 at 25 mg/kg. In other tissues, PCB concentrations were generally less in the fetuses than in the dams.

Allen et al [232] in 1974 presented evidence of possible fetotoxicity in a short term PCB feeding experiment with 12 adult female rhesus monkeys. The monkeys ranged in age from 7 to 10 years and had an average weight of 5.6 kg. Each previously had delivered at least one infant and the menstrual cycle of each had been recorded for at least 2 years. Six of the

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monkeys were fed an unspecified diet containing 25 ppm of Aroclor 1248 for 2 months. The other six monkeys were controls. After 2 months, the PCB-exposed animals were placed on PCB-free diets of commercial monkey chow.

The monkey which had consumed the largest amount of PCBs died on the 128th day of the experiment [232]. At the beginning of the 5th month, ie, 3 months after the test animals had been removed from the PCB-containing diet, the remaining five test monkeys and the six controls were mated again. Three PCB-exposed monkeys were thought to have conceived since each showed the characteristic post-conceptual bleeding, lack of the subsequent menstrual period, and an enlarged uterus. Two either aborted or reabsorbed their fetuses during the 2nd month of pregnancy and the third monkey delivered a well-developed but smaller-than-normal (375 g ± 1 g vs 544 g ± 101 g) infant. High concentrations of PCBs were found in the adipose tissues and adrenals of this infant with means of 27.7 and 24.4 μg/g, respectively, as compared to a range from 0.01 to 0.98 μg/g in the other infant tissues analyzed. The PCB levels in the placenta averaged 0.9 μg/g, and 50 μg/g in the mother's adipose tissue. Two additional attempts were made to breed the nonpregnant females during the next 5 months. Only the controls became pregnant and all delivered normal infants. Six of the monkeys were fed an unspecified diet containing 25 ppm of Aroclor 1248 for 2 months. The other six monkeys were used as controls. After 2 months, the PCB-exposed animals were placed on PCB-free diets of commercial monkey chow.

In 1976, Barsotti et al [233] and Allen and Barsotti [234] reported their findings on reproductive dysfunction in female and male adult rhesus monkeys fed Aroclor 1248 in their diets. One test group of female monkeys

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received 2.5 ppm and the other group received 5.0 ppm of Aroclor 1248 in a commercial diet. The control group, containing 12 females and 6 males, was fed the commercial diet alone. Females received 200 g, and the males received 300 g of their respective diets daily. Food left in the feeding cups at the end of the day was removed and weighed to determine the daily intake. After the end of the first 6 months, the average PCB intakes were 180 and 364 mg for females fed the 2.5- and 5.0-ppm diets, respectively [233].

Some of the exposed females began to exhibit the characteristic skin and blood chemistry signs of PCB intoxication within 2 months. At 6 months, all exhibited these signs in varying degrees. Menstrual cycles were irregular and menstrual bleeding was excessive and prolonged [233].

The conception rates for the control females and for those fed the 2.5-ppm Aroclor diet were 12 of 12 and 8 of 8, respectively, whereas 6 of 8 females fed the 5.0-ppm Aroclor diet conceived [233]. All 12 of the control group pregnancies resulted in normal births, compared to 5 and 1, respectively, for the exposed females fed the 2.5- and 5.0-ppm diets. Three of the eight fetuses of monkeys fed the 2.5-ppm Aroclor diet were resorbed shortly after conception. Profuse uterine hemorrhaging was observed rather than the implantation bleeding which usually occurred 17 days after conception, according to the authors [233]. The two females from the group fed the 5.0-ppm diet who did not conceive initially were bred five times without success. Of the six females of this group that did become pregnant, three aborted at 46, 67, and 107 days of gestation; one fetus was resorbed, one was stillborn, and one delivered normally. The six live infants born to PCB-fed mothers had body weights that were less than

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normal for the colony by one to two standard deviations. These infants began showing signs of PCB toxicity (acne, swollen eye lids, increased skin pigmentation) after nursing their mothers for less than 2 months [234]. In samples obtained from three of their mothers after the infants developed the poisoning signs, the milk contained PCBs at 0.154-0.397 ppm, and the milk fat from a fourth mother contained 16.44 ppm. Three of the infants died 44-112 days after birth.

The effects of Aroclor 1254 on reproductive performance and fetal integrity were evaluated in beagle dogs and Hormel miniature swine by FL Earl et al (written communication, 1976). Aroclor 1254 was administered orally in capsules as a solution in corn oil to 46 purebred beagle bitches once daily after the 1st day of gestation. Ten bitches were given 0.25 mg/kg/day, 16 were given 1 mg/kg/day, and 20 were given 5 mg/kg/day. Sixteen untreated bitches served as controls.

The data presented show that Aroclor 1254 at 5 mg/kg/day significantly interfered with reproductive performance and was teratogenic in the beagle. When Aroclor 1254 was administered at 0.25 and 1.0 mg/kg/day, no effects on reproduction were observed but the incidence of patent fontanelles in the offspring of the 1.0-mg/kg/day group was increased sharply. Dosage at 5.0 mg/kg/day resulted in 45.5% resorptions (4-fold increase over the control rate) and an average of only two live pups per litter. Patent fontanelles were present in 50% of the offspring.

Earl and his coworkers fed Aroclor 1254 to Hormel miniature swine in doses of 1.0 (4 sows), 10.0 (6 sows), and 30.0 (7 sows) mg/kg/day for 21 days before breeding and throughout gestation. Five sows served as controls. The 1-mg/kg/day dose produced a statistically significant

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percentage of fetal resorptions (23%). Increasing the dose to 10 mg/kg/day lowered the fertility rate to 50% (80% in controls) and increasing the dose to 30 mg/kg/day lowered the fertility rate to 43%. Cleft palate and syndactyly in three feet were observed in one fetus from the group fed 10 mg/kg/day. At this dose level, there was also a significant decrease in survivability with only 71% of the offspring alive after 5 days. At the 30-mg/kg/day dose, 14 of the 15 implantations were resorbed and teratogenic abnormalities were present in 100% of the observed fetuses. Cleft palates, syndactyly, and patent fontanelles were the teratogenic effects observed. The fact that pigs are normally born with closed fontanelles increases the signficance of the teratogenic findings.

(e) Studies on Mutagenicity and Cytotoxicity

To evaluate the effects of PCBs on the testes of rats, Dikshith et al [235] administered, by oral intubation, 50 mg/kg/day of Aroclor 1254 dissolved in corn oil to a group of 18 adult male Sprague-Dawley rats for 7 consecutive days. A control group of 18 rats received corn oil without PCBs. Three rats from each group were killed 1, 7, 15, and 30 days after the last PCB administration. The testes and epididymises were separated and weighed, as were the livers. Microscopic, histochemical (acid phosphatase), and cytogenetic examinations were performed. Rats used for cytogenetic examination were injected ip with colchicine 2 hours before being killed and the chromosomes in testicular tissues were examined.

No effects on weight or gross appearance of either the testes or epididymis were noted, nor was there evidence of atrophy or hypertrophy of the testes. The only structural changes noted in the testes of the exposed group was a proliferation of interstitial tissue cells. These cells showed

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an increase in acid phosphatase activity, which, according to the authors [235], denoted a change from particulate enzyme localization in testicular interstitial cells of the controls to a disseminated, diffuse localization in the testes of the exposed group.

Cytogenetic analyses showed similar chromosomal configurations in both the control and the exposed groups. In the PCB-treated rats, some apparently sporadic abnormal chromosomes were seen in a few of the metaphase figures; chromosomal abnormalities also included breaks, exchange figures, chromatin bridges at anaphase, and chromosome fragments. The significance of these findings was unclear to the authors [235].

Green et al [236] looked for mutagenic effects in the bone marrow and spermatogonial cells of male Osborne-Mendel rats fed various doses of PCBs. Rats were given Aroclor 1242 either in single oral doses of 1,250, 2,500, or 5,000 mg/kg or in multiple oral doses of 500 mg/kg/day for 4 days. Aroclor 1254 was administered orally in daily doses of 75, 150, or 300 mg/kg for 5 days. The Aroclors were mixed with corn oil, except the 5,000-mg/kg dose of Aroclor 1242, which was given undiluted. Controls were fed uncontaminated corn oil. The animals were given Colecimid (a colechicine derivative) at 4 mg/kg 24 hours after PCB dosing was completed and they were killed 3 hours later.

Aroclor 1242 produced no statistically demonstrable evidence of chromosomal damage in bone marrow cells at doses of 1,250 or 2,500 mg/kg, or at the 500-mg/kg dose level [236]. At 5,000 mg/kg, there appeared to be an increase in the number of chromosomal abnormalities. However, since most of the changes occurred in one animal, the findings were not considered to be significant. Aroclor 1254 did not produce statistically

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significant numbers of chromosomal abnormalities in bone marrow cells at any dose level tested. A statistically significant number of chromosomal abnormalities was not identified in spermatogonial cells from rats fed Aroclor 1242. Spermatogonial cells from rats given Aroclor 1254 were not examined since the results with the more acutely toxic Aroclor 1242 were negative. All observed chromosomal lesions were single chromatids. The authors [236] did not exclude the possibility of point mutations since the procedures used in this experiment would not have detected such damage.

Green et al [237] also investigated the possible induction of dominant lethality in rats given Aroclor 1242 or Aroclor 1254 by oral intubation. Except for the positive controls, results showed nonreproducible positive effects that were not related to dose or stage sensitivity. The authors concluded that the two Aroclors did not appear to be mutagenic.

Wyndham et al [116] performed the "Ames" bacterial test for mutagenicity on a variety of PCBs, using Salmonella typhimurium mutant strain TA1538. A comparison was made of the mutagenic potentials of Aroclor 1254, 2,2',5,5'-tetrachlorobiphenyl, Aroclor 1268, Aroclor 1221, and 4-chlorobiphenyl. The results showed clearly that as the degree of chlorination decreased, the mutagenic potential increased. A concentration of 100 μg of 4-chlorobiphenyl in the test medium gave over 2,000 revertant colonies/plate. The more highly chlorinated biphenyls showed very little activity as mutagens.

Hoopingarner et al [238] studied the toxicities of various Aroclors at 50 ppm in the culture medium of Chinese hamster cells, and found increasing toxicity (measured by cell population survival) with decreasing

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chlorination. Aroclor 1016 appeared to be disproportionately cytotoxic, on the basis of its chlorine content, suggesting to the authors that this product contained certain toxic components in higher proportions than either Aroclor 1232 or Aroclor 1242, which it resembled chromatographically. Aroclor 1254 at 100 ppm showed no apparent effect on the chromosomal integrity of human lymphocytes in vitro.

Popper et al [239] studied the effect of hepatic microsomal biotransformation systems from control mice and from mice treated with PCBs on the mutagenic potentials of the primary carcinogen N-methyl-N'-nitro-N-nitrosoguanidine (MNNG), and the secondary carcinogen dimethylnitrosamine (DMN). Hepatic microsomes were isolated from male Swiss-Webster mice that had been given 500 mg/kg of Aroclor 1254 4 days earlier, and from untreated control mice. The mutagenicities of MNNG and DMN were assayed by a bacterial auxotroph reversion test using Bacillus subtilis.

Microsomes prepared from the livers of the PCB-treated mice had 2-3 times as much cytochrome P-450 activity as the controls [239]. DMN added directly to the cultures was not mutagenic at concentrations as high as 300 mM. However DMN was converted to a mutagen when exposed to such microsomes in the presence of an NADPH-generating system. When MNNG was incubated with isolated microsomes, its mutagenic activity was reduced. The authors concluded that isolated hepatic microsomes can modify the biologic activities of mutagens and that the hepatic microsomal biotransformation system could play a key role in chemical mutagenesis.

(f) Studies on Tumorigenesis

Kimbrough et al [218] distributed 400, 21- to 26-day-old weanling, Sherman strain, "COBS" female rats randomly into two equal-size groups.

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Half of the rats were fed a plain commercial laboratory chow. The other 200 were fed laboratory chow containing 100 ppm of Aroclor 1260. The dosed group of rats was fed the PCB diet until 6 weeks before they were killed at the age of 23 months. Autopsies were performed on these rats as well as those that died before the exposures ended.

Microscopic examination was completed on 184 dosed animals and 173 controls. From a few to multiple elevated tan nodules were found on the liver surfaces of 170 PCB-fed rats. The nodules varied from 0.1 to several cm in diameter. Only one such abnormality was found in the controls. Of the tumors, 26 of those in exposed animals and the 1 from the control animal were hepatocarcinomic; the other 144 experimental animals had hepatocellular nodules that were described as characteristic of neoplastic nodules or synomously, hyperplastic nodules. The authors [218] said "neoplastic nodules are part of the spectrum of response to hepatocarcinogens and must be included in the evaluation of tumorigenesis." Tumors identified and analyzed from other organs had no unusual features; no apparent differences in incidence were observed between the experimental and control groups [218].

Evidence of PCB-induced hepatocarcinomas was reported by a group of Japanese investigators in 1972 [240] and in 1973 [241]. Nine groups of 12 male dd mice were fed a commercial stock diet supplemented with 100, 250, or 500 ppm of Kanechlors 300, 400, or 500. A control group of eight mice was fed the stock diet. All mice were given water ad libitum. After 32 weeks, the animals were starved for 18 hours, killed, and examined macroscopically for tumors. Seven of the 12 mice fed Kanechlor 500 at 500 ppm developed hyperplastic liver nodules and five had well-developed

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hepatocellular carcinomas. None of the mice fed Kanechlor 500 at lower concentrations or Kanechlor 400 or 300 at any concentration developed hepatocarcinomas.

In 1973, Kimura and Baba [242] described neoplastic changes in the livers of rats exposed to Kanechlor 400. Thirty 10-week-old rats were separated into an experimental group of 10 males and 10 females and a control group of 5 males and 5 females. The experimental group was fed a diet supplemented with olive oil containing various concentrations of Kanechlor 400. The control group received an olive oil-supplemented diet. The diet of the experimental group of rats contained 38.5 ppm of Kanechlor 400 for the first 4 weeks, followed by 77 ppm for 8 weeks, 154 ppm for 3 weeks, 308 ppm for 3 weeks, and 616 ppm for 8 weeks. Body weights were checked weekly and showed rapid decreases during the 616-ppm feeding period; for this reason the Kanechlor 400 content of the diet was reduced to 462 ppm for the next 32 weeks. The total feeding period for the experimental and control animals was about 58 weeks (400 days).

All rats that ingested total doses of more than 700 mg of Kanechlor 400 developed hypertrophy of the liver [242]. Pale brown nodules were present on the parietal and cut surfaces of the livers of female rats that had ingested more than 1,200 mg of PCBs. However, none of the male rats had such hepatic nodules, despite having ingested equal or greater amounts of Kanechlor 400. On microscopic examination, the livers of female rats were observed to have fatty degeneration and multiple adenomatous nodules that appeared to be benign neoplastic lesions. Males did not develop such neoplastic lesions; however, their livers did exhibit fatty degeneration. Lung abscesses, pneumonia, splenic atrophy, and intracranial abscesses were

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found frequently in the experimental group. The authors [242] thought that resistance to infection was lowered in the rats fed Kanechlor 400.

A formal rulemaking hearing was convened August 20, 1976 by the US Environmental Protection Agency on its proposed toxic pollutant water effluent standards for PCBs (Federal Register 42:6532-55, February 2, 1977). Part of the testimony concerned comparative studies in which groups of 100 male and female Charles River rats were fed 1, 10, and 100 ppm of Aroclors 1242, 1254, or 1260 for 24 months. The survival of the rats was poor and the experiment was said to have been inconsistently reported. A reevaluation of the pathology slides revealed the occurrence of liver tumors (hepatomas and cholangiohepatomas) in the rats fed any one of the three Aroclor products. The incidence of liver tumors in the rats dosed at 100 ppm was 3/20 for Aroclor 1242, 6/27 for Aroclor 1254, and 7/27 for Aroclor 1260, compared with 0/20 for the controls. In addition to the tumors there was a high frequency of nodular hyperplasia. The incidence of nodular hyperplasia at 100 ppm was 8/20 for Aroclor 1242, 13/27 for Aroclor 1254, and 7/27 for Aroclor 1260, compared with 1/23 for the controls. Nodular hyperplasia in the rats dosed at 10 ppm occurred in 2/10 for Aroclor 1242, 3/26 for Aroclor 1254, and 9/23 for Aroclor 1260, and 1/23 for the controls. The incidence of tumors of the pituitary gland also was elevated in each treated group.

Correlation of Exposure and Effect

(a) Absorption, Metabolism, Excretion, and Body Burdens

It has been demonstrated in experimental animals that PCBs can be absorbed into the blood from inhaled air [97] and from the digestive tract

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[50,51,95,96]. Qualitatively, the effects in experimental animals from absorption by either route were similar [98,99,202-206]. When PCBs were applied to the skin, certain effects, such as those on the liver, were similar to those obtained when PCBs were ingested or inhaled [205-208]. Thus, it appears that PCBs were also absorbed by this route.

In experimental animals, most PCB isomers were metabolized in varying degrees to more polar compounds such as hydroxylated derivatives [41,48,49,51-56,58-81,85,87]. The more highly chlorinated isomers were metabolized slowly and accumulate in the tissues [41,50,51,55,61-64,66,82-84,96,103,107-110]. The hydroxylated derivatives were excreted in the bile, urine, and milk [41,48,50-56,58-61,63-66,69,71-80,85]. Unmetabolized compounds were excreted in feces, milk, and hair [41-44,50,51,53-56,100-102], and traces were found in urine [42,51-55,57-62,103-105].

In man, the metabolism of PCBs has not been studied. However, finding that PCB isomers that are difficult to metabolize become concentrated in residual PCBs of tissues from the general population, from persons who have ingested PCBs, and from those with occupational exposure suggests that man metabolizes, eliminates, and stores the compounds in ways similar to those of animals [7,36,136,168,171-175]. Determinations of PCBs or their metabolites in urine or feces of humans have not been reported. PCBs have been found in human hair [102,142]. Excretion in human milk of PCBs with compositions similar to those in blood, has been reported in association with general environmental exposures and following ingestion and occupational exposures [143,144,168,192]. These findings of PCBs in human hair and milk also suggest metabolism and excretion similar to those of animals.

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Because PCBs are widespread in the environment, detectable concentrations have been found in tissues and body fluids of a substantial portion of the US population [36,102,134,135,137,140,144]. Detectable concentrations have been found in up to 62% of blood serum samples, with concentrations ranging up to 30 ppb [137]. In emaciated patients, blood PCB concentrations as high as 100 ppb have been found [140]. PCB concentrations in about three-fourths of adipose tissue samples from the general population were <1 ppm, and the remainder were mostly in the range of 1-2 ppm [36,136]. Usually the PCB isomers found in blood and adipose tissue have been penta-, hexa-, and heptachlorobiphenyls [7,135,136], and a high correlation was found between the concentrations in these two tissues [141]. PCB isomers in cord blood were qualitatively identical to those in maternal blood [138]. PCB isomers excreted in human milk were similar or identical to those in blood [168], and the concentrations in milk were positively correlated with adipose tissue concentrations [143]. In human milk samples from the general US population, PCB concentrations up to 13 ppm (fat basis) have been reported (EP Savage, written communication, February 1977).

These concentrations of PCBs in blood, adipose tissue, and milk of the general US population arise from dietary intakes estimated to be of the order of 10-20 μg/day [46] and from inhalation of air that may contain up to 100 ng/cu m [26,38].

(b) Irritation Effects and Chloracne

The first reports of adverse effects of PCBs on workers included chloracne [120,123,130], digestive disturbances [123], irritation of mucous membranes [120,123,130], and impotence [123]. The exposures associated

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Because PCBs are widespread in the environment, detectable concentrations have been found in tissues and body fluids of a substantial portion of the US population [36,102,134,135,137,140,144]. Detectable concentrations have been found in up to 62% of blood serum samples, with concentrations ranging up to 30 ppb [137]. In emaciated patients, blood PCB concentrations as high as 100 ppb have been found [140]. PCB concentrations in about three-fourths of adipose tissue samples from the general population were <1 ppm, and the remainder were mostly in the range of 1-2 ppm [36,136]. Usually the PCB isomers found in blood and adipose tissue have been penta-, hexa-, and heptachlorobiphenyls [7,135,136], and a high correlation was found between the concentrations in these two tissues [141]. PCB isomers in cord blood were qualitatively identical to those in maternal blood [138]. PCB isomers excreted in human milk were similar or identical to those in blood [168], and the concentrations in milk were positively correlated with adipose tissue concentrations [143]. In human milk samples from the general US population, PCB concentrations up to 13 ppm (fat basis) have been reported (EP Savage, written communication, February 1977).

These concentrations of PCBs in blood, adipose tissue, and milk of the general US population arise from dietary intakes estimated to be of the order of 10-20 μg/day [46] and from inhalation of air that may contain up to 100 ng/cu m [26,38].

(b) Irritation Effects and Chloracne

The first reports of adverse effects of PCBs on workers included chloracne [120,123,130], digestive disturbances [123], irritation of mucous membranes [120,123,130], and impotence [123]. The exposures associated

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terphenyls was used; the PCB used in the other process [189] was not described, but extensive skin exposure from wearing PCB-soiled clothing and from immersion of unprotected hands into the PCB mixture was described.

A case of chloracne that developed in an Australian worker after exposure to Aroclor 1242 at concentrations of 1-2 mg/cu m was reported by Ouw et al [196]. The PCB preparation was heated during a capacitor-filling process. Complaints of process workers included irritation of the face, eyes, and skin. Eczematous rashes were also found on their hands and legs.

In the reports of chloracne development in occupations involving PCBs (where environmental concentrations of PCBs were measured) [125,130,186-189,196], the sampling and analytical methods did not distinguish between vapor and particulate forms of the PCBs. However, a common factor in many of these reports [186-189,196] was the use of heat in the process which would tend to generate PCB vapors.

In their study of capacitor and PCB manufacturing plants in Japan, Hasegawa et al [191] found that concentrations of PCB vapors (or particles <0.1 μm in diameter) exceeded the concentrations of PCBs in particles >0.1 μm in diameter. The compositions of PCBs in the particulate were similar to those in the PCB preparations in use, but the less highly chlorinated compounds were concentrated in the vapors. In this study, where PCB vapors ranged from 0.026 to 0.965 mg/cu m and PCBs in the larger airborne particulates ranged from 0.19 to 0.650 mg/cu m (maximum total PCBs of 1.6 mg/cu m), dermal ailments included a brown chromodermatosis of the hands and chloracne. The workers had been exposed to PCBs from <1 to 20 years.

Meigs et al [190] described a process in which chloracne developed where the exposures had to have been to PCB vapors. The PCB which was used

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as a heat-exchange medium was not described, but PCB concentrations were reported to be about 0.1 mg/cu m in the workroom air where the workers were exposed. Under these conditions, chloracne developed after a minimum of 5 months of exposure.

Chloracne has also been studied in connection with determinations of PCB concentrations in blood. Hara et al [192,193] found whole blood PCB concentrations of 7 to 300 ppb in Japanese workers engaged in capacitor filling. About 40% of these workers had chloracne and 13% had irritation of the skin. Kitamura et al [194] found PCBs at 320-820 ppb in blood samples from Japanese workers engaged in capacitor manufacture. Skin ailments, including chloracne, were found in 10 of 13 workers studied. Inoue et al [195] found chloracne in a man exposed to PCBs in a silk-glossing factory who had a concentration of about 200 ppb of PCBs in his blood, but they [195] found what were described as relatively mild skin abnormalities in 28 other workers engaged in similar processes who had blood PCB concentrations mostly under 100 ppb (2 had concentrations >100 ppb). Ouw et al [196] concluded from their study of capacitor workers that no adverse effects were found in workers with blood PCB concentrations <200 ppb.

Studies of PCB-exposed workers where chloracne has not been found include those of Levy et al [197], Karppanen and Kolho [198], and Bumgarner et al [199]. In the study by Karppanen and Kolho [198], workers who had been exposed to PCBs for 4 years in a capacitor-impregnating operation had PCB concentrations of 74-1,000 ppb in samples of their blood. The environmental exposure concentrations of PCBs were reported to meet "internationally accepted standards." Other factors of the work situation,

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such as the skin protection used, were not reported. In the study by Levy et al [197], workers who had been exposed to PCBs for 2.5-18 years had concentrations of PCBs in samples of their blood ranging from 36 to 286 ppb. PCB exposure concentrations at the time of the study were 0.013-0.264 mg/cu m. Although some of the workers complained of throat or eye irritation, and some skin rashes were found, no cases of chloracne were seen. From the description of the work situation, it is unlikely that skin exposure to liquid or solid PCBs was an important factor in the total exposure of these workers. In their study of refuse workers, Bumgarner et al [199] found blood PCB concentrations to be 4-14 ppb. One possible source of exposure of these workers was airborne incinerator effluents, and it is unlikely that additional exposure from skin contact occurred.

Although skin exposure was unlikely in these two reports [197,199] where chloracne was not found, skin exposure is not necessary for chloracne to develop. Chloracne has been observed in Japanese people estimated to have ingested total PCB doses of 0.3-4 g [146,164-167], and chloracne-like lesions have been produced in experimental rhesus monkeys fed PCBs at 3 ppm in their diets [222].

Thus, although eliminating exposure of the skin through engineering controls and using appropriate protective clothing and work practices will reduce the total absorption of PCBs, these practices will not necessarily eliminate chloracne. The data indicate that chloracne may occur with exposures to PCB vapor concentrations as low as 0.1 mg/cu m for several months, and with PCB concentrations in the blood of about 200 ppb.

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(c) Effects Referable to the Liver

Some clinical and autopsy findings in Yusho, the disease that occurred after ingestion of PCB-contaminated rice oil by humans, were indicative of liver injury [155-158,179-181]. These findings included changes in liver cell anatomy considered consistent with microsomal enzyme stimulation and increased SAP activity. Effects that persisted for several years included decreased concentrations of iron and bilirubin in the serum [155,179] and increased serum concentrations of triglycerides. The latter were found to increase with residual concentrations of PCBs in the serum [180].

The maximum amounts of PCBs consumed by individuals manifesting these effects were estimated to have been of the order of 3-4 g total intake over several months [165]. For two Yusho patients a daily PCB consumption of 67 μg/kg for 3 months was estimated [167]. The maximum intake would have been of the order of 50 ppm in the diet or 0.5-1 mg/kg/day. For comparative purposes, absorption of PCBs from inhalation during maximum occupational exposures that have been reported (10 mg/cu m) probably did not exceed 0.15 mg/kg/day.

The extent to which PCB consumption was responsible for the effects on the liver is not known since the contaminated oil also contained PCDFs [20,160] in quantities that could have resulted in a maximum PCDF consumption of 20-50 mg. Autopsy findings 1-3 years after the poisonings indicated unusually high concentrations of PCDFs (0.3-2.5 μg/g) relative to PCBs (3.5-5.6 μg/g) in liver fat [160].

Although most animal feeding experiments have been conducted with dietary levels of PCBs that are much higher than those ingested by Yusho

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patients, others have been conducted with dietary PCB levels that seem to confirm the Yusho findings. Experiments have been reported with various commercial PCB mixtures (Aroclors 1242, 1254, 1260, and Clophen A60) added to the diet at 1-10 ppm [101,209-212,215,228,233]. These experiments demonstrated increased liver weights at all concentrations, dose dependent stimulation of microsomal enzyme activities, detectable proliferation of the SER at concentrations of 10-100 ppm, and other microscopic changes including enlarged hepatocytes, hepatocytic vacuolization, and, with prolonged exposures, development of adenofibrosis.

At high PCB concentrations (>1.5 mg/cu m), inhalation experiments with animals have demonstrated increased liver weights [98,99,202,203]. Microscopic changes similar to those seen from PCB ingestion were found in livers of rats after inhalation of Aroclor 1254 at 1.5 mg/cu m or more [203], and from other commercial preparations (Decachlorodiphenyl and Solvol) at much higher concentrations (>4 mg/cu m) [99,202].

These data from the Yusho poisonings and from animal experiments indicate that hepatic effects seen in human are similar to those seen in animals. They also indicate that some commercial preparations may be less severe liver poisons than others, but the data are not definitive in this regard. The ingestion experiments demonstrated increased liver weights from feeding PCBs at 1 ppm, and increasing evidence of liver injury as dietary PCB levels were increased. A dietary level of 1 ppm may be considered roughly equivalent to a daily intake of the order of 0.01-0.02 mg/kg, which would be somewhat similar to the intake from inhaling PCBs at 1 mg/cu m.

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Several reports of occupational exposures to PCBs have involved the liver in various ways [123,125,127,186,190,191,197,198,200].

In the earliest reports of PCB toxicity [123,135,127], the PCBs were mixed with chlorinated naphthalenes. The mixtures caused many cases of chloracne and, in some cases, jaundice. Liver cirrhosis with superimposed yellow atrophy was found in at least one fatality [125]. Similar findings have not been reported where exposures were to only PCBs in the absence of chlorinated naphthalenes.

Mention of nausea and digestive disturbances in some reports [123,197] may have indicated liver injury. In the study by Schwartz [123], neither liver function test findings nor exposure concentrations were reported. In the Levy et al report [197], liver function tests (SAP, SGOT, SGPT, total bilirubin) performed at the time of the study did not indicate current liver injury. The workers had been exposed to unidentified PCBs at 0.013-0.264 mg/cu m, and blood PCB concentrations were 36-286 ppb. Even though there were no findings of current liver injury, these investigators' [197] examination of past medical records showed occasional findings indicative of slight liver injury (elevated serum enzymes, triglycerides, and uric acid). A report of a worker who was removed from further exposure after experiencing nausea on exposure to an askarel containing Aroclor 1254 was not accompanied by liver function test results or exposure concentration data (In the Matter of General Electric Company, File No. 2833, New York State Department of Environmental Conservation, 1975).

More conclusive studies of liver function were reported by Meigs et al [190], Hasegawa et al [191], Hara et al [192,193], and Ouw et al [196]. Of the workers exposed to vapors of an undefined PCB at 0.1 mg/cu m in the

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study by Meigs et al [190], liver function tests were performed on seven. Findings in six of the workers were normal and, in the other one, cephalin flocculation and thymol turbidity tests were on the borderline of abnormality. Hasegawa et al [191] found some changes in liver function tests (increased SGOT, SGPT, and SAP, and decreased serum cholinesterase and lipids) of 99 workers exposed to Kanechlors but the investigators considered that only the decreased serum lipids were significant. PCB exposure concentrations at the time of the study were 0.045-1.6 mg/cu m. The workers had exposure histories of <1 to 20 years. PCB concentrations in blood samples of the workers averaged 370 ppb.

Hara et al [192] did not find evidence of a correlation of serum triglyceride concentrations with blood PCB concentrations during the first year after the work with PCBs was discontinued. However, when the same workers were studied 2 years after stopping work with PCBs, the proportion of workers with elevated serum triglycerides increased as residual blood PCB levels increased [193]. The effect was particularly prominent in workers with residual blood PCB concentrations >50 ppb. In a study of 34 workers exposed to Aroclor 1242 in capacitor manufacture, Ouw et al [196] found individual abnormalities in SGPT, SAP, and serum bilirubin, but average values for the group were normal. Bromsulphalein retention tests were elevated in four workers. Ouw et al [196] considered that there were no adverse responses in workers with blood PCB concentrations below 200 ppb. The PCB exposure concentrations were 0.32-1.44 mg/cu m.

No evidence of impaired liver function was found in other studies [186,194,195,198] where PCB exposures were reported as: Aroclor 1254 at 5-7 mg/cu m for 2-4 years [186]: Kanechlors at >0.25 mg/cu m [195]: and

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unidentified PCBs at <1 mg/cu m for 4 years [198].

Evidence relating to impaired liver function from occupational exposures to PCBs is generally consistent with findings in Yusho patients and in animal studies that indicated some effects could be expected from PCB intakes equivalent to PCB inhalation at about 1 mg/cu m. The occupational exposure studies show occasional evidence of liver injury in workers exposed at concentrations of 0.013-0.264 mg/cu m [197], 0.1 mg/cu m [190], 0.045-1.6 mg/cu m [191], and 0.32-1.44 mg/cu m [196]. Whether the observed effects occurred with exposures at the lower end of all these ranges is not known.

The occupational exposure studies also showed delayed recovery of normal serum triglycerides after exposures to PCBs stopped [193]. The elevated serum triglycerides were related to the higher residual blood PCB concentrations, and these in turn were related to the years of exposure. Residual PCBs have repeatedly been shown to be the more highly chlorinated isomers and those metabolized with greater difficulty [7,36,51,83,103,110,135,136].

Summaries of effects of PCBs on humans and animals are presented in Tables III-9 and III-10, respectively.

Carcinogencity, Mutagenicity, Teratogenicity, and Effects on Reproduction

(a) Carcinogenicity

There is extensive evidence for formation of arene oxide intermediates during the metabolism of PCBs by several species including rhesus monkeys [51,68,69,74,75,81,115,116,118]. Arene oxide formation was also proposed as a plausible intermediate in the metabolism of the slowly

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metabolized 2,2',4,4',5,5'-hexachlorobiphenyl [70,79]. Binding PCB metabolites to nuclear components of liver cells has been demonstrated on administration of PCBs to monkeys [51], and to rats [81], and by in vitro experiments [51,82,86,116,117]. This information is sufficient to arouse suspicions that PCBs could have carcinogenic potential in humans.

Hepatomas were produced in 170 of 184 examined female rats fed Aroclor 1260 at 100 ppm from 3-4 to 23 months of age [218], and in 9 of 22 BALB/cj male mice fed Aroclor 1254 at 300 ppm for 11 months [221]. The tumors found in the rats included 26 hepatocarcinomas and 144 neoplastic nodules. Only one liver tumor, a hepatocarcinoma, was found in 173 control rats.

In another report (Federal Register 42:6532-55, February 2, 1977), dose-related incidences of liver tumors were reported in rats fed Aroclors 1242, 1254, or 1260 at 1, 10, and 100 ppm in the diet for 24 months. No liver tumors were reported in rats fed the diets containing PCBs at 1 ppm. Only one tumor, a hyperplastic nodule (neoplastic nodule), was found in 23 controls. Neoplastic nodules were found in the livers of rats fed the diet containing 10 ppm of PCBs (2/10, 3/26, and 9/23 for Aroclor 1242, 1254, and 1260, respectively). Higher tumor incidences were found when diets containing PCBs at 100 ppm were fed (11/20, 19/27, and 14/27 for Aroclors 1242, 1254, and 1260, respectively) and the tumors included hepatomas and cholangiohepatomas (3, 6, and 7 for Aroclors 1242, 1254 and 1260, respectively). In this experiment the incidence of pituitary tumors was high in PCB-fed rats.

In a study sponsored by the National Cancer Institute, Aroclor 1254 was fed to groups of 24 rats at 25, 50, and 100 ppm in the diet. No liver

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tumors were found in the controls, in the experimental females at any dose level, or in experimental males fed PCBs at 25 ppm. However, hepatocellular carcinomas were found in a male rat fed Aroclor 1254 at 50 ppm and in two males fed the PCB at 100 ppm. The data also indicated that the incidence of leukemias in males was dose-related (3/24 in controls; 8/24 in rats fed 100 ppm).

Kanechlors have also been found to produce liver tumors when fed to mice and rats [240,241,242]. Of 12 mice fed Kanechlor 500 at 500 ppm for 32 weeks, 7 developed neoplastic liver nodules and 5 had well-developed hepatocellular carcinomas [240,241]. In this experiment which had only 12 mice/group and continued for only 32 weeks, liver tumors were not found with Kanechlors 300 and 400 or with lower dose levels of Kanechlor 500. However in another experiment [242], Kanechlor 400 fed to 10 male and 10 female rats for 58 weeks did produce liver tumors in the females. In this experiment the amounts fed (38-616 ppm) varied from time to time, but were in the 308-616 ppm range for the last 43 weeks.

These findings from animal studies indicated to NIOSH that PCBs have potential carcinogenic activity in humans. They indicate, but do not conclusively demonstrate, with the dietary levels used, that the less highly chlorinated mixtures (Aroclor 1242 and Kanechlors 300 and 400) have less carcinogenic potential than the more highly chlorinated mixtures (Aroclors 1254 and 1260 and Kanechlor 500). However, all PCB mixtures adequately tested in rats and mice have shown carcinogenic activity. The intakes of PCBs at the lowest dietary level that has produced tumors in rats (10 ppm) would be somewhat comparable to intakes from occupational exposures at 5-10 mg/cu m. However PCBs are slowly eliminated from the

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body and the higher chlorinated compounds may accumulate in the body for years. Thus animal experiments that are limited to 2 years by the life span of the animals may not be informative relative to workers exposed for up to 45 years.

In humans, there are no adequate studies to confirm or deny carcinogenicity although preliminary data suggest that among Yusho patients, deaths due to cancers exceed expectations [160,161] and preliminary studies of two occupationally exposed groups in the US indicate that the occurrence of certain cancers may be excessive (HA Sinclaire, written communication, June 1976; G Roush, written communication, September 1976). However, the two reports are not consistent as to the types of cancers found to occur more frequently than expected.

(b) Mutagenicity

Several PCBs and PCB mixtures, including the 4- and the 2,2',5,5'-isomers and Aroclors 1221, 1254, and 1260, were subjected to the "Ames" test for mutagenicity [116]. Although 4-chlorobiphenyl had mutagenic activity in this test, the more highly chlorinated PCBs showed very little activity. Aroclor 1254 did not cause significant chromosomal changes in the testes of rats after it was administered for 7 days at 50 mg/kg/day [235]. In another experiment [236], neither Aroclor 1254 administered at 300 mg/kg/day for 5 days nor Aroclor 1242 administered at 500 mg/kg/day for 4 days produced chromosomal aberrations in spermatagonial or bone marrow cells of rats. These mixtures also did not produce any evidence of dominant lethal mutations in rats [237]. Although PCBs have little mutagenic potential, they may alter the mutagenicity and carcinogenicity of other compounds by stimulating microsomal enzyme activities [239].

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(c) Teratogenicity

PCBs have been found in embryonic and fetal tissues of humans [139,168] and experimental animals [101] after introduction of PCBs into the maternal body, demonstrating that the potential for direct teratogenic effects exists. Several experiments have been conducted with rats [101,228], rabbits [229], monkeys [232], and dogs and pigs (FL Earl et al, written communication, 1976) that are relevent to a discussion of PCB teratogenicity. In some of these experiments, the PCBs were administered by gavage and doses were reported in mg/kg; in other experiments, the PCBs were reported as ppm fed in the diet. For purposes of relative comparison, 50 ppm in the diet can be equated to 1 mg/kg/day. This is the order of magnitude of the maximum rate of PCB intake by Yusho patients. Animal experiments have used PCBs in dietary-equivalent amounts of 1-2,500 ppm. In most experiments with PCBs administered in amounts equivalent to dietary levels of 100 ppm or more, fetotoxicity (resorptions, absortions) has been such that teratogenic effects may have been masked [101,228,229]. In the two-generation feeding study of rats by Linder et al [228], no terata were reported. This study covered Aroclor 1254 in the concentration range of 1-100 ppm and Aroclor 1260 in the range of 5-100 ppm. Although terata were not reported, Aroclor 1254 concentrations of 20-100 ppm resulted in reduced litter sizes. In rhesus monkeys [232], feeding Aroclor 1248 at 2.5 and 5 ppm caused abortions in some cases and lower than normal birth weights, but no terata were reported. In dogs, terata were not found in pups born from dams fed the equivalent of 12 ppm in the diet, but were present when 48- or 200-ppm equivalents were fed. Sows fed the equivalent of 50 ppm in the same experiment had high rates of resorptions and, at 10-30 times this

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level, terata were definitely present in the piglets (FL Earl et al, written communication, 1976).

Although there were retarded intrauterine growth and signs of PCB toxicity in Yusho babies at birth, no terata were reported [149,159,176,182,183]. A normal baby was born to a woman exposed to PCBs in her work. The PCB exposure concentrations were not reported but the PCB concentration in her blood was 25 ppb at the time the baby was born.

These studies indicate that PCBs have teratogenic potential for humans. However, the terata observed in animals occurred at levels at or above doses equivalent to the maximum doses of the Yusho patients and at intake rates 3-4 times greater than intakes expected from inhalation at maximum reported occupational exposures.

(d) Other Effects on Reproduction

Feeding rats Aroclor 1254 at 5 ppm or Aroclor 1260 at 100 ppm had no effects on reproduction over two generations [228]. At higher dietary levels, reproductive effects included poor mating performances, fewer litters, reduced litter size, and high postnatal death rates in the litters. In rabbits, Aroclors 1221 and 1254 were not fetotoxic when administered only during gestation in amounts equivalent to dietary levels of about 50-500 ppm [229]. However, when administered during gestation at higher levels (600-2,500 ppm dietary equivalent), Aroclor 1254 caused resorptions, abortions, maternal death, and, in two fetuses, asymmetric skulls [230]. Delaying administration of PCBs until after the first week of pregnancy did not eliminate the effects.

Feeding rhesus monkeys Aroclor 1248 at 25 ppm for 2 months resulted in a high degree of infertility that persisted for at least 8 months after

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the last ingestion of PCBs [232]. In another experiment, rhesus monkeys fed Aroclor 1248 at 2.5 and 5 ppm for 6 months had irregular menstrual cycles with excessive and prolonged bleeding [233]. Even though these monkeys conceived well on mating, resorptions and abortions were frequent, and infertility was common in subsequent matings [233]. Nursing infants developed chloracne-like signs within 2 months and infants frequently died during the nursing period. The milk contained PCBs at 0.154-0.397 ppm [234].

There are no reports of infertility or abortions attributed to human PCB consumption or exposure. There are reports of undesirable effects in children born to mothers exposed to PCBs in the diet and of undesirable effects developing from nursing such mothers.

Babies born from mothers with Yusho were often dark colored and developed signs of Yusho after nursing [176,182,183]. In at least one case, Yusho developed in a baby who was only exposed to PCBs by nursing [182]. Concentrations of PCBs in milk were not determined at the time of the Yusho poisoning. A milk sample obtained after birth of a normal baby from a woman exposed to PCBs at work contained PCBs at 0.25 ppm, and nursing was discontinued [195]. The woman's exposure history and time of last exposure were not given, but PCBs were present in her blood at 24 ppb. Based on the findings in monkeys [234] the decision to not nurse the baby seems entirely justified.

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TABLE III-9

EFFECTS OF PCBs ON HUMANS

PCB Intake		Exposure Index			
Source	Duration	Environmental, Amount/kind	Blood (ppb)	Effects	Ref.
Ingestion	Up to 8 mon	0.3-4g Kanechlor 400	>50	Yusho	145-185
Occupational	Not known	10 mg/cu m	-	Unbearable irritation	130
"	4-8 mon	5-7 mg/cu m Aroclor 1254	-	Chloracne, no liver injury	186
"	2.5-4 mon	Not reported	-	Chloracne, hyperpigmentation	187
"	<1-20 yr	0.2-1.6 mg/cu m Kanechlors	370, ave.	Chloracne, hyperpigmentation, liver injury	191
"	2.5 yr ave.	Not reported Kanechlors	820, ave.	Chloracne, no liver injury	194
"	Not reported	>0.25 mg/cu m Not reported	130-520	Chloracne, liver injury	195
"	2.5-18 yr	0.013-0.27 mg/cu m Not reported	36-286	Irritation, liver injury	197
"	14 mon ave.	0.1 mg/cu m Not reported	-	Chloracne, liver injury	190
"	"	Not reported refuse workers	<1-14	No effects	199

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TABLE III-9 (CONTINUED)

EFFECTS OF PCBs ON HUMANS

PCB Intake		Exposure Index			
Source	Duration	Environmental, Amount/kind	Blood (ppb)	Effects	Ref.
Occupational	2-23 yr	0.32-1.44 mg/cu m Aroclor 1242	>200	Chloracne, liver injury	196
"	1-23 yr	0.32-1.44 mg/cu m Aroclor 1242	<200	No effects	196
"	Up to 15 yr	Not reported Kanechlors	7-300	Chloracne, elevated triglycerides	192, 193
"	Not reported	Not reported Kanechlors	24 10-100	Normal baby Mild chloracne	195
"	4 years	(>1 mg/cu m) Aroclor 1242	74-1,900	No effects	198
General environment	Continuous	Air, 1-100 Food, 10-20 µg/d	>1-30	No effects	137-141

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TABLE III-10

EFFECTS OF PCB INHALATION ON ANIMALS

Material	Exposure Conditions mg/cu m	Duration	Species	Effects	Ref.
Pydraul A 200	30,000	2 hr	Rats	PCB in liver, 70 ppm	97
Solvol	10,000	3 hr	"	100% mortality, liver necrosis	202
"	250-500	8-69 3-hr exposures	"	Liver necrosis, hyperplasia of Kupffer cells	202
Decachlorodiphenyl	2,500	6 hr	"	Irritation, no gross effects	98
"	800	6 hr/d, 5 d/wk, 4 wk	"	Irritation, increased liver weights, microscopic liver changes blood cell changes	99
"	4 and 80	"	"	No irritation, increased liver weights in females	99
Aroclor 1242	8.6	7 hr/d, 5 d/wk, 3 wk	Mouse, rat, cat, guinea pig, rabbit	None	203
"	6.8	7 hr/d, 5 d/wk, 17 wk	"	"	203
"	1.9	7 hr/d, 5 d/wk, 31 wk	"	"	203
Aroclor 1254	5.4	7 hr/d, 5 d/wk, 17 wk	"	Microscopic liver changes	203
"	1.5	7 hr/d, 5 d/wk, 31 wk	"	Microscopic liver changes; reversible	203

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Environmental Concentrations

Two reports of workroom air concentrations of PCBs appeared in 1954 [186,190]. Puccinelli [186] studied the concentrations in air of a capacitor factory in Italy, using the methods of Elkins [130], and found concentrations in 500-liter air samples of 5.2-6.4 mg/cu m. Miegs et al [190] did not report on the analytical methods they used to determine concentrations of PCBs in the breathing zones of workers exposed when a heat exchange unit in a Connecticut factory leaked. From the description of the factory, it is likely that the exposures were largely to vapors; the concentration found was 0.1 mg/cu m.

In 1959, Elkins [130] reported that over a number of years, PCBs in some Massachusetts plants ranged up to 10.5 mg/cu m of air (Table IV-1).

TABLE IV-1

PCB CONCENTRATIONS MEASURED IN MASSACHUSETTS FACTORIES

Process	PCB Concentrations (mg/cu m)	
	Maximum	Average
Capacitor impregnating	10.5	5.8
"	5.5	4.5
"	0.3	0.2
Capacitor soldering	0.9	0.8
Oil mixing	1.1	0.6
Regulator filling	0.2	0.1

Adapted from reference 130

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Of 21 air samples collected in capacitor impregnating operations, Elkins considered that hazardous concentrations (>1 ppm for Aroclor 1242; >0.5 ppm for Aroclor 1254) existed in 15. While the sampling and analytical methods used were not documented, Elkins [130] recommended sampling with either a fritted bubbler or two impingers in series, both containing amyl acetate, and analyzing by the sulfur lamp method.

Occupational environmental studies were conducted in five Japanese plants by Hasegawa et al [191]. Kanechlors 200 (predominantly dichlorobiphenyls), 300 (mostly trichlorobiphenyls), and 400 (mostly tetrachlorobiphenyls) were used or manufactured in the plants. Air samples were drawn through filter paper to collect particulate matter and normal hexane to collect vapors and analyzed by GLC. The data are summarized in Table III-7. In the paired samples, the vapor concentrations exceeded the particulate concentrations. One of the plants was a biphenyl recovery plant where PCBs were not used. In this plant, PCB concentrations were <0.02 mg/cu m. In the PCB manufacturing plant, PCB vapor concentrations were 0.026-0.163 mg/cu m, and particulate PCB concentrations were 0.019-0.037 mg/cu m. Higher PCB concentrations were found in the capacitor plants: 0.095-0.965 mg/cu m of vapors, and 0.20-0.65 mg/cu m of particulates. In one particulate sample collected in a capacitor plant after a spill, the PCB concentration was 6.2 mg/cu m.

Staiff et al [243] in a 1974 report were concerned about emissions from burned-out PCB-containing ballasts in fluorescent fixtures in their laboratory. The investigators collected samples in two midget impingers, containing ethylene glycol and connected in series. The samples were analyzed by GLC. PCB concentrations in the air ranged from 0.012 to 0.166

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mg/cu m when the ballasts burned out and were 0.002 mg/cu m 3 days later.

In a 1976 report of a survey of Australian workers exposed to Aroclor 1242, Ouw et al [196] listed breathing zone concentrations ranging from 0.32 to 2.22 mg/cu m before corrective measures were taken, and from 0.08 to 0.75 mg/cu m after installing improved ventilation. Breathing zone samples were collected at 30 liters/minute using Greenburg-Smith impingers containing 75 ml of isopropanol. The concentrations found are shown in Table IV-2.

TABLE IV-2

PCB CONCENTRATIONS IN THE AIR INSIDE A CAPACITOR PLANT BEFORE AND AFTER IMPROVEMENT OF EXHAUST VENTILATION SYSTEM

Areas in the Impregnation Room	PCB Concentrations mg/cu m	
	Before	After
Area in the unloading tank in front of exhaust register from operator's breathing zone	1.44	0.75
Area in the unloading tank not in front of exhaust register	2.22	0.7
General atmosphere near tank	1.08	0.18
Soldering area	0.32	0.08

Adapted from reference 196

Exposures of electrical and materials technicians during 1976 to PCBs contained in materials they tested were evaluated by Levy et al [197]. Air samples were collected on magnesium silicate "Florisil" at 50 ml/minute for

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4-8 hours and analyzed by GLC utilizing electron capture detection. Breathing zone samples were collected on a single day from nine employees for 8 hours. The concentrations in the nine breathing zone samples, which would represent TWA exposure concentrations for the day, ranged from 0.014 to 0.073 mg/cu m. Concentrations of PCBs in nine point source samples collected over 4-8 hours on each of 3 days ranged from 0.013 to 0.264 mg/cu m, and in 19 room air samples collected over 4 hours on each of 3 days, from 0.08 to 0.16 mg/cu m.

A plant manufacturing PCBs in the US was surveyed for worker exposure in July 1976 [244]. Three Aroclors (1016, 1242, and 1254) were made in the PCB production area. To begin the process, biphenyl and chlorine were piped into a chlorinator with a catalyst and allowed to react. Two separate groups of chlorinators were used for Aroclors 1242 and 1254. The product resulting from the reaction passed through a purifying operation, or to a distillation column as in the case of converting Aroclor 1242 to Aroclor 1016, and then on to the storage tanks. Mixing tanks were used to give the desired properties to the final product.

Although the operation was outdoors and theoretically a closed system, potential for employee exposure existed when samples were drawn or leaks occurred. Local exhaust ventilation was used in two operations: (1) while filling 55-gallon drums, hoses were placed near the openings, and (2) when employees tested samples drawn from the chlorinators, their work station was equipped with an exhaust fan and hood.

Eleven personal and seven area air samples were taken in the PCB production area for 6-8 hours at a flow rate of 200 cc/minute [244]. PCBs were collected on Florisil, desorbed with hexane, and analyzed by GLC with

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EC detection. Aroclor 1016 was the PCB produced on the sampling dates, and it was used as the standard for quantitating airborne PCBs. Personal air sample concentrations of PCBs reported as Aroclor 1016 ranged from 20 to 86 μg/cu m, while PCBs in area samples ranged from 16 to 55 μg/cu m. The data are presented in Table IV-3.

TABLE IV-3

PCB CONCENTRATIONS FOUND IN A PLANT MANUFACTURING PCBs ON 2 CONSECUTIVE DAYS (μg/cu m)*

Personal Air Samples Job Title	7/21/76	7/22/76
Premium operator	47	20
Second operator	46	43
Column operator	64	51
Still operator	40	86
Standard operator	-	61
Distribution operator	54	36
Area Air Samples		
Location	7/21/76	2/22/76
Drumming	43	51
Temperature testing	25	52
Chlorinators	55	36
Incinerator burner	16	-

*Total sampling time varied from 409 to 455 minutes and sample volumes varied from 67.6 to 201.6 liters.

Adapted from reference 244

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Sato and Hasegawa [32] studied concentrations of PCBs in factories that had discontinued their use in production of pressure-sensitive copying paper 2 years earlier. PCB concentrations in the factories had not been determined when PCBs were being used, but were considered [3] to have been similar to those found by Hasagawa et al [196] in capacitor manufacturing plants. The concentrations found by Sato and Haswgawa [32] at the time of sampling ranged from 0.13 to 4.4 μg/cu m. The PCB concentrations in the outdoor air around the factories were 0.043-0.09 μg/cu m [3].

Another study of contamination in factories after PCB use had been discontinued was reported by Fujiwara et al [33]. These investigators found 0.25 mg/cu m in air of a factory that had previously used PCBs in silk glossing. In addition to air contamination, PCBs were found in the dust around machinery and in the floor boards.

PCB concentrations found in the air of some other factories and their surrounding environments in Japan were summarized in 1976 by Tatsukawa [245]. Concentrations found before 1957 in a factory producing transformers and capacitors ranged from 0.39 to 4.5 mg/cu m. The factory was said to have been old-fashioned with bad ventilation [245]. Concentrations found in warehouses for carbonless copying paper in 1972 ranged from 2 to 70 μg/cu m. In the same year, concentrations of 0.04-0.05 μg/cu m were found in a university laboratory where PCBs were used, and concentrations of 0.006-0.12 μg/cu m were found in areas of mills that recycled paper. Background concentrations found in urban areas of Tokyo, Osaka, and Matsuyama City were <0.002-0.04 μg/cu m.

Background concentrations of PCBs in ambient air over the US have been reported in ng/cu m quantities [26,38]. Average concentrations of

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about 100 ng/cu m were found in Florida and Colorado in 1975 [38].

Control of Exposure

The present primary use of PCBs is as dielectric or insulating fluids for electrical capacitors and transformers. Potential hazards of PCBs in these industries result from inhalation and dermal exposures. It is here that engineering controls, such as local exhaust systems, are necessary.

Local exhaust systems should be designed and operated in conformance with American National Standard Z9.2-1971 Fundamentals Governing the Design and Operation of Local Exhaust Systems [246]. Guidelines for handling capacitor and transformer askarels include the following recommendations from the American National Standards Institute (ANSI) [4]: (1) Enclosed systems of sealed piping, properly gasketed joints, valves, containers, and processing chambers should be used for any portion of the operation where askarel temperatures may exceed 55 C; (2) Enclosure should preferably extend to all other portions of the system insofar as practicable; (3) Operations utilizing PCBs should be isolated from other manufacturing areas to avoid cross contamination; (4) Provision should be made for adequate ventilation and regulation of manufacturing operations to avoid open exposure to askarels; (5) When askarels are used at elevated temperatures (especially 55 C or higher), engineering controls must be applied, either by the use of closed systems or by effective local exhaust ventilation with general workroom exhaust.

Durfee et al [247] cited the following potential sources of air emissions of PCBs in transformer and capacitor manufacturing operations: (1) vapor exhaust from stream jet ejectors; (2) evaporation from accidental

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spills; (3) evaporation from hot surfaces as part of flood-filling, inspection, or holding operations; (4) vacuum pump exhausts; (5) evaporation from plant waste water.

There are currently no commercially available fluids which can be considered as totally acceptable substitutes for PCBs in the broad range of AC capacitors, nor are there substitute dielectric systems which would satisfy reliability and safety requirements in most applications [28]. Transformers containing PCBs represent only about 5% of the US transformer market, and are used only where safety and reliability are of prime importance. For new installations, building and installation design provisions could be made to accommodate the use of filled, open dry-type, or sealed dry-type transformers. Major construction changes would be required to compensate for the fire resistance of askarel-filled units if existing askarel-filled transformers are to be replaced with oil-filled units of equivalent electrical ratings [4].

Environmental Sampling and Analytical Methods

(a) Air Sampling

Before discussing the various methods available for sampling airborne PCBs, it is pertinent to discuss the criteria for an ideal sampling device. NIOSH evaluated an industrial worker's exposure and found that sampling in the breathing zone gives a truer picture of actual exposure than does area sampling. The first criterion for an ideal air sampling device then is that it be amenable to personal sampling. In addition, it should be light, compact, and small enough so that workers can pursue their daily activities without being aware of its presence. The second criterion is that the

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sampling device have a sufficient capacity for PCBs to enable the collection of an air sample representative of a typical workday. Thirdly, recovery of PCBs from the sampling device should be quantitative or, at the least, reproducible. Finally, the sample must be stable in or on the sampling device between the time of sampling and the time of analysis. This latter criterion is hardly of concern here due to the general stability of PCBs.

An air sampling procedure using fritted bubblers or impingers filled with toluene was published by ANSI in 1974 [4]. Neither the sampler capacity nor the sampling efficiency had been experimentally evaluated. Where high sampling flow rates or high capacities were required, additional bubblers or impingers in series were recommended.

Bidleman and Olney [248] used porous polyurethane foam for collecting samples of atmospheric PCBs. They found that the polyurethane foam showed excellent collection efficiency (99% or better) for tri-, tetra-, and pentachlorobiphenyls. The authors [248] did not address the matter of sample recovery from the sorbent.

In an environment where carbonless copy paper was being used, Nishiyama et al [249] collected PCBs by drawing the air through a cooled column filled with Shimalite, a gas chromatographic solid support similar to Chromosorb W. The collection efficiency of the device was 95% and the PCBs were eluted from the column with hexane. Other investigators used 5% glycerol-coated Florisil for collecting organochlorine pesticides and PCBs from air [250]. Collection efficiencies were 90-100% for PCBs.

Harvey and Steinhauer [251] collected ambient air samples of PCBs using 0.25% OV-17 silicone oil coated on ceramic saddles (distillation

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column packing). The collection efficiency of this device was 70%. More recently, Giam et al [252] found that sorbent tubes packed with deactivated Florisil could be used for collecting PCBs and phthalates from air [252]. These compounds were found to be effectively retained by Florisil. The authors did not discuss efficiency of recovery.

In 1976, Laveskog and Lindskog [253] described a stack sampling device for chlorinated hydrocarbons which they used for PCB collection. This device utilized glass wool for the collection of particulates followed by a sorbent, 25-40% Apiezon M on Chromosorb W, to collect vapors. The collection efficiency of the column was 99%, and desorption efficiency with absolute ethanol was 87%. The authors investigated charcoal as a sorbent, but found it unsuitable for their purposes since the PCBs could only be recovered by extraction in a soxhlet apparatus with chloroform which in turn could not be used with electron capture detection.

Occupational Safety and Health Administration (OSHA) workers have used charcoal tubes for personal air sampling for PCBs (RG Kupel, written communication, 1976). While the sampling device would be expected to have good capacity for PCBs, recovery from charcoal is not quantitative. Little other information is known about this method.

A NIOSH Standards Completion Program Report [254] indicated that PCBs with 54% chlorine content were effectively trapped on a fibrous glass filter. However, the presence of PCB vapor either apparently was not addressed or was assumed to be negligible. This may not be a valid assumption, particularly since another report from the same program [255] showed that PCBs with 42% chlorine content have appreciable vapor pressure.

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NIOSH has also investigated the method of Giam et al [252], using Florisil as a sampling medium, in industrial environments. Florisil (30/48 mesh) was placed in a tube similar to that used in the charcoal tube method for solvents, 100 mg in the front section and 50 mg in the back. The retention capacity of this sampling device for PCBs was evaluated under laboratory and field conditions, using various vapor generation techniques. In laboratory experiments, PCBs at 10 μg/liter and 75% relative humidity were sampled through a 100-mg Florisil bed at 0.2 liter/minute with no evidence of breakthrough after 4 hours (48 liters). Of 21 samples collected on Florisil in a capacitor plant, only 6 had PCBs on the backup section and all 6 backup sections contained 1% or less of the total PCBs in the tube. The volumes of air sampled ranged up to 61 liters, and PCB concentrations in air as high as 1.5 μg/liter were measured. Other laboratory experiments showed that PCBs could be desorbed quantitatively from Florisil with hexane. Results from Florisil tube and impinger samples taken side by side in the capacitor plant and analyzed with a single commercial PCB product as a standard were statistically similar.

Impingers are not suitable for personal sampling and are inconvenient to use because they must be recharged with the sampling solvent frequently and must be used in series. The handling of absorber solutions is difficult because of the potential for spillage and leakage of the solvent and samples during transport to and from the sampling site. Solid sorbent sampling devices are well suited for personal sampling since they are relatively small, and personnel wearing the devices quickly become unaware of their presence, enabling more representative sampling. Shipment of these devices is relatively simple.

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Of the solid sorbent sampling devices discussed, Florisil-filled tubes are deemed the most advantageous because Florisil has a high capacity for PCBs and can be quantitatively desorbed; field evaluations have shown that Florisil-filled tubes are easier to handle and more convenient than impingers. Therefore, the Florisil-filled tube method is recommended for collection of PCBs from air, as detailed in Appendix I.

(b) Analytical

The chemistry of PCBs was extensively reviewed by Hutzinger et al [1], and PCB analytical chemistry has been reviewed by several authors [256-264] but only references pertinent to selection of an analytical method for determination of PCBs in industrial air samples will be discussed here. Of the analytical techniques available, the one most widely used for determining PCBs is GLC with EC detection. This technique is rapid, precise, and very sensitive. The far greater sensitivity of EC detection compared with that of the flame ionization detector (FID) is demonstrated by comparison of their relative responses to various PCB isomers, shown in Table IV-4 [1].

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TABLE IV-4

RELATIVE MOLAR RESPONSES OF ELECTRON-CAPTURE AND FLAME-IONIZATION DETECTORS TO SOME PCBs

PCB	Relative Molar Response	
	Electron Capture	Flame Ionization
2-chloro	1.00	1.00
3-chloro	0.20	0.92
4-chloro	1.10	0.87
2,2'-dichloro	5.16	0.99
2,4-dichloro	17.7	0.86
2,6-dichloro	32.0	0.91
3,3'-dichloro	6.10	0.94
3,4-dichloro	15.2	0.86
4,4'-dichloro	5.97	0.81
2,4,4'-trichloro	135	0.78
2,2'4,4'-tetrachloro	106	0.87
2,2'6,6'-tetrachloro	20.6	0.90
3,3'4,4'-tetrachloro	396	0.87
3,3'5,5'-tetrachloro	320	0.85
2,3,4,5-tetrachloro	367	0.87
2,3,5,6-tetrachloro	259	0.71
2,2'4,4'6,6'-hexachloro	347	
3,3'4,4'5,5'-hexachloro	726	
2,2'3,4'5,5'6,6'-octachloro	1,180	
2,2'3,3'5,5'6,6'-octachloro	1,150	
decachloro	1,410	

Adapted from reference 1

During the GLC-EC detection analysis of PCBs, multicomponent mixtures of various PCBs are almost always encountered. The samples analyzed may or may not resemble a commercial PCB mixture. If so, the appropriate commercial PCB mixture can be used as a standard for quantitation; if not, a commercial mixture should not be used. Quantitation cannot be accurate since it is based on incomplete resolution of PCB isomers. Even if complete resolution were possible, all PCB isomers are not available for standards and the specific EC detection response of each isomer would need

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to be known.

Many different methods have been used to "quantitate" or estimate PCBs. Heights or areas of one [263], two [264], three [265], or more [266,267], or of all chromatographic peaks [268-270] of a given sample have been used for comparison with standard commercial PCB mixtures. The chief disadvantage of such methods is that when the chromatogram of the sample does not closely resemble that of the standard the estimates are neither precise nor accurate. An improvement upon these methods is the use of mixed PCB standards, as described by Beezhold and Stout [271]. This procedure involves mixing various proportions of different PCB commercial mixtures, such as Aroclor 1242 and Aroclor 1254, and obtaining sets of chromatograms. The chromatogram most closely resembling the sample is selected and the corresponding mixture is used as the standard.

Sawyer [269], in a collaborative study, evaluated the quantitation of PCBs in chicken fat. He found that the use of the total peak area or the sum total of all peak heights gave better results than did the use of selected peaks. The use of mixed standards gave good results when the composition which best duplicated the response pattern of the sample was used. This was adopted as an official method by the Association of Official Analytical Chemists [272].

Using a different approach to standardization, Rote and Murphy [273] produced a standard response curve using Aroclors 1232, 1242, 1248, 1254, 1260, and 1262. This plot was of the total area responses on the GLC trace divided by the weights of the Aroclors injected versus the average number of chlorine atoms in the molecule. The peaks in each chromatogram were identified as to chlorine content per chlorobiphenyl molecule, and

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each sample could then be quantitated using the response curve. The accuracy of this method is not greater than that of the methods previously mentioned, since it has been shown that the response of EC detection varies greatly with the degree of chlorine substitution and also with the relative position of the chlorine substitution [1].

Risebrough et al [274] and Collins et al [268] used dichlorodiphenyldichloroethylene (p,p'-DDE) as a standard and assumed that the response of each chlorobiphenyl isomer was equal to that of p,p'-DDE. This method can only be grossly approximate, since the response of EC detection to individual PCB isomers varies greatly [1].

Risebrough et al [274] also reported the use of microcoulometric detection to determine total chlorine content, using a commercial PCB mixture as a standard. Sawyer [269] compared the EC detection with the microcoulmetric and electrolytic conductivity detectors and found that the latter two detectors are subject to more operational problems than is the EC detection.

An analytical method utilizing a computer for the quantitation of PCBs was described by Zobel [275]. This method would not be of value for routine sample analysis in industrial hygiene laboratories because of the expense or unavailability of a computer.

The method of Webb and McCall [276] involves standardization of an Aroclor mixture whose peak-by-peak composition has been determined as weight percentages of the total. Since the response-to-weight factor is known for each peak, the actual weight equivalent of each peak in the sample can be calculated despite vast differences of overall GLC patterns. To utilize this method as a standard procedure, it is necessary that some

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agency serve as a central repository for distribution of the reference materials. Presently, standards for Aroclors 1242, 1254, and 1260 as dilute solutions in iso-octane are available from Webb and McCall [276]. However, a fully characterized standard for the widely used Aroclor 1016 is not available. Potential future sources for these types of standards may be either the Association of Official Analytical Chemists or the US Food and Drug Administration. These organizations currently are interested in this method [277] and are planning to test it collaboratively.

The US Environmental Protection Agency has adopted the method of Webb and McCall [276] as a recommended procedure for quantitation of PCBs in industrial effluents [278]. Other investigators have also concluded that this method is the best available method of quantitation [279].

Berg et al [280] investigated the quantitation of PCBs in terms of derivatives. PCBs could be quantitatively converted by catalytic dechlorination to bicyclohexyl. However the authors [280] found that the relatively low level of sensitivity, because bicyclohexyl had to be determined by GLC with FID, was a marked disadvantage. They [280] found that treatment of PCBs with anitmony pentachloride under elevated temperatures and anhydrous conditions gave good yields (85%) of decachlorobiphenyl which could be determined by GLC with EC detection.

Armour [281] evaluated the perchlorination procedure of Berg et al [280] to determine its utility as a routine method for the confirmatory quantitation of PCBs. It was found necessary to modify that procedure because of observed inconsistencies in the efficiency of conversion of Aroclors 1254 (90-100%) and 1242 (30-70%) to decachlorobiphenyl. Armour [281] attributed this to volatilization of the lower molecular weight PCB

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components during solvent evaporation before their reaction with antimony pentachloride. The remedy selected was to end evaporation while a small amount (0.1 ml) of solvent still remained, but this rendered the choice of solvents a more critical matter because of possible interferences during the perchlorination step. Chloroform was the solvent chosen because it minimized volatility and reacted favorably at the selected conditions. The increased pressure produced as a result of this substitution of chloroform required discontinuing use of flame-sealed Carius tubes as recommended by Berg et al [280] for containing the elevated temperature-pressure perchlorination reaction. The recommended substitute was a vacuum hydrolysis tube having the same volume specifications (10 mm O.D. X 150 mm), a tight Teflon sealing valve, and a side venting arm [281].

Other modifications devised by Armour [281] included the addition of methanol to the reaction mixture's extract to produce an azeotrope with the residual chloroform which could then be evaporated to a small volume before dilution, preparatory to determination of decachlorobiphenyl. To determine the feasibility of a shortened reaction time, Armour et al tested iron as a catalyst, but decided that although a reaction time of 6 hours with iron catalyst resulted in quantitative (99% average conversion for six Aroclors) and reproducible (83-110%) conversions, the catalytic modification offered little advantage over the overnight procedure.

Perchlorination has been used for the quantitation of PCBs by others [282,283]. While the sole perchlorination product was usually decachlorobiphenyl, there have been reports of undesired byproducts resulting from contamination of the antimony pentachloride with bromide ions [284,285]. Results of NIOSH investigations indicate that this

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contamination problem can be eliminated by vacuum distillation of the antimony pentachloride. Factors for converting decachlorobiphenyl to Aroclors are presented in Table IV-5.

TABLE IV-5

FACTORS TO CONVERT DECACHLOROBIPHENYL TO AN EQUIVALENT AMOUNT OF AROCLOR

Aroclor	Average Molecular Weight	Q*
1221	188.5	0.38
1232	223	0.45
1242	257.5	0.52
1016	257.5	0.52
1248	292	0.59
1254	326.4	0.65
1260	361	0.72
1262	395.3	0.79

*Calculated by dividing the average molecular weight by 499, the molecular weight of decachlorobiphenyl

Adapted from reference 281

From a review of the literature, NIOSH concludes that the simplest method of PCB quantitation involves standardization of samples with single commercial mixtures of PCBs. Should the composition of a sample not closely resemble that of a single commercial PCB mixture, the most accurate and precise method of quantitation available would be that of

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perchlorination, which seems to offer the best approach for determining total PCB content in samples when the initial concentrations of individual PCBs are of little or no concern.

NIOSH recommends desorption of PCBs from Florisil with hexane, analysis by GLC, and quantitation of the sample by comparison with a standard PCB mixture of similar composition (Appendix II). If a PCB mixture with a composition similar to that of the sample is not available as a standard, NIOSH recommends converting the sample PCBs to decachlorobiphenyl for quantitation.

The methodology presented in Appendices I and II has been tested with Aroclor 1016 in the laboratory and in practice. Operating parameters found by NIOSH are presented in the Appendices.

Biologic Evaluation

While there is presently no adequate method for biologically monitoring industrial workers for exposure to PCBs, additional research may make feasible the routine measurement of residues of these compounds in blood or other body fluids.

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V. WORK PRACTICES

The employment of good work practices is required if hazardous occupational exposures to PCBs are to be prevented. The carcinogenic, teratogenic, dermatologic, and fetotoxic effects of PCBs largely determine the nature of necessary work practices.

(a) All locations where occupational exposure to PCBs occurs should be established as regulated areas and posted with signs warning persons of the procedures necessary upon entering or leaving.

When an otherwise closed PCB system is opened, eg, during the loading and unloading of storage tanks, the following work practices are desirable:

(1) Only authorized personnel should be permitted in the area;

(2) Adequate ventilation should be provided and the exhaust air should not be discharged into any environment until it has been adequately decontaminated;

(3) To prevent skin contact with PCBs, workers should be required to wear and use PCB-resistant protective clothing and equipment, including respirators.

(4) Upon leaving regulated areas, workers should be required to remove such protective clothing and equipment and place it in impervious containers pending either decontamination or disposal;

(5) After removing such protective clothing and equipment, workers should be required to wash their hands, forearms, and faces, and to shower after the last exposure of the day.

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Whenever a worker must come into direct contact with PCBs, eg, during cleanup of spills or maintenance of vessels, PCB-resistant protective clothing and an appropriate respirator must be worn.

(b) Leakage and Spill Procedures

PCB spills are to be cleaned up promptly, either by the use of sorbent materials, such as sawdust, or by trapping and removal through pumping or other suitable means. In case of spillage of PCBs on clothing, the contaminated clothing should be removed as soon as practical, the skin should be thoroughly washed, and the clothing should be laundered or disposed of properly. Facilities and procedures for such cleanup must be provided at manufacturing facilities producing capacitors and transformers, because spills of PCBs are quite likely to occur during the filling and handling of such devices. Users of PCB-filled transformers should inspect them periodically for leakage. If leakage is found, the cause should be corrected and the spillage should be soaked up with sawdust or other absorbent material. The leak area should be cleaned finally with rags soaked with an appropriate safe solvent. Leaky transformer gaskets can be sealed temporarily by painting over the leaky area with epoxy cement. Refer to Transformer Askarel Inspection and Maintenance Guide [25], and Guidelines for Handling and Disposal of Capacitor and Transformer Grade Askarels Containing Polychlorinated Biphenyls [4] for further maintenance procedures.

(c) Emergencies

In emergencies, immediate measures must be taken to eliminate hazardous conditions. Non-essential workers must be evacuated until the emergency no longer exists. Any worker having visible contamination of the

skin with PCBs must shower immediately unless other action is warranted.

(d) Respiratory Protection

To ensure against inadvertent exposure to PCBs, workers' respirators must be properly selected, fitted, and maintained. A guide to industrial respiratory protection [286] has been developed which contains sufficient information to enable the establishment and maintenance of a respirator program that meets the requirements outlined in 29 CFR 1910.134. The guide [286] includes information on respirator selection, use, maintenance, and inspection, as well as a complete description of various types of respirators and their advantages and limitations, respirator fitting procedures, wearer training instructions, and physiologic and psychologic constraints on respirator use.

Several NIOSH studies [287-289] have shown that respiratory protection may be inadequate in many occupational situations, eg, abrasive blasting, coal mining, and paint spraying. For this reason, respirators are generally regarded by NIOSH as a type of control to be used only where engineering controls cannot be used, made adequate, or provided.

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Basis for Previous Standards

In 1942, the Subcommittee on Threshold Limits of the National Conference of Governmental Industrial Hygienists compiled a list of maximum permissible concentrations of atmospheric contaminants recommended by various state industrial hygiene units [290]. The eight states that made recommendations for PCBs (chlorodiphenyls) were unanimous in recommending 1 mg/cu m. No basis for the recommendations was given.

Cook [291], in his 1945 listing of Maximum Allowable Concentrations of Industrial Atmospheric Contaminants, cited PCB standards for California and Utah of 1 mg/cu m and Oregon of 0.3 mg/cu m. He [291] also cited unofficial guidelines for Massachusetts of 5 mg/cu m and for New York of 1 mg/cu m and he recommended 1 mg/cu m, based on the report of Drinker [132].

The American Conference of Governmental Industrial Hygienists (ACGIH) began listing PCBs (chloro di phenyl) with "toxic dusts, fumes and mists" in its recommendations of maximum allowable concentrations of air contaminants for 1946 [292]. It compiled its 1946 list from its 1942 list [290] and from Cook's [291] list, and continued to recommend 1 mg/cu m for PCBs.

The ACGIH continued to recommend 1 mg/cu m for PCBs (chlorodiphenyl) until 1956 when it specified 1 mg/cu m as the limit for PCBs with 42% chlorine and proposed a limit of 0.5 mg/cu m for PCBs with 54% chlorine [293]. Each recommendation was clearly defined as a threshold limit value (TLV) for an 8-hour TWA concentration to which it was "felt" workers could be repeatedly exposed without adverse effect on their health.

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In 1961, the ACGIH added the notation "skin" to the TLV of those substances, including PCBs, which in liquid form can penetrate the skin to cause systemic effects [294,295].

In 1962, the ACGIH published documentation of its TLV recommendations [296]. Based on information in the reports of Schwartz [123], Drinker et al [125], Meigs et al [190], and Treon et al [203], the ACGIH [296] concluded that for PCBs chlorinated to 42%, 1 mg/cu m would seem to offer reasonably good protection against severe systemic toxicity but may not guarantee complete freedom from chloracne. They also cited the information [207] that PCBs could be absorbed through the skin, causing fatty degeneration of the liver. In documenting its recommendation for PCBs containing 54% chlorine, the ACGIH [296] cited Drinker et al [125], Drinker [132], and Treon et al [203], and on the basis of these reports it [296] considered that 0.5 mg/cu m appeared to be reasonable for repeated occupational exposures.

The American Industrial Hygiene Association's Hygienic Guide "Chlorodiphenyls (containing 42% and 54% chlorine)" [297], published in 1965, adopted the ACGIH recommendations for time-weighted average exposures and suggested a short-exposure tolerance for PCBs of 10 mg/cu m to prevent unbearable irritation, based on the report of Elkins [130]. The Hygienic Guide [297] provided information that minimum lethal doses applied to the skin of rabbits for 24 hours were 1 g/kg for PCBs containing 42% and 1.5 g/kg for PCBs containing 54% chlorine. It also recommended avoiding prolonged or repeated skin contact, and it recommended laundering of contaminated clothing before reuse, protecting the eyes from liquid splashes, treatment of the eyes if PCBs were splashed into them, and

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periodic examinations to detect early evidence of skin irritation or liver damage.

In 1970, the International Labour Office published permissible levels of toxic substances for several nations [298]. The PCB standards for six nations are given in Table VI-1.

TABLE VI-1

PERMISSIBLE LEVELS OF PCBs FOR SIX NATIONS

Country	Standard (mg/cu m)	Type of Standard
Czechoslovakia		
42% Chlorine	1.0	MAC
54% Chlorine	0.5	"
Finland		
42% Chlorine	1.0	MAC 8-hour
54% Chlorine	0.5	"
Poland	0.1	MAC
Romania		
42% Chlorine	1.0	"
54% Chlorine	0.5	"
USSR	1.0	"
Yugoslavia		
42% Chlorine	0.5	"
54% Chlorine	0.5	"

Adapted from reference 298

In 1975, Winell [299] compiled a list of international occupational hygienic standards for chemicals, including "chlorodiphenyl." She listed values for Sweden of 0.5 mg/cu m and for the German Democratic Republic of 1.0 mg/cu m. In both countries the standards were the same for PCBs containing 42% and 54% chlorine. The standards listed for the Federal Republic of Germany were 1.0 mg/cu m for PCBs containing 42% chlorine and

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0.5 mg/cu m for those with 54% chlorine, respectively.

The TLV documentations for PCBs published by the ACGIH in 1976 [300] did not differ significantly from the original documentations [296]. However, the ACGIH [300] recalled, citing von Wedel et al [205], that several deaths due to liver atrophy occurred among workers exposed to fumes of chlorobiphenyls and chloronaphthalenes, but pointed out that relatively few, if any reports had appeared of sytemic poisoning of workers exposed only to fumes of PCBs.

The ACGIH has retained a TWA of 1 mg/cu m as the TLV for PCBs with 42% chlorine content and a TWA of 0.5 mg/cu m as the TLV for those with 54% chlorine content (through 1976) [301]. However, a tentative short-term exposure limit (TLV-STEL) was added to the recommendations in 1976. STEL is defined by ACGIH [299] as the maximum concentration to which workers can be exposed for up to 15 minutes continuously without suffering from irritation, chronic or irreversible tissue change, or narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency. According to the ACGIH [301], the STEL is to be considered a maximum allowable concentration, or absolute ceiling not to be exceeded at any time during the 15-minute excursion period; such excursions are not to occur more than 4 times a day and there must be at least 60 minutes between them. The STEL recommended for PCBs was 1 mg/cu m regardless of the degree of chlorination. This recommendation was made on the basis that the TLV documentation for PCBs [300] suggested that the values should be ceilings never to be exceeded, rather than TWA values for 8 hours of exposure [301].

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The 1968 ACGIH recommendations [302], adopted as the federal standards for PCBs (29 CFR 1910.1000, Table G-1) are TWA 8-hour exposure concentrations of 1.0 mg/cu m for mixtures containing 42% chlorine and 0.5 mg/cu m for mixtures containing 54% chlorine.

Basis for the Recommended Standard

(a) Permissible Environmental Limit

The major effects that have been found in workers exposed to PCBs are chloracne [186-191,195,196], liver injury [190-193,196], and irritation of skin and mucous membranes [192,196,197]. Exposures at peak PCB concentrations of 5-10 mg/cu m have been reported as "unbearably" irritating [130].

Chloracne has been reported after occupational exposure to Aroclors 1242 [196] and 1254 [186], and to various Kanechlors [191,192,194,195], as well as after ingestion of Kanechlor 400 [146,153]. Chloracne has frequently been associated with processes where the PCBs were heated [186-189,196]. The methodology in most of the exposure studies did not differentiate between vapor and particulate forms of the PCBs [186,190,196]. In one study of Kanechlors in capacitor manufacturing plants where chloracne was common, vapor (or small particulate) concentrations (0.095-0.95 mg/cu m) exceeded particulate concentrations (0.02-0.65 mg/cu m) [191]. In another capacitor plant where heated Aroclor 1254 was used, exposure concentrations were 5-7 mg/cu m, but the vapor components were not seperately determined [186]. In this plant, chloracne developed among workers after 4-8 months of exposure. A study of workers, in a plant where the work situation indicated the exposures were to PCB

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vapors, showed that chloracne developed after a minimum of 5 months and an average of 14 months of exposure [190]. In this study, exposure concentrations of an undefined PCB were reported as 0.1 mg/cu m. In other studies where PCB concentrations were not measured, chloracne developed after 3-8 months of exposure [187,189].

These data show that chloracne can develop after prolonged exposures to PCBs in concentrations as low as 0.1 mg/cu m, and that as the PCB exposure concentrations increase, the duration of exposure required for the development of chloracne decreases. The data also indicate that PCBs in the vapor phase may contribute substantially to development of chloracne. However, they do not prove that only PCB vapors cause chloracne. Particulate PCBs have been shown to be absorbed from inhaled air by experimental animals [97], and ingested PCBs have caused chloracne [146,153]. Occupational exposure to a variety of PCB mixtures (Aroclors 1242, and 1254, various Kanechlors, and others) has caused chloracne, and no commercial PCB mixture has been shown to have more or less chloracnegenic properties than others.

There are some studies of PCB workers in which chloracne was not found [197-199]. In one of these studies, the Aroclor 1242 concentrations were imprecisely reported [198] and in the others the PCB mixtures were undefined [199]. The report by Levy et al [197] gave possible PCB exposure concentrations of 0.013-0.264 mg/cu m and breathing zone concentrations of 0.014-0.073 mg/cu m. Thus the data indicate that chloracne may be prevented by keeping PCB exposures below 0.1 mg/cu m (100 μg/cu m).

In some of the studies where chloracne developed, signs of liver injury were not found [186,194,195], but in the majority of studies where

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chloracne was found, there were also indications of liver injury [190-193,196]. Evidence of impaired liver function was found by other investigators [197] in a study where workers had not developed chloracne. Meigs et al [190] found evidence of slight liver injury in workers exposed to PCBs at 0.1 mg/cu m, and Levy et al [197] found historical evidence of liver injury in the medical records of workers in the plant where they found exposures were <0.25 mg/cu m. Among the findings in these medical records were elevated serum triglycerides [197]. Abnormal serum triglycerides have been found in exposed workers by others [191-193], and in the Japanese people who accidentally consumed PCBs [155,157,158,175,179-181]. The effect on serum triglycerides in workers was related to duration of exposure [193] and, in the workers and in the Yusho patients, to residual PCBs in the blood [175,180,193]. In the Japanese workers who were removed from exposure, the effect remained for at least 2 years [193].

Other indications of liver injury in exposed workers included occasional findings of elevated serum enzyme activities, and abnormalities in various other liver function tests [190,191,196,197]. A level of exposure at which liver injury will not occur is not indicated by the occupational exposure studies, since evidence of liver injury has been found in the occupational studies with the lowest PCB concentrations. It is not possible to determine whether liver injury occurred with exposures at the lower levels of all the occupational exposure ranges reported, but to protect workers from any liver injury it seems that exposures should be maintained below 0.01 mg/cu m (10 μg/cu m).

Animal experiments do not demonstrate a safe exposure level either. Although Treon et al [203] found no evidence of liver injury in

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experimental animals (rabbits, guinea pigs, cats, rats, and mice) exposed to Aroclor 1242 at concentrations of 1.9-8.6 mg/cu m for up to 31 weeks, Ouw et al [196] found evidence of liver injury in workers exposed to Aroclor 1242 at 0.32-1.44 mg/cu m. In their experiments with Aroclor 1254, Treon et al [203] found microscopic evidence of liver injury in animals exposed at 1.5 mg/cu for 31 weeks. Linder et al [228] found increased liver weights in rats fed Aroclor 1254 at 1 ppm for two generations. The intake of PCBs at this dietary level can be compared to the intake from inhalation exposure at about 0.1-0.2 mg/cu m; thus, the animal experiments appear to confirm indications of liver injury in workers exposed to PCBs in this range. The combined studies of Levy et al [197], Meigs et al [190], Hasegawa et al [191], and Ouw et al [196], and the animal studies [203,228], provide further support to the conclusion that PCB exposures must be maintained at lower levels to prevent liver injury than to prevent chloracne.

Since indications of liver injury can be found in reports of both occupational studies [190,191,196] and animal experiments [203,228] with the lowest PCB exposure, there is no proof of an exposure level that is adequately low to prevent liver injury.

The prevention of liver injury is of particular concern because there is substantial evidence that arene oxides are formed during the metabolism of PCBs by animals [51,68,69,74,75,81,115,116,118], and the data offer no reason to suspect that humans metabolize PCBs differently from animals. PCB metabolites have been demonstrated to bind to nuclear components of hepatic cells of rhesus monkeys [51] and rats [81] and this is sufficient evidence to arouse suspicions that PCBs could be potential carcinogens in

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the workplace. Commercial PCB preparations that have been adequately tested in rats [218,242] (Federal Register 42:6532-55, February 2, 1977) and mice [221,240,241] have been demonstrated to cause liver tumors. No liver tumors were found in rats fed Aroclors 1242, 1254, and 1260 at 1 ppm in the diet, but each of these mixtures produced tumors at 10 ppm (Federal Register 42:6532-55, February 2, 1977). In this same experiment a high incidence of pituitary tumors was found in PCB-fed rats. In Yusho patients [160,161], and in American workers (written communications, HA Sinclaire, June 1976; G Rousch, September 1976), preliminary studies only indicate that the occurrence of certain cancers may be excessive. However, the findings in rats and mice demonstrate reproducible production of liver tumors after ingestion of various PCB mixtures, and NIOSH concludes that PCBs in workplace air are potential carcinogens.

Additional concerns for the health of workers and their families are adverse reproductive effects [228,230,232,233], including terata in animals fed various PCBs (FL Earl et al, written communication, 1976), and adverse effects in human and animal infants nursed by PCB-exposed mothers [101,182,233]. PCBs resembling those in maternal blood both qualitatively and quantitatively have been found in human cord blood and in tissues of newborn humans and animals [101,138,139,168]. Fetal resorptions were common, and dose related incidences of terata were found in pups and piglets when bitches and sows were fed Aroclor 1254 at 1 mg/kg/day or more. Terata were not found in babies of Yusho patients (maximum consumption of PCBs of about 0.15 mg/kg/day); however, many undesirable effects including low birth weights and chloracne-like lesions at birth and after nursing were found [176,182,183].

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Based on the findings of adverse reproductive effects, on its conclusion that PCBs are potential carcinogens in humans and on its conclusion that occupational and animal studies have not demonstrated a level of exposure that will not subject the worker to possible liver injury, NIOSH recommends that the TWA concentrations of PCBs in the breathing zone of workers be maintained at or below the minimally detectable TWA concentration for up to a 10-hour workday, 40-hour workweek. NIOSH considers the minimally detectable concentration of PCBs for the monitoring of occupational exposures to be 1 μg/cu m, based on its review of the literature and the methodology presented in Appendices I and II.

Maintenance of exposures to PCBs at or below this concentration should reduce risks of reproductive and carcinogenic effects, and protect the employees from metabolic dysfunction, hepatic injury, and dermal effects due to PCB exposures during their working lifetimes.

It is recognized that employees handling PCBs may have skin contact with these substances, potentially resulting in dermatologic and systemic effects. Consequently, appropriate work practices, training programs, and other measures should be required, regardless of the concentrations of airborne PCBs. Therefore, occupational exposure to PCBs has been defined as working with PCBs or with equipment containing PCBs that can become airborne or that can spill or splash on the skin or into the eyes, or the handling of any solid products that may result in exposure to PCBs by skin contact or by inhalation.

(b) Sampling and Analysis

Based on an evaluation of the literature and on its own studies, NIOSH recommends sampling and analysis for PCBs as detailed in Appendices I

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and II. Florisil has been selected as the solid sorbent for PCBs because it will collect vapors as well as particulates and PCBs can be quantitatively recovered from it. The recommended Florisil sampling tubes have been shown to have an adequate sorption capacity (at least 100 μg) for monitoring occupational exposures at the recommended limit for up to a 10-hour workday. NIOSH has used the sampling method for monitoring TWA occupational exposures at 10-250 μg/cu m [197,244] by sampling at about 200 ml/minute for the entire workday. Total sample volumes of up to 100 liters were collected. At 1 μg/cu m, 100 liters of air would contain 100 ng of PCBs. The lower limit of PCB detection by GLC with EC detection was found to be 32 pg/4-μl injection. Since the contents of the Florisil tubes are dissolved in 5 ml of solvent, this represents a total of 40 ng of adsorbed PCBs. Although NIOSH recommends sampling at 200 ml/minute, it may be feasible to use pumps that sample at faster rates if there are analytical difficulties with samples of about 100 liters due to low concentrations of PCBs.

(c) Medical Surveillance

Occupational exposure to PCBs has been shown to cause signs of liver injury and impaired liver function. Ouw et al [196], Hasegawa et al [191], and Levy et al [197] all found occasional incidents of elevated serum enzymes: exposure conditions under which these will not occur are not known. Therefore, NIOSH recommends determination of SGOT and SGPT initially and at annual intervals. The responsible physician may also wish to determine serum triglyceride concentrations since these have been found to be abnormal in some workers chronically exposed to PCBs [191-193,197]. Especially, elevated serum triglyceride concentrations have been found to

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be related to duration of exposure and to the concentration of residual PCBs in the blood [193].

Although the data indicate that the recommended standard will prevent chloracne, it is not known that it will prevent other skin ailments. NIOSH recommends that in comprehensive physical examinations, special emphasis be given to the condition of the skin.

PCBs fed to bitches and sows have been found to be teratogenic (FL Earl et al, written communication, 1976). Although terata have not been observed in human babies whose mothers had been exposed to PCBs [176,182,183], PCBs have been found in human embryos and fetuses [138,139,168], and undesirable effects (abnormal skin color and low birth weights) have been observed in neonates [176,182,183] born after their mothers had ingested PCBs. A woman who was occupationally exposed to PCBs had a blood PCB concentration of 25 ppb when her normal baby was born [195]. NIOSH considers that its recommended standard will protect unborn babies but recommends that women exposed to PCBs at work be advised of the potential hazards of PCB exposure to unborn children.

PCBs have been found in milk of women who have been exposed to PCBs [168,195] and babies have been adversely affected after being nursed by PCB-exposed mothers [182]. A safe level of PCBs in the milk of mothers occupationally exposed to PCBs is not known. Human milk samples in the general US population usually contain detectable amounts of PCBs, and about one-third of the whole milk samples have been found to contain >50 ppb and up to about 350 ppb (EP Savage, written communication, February 1977). It is not known if all the mothers from whom these samples were taken nursed their babies without effect. Infant monkeys who were nursed by mothers

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in their milk at 150-350 ppb became sick and developed chloracne [234]. After consultation, the woman who was occupationally exposed to PCBs and who had PCBs in her milk at about 250 ppb, stopped nursing her baby out of concern for its health [195]. Based on these considerations, NIOSH recommends that women working with PCBs be counseled concerning the advisability of nursing their babies.

(d) Personal Protective Equipment and Clothing

PCBs applied to the skin or cornea of experimental animals have been shown to cause local lesions and liver and kidney injuries [205-208,225]. One worker who developed chloracne after 3 months of exposure to PCBs was described as having frequently immersed his hands in the PCB mixture and his clothes were described as often being impregnated with PCBs [189]. Employees working with an askarel containing 60% Aroclor 1254 frequently developed skin rashes which were considered by the company physician to be allergic or contact dermatitis from the askarel (In the Matter of General Electric Company, File No. 2833, New York State Department of Environmental Conservation, 1975). Other complaints of these workers that were ascribed to the askarel included irritation of the eyes, nose and throat. Levy et al [197] and Ouw et al [196] found that employees exposed to PCBs at 0.013-0.264 mg/cu m and 0.32-1.44 mg/cu m, respectively, complained of similar irritations and, on examination, there were findings of skin rashes and nasal irritation. Ouw et al [196] considered that one reason the blood PCB concentrations in workers they studied did not decline (after improvements in the ventilation system had reduced the environmental concentrations of PCBs) was because the workers did not comply with the recommendations for protecting their skin from PCB contact.

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Based on these reports [189,196,197,205-208,225], NIOSH recommends that employees working in situations where skin contact may occur be provided with clothing that is impervious to PCBs and that will cover all body surfaces where contact may occur. To prevent splashing PCBs into the eyes, NIOSH recommends that employees wear appropriate goggles or safety glasses in accordance with 29 CFR 1910.133 and ANSI Z87.1-1968. Since NIOSH has found PCBs to be potential carcinogens and recommends that exposures be maintained at or below 1 μg/cu m, it considers that only a self-contained breathing apparatus with a full facepiece operated in the positive-pressure mode will provide adequate protection when workers are in areas where higher concentrations exist. Based on NIOSH studies [287-289], other respiratory protective devices are not considered adequate to provide the needed protection.

(e) Other Considerations

Engineering controls are recommended to maintain PCBs in closed systems to reduce exposures to the extent feasible. Such a recommendation is consistent with the Toxic Substances Control Act (Public Law 94-469) and with the need to protect employees from exposure to PCBs. However, there are situations, such as in accidental leakage from closed systems and in repair of equipment, when PCBs may not be confined. The recommended standard prescribes general work practices for PCBs as well as emergency work practices. Employees should be informed of the hazards of working with PCBs, and trained in the recommended general work practices and the procedures to follow in emergencies. The advantages to their health of complying with the work practices and medical monitoring requirements of the recommended standard should be explained to the employees. As Ouw et

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al [196] pointed out, improving air quality does not go far in alleviating the workers' body burdens of PCBs without their cooperation in implementing the recommendations for protecting their skin from PCB contact.

NIOSH also recommends certain sanitation practices to minimize intake of PCBs by employees. Among these practices is the requirement that employees be provided with clean work clothing daily and that they change clothing before leaving work. The importance of this measure to the employee and the employee's family is exemplified in finding up to 180 ppm of PCBs in the dust of PCB-workers' homes [36]. PCBs may remain in contaminated premises for years [33]. Partly for the same reason, and because PCBs in contact with the skin can be irritating [196,197] and also because they have caused systemic effects in experimental animals [205-208,225], NIOSH recommends that workers shower before leaving work.

Toxic effects from ingestion of PCBs have been well documented in humans [145-185] and experimental animals [101,209-224,226-237,240-248]. Workers may have an intake of PCBs from their normal diet of 10-20 μg/day [46], and the maximum additional intake expected from NIOSH's recommended allowable work exposures might be of the order of 10 μg. NIOSH recommends that workers wash their hands before eating and that food, drinks, and smoking materials not be permitted in PCB work areas. The importance of this recommendation may be evaluated by considering that one drop of PCBs spilled on food, in drinks, or otherwise conveyed into the mouth may contain about 50 μg of PCBs, compared to a total intake of 20-30 μg from other sources, including allowable occupational exposures.

Because the consequences of working with PCBs may be substantial, NIOSH recommends that entry into PCB work areas be restricted to authorized

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employees whose entry is logged daily, and whose exposures are monitored at least annually to ensure that airborne exposures are at or below the recommended TWA limit.

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VII. RESEARCH NEEDS

There is a clear need for information in the following areas:

(a) The effects of chronic exposure of animals and humans to PCBs at low concentrations require investigation. Epidemiologic studies of occupational groups and information on concentrations of PCBs in workroom air and any related clinical findings would be useful.

(b) Chronic exposures of animals to PCBs at concentrations in the range of the recommended environmental limit.

(c) Studies of the reproductive histories of women who have been exposed to PCBs in their occupational environments, including studies of status and development of infants born to these women.

(d) The absorption efficiencies of various PCB mixtures by the dermal and respiratory routes.

(e) The method of transport of PCBs in the blood and the partition between blood on the one hand, and fat stores and milk on the other.

(f) A problem that confounds our understanding of the toxicity of PCBs is that of the toxic activity of contaminants associated with PCBs. The contaminants found in commercially important PCB products should be identified, prepared in pure form and studied toxicologically both as individual substances and as mixtures with other, related compounds.

(g) Studies regarding methods of removing PCBs from the skin (cleansing).

(h) Studies on the use of various barrier creams as a means of minimizing dermal exposure to PCBs.

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(i) There is uncertainty regarding baseline values for PCBs in the blood of humans; research should be conducted to determine baseline values for the general population and for non-exposed industrial populations.

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IX. APPENDIX I

SAMPLING PROCEDURE FOR COLLECTION OF POLYCHLORINATED BIPHENYLS

General Requirements

(a) Air samples representative of the breathing zones of workers must be collected to determine the exposure from each job or from the specific operation in each work area.

(b) Suggested records:

(1) Date and time of sample collection;

(2) Pump model and serial number;

(3) Sample tube type and number;

(4) Sampling duration;

(5) Total sample volume;

(6) Location of sampling;

(7) Temperature, pressure, and relative humidity at time of sampling;

(8) Other pertinent information.

Calibration

Since the accuracy of environmental sampling can be no greater than the accuracy of the air volume measurement, the accurate calibration of the sampling pump is essential to the correct estimation of the volume of the sample that is collected. The required frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. Pumps should be calibrated initially and recalibrated if misused or

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repaired. If pumps receive hard usage, more frequent calibration may be necessary. Regardless of use, maintenance and calibration should be performed on a regular schedule and records of these should be kept.

The accuracy of calibration depends on the type of instrument used as a reference. The choice of calibration instrument will depend largely upon where the calibration is to be performed. Ordinarily, pumps should be calibrated in the laboratory. For laboratory testing, primary standards, such as a spirometer or a soapbubble meter, are recommended, although other standard calibration instruments, such as a wet-test meter or dry gas meter, can be used. The calibration setups will be similar for all instruments.

Instructions for calibration with the soapbubble meter follow. If another calibration device is selected, equivalent procedures should be used. Since thezflowrate of a pump depends on the pressure drop across the sampling device, in this case a "Florisil" tube, the pump must be calibrated while operating with a representative tube in line. The calibration system should be assembled in series following this order: soapbubble meter, water manometer, Florisil tube, and pump.

(a) Check the voltage of the pump battery with a voltmeter to ensure adequate voltage for calibration, and change or charge the battery if necessary.

(b) Turn on the pump and moisten the inside of the soapbubble meter by immersing the buret in the soap solution and drawing bubbles up the inside until they travel the entire buret length without bursting.

(c) Adjust the pump rotameter to provide the desired flowrate.

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(d) Check the water manometer to ensure that the pressure drop across the sampling train does not exceed 2.5 inches of water at 0.2 liter/minute.

(e) Start a soapbubble up the buret and measure with a stopwatch the time required for it to move between calibration marks.

(f) Repeat procedure (e) at least twice, average the results, and calculate the flowrate from the volume between the preselected marks divided by the time required for the soapbubble to traverse the distance.

(g) Record the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure, serial number of pump, date, time, and name of person performing the calibration.

(h) The rotameter reading should be corrected for temperature and pressure, if necessary.

Sampling

(a) Samples should be collected as near as practicable to the faces of workers without interfering with freedom of movement.

(b) Samples should be collected to permit determination of TWA exposures for every job involving exposure to PCBs and in sufficient numbers to express the variability of the exposures in the work situation.

(c) Apparatus for Breathing Zone Sampling

(1) Pump, battery-operated, with clip for attachment to the worker's clothing. Airflow through the pump should be controlled within 5% of the desired rate during the entire sampling period.

(2) Sorbent Tubes

Glass tubes at least 7 cm long with 4 mm I.D. and containing

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two sections of 30/48 mesh deactivated Florisil. (Florisil, 30/60 mesh, is sieved to the proper mesh size.) The front section, preceded by a glass wool plug, contains 100 mg adsorbent, and the backup section contains 50 mg. A urethane foam plug is placed between these sections and also behind the backup section. The ends of the tube are flame-sealed to prevent contamination before use.

Deactivate the Florisil before packing the tubes by drying a weighed amount at 105 C for 45 minutes. After cooling to room temperature, add the Florisil to a round bottom flask which can be attached to a rotary evaporator. Add water at 3 ml/100 g of Florisil (ie, 3% W/W water) and turn the mixture in the rotary evaporator for 1 hour or until it is uniformly mixed (free-flowing).

(d) Collection and Shipping of Samples

(1) Immediately before sampling, break each end of the sorbent tube to provide an opening at least one-half the internal diameter of the tube (2 mm).

(2) The smaller, or backup, section of Florisil should be positioned nearest the sampling pump.

(3) The sorbent tube must be vertical during sampling. Tubes should not be placed in a horizontal position since this may lead to "channeling" of the sorbent bed.

(4) Do not pass air being sampled through any hose or tubing before it enters the tube.

(5) Collect the air sample at a flow rate of 200 cc/minute or less to obtain the total sample volume required. The recommended maximum sampling volume for this method is 50 liters.

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(6) Cap the sorbent tubes with inert plastic caps immediately after sampling. Under no circumstances are rubber caps to be used. Label tubes and note precise location assignments.

(7) Handle one additional tube in the same manner as the sample tubes except that no air is to be drawn through it. Label this tube as a blank.

(8) If the tubes are to be shipped, pack them tightly to minimize breakage in transit.

(9) Do not subject the tubes to extremes of temperatures or to low pressures.

(10) Provide bulk samples of the PCB preparation whose presence in the environment is suspected to the analytical laboratory. Do not transport these bulk materials in the same container as the samples or blank tubes. If possible, also provide a bulk air sample to use for qualitative identification.

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X. APPENDIX II

ANALYTICAL METHOD FOR POLYCHLORINATED BIPHENYLS

Principle of the Method

A known volume of air is drawn through a tube containing Florisil to adsorb the PCBs present in the air sample. The collected PCBs are desorbed with hexane, and the resulting solutions are analyzed using gas-liquid chromatography with electron capture detection. The concentration of PCBs relative to a standard PCB preparation is read from a standard curve. If the air sample is found to differ significantly in composition from available PCB standards, then use the alternate procedure of perchlorination described in paragraph (b)7 of Procedure.

Range and Sensitivity of the Standard Analysis

NIOSH has found with Aroclor 1016, that the minimum detectable amount of PCB is 32 pg/4 µl. With a total desorption volume were 5 ml, this would represent a total sample of 40 ng of Aroclor 1016. Thus the method is capable of detecting a concentration of 40 ng in a 1 cu m air sample, or a concentration of about 1 µg/cu m in an air sample of 50 liters. The upper range of the analytical method is apparently limitless depending only upon the degree of dilution needed to maintain the concentration of the sample within the linear range of the electron capture detector (32 pg to 3 ng/injection). In practice, concentrations in workplace air have been found to be as high as 1.5 mg/cu m.

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Interferences

(a) Strict measures to avoid contamination are required when using the electron capture detector. Foremost, the syringe must be thoroughly cleaned after each injection. Hexane to be used in the analytical procedure should be periodically analyzed by GLC for purity. It should show no chromatographic peaks later than 45 seconds, if less than 5 μl have been injected.

(b) Any compound which has nearly the same retention time on the GLC column as one of the PCBs is an interferent. This type of interference can often be overcome by changing the GLC operating conditions or by selecting another column. Retention time data on a single column, or even on a number of columns, cannot be considered as proof of chemical identity. It is important, therefore, that a sample of the bulk mixture of PCBs be analyzed at the same time as the contents of the sample tubes so that chemical identification of possible interferences can be made.

(c) The interferences which have been reported in the literature in the GLC analysis of PCBs are not expected to be important for this method. Chlorinated pesticides, such as DDT, DDE, etc, have been reported as interferences due to coextraction with PCBs during workup of samples such as water, tissue, soil, or biologic fluids. In the case of personal air sampling in an industrial environment, these interferences would not be present in amounts that would significantly interfere unless they were manufactured in the same area. Thus, unless these chlorinated pesticides are specifically known as potential interferents, extra cleanup or separation steps for these materials are not necessary.

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(d) Sulfur-containing compounds in petroleum products have been reported as interferences.

(e) If present in the PCB mixture, biphenyl will be an interference when samples are analyzed by perchlorination; however, PCBs for the purpose of this recommended standard include biphenyl.

(f) Brominated impurities in antimony pentachloride have also been found to lead to interferences in perchlorination procedures. Results from NIOSH laboratories indicate, however, that these brominated impurities may be removed by vacuum distillation of the antimony pentachloride.

Precision and Accuracy

The performance characteristics of the method as found by NIOSH are presented below.

(a) The volume of air sampled can be measured to ±1% if a pump with a calibrated volume indicator is used. Volumes calculated from initial flow rate settings may be less accurate (±5%) because of changes in flow rate during sampling.

(b) At airborne PCB concentrations of up to 10 mg/cu m, the front section of the Florisil tube has a 100% collection efficiency for 50-liter air samples.

(c) Recovery of known amounts of PCBs adsorbed on Florisil is quantitative (100%).

(d) Sealed tubes or desorbed sample solutions can be stored for 2 months without PCB loss.

(e) The precision of the analysis is dependent upon the precision and sensitivity of the technique used to quantitate the GLC peaks of the

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samples and standards. The precision of the standard analytical procedure has a relative standard deviation of 4.4%.

(f) The average conversion of PCBs to decachlorobiphenyl is about 100% with a relative standard deviation of about 2%.

(g) Recovery of decachlorobiphenyl subjected to the decachlorination procedure is >99% with a relative standard deviation of 1.8%.

(h) The accuracy of these procedures is not known; accuracy depends on the ability to separate and identify each compound in the PCB mixture and to compare each with a known standard. Many of the isomers in commercial PCB mixtures have not been separated or identified, and standards for many of the isomers are not available.

Advantages of the Sampling and Analytical Methods

(a) The sampling device is small, portable, and involves no liquids.

(b) The capacity of the solid sorbent sampling device for PCBs is large and recovery of PCBs from the sorbent is quantitative.

(c) The contents of the sample collection tubes are analyzed by means of a rapid instrumental method.

(d) Interferences are minimal, and most of those which do occur can be eliminated by altering chromatographic conditions.

(e) The perchlorination procedure provides qualitative confirmation and quantitative measure of PCBs, since it is based on measurement of the single GLC-EC detection response of decachlorobiphenyl.

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Disadvantages of the Sampling and Analytical Methods

(a) The precision of the sampling method is limited by the reproducibility of the pressure drop across the tubes. Pressure drop changes will result in variability in the flow rate and cause the sampling volume to be imprecisely known because the pump is usually calibrated for only one tube.

(b) A substantial difference between the composition of PCBs in the air sample and that of the commercial PCB mixture being used as a standard will result in a large error in accuracy when the standard analytical procedure is used, since estimation of the PCB content of the sample is based on comparison with such a PCB mixture.

Apparatus

(a) Gas liquid chromatograph equipped with an electron capture detector capable of maintaining a detector temperature of 350 C.

(b) Glass column (6 feet x 2 mm I.D.) packed with 1.5% OV-17/1.95% QF-1 on 80/100 mesh Supelcoport.

(c) Vials (20-ml), with aluminum-lined caps.

(d) Microliter syringe (10-µl).

(e) Volumetric flasks (10-ml for standards) with glass stoppers.

(f) Method for determining peak areas.

(g) Culture tubes, 13 x 100 mm, with unlined screw top caps.

(h) Oven, capable of maintaining 160 C ± 5 C.

(i) Sand bath.

(j) Vortex mixer.

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Reagents

(a) Hexane, pesticide-grade quality.

(b) Nitrogen carrier gas, prepurified.

(c) PCB mixture under study.

(d) Antimony pentachloride, distilled under vacuum.

(e) Decachlorobiphenyl.

(f) Sodium sulfate, anhydrous.

(g) Hydrochloric acid, 20% aqueous.

Calibration and Standards

(a) Standardization Procedure

Use the particular PCB mixture as the standard that was being used in the work area in which air samples were taken. Prepare standards in hexane at concentrations ranging from 8 to 500 ng/ml. Calibration curves should be established daily since the electron capture detector response may vary from day to day. Plot the standard curve in terms of concentration (ng/ml) versus area. Since the injection volumes of the standard and the sample are identical, the concentration of the sample can be read directly from the standard curve.

(b) Alternate Standardization Procedure (Perchlorination)

The product of the perchlorination of the PCB mixture with antimony pentachloride is decachlorobiphenyl. Standards of decachlorobiphenyl are prepared in hexane at concentrations ranging from 70 to 440 ng/µl. Calibration curves are established daily since the electron capture detector response may vary from day to day. The standard curve is plotted in terms of concentration (ng/ml) versus peak area. Since the injection

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volume of the standard and the sample are identical, the concentration of the sample can be read directly from this curve.

Procedure

(a) Cleaning of Equipment

All glassware used for the laboratory analysis should be washed with a detergent, throughly rinsed with tap water, distilled water, pesticide-grade acetone, and finally pesticide-grade hexane and then dried.

(b) Analysis of Samples

(1) Preparation of Samples

Score each tube with a file and place the glass wool and front section in a clean, dry vial. Place the separating urethane foam plug, the back section of the sorbent, and the retaining urethane foam plug in a second clean, dry vial. The front and back sections are analyzed separately.

(2) Desorption of Samples

Prior to analysis, pipet 5.0 ml of hexane into each vial. Florisil particles should not be allowed to cling to the glass above the solvent. A minimum desorption time of 10 minutes is required before analysis.

(3) Gas-liquid chromatographic conditions for PCB determination by this procedure are:

(A) Nitrogen carrier gas flow rate, 60 ml/minute.

(B) Injector temperature, 300 C.

(C) Interface and detector temperatures, both 325 C.

(D) Column temperature, 180 C.

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(4) Sample Injection

The solvent-flush technique is recommended for injection of materials into the GLC apparatus. With this method, the following procedure would be used to inject 4 μl of sample. Three microliters of hexane would be drawn into the syringe, followed by 1 μl of air, followed by 4 μl of sample solution. After the needle is removed from the sample solution, 1 additional μl of air is drawn into the syringe to minimize evaporation at the tip of the needle. The plunger now rests at the 9-μl mark. Inject at least 7 μl of the syringe contents into the gas chromatogram. Not less than 1 μl of flush-solvent should be used. Larger volumes of flush may give a solvent peak which interferes with sample component peaks. The syringe must be cleaned with hexane after each injection.

(5) Preliminary Analysis

Using the solvent-flush method of subsection b(4), inject 1 μl of sample and 1 μl of flush-solvent at the conditions specified under subsection b(3). If the sample is too concentrated, further dilutions will be necessary to bring the concentration of the sample solution into the linear range of the electron capture detector. Once the concentration of the sample is appropriately adjusted, its chromatogram should be compared to that of a standard to determine if the air sample is qualitatively different in composition from the standard. If there is little difference between the two chromatograms, then proceed with the standard analysis using the PCB mixture for standardization, subsection b(6). On the other hand, should there be a significant difference between the two chromatograms (such that comparison with the PCB mixture could result in

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gross error), then use the alternate procedure for standardization, subsection b(7).

(6) Standard Analysis

Select at least five prominent peaks in the sample chromatogram and compare their heights or areas with those of the standard. Calculate the concentration of PCBs by comparing the heights or areas of the selected peaks in the sample chromatogram of those in the standard chromatograms of known amounts of material.

(7) Alternate Standardization Procedure

A 200-µl aliquot of the sample is placed in a 13-mm x 100-mm culture tube and the hexane is slowly evaporated with dry nitrogen until 10 µl or less remain. Do not allow hexane to climb the tube during evaporation and do not allow the sample to evaporate to dryness. Immediately add 0.2-0.5 ml of distilled antimony pentachloride with a disposable pipet as rapidly as possible (antimony pentachloride decomposes rapidly in air) and cap the tube. The sample should remain light yellow after this addition, but if the sample turns dark brown or black, it must be discarded and another aliquot of that sample must be used. All samples are placed together in a sand bath. There should be no liner in the cap of the tube, since most liners are attacked by antimony pentachloride. A sample of decachlorobiphenyl is treated in a manner similar to the samples. The sand bath containing all of the treated samples is placed in a preheated oven at 160 C for at least 3 hours. Samples may also be treated overnight. After perchlorination, the sand bath is removed from the oven and the samples are removed from the sand and allowed to cool to room temperature. To each sample is added dropwise 0.5 ml of 20% hydrochloric acid. This mixture is

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then extracted four times with 1-2 ml of hexane each time. Each extract is passed through a funnel containing approximately 0.5 g of anhydrous sodium sulfate (retained by a glass wool plug) into a 10-ml volumetric flask. The volume of the sample is brought to 10 ml by rinsing the pipet, sodium sulfate, and funnel tip with hexane. The funnel should not rest on thezlip of the flask during filtration. The glass wool plug and sodium sulfate in the funnel are replaced after each sample. An aliquot of the sample solution is injected under the GLC conditions described above. The solvents flush technique is recommended using 2 μl of solvent back flush and 6 μl of standard or sample solution. The syringe must be cleaned with hexane after each injection. The height or area of the decachlorobiphenyl peak is compared to that of the decachlorobiphenyl standard and the weight of decachlorobiphenyl present is calculated.

(8) Gas-liquid chromatographic conditions for decachlorobiphenyl determination:

(A) Nitrogen carrier gas flow rate, 90 ml/minute.

(B) Injector temperature, 300 C.

(C) Interface and detector temperature, 325 C.

(D) Column temperature, 220 C.

(c) Determination of Desorption Efficiency

NIOSH has found average desorption efficiency is >99.3%, thus, results of sample analyses need not be corrected for desorption efficiency.

Calculations

(a) Standard Analytical Procedure

The following are the steps in the calculation of concentrations of

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PCBs in air when determined with a PCB mixture as the standard.

(1) Add the heights or areas of several selected prominent peaks (at least five) in the chromatogram, compare with the total heights or areas of those same peaks in the standard, and read the concentration of the sample solution (ng/ml) from the standard curve.

(2) Multiply the concentration, in ng/ml, of the sample solution by the total volume, in ml, of the sample solution and calculate the weight of PCBs in the sample. Make corrections for the blanks if necessary.

(3) Add the weights found on the front and the back sections of the tube to find the total weight of PCBs in the air sample.

(4) Divide the total weight of the PCBs in the air sample by the volume, in liters, of air sampled and report the PCB concentration in ng/liter or its equivalent in μg/cu m.

(b) Alternate Standardization Procedure

The following are the steps in the calculation of concentrations of PCBs in air using the perchlorination method.

(1) The height or area of the decachlorobiphenyl peak in the chromatogram of the sample aliquot is compared to the height or area of the decachlorobiphenyl peak in the chromatograms of the standard. The concentration of decachlorobiphenyl in the sample aliquot is read from the standard curve.

(2) The concentration of decachlorobiphenyl in this aliquot (ng/ml) is multiplied by the total volume (ml) of the sample solution to give the total weight of PCBs in the sample as decachlorobiphenyl.

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(3) The weights of PCBs, as decachlorobiphenyl, found on the front and back sections of the tube are summed, corrections for blanks are made, and the total weight of PCB, as decachlorobiphenyl, in the air sample is calculated.

(4) The total weight of PCB is divided by the volume of air sampled and the air concentration is reported in ng/liter or its equivalent in μg/cu m.

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XI. APPENDIX III

MATERIAL SAFETY DATA SHEET

General instructions for preparing a Material Safety Data Sheet (MSDS) are presented in this chapter. The examples used in the text are for illustrative purposes and are not intended to apply to any specific compound or product. Applicable information about a specific product or material shall be supplied in the appropriate block of the MSDS.

The product designation is inserted in the block in the upper left corner of the first page to facilitate filing and retrieval. Print in upper case letters as large as possible. It should be printed to read upright with the sheet turned sideways. The product designation is that name or code designation which appears on the label, or by which the product is sold or known by employees. The relative numerical hazard ratings and key statements are those determined by the guidelines in Chapter V, Part B, of the NIOSH publication, An Identification System for Occupationally Hazardous Materials. The company identification may be printed in the upper right corner if desired.

(a) Section I. Product Identification

The manufacturer's name, address, and regular and emergency telephone numbers (including area code) are inserted in the appropriate blocks of Section I. The company listed should be a source of detailed backup information on the hazards of the material(s) covered by the MSDS. The listing of suppliers or wholesale distributors is discouraged. The trade name should be the product designation or common name associated with the material. The synonyms are those commonly used for the product, especially

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formal chemical nomenclature. Every known chemical designation or competitor's trade name need not be listed.

(b) Section II. Hazardous Ingredients

The "materials" listed in Section II shall be those substances which are part of the hazardous product covered by the MSDS and individually meet any of the criteria defining a hazardous material. Thus, one component of a multicomponent product might be listed because of its toxicity, another component because of its flammability, while a third component could be included both for its toxicity and its reactivity. Note that a MSDS for a single component product must have the name of the material repeated in this section to avoid giving the impression that there are no hazardous ingredients.

Chemical substances should be listed according to their complete name derived from a recognized system of nomenclature. Where possible, avoid using common names and general class names such as "aromatic amine," "safety solvent," or "aliphatic hydrocarbon" when the specific name is known.

The "%" may be the approximate percentage by weight or volume (indicate basis) which each hazardous ingredient of the mixture bears to the whole mixture. This may be indicated as a range or maximum amount, ie, "10-40% vol" or "10% max wt" to avoid disclosure of trade secrets.

Toxic hazard data shall be stated in terms of concentration, mode of exposure or test, and animal used, eg, "100 ppm LC50-rat," "25 mg/kg LD50-skin-rabbit," "75 ppm LC man," or "permissible exposure from 29 CFR 1910.1000," or, if not available, from other sources of publications such as the American Conference of Governmental Industrial Hygienists or the

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American National Standards Institute Inc. Flashpoint, shock sensitivity or similar descriptive data may be used to indicate flammability, reactivity, or similar hazardous properties of the material.

(c) Section III. Physical Data

The data in Section III should be for the total mixture and should include the boiling point and melting point in degrees Fahrenheit (Celsius in parentheses); vapor pressure, in conventional millimeters of mercury (mm Hg); vapor density of gas or vapor (air = 1); solubility in water, in parts/hundred parts of water by weight; specific gravity (water = 1); percent volatiles (indicate if by weight or volume) at 70 degrees Fahrenheit (21.1 degrees Celsius); evaporation rate for liquids or sublimable solids, relative to butyl acetate; and appearance and odor. These data are useful for the control of toxic substances. Boiling point, vapor density, percent volatiles, vapor pressure, and evaporation are useful for designing proper ventilation equipment. This information is also useful for design and deployment of adequate fire and spill containment equipment. The appearance and odor may facilitate identification of substances stored in improperly marked containers, or when spilled.

(d) Section IV. Fire and Explosion Data

Section IV should contain complete fire and explosion data for the product, including flashpoint and autoignition temperature in degrees Fahrenheit (Celsius in parentheses); flammable limits, in percent by volume in air; suitable extinguishing media or materials; special firefighting procedures; and unusual fire and explosion hazard information. If the product presents no fire hazard, insert "NO FIRE HAZARD" on the line

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labeled "Extinguishing Media."

(e) Section V. Health Hazard Information

The "Health Hazard Data" should be a combined estimate of the hazard of the total product. This can be expressed as a TWA concentration, as a permissible exposure, or by some other indication of an acceptable limit. Other data are acceptable, such as lowest LD50, if multiple components are involved.

Under "Routes of Exposure," comments in each category should reflect the potential hazard from absorption by the route in question. Comments should indicate the severity of the effect and the basis for the statement, if possible. The basis might be animal studies, analogy with similar products, or human experiences. Comments such as "yes" or "possible" are not helpful. Typical comments might be:

> Skin Contact--single short contact, no adverse effects likely; prolonged or repeated contact, irritation, and cracking. Readily absorbed through the skin with severe systemic effects.
>
> Eye Contact--some pain and mild transient irritation; no corneal scarring.

"Emergency and First Aid Procedures" should be written in lay language and should primarily represent first-aid treatment that could be provided by paramedical personnel or individuals trained in first aid.

Information in the "Notes to Physician" section should include any special medical information which would be of assistance to an attending physician including required or recommended preplacement and periodic medical examinations, diagnostic procedures, and medical management of overexposed workers.

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(f) Section VI. Reactivity Data

The comments in Section VI relate to safe storage and handling of hazardous, unstable substances. It is particularly important to highlight instability or incompatibility to common substances or circumstances such as water, direct sunlight, steel or copper piping, acids, alkalies, etc. "Hazardous Decomposition Products" shall include those products released under fire conditions. It must also include dangerous products produced by aging, such as peroxides in the case of some ethers. Where applicable, shelf life should also be indicated.

(g) Section VII. Spill or Leak Procedures

Detailed procedures for cleanup and disposal should be listed with emphasis on precautions to be taken to protect workers assigned to cleanup detail. Specific neutralizing chemicals or procedures should be described in detail. Disposal methods should be explicit including proper labeling of containers holding residues and ultimate disposal methods such as "sanitary landfill," or "incineration." Warnings such as "comply with local, state, and federal antipollution ordinances" are proper but not sufficient. Specific procedures should be identified.

(h) Section VIII. Special Protection Information

Section VIII requires specific information. Statements such as "Yes," "No," or "If Necessary" are not informative. Ventilation requirements should be specific as to type and preferred methods. Specify respirators as to type and NIOSH or US Bureau of Mines approval class, ie, "Supplied air," "Organic vapor canister," "Suitable for dusts not more toxic than lead," etc. Protective equipment must be specified as to type and materials of construction.

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(i) Section IX. Special Precautions

"Precautionary Statements" shall consist of the label statements selected for use on the container or placard. Additional information on any aspect of safety or health not covered in other sections should be inserted in Section IX. The lower block can contain references to published guides or in-house procedures for handling and storage. Department of Transportation markings and classifications and other freight, handling, or storage requirements and environmental controls can be noted.

(j) Signature and Filing

Finally, the name and address of the responsible person who completed the MSDS and the date of completion are entered. This will facilitate correction of errors and identify a source of additional information.

The MSDS shall be filed in a location readily accessible to workers potentially exposed to the hazardous material. The MSDS can be used as a training aid and basis for discussion during safety meetings and training of new employees. It should assist management by directing attention to the need for specific control engineering, work practices, and protective measures to ensure safe handling and use of the material. It will aid the safety and health staff in planning a safe and healthful work environment and in suggesting appropriate emergency procedures and sources of help in the event of harmful exposure of employees.

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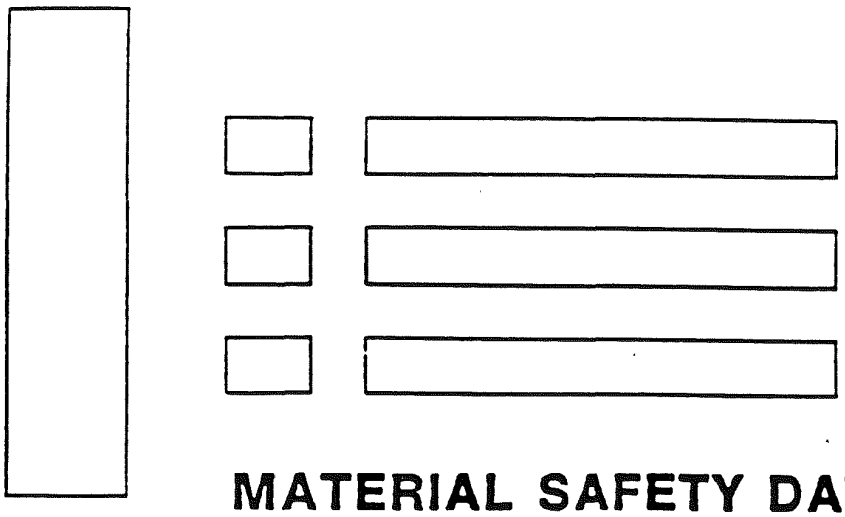

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION	
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.
ADDRESS	
TRADE NAME	
SYNONYMS	

II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA

III PHYSICAL DATA			
BOILING POINT, 760 MM HG		MELTING POINT	
SPECIFIC GRAVITY (H_2O = 1)		VAPOR PRESSURE	
VAPOR DENSITY (AIR = 1)		SOLUBILITY IN H_2O, % BY WT	
% VOLATILES BY VOL		EVAPORATION RATE (BUTYL ACETATE = 1)	
APPEARANCE AND ODOR			

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IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	

FLAMMABLE LIMITS IN AIR, % BY VOL.	LOWER		UPPER	

EXTINGUISHING MEDIA	
SPECIAL FIRE FIGHTING PROCEDURES	
UNUSUAL FIRE AND EXPLOSION HAZARD	

V HEALTH HAZARD INFORMATION

HEALTH HAZARD DATA

ROUTES OF EXPOSURE

INHALATION

SKIN CONTACT

SKIN ABSORPTION

EYE CONTACT

INGESTION

EFFECTS OF OVEREXPOSURE

ACUTE OVEREXPOSURE

CHRONIC OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

EYES

SKIN.

INHALATION.

INGESTION

NOTES TO PHYSICIAN

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VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

INCOMPATIBILITY

HAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

NEUTRALIZING CHEMICALS

WASTE DISPOSAL METHOD

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL)

EYE

GLOVES

OTHER CLOTHING AND EQUIPMENT

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IX SPECIAL PRECAUTIONS

PRECAUTIONARY STATEMENTS

OTHER HANDLING AND STORAGE REQUIREMENTS

PREPARED BY

ADDRESS

DATE

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TABLE XII-1

CHEMICAL AND PHYSICAL PROPERTIES OF SOME AROCLORS

Aroclor	Chlorine, % w/w	Distillation Range, C (corrected)	Density g/ml 25 C	Flash-point* F	Fire-Point* F	Appearance
1221	20.5-21.5	275-320	1.18	286-302	349	Clear, mobile oil
1232	31.4-32.5	290-325	1.26	305-310	460	"
1242	42	325-366	1.38	384-356	none**	"
1248	48	340-375	1.44	379-384	"	"
1254	54	365-390	1.54	none**	"	Light-yellow visous liquid
1260	60	385-420	1.62	"	"	Light-yellow soft, sticky resin
1262	62	390-425	1.64	"	"	Light-yellow sticky, viscous resin
1268	68	435-450	1.82	"	"	White to off-white powder

*Cleveland Open Cup
**None to boiling point

Adapted from reference 1

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TABLE XII-2

QUALITATIVE AND PERCENT CHLOROBIPHENYL AND BIPHENYL COMPOSITIONS OF COMMERCIAL PCB PREPARATIONS

(Qualitatively major peaks = M, minor peaks = m, ambiguous identities = ?; quantitatively, percentages rounded)

Cl-Substituted Positions	Commercial Preparation Designations (trade names omitted)																				
	1221	1221	1221	1221	1232	1016	1242	1242	1242	1248	1248	1254	1254	1254	A50	1260	1260	1260	A60	A60	DP6
0	13	16	m	16	m	0 5	m		m	m				m							
2	28	32	m	35	m	1	m	0 8	m	m				m			m				
3		3	m	3																	
4	19	19	m	20	m	2								m			m				
2.3						0 4															
2.4	4	3		2		1		< 0 7	m	< 0 1				m			m				
2 5		0 2		tr				m	m												
2.6		0 3		0 4		tr		m													
2.2'	9	5	m	5	m	7	m	< 1 0	M	m				m			m				
2.3'		3	m	2	m	1	m	m	M	m				m			m				
2.4'	14	10	m	11	m	11	m	< 5	M	m	0 5			m			m				
3.4		1		m				m													
3.5						tr															
3.3'																					
3.4'				1				m			< 3										
4.4'	6	4	m	4	m	2		1	M		< 3			m			m				
2.3.4																					
2.3.5																					
2.3.6																					
2.2'.3					m	5	m		M?	m											
2.3.3'		0 1				tr			M?												
2.3.4'						tr															
2.4.5																					
2.4.6																					
2.2'.4		0 3	m	m	m	4	m	11	M	m	8			m			m				
2.3'.4				m	m	4	m	< 15	M	m	< 13			m			m				
2.4.4'		0 2		m	m	4	m	7	M?	m	3										
2.2'.5		0 6		0 6	m	12	m	2	M	m	0 1			m			m				
2.3'.5		0 2				9		m	M	m	< 13										
2.4'.5		0 2		m	m	10	m		m	m				m			m				
2.2'.6					m	1	m		m	m				m			m				
2.3'.6						0 3			M?												
2.4'.6						2			M					m			m				
3.4.5																					
2'.3.4		0 1				tr	m	16	M	m	21		0 3	m			m				
3.3'.4									m												
3.4.4'						2			M												

775520

GENP 007119

WATER_PCB-SD0000056880

TABLE XII-2 (Continued)

QUALITATIVE AND PERCENT CHLOROBIPHENYL AND BIPHENYL COMPOSITIONS OF COMMERICAL PCB PREPARATIONS

(Qualitatively major peaks = M, minor peaks = m, ambiguous identities = ?; quantitatively, percentages rounded)

CL-Substituted Positions	Commercial Preparation Designations (trade names omitted)																			
	1221	1221	1221	1221	1232	1016	1242	1242	1242	1248	1248	1254	1254	1254	A50	1260	1260	1260	A60	A60	DP6
2'.3.5						tr															
3.3'.5																					
3.4'.5						tr															
2.3.4.5																					
2.3.4.6																					
2.3.5.6																					
2.2'.3.4						3									1				0.7		
2.3.3'.4						0.4			M		7		m								
2.3.4.4'									m		m		m								
2.2'.3.5									M?												
2.3.3'.5																					
2.3.4'.5						0.2															
2.2'.3.6						<2															
2.3.3'.6								6	M?		m										
2.3.4'.6															2				1		
2.2'.4.5						tr			M?												
2.3'.4.5																					
2.4.4'.5																					
2.2'.4.6														m				m			
2.3'.4.6						<2			M?		m										
2.4.4'.6						tr															
2'.3.4.5									M?												
3.3'.4.5																					
3.4.4'.5																					
2.2'.3.3'						1								m							
2.2'.3.4'						tr															
2.2'.3.5'						1	m			m		m	4	M	2	<0.4			1		
2.2'.3.6'						1															
2.3.3'.4'								4	m												
2.3.3'.5'																					
2.2'.4.4'				m		1	m			m											
2.2'.4.5'						3	m	12	M?	m	16	m			1						
2.2'.4.6'						0.1															
2.3'.4.4'						tr	m	m		m											
2.3'.4.5'																					
2.3'.5.5'									M?												
2.2'.5.5'		0.14				2	m	tr	M?	m		m	8	M	5			m			

775521

GENP 007120

WATER_PCB-SD0000056881

	1221	1221	1221	1232	1016	1242	1242	1242	1248	1254	1254	1254	1254	A50	1260	1260	1260	A50	A60	DPC
2,2',5,6'					2															
2,2',6,6'					3															
3,3',4,4'				1																
3,3',4,5'																				
3,3',5,5'																				
2',3',5',6																				
2',3,4,5'					0.5	m	9	M	m	24					M	4	<0.4	m		
2,3',4',6															m					
2,3,4,5,6																				
2,2',3,4,5														1						
2,3,3',4,5																	<16			
2,3,4,4',5										2		23.7	M	m	m	m	m	1		
2,2',3,4,6																				
2,3,3',4,6																				
2,3,4,4',6																				
2,2',3,5,6																				
2,3,3',5,6																				
2,3,4',5,6																				
2,2',3,3',4																				
2,2',3,4,4'																				
2,2',3,4,5'																				
2,2',3,4,6'																				
2,3,3',4,4'																				
2,3,3',4,5'																				
2,2',3,3',5																				
2,2',3,4',5																				
2,2',3,5,5'																				
2,2',3,5,6'																				
2,3,3',4',5																				
2,3,3',5,5'																				
2,2',3,3',6									m		m	m	M	3			0.3			
2,2',3,4',6											m	17								
2,2',3,5,6			m					M?			m	14	M	4	2	M		3		
2,2',3,6,6'						m														
2,3,3',4',6			m						m		m	m					m			
2,3,3',5,6											m	m	M	8				3		
2,2',3,4,5			m				m	m	m		m		M	1	m					
2,2',4,4',5									m	2	m		M	2	m					tr
2,2',4,5,5'			0.1						m	1	m	m	M	7		M				6
2,2',4,5,6'																				
2,3,4,4',5			m						m	1	m	14	M	5	<16	m		2		
2,3',4,5,5'																				
2,2',3',4,6					tr															
2,2',4,4',6							8	M?												

775522

GENP 007121

WATER_PCB-SD0000056882

TABLE XII-2 (Continued)

QUALITATIVE AND PERCENT CHLOROBIPHENYL AND BIPHENYL COMPOSITIONS OF COMMERCIAL PCB PREPARATIONS

(Qualitatively major peaks = M, minor peaks = m, ambiguous identities = ?; quantitatively, percentages rounded)

CL-Substituted Positions	Commercial Preparation Designations (trade names omitted)																				
	1221	1221	1221	1221	1232	1016	1242	1242	1242	1248	1248	1254	1254	1254	A50	1260	1260	1260	A60	A60	DP6
2,2',4,5',6																					
2,2',4,6,6'																					
2,3',4,4',6																					
2,3',4,5',6																					
2,3,3',4',5																					
2,3',4,4',5																					
2,3',4',5,5'																					
2,3',4',5',6																					
3,3',4,4',5																					
3,3',4,5,5'																					
2,2',3,4,5,6																					
2,3,3',4,5,6																					
2,3,4,4',5,6																					
2,2',3,3',4,5																					
2,2',3,4,4',5																					
2,2',3,4,5,5'																					
2,2',3,4,5,6'																					
2,3,3',4,4',5														m	0.8	<9	m		2		
2,3,3',4,5,5'																					
2,2',3,3',4,6																					
2,2',3,4,4',6																					
2,2',3,4,5',6																					
2,2',3,4,6,6'																					
2,3,3',4,4',6		m															m				
2,3,3',4,5',6																					
2,2',3,3',5,6																					
2,2',3,4',5,6																					
2,2',3,5,5',6			m												1				3		
2,2',3,5,6,6'																					
2,3,3',4',5,6																					
2,3,3',5,5',6																					
2,2',3,3',4,4'													2	m	1		M		2		
2,2',3,3',4,5'															<1				2		
2,2',3,4,4',5'			m										12	M	5		M	m	11	m	m
2,3,3',4,4',5'	m																				
2,2',3,3',4,6'			m											M	2		M		3		
2,2',3,4,4',6'																					

222

775523

GENP 007122

WATER_PCB-SD0000056883

	1221	1221	1221	1232	1016	1242	1242	1242	1248	1248	1254	1254	1254	1254	1260	1260	1260	A50	A60	A60	A60	DP6
2,2',3,3',5,5'																				3		
2,2',3,4',5,5'			m															0.9	<16		2	
2,3,3',4',5,5'										<0.1												
2,2',3,3',5,6'			m															1			4	
2,2',3,4',5,6																			<15			
2,2',4,4',5,6		m																				
2,2',4,4',5,5'											m	4	M	4	M	m	M		<4	m	13	m
2,3',4,4',5,5'			m									0.4	m	0.5							1	
3,3',4,4',5,5'																						
2,3',4,4',5',6																						
2,2',4',5,6,6'		m																				
2,2',4,4',6,6'																						
2,3,3',4',5',6											m							0.5	4	m	1	m
2,2',3,3',6,6'			m																			
2,2',3',4,5,6			m								m		M	2	M	m	M				7	m
2,2',3,3',4,5,6																						
2,2',3,4,4',5,6																						
2,2',3,4,5,5',6																						
2,2',3,4,5,6,6'																						
2,3,3',4,4',5,6																						
2,3,3',4,5,5',6																						
2,2',3,3',4,4',5											m							1	<4	M	4	m
2,2',3,3',4,5,5'																		0.2	<9	m	0.9	
2,2',3,3',4,5,6'			m															0.3			4	m
2,2',3,4,4',5,5'			m															1	12	M	8	m
2,2',3,4,4',5,6'																			<20	m		
2,3,3',4,4',5,5'																		lr			lr	
2,2',3,3',4,4',6																		0.1			0.4	
2,2',3,3',4,5',6													m									
2,2',3,3',4,6,6'																		0.1			0.4	
2,2',3,4,4',5',6																		0.2	<20	M	2	
2,2',3,4,4',6,6'																						
2,3,3',4,4',5',6		m																m				
2,2',3,3',4,5,6																		0.3			2	
2,2',3,3',5,5',6																		lr			0.5	
2,2',3,3',5,6,6'																		1			1	
2,2',3,4',5,5',6																		0.4			3	
2,2',3,4',5,6,6'			m																			
2,3,3',4',5,5',6																						
2,2',3,3',4,4',5,6																	m					
2,2',3,4,4',5,5',6																	m					
2,2',3,3',4,5,5',6																						
2,2',3,3',4,5,6,6'																						
2,2',3,4,4',5,6,6'																						

775524

GENP 007123

WATER_PCB-SD0000056884

TABLE XII-2 (Continued)

QUALITATIVE AND PERCENT CHLOROBIPHENYL AND BIPHENYL COMPOSITIONS OF COMMERCIAL PCB PREPARATIONS

(Qualitatively major peaks = M, minor peaks = m, ambiguous identities = ?; quantitatively, percentages rounded)

Cl.-Substituted Positions	Commercial Preparation Designations (trade names omitted)																				
	1221	1221	1221	1221	1232	1016	1242	1242	1242	1248	1248	1254	1254	1254	A50	1260	1260	1260	A60	A60	DP6
2,3,3',4,4',5,5',6																					
2,2',3,3',4,4',5,5'															0 4	2	m		0 7		
2,2',3,3',4,4',5,6'		m															m				
2,2',3,3',4,5,5',6'															0 1	5	m		0 7		
2,2',3,3',4,4',6,6'															tr	m					
2,2',3,3',4,5',6,6'															tr		m				
2,2',3,3',5,5',6,6'															tr		M				
2,2',3,3',4,4',5,6,6'																0 4	m		tr		
2,2',3,3',4,5,5',6,6'		m															m				
2,2',3,3',4,4',5,5',6																m	m				
2,2',3,3',4,4',5,5',6,6'																	m				
Reference No	17	*	16	*	16	*	16	*	14	16	*	16	*	14	7	*	14	8	7	16	8

* PW Albro, written communication, November 1976

775525

GENP 007124

WATER_PCB-SD0000056885

bcc: W. B. Papageorge
G. J. Levinskas

November 7, 1975

Dr. Michael Modan
Manager, Ventura Programs
General Electric Company Hudson Falls
One Plastics Avenue
Pittsfield, Mass. 01201

Dear Mike:

I enclose the data concerning polychlorinated biphenyls which you discussed with Dr. Richard. The enclosed data consists of the following documents:

1) Toxicity Information on Aroclor 1016.

2) The Degradation Of Polychlorinated Biphenyls By Micro-organisms- R. A. Baxter, P. E. Gilbert, R. A. Lidgett, J. E. Mainprize and N. A. Vodden.

3) Identification of chlorinated dibenzofurans in American polychlorinated biphenyls.- R. W. Risebrough

4) Polychlorinated Biphenyls - Storage, Distribution, Excretion, and Recovery: Liver Morphology After Prolonged Dietary Ingestion - Virlyn W. Burse, Renate D. Kimbrough, Ellen C. Villanueva, Ralph W. Jennings, Ralph E. Linder, G. Wayne Bovocool.

5) Laboratory Model Ecosystem Studies of the Degradation and Fate of Radiolabeled Tri, Tetra, and Pentachlorobiphenyl Compared with DDE - Robert L. Metcalf, James R. Sanborn, Po-Yung Lu and Donald Nye.

6) A Comparative Study of Two Polychlorinated Biphenyl Mixtures (Aroclors 1242 and 1016) Containing 42% Chlorine on Induction of Hepatic Porphyria and Drug Metabolizing Enzymes.

NEV 028031

741285

WATER_PCB-SD0000056886

7) Biodegradation of Polychlorinated Biphenyls - E. Scott Tucker, Victor W. Saeger and Orville Hicks.

8) Tissue Residues From Subacute Oral Feeding of Polychlorinated Biphenyl Dielectric Fluids - Robert G. Kaley, Orville Hicks, William M. Mees, E. Scott Tucker, James P. Mieure, Frederick R. Johannsen and George J. Levinskas.

9) Migration of Polychlorinated Biphenyls in Soil Induced by Percolating Water - E. S. Tucker, W. J. Litschgl, and W. M. Mees.

10) Acute Toxicity Studies with MCS (Aroclor) 1016.

11) Presentation To The Interdepartmental Task Force on PCBs, Washington, D. C. - Monsanto Company.

Yours sincerely,

David Wood
Market Manager
Dielectrics

/deb
Enclosures

NEV 028032

741286

WATER_PCB-SD0000056887

Monsanto

FROM (NAME & LOCATION): David Wood-St. Louis-B2SD

DATE: August 29, 1975

SUBJECT: TELEPHONE CALL REPORT

REFERENCE: 8/29/75

TO: W. B. Papageorge
B2SK

CC:
H. S. Bergen-B2SL
C. Paton/T. L. Gossage-B2SC/B2S
G. Roush-A2SA
G. Levinskas-A2SC
R. Keller-T1B
J. P. Mieure-T2B
W. R. Richard/R. H. Munch-T3A/T
W. W. Withers-B2SA

CALL FROM: Dr. J. R. Allen
University of Wisconsin
(608)263-3524

Dr. Allen called about Dibenzylfurans and Dioxins in Chlorinated Biphenyls as a result of his reading the Risebrough paper. He is concerned about levels of these compounds in the Aroclors which he is using for his U. of Wisconsin feeding studies since he is unclear as to potential interferences in results which can be ascribed to PCB per se or contaminants in PCB.

He asked if we could check samples to be used in his studies to determine positively if contaminants were or were not present in those specific samples. I said that I did not believe our analytical techniques were fully developed to the stage where we were confident that we could properly consider ourselves able to meet his need. I told Dr. Allen that we would discuss his request and call him next week.

David Wood

/deb

NEV 018503

PLAINTIFF'S EXHIBIT 425

726554

WATER_PCB-SD0000056888

Monsanto

D.V.N. Hardy, London

12th January, 1967

JAN 16 1967.

FILE	✓	
Destroy		
JTG		
WHH	✓	✓
MNJ	✓	
REK	✓	✓
RAM		
EPW	✓	✓

Aroclor - Sweden

DVNH/ARW

10

P.G. Benignus, St. Louis
G.R. Buchanan, St. Louis
D.S. Cameron, Brussels
Dr. R. Emmet Kelly, St. Louis
G.R. Graham, New York
R.A. Steenrod, St. Louis
D. Wood, Brussels
J.A. Evans, London
R.A. Baxter, Ruabon

On 2nd January 1967 Mr. A. Richardson of Shell Chemicals' Tunstall Laboratory, Sittingbourne, Kent talked with me over the telephone concerning the Swedish Press report relating to the identification of "Polychlorinated Biphenols" as trace contaminant in sea birds, fish etc. Richardson has been working for some years on the similar problem with insecticides such as DDT, which are known to have wide distribution in trace quantities. He had already found that the chlorine-containing residue contained substances more stable than DDT. and just as Sören Jensen reports he has obtained spectrographic evidence that these are very similar if not identical with Aroclors. He has obtained samples of Aroclors 1242, 1254, 1262 and 5460 from us, and would now like to have small samples of any chemically pure Aroclor constituents which we may be able to supply. Milligram quantities would suffice for his purpose.

Mr. Richardson was quite sure that the compounds reported to be "polychlorinated biphenols" are really meant to be polychlorinated biphenyls and as support he has sent me a copy of the synopsis of a paper entitled "Pesticide Analysis: Presence of Polychlorinated Biphenyls at Residue Analysis of Biological Samples" by Sören Jensen and Gunner Widmark (photocopy attached).

I discussed with Richardson the soundness of Jensen's claims, and was assured that his work and findings are sound. Jensen is on the staff of the Institute of Analytical Chemistry, University of Stockholm. A note on the staff and work of the Institute is attached. From this you will see that Jensen is wholly concerned with the analysis of chlorinated pesticides and with the work of stations for routine analysis.

I would be glad if Dr. Baxter and Dr. Buchanan would arrange to send me milligram samples of any pure Aroclor constituents that may be available at Ruabon and St. Louis respectively.

PLAINTIFF'S EXHIBIT 1475

D.V.N. HARDY

NEV 022115

732170

WATER_PCB-SD0000056889

Monsanto

FROM (NAME & LOCATION) R.A. Baxter - LLN

DATE 19th August 1975

SUBJECT CHLORINATED DIBENZOFURANS

REFERENCE RAB/AK

TO : R.E. Keller - St Louis

cc W. Richard - St Louis
H.S. Bergen - St Louis
W.B. Papageorge - St Louis
D. Wood - St Louis
R.A. Lidgett - LLN
J.N. Haggart - BXLS

Bob,

Reference your memo of August 15th, Alf Vodden has had some contact with the Bayer technical people and they have promised to come back to us after the vacation period. We will follow this up again but I don't expect anything more positive until early September. To speed things up we are attempting to arrange an exchange of samples through the commercial channels and will send these on to you as soon as we get them. .

From the preliminary discussions it seemed that Bayer had not done any serious in-house work on the analysis of dibenzofurans in PCBs.

Predelec were even less forthcoming and didn't want to commit.

Now that Risebrough's paper has appeared in Nature we may see more inter by the European PCB producers. We will keep you in the picture.

Regards,

R.A. Baxter

PLAINTIFF'S EXHIBIT 1498

NEV 021407

729462

WATER_PCB-SD0000056890

20 November 1975

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or

Session V:

ECONOMICS AND SUBSTITUTES

Warren Muir, Ph.D.*
Session Chairman

*Senior Staff Member for Environmental Health, Council on Environmental Quality, Washington, D.C.

NEV 026149

PLAINTIFF'S EXHIBIT 1510

739404

WATER_PCB-SD0000056891

INTRODUCTORY REMARKS

Warren Muir, Ph.D.

I guess we have all had an opportunity to hear about health and ecological impact and other aspects of PCB's in the last day and a half. The history of PCB's, as I am sure most of you are aware, is several years old. By 1971 and 1972 there was sufficient concern over their potential environmental effects that a Federal task force was created under the sponsorship of the Council on Environmental Quality and the Federal Council for Science and Technology, which looked into the situation and made a variety of recommendations.

In addition, at that time the Monsanto Chemical Company developed a restricted sales policy with regard to uses of PCB's, and also shortly thereafter, the Organization for Economic Cooperation and Development had an international agreement with regard to uses of PCB.

All of these actions were directed in one fashion or another toward inappropriate uses of the chemical. Yet, as of this date, there is no Federal authority to control the use of these chemicals, despite 5 years of consideration of toxic substances control legislation.

This particular session of the conference deals with economics and substitutes; we will have a presentation or a brief description of two economic case studies that have been done on PCB's, and then several speakers will discuss the substitutability or nonsubstitutability for uses of PCB's.

In dealing with environmental problems such as PCB's and a variety of other chemicals, I am sure you are aware that there is a great deal of scientific uncertainty with regard to particular health or ecological impacts. For example, there is a certain amount of uncertainty as to whether or not something is carcinogenic or whether it can bioaccumulate.

There typically appears to be, however, a much greater uncertainty about the economic implications or the economic impacts of any action that might be taken to mitigate the suspected problems. Much of this arises from uncertainty, about substitutes and also about the inability to predict the actual individual or corporate responses that would be made under a given type of regulatory action or other type of mitigating action. Thus in my view, there is much greater economic uncertainty in many of these issues than there is scientific uncertainty.

Also, irrespective of all the uncertainties, we know that the further along in the chemical marketing and development process, the longer it has been manufactured, and the larger the market, generally the greater the health and environmental effects of the particular chemicals and the greater the economic impact there is of mitigating action, to the extent that they are necessary.

Thus, if we are to deal with problems such as PCB's, we must change our approach toward environmental chemical problems; we must get out of a reactive posture. We must undertake the task of identifying potential hazardous chemicals early in the development process. By so doing, health and ecological problems can be avoided before they develop. And, by so doing, the economic dislocation and impacts from any potential regulatory action will be eliminated or minimized to the benefit of all.

NEV 026150

739405

WATER_PCB-SD0000056892

PCB's IN CAPACITOR APPLICATIONS

Richard L. Rollins*

Abstract

Alternating current (AC) capacitors have used a grade of polychlorinated biphenyls (PCB's) since the 1930's. Long life, high reliability and a high degree of flame retardancy are imparted to the capacitors by these fluids.

The latter characteristic is very important in applications where high exposure to the general population exists such as in fluorescent lights and television sets. The main disadvantage with the fluid is its long persistence in nature. When the capacitor industry became aware of the environmental problem, it generated guidelines for handling and disposal of the material, then voluntarily imposed these restrictions upon itself. Now of the 70,000 pounds per day processed, only 7 pounds are being discharged into plant water effluents. Liquid waste materials are sent to proper incineration facilities and solid waste materials are placed in sanitary landfills to prevent escape into the environment. For 4 years the industry has been using a significantly more biodegradable grade of Aroclor identified as 1016 by Monsanto. In that time, Aroclor 1016 has not been identified as a PCB commonly found in the environment. Non-PCB materials are continuing to be evaluated, but there are not dielectric fluids available today which can be considered an acceptable substitute for PCB's in the broad range of AC capacitors.

On behalf of the electronic industrial association and the manufacturers of PCB capacitors, I appreciate this opportunity to present our point of view. I will discuss PCB capacitors, the industry's response to the environmental problem, and possible alternative candidates to PCB's.

Manufacturers of AC capacitors have used PCB's since the early 1930's, and have used them almost exclusively since World War II. They are presently used, for example, in capacitors for fluorescent lighting, air conditioners, and television sets. These capacitors are in the plant where you work, in the home, and in public gathering facilities. They are therefore near you a high percentage of the time. Manufacturers are very cognizant of their responsiblities in providing a capacitor that will operate satisfactorily in these applications for providing long life and high reliability at a reasonable cost.

*Vice President for Engineering, Jard Corporation, Bennington, Vermont.

The consequence of these requirements in a competitive marketplace is that the products and their components are constantly being reevaluated to increase life, increase reliability, decrease size, and decrease cost. The capacitor manufacturer indeed daily sees pressures for improvements. It is, therefore, an obvious question to ask why are PCB's still used after 40 years during which the best capacitor research and development scientists in the United States were constantly seeking substitutes.

One of the reasons lies in the nonflammability of the PCB material. Because of applications, such as lighting, where personnel and equipment safety are paramount, capacitors must be manufactured since they not only fail infrequently but also fail safely. In applications such as the World Trade Center in New York, where 250,000 fluorescent lights are installed, it is obvious that high reliability and a nonflammable capacitor characteristic are mandatory.

A capacitor which fails violently and contains a flammable fluid could create a serious problem, especially in densely populated buildings, giving visions of a towering inferno. The Consumer Products Safety Commission, as an example, has shown considerable concern over television set fires and has requested Underwriters' Laboratories to develop standards for safety for television set receivers.

A second reason lies in the reliability of the product as it is known today. Presently, the capacitors our companies manufacture have a survival rate per year greater than 99.9988 percent. The requirement that more than 95 percent of our capacitors must survive after 13 years of normal application conditions must also be met.

The test time and the amount of test necessary to guarantee the above reliability is mind boggling to say the least. Many thousands of units and millions of unit hours at or referred to application conditions are required to satisfy our statisticians that any change in product will conform to these present day standards.

Even with the large amount of previous testing and history on the PCB-containing capacitor, there have been many instances which despite all controls in existence cause consumer concern due to extreme failure rates. That is at a rate greater than 10 percent.

The first occurred in 1957, when a variation in the quality of the PCB fluid, as synthesized, resulted in a highly unstable capacitor. Standard analytical tests in use at the time did not detect the quality difference. The result was a large number of capacitors failing in a very short period of application life.

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The consequence was the requirement by the customer that the capacitor manufacturer not only provide compensation for the cost of the capacitor, but the cost of the equipment which contained the capacitor, plus the labor charge for placing the equipment in the installation. The total replacement cost the manufacturer 100 times the original price of the capacitor.

The second instance of numerous failures occurred 6 years later, this time involving the capacitors of most manufacturers. In this circumstance reduced-size capacitors were tested and approved by industry-accepted accelerated life testing and a new size was shipped to customers.

Approximately 1 year later, up to 15 percent of these capacitors began failing in some applications. A subsequent modification in the accelerated-life testing based upon findings in the field failure analyses now provides proper screening to eliminate the chance of such a problem occurring. Therefore the AC capacitor industry now does very extensive evaluations before releasing new designs or using new materials.

The capacitor industry became aware that PCB's were possible environmental problems in 1970. Soon thereafter, in 1971, a committee was formed under the sponsorship of the American National Standards Institute, ANSI, to develop standard industry guidelines for the handling and disposal of capacitor grade PCB's. An interim standard was published as an official standard proposal by the National Electric Manufacturers Association, NEMA, in January 1973. And a final document, C107.1 1974, was published in January 1974.

Briefly, properly planned housekeeping, considerations for employee safety, and scrap disposal procedures were detailed. Today, to the best of my knowledge, all manufacturers of PCB capacitors in the United States have applied these guidelines for the handling and disposal of PCB's.

The success of the manufacturer's control in handling practices is apparent from the fact that of the approximately 70,000 pounds per day used, less than .01 percent or 7 pounds per day is discharged into the water effluents of the plants. The ANSI guidelines also recommended that the capacitor companies change from Aroclor 1242 to a PCB with less toxic effects which Monsanto identified as Aroclor 1016.

Here it must be pointed out that various grades of PCB's cannot, as so often is assumed, be classified as having the same chemical, physical, or biological characteristics. For instance, in "A Comparative Study of Two Chlorinated Biphenyl Mixtures . . .," by Goldstein et al., significant differences were shown to exist in the biological effects of Aroclor 1242 and 1016 on equal doses of the two mixtures. Aroclor 1016 also reduces by greater than 94 percent those higher homologs existing in Aroclor 1242 which were the most persistent in nature. With these benefits, and without sacrificing the capacitor characteristics, all capacitor manufacturers began using the new material by 1972, despite the fact that it was 50 percent more expensive.

After 4 years of use by the capacitor industries, Aroclor 1016 has not been identified as a PCB that is commonly found in the environment. Nor should it be suspected that 1016 would be commonly found, because the industry is exercising control over waste disposal from its capacitors, so that there is little or no opportunity for leaking PCB's.

Our industry believes it is much more important to reduce the environmental problems and to allow continued use of the capacitor-grade PCB than to be concerned with the material cost increase and immediately turn to a substitute which is not thoroughly evaluated and may be flammable.

Alternates have been considered ever since the original introduction of PCB's. The substitutes must be not only a satisfactory dielectric fluid providing acceptable life, reliability, and safety, but in addition must not cause environmental problems. Our experience with PCB's has demonstrated that some material will escape into the environment through processing and handling. Therefore, alternate fluids must be evaluated on this basis. The effects on man and his environment must be determined before the product is introduced. It would be a very serious error to replace capacitor-grade PCB's with a fluid which eventually becomes a greater threat to man.

Further PCB modification which would provide even less toxicity and persistence in nature but still maintain good dielectric properties and good nonflammability would seem to be one alternative to Aroclor 1016. Our companies respectfully urge Monsanto to pursue this possibility.

Non-PCB alternatives are now being offered and suggested. Some are new and some have been available for many years. The industry's position on these is as follows.

Mineral oil is a flammable fluid which was replaced by PCB's in the 1930's. Capacitors using it are 50 to 100 percent larger, much less reliable, and much less safe than those using PCB's. The substitution of mineral oil necessitates redesign of equipment to utilize the larger capacitor, an increase in the capacitor manufacture facility, and will result in increased use of basic materials which are presently in short supply.

Modified synthetic hydrocarbon oils have been developed which while flammable would allow capacitors to approximate today's size. Samples have been dis-

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tributed for testing, but the material is not commercially available.

Phthalate ester, also a flammable fluid and also with biodegradability problems, has been used in certain restricted applications where conditions of limited temperatures exist. The unknown factors of reliability and safety in the broad consumer use areas such as lighting now prevent its use. Evaluations, however, are continuing.

Substituted aromatic compounds are possible candidates, and one has been proposed that has less fire resistance than PCB's; it is suggested to be a good dielectric fluid but only for high-voltage power factor correction. This, to our estimation, represents only 17 percent of the PCB used in closed systems, and leaves completely unanswered an alternative or alternatives for the remaining 83 percent of the applications. Some material has been produced but the fluid has not been made commercially available. In fact, our companies are having trouble obtaining samples from the manufacturer. When samples become available, the time-consuming testing can begin. It has been estimated that 3 years are required before final commercial use after initial testing of a change in capacitor fluids.

Also proposed for limited applications is the use of a plastic film replacing the kraft paper dielectric in the AC capacitor. Although evaluations with the highest quality film have been underway for more than 2 years using the current processing techniques, the reliability of the product is only 1/20th of that of present capacitors in most applications. Significant additional testing is required to determine if the cause of poor reliability is totally inherent or if improvements can be made by modifications in capacitor design.

In summary, there are no commercially available fluids which today can be considered a totally acceptable substitute for PCB's in the broad range of AC capacitors, nor are there substitute dielectric systems which would satisfy the requirements of reliability and safety in most applications.

I would like to reiterate that our companies have shown responsiveness to the environmental problems of PCB's by the following actions.

1. Working as a group with government and consumers in providing guidelines for proper handling and disposal of capacitor- and transformer-grade PCB's.
2. Reducing discharge levels of PCB's in a 16-capacitor plant. Further reductions are now being planned.
3. Converting to a more expensive grade of PCB's which is less persistent and has less toxic effects.

Finally significant differences do exist between Aroclor 1016, which capacitor manufacturers are now using, and material which is predominantly being found in the environment. Our industry believes that all concerned should be aware of the differences.

We respectfully urge this awareness in environmental studies and in drafting of regulations.

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THE ECONOMIC IMPACT OF A BAN ON POLYCHLORINATED BIPHENYLS

Duncan MacArthur* and Stephen F. Nagyt

Abstract

The study described below assessed the effects of a hypothetical total ban on PCB's. In order to compile a realistic scenario, the proposed Toxic Substances Control Act was used as a model. A complete phaseout was estimated to take 76 months, and would involve publication of rules, testing, hearings, halting of imports and manufacturing of PCB's, and depletion of stocks of PCB-containing products.

Mineral oil was assumed to be the primary substitute for PCB's, since a major technological breakthrough in the development of alternate fluids is unlikely in the near future.

Minimum estimates are given for the one-time and annual capital expenditures by industry of a ban on PCB's, and for the primary and secondary impact costs. Intangible issues, such as the effect of a PCB ban on public safety, are also discussed.

In the course of our work with private and public clients, we have examined polychlorinated biphenyls, PCB's, in a number of areas, ranging from product design to economic impact. The work to be discussed here was completed in 1975 as part of a study to examine the effects of the proposed Toxic Substances Controls Act, as illustrated by Senate Bill S776 (20 Feb. 75).

We selected as an example a case study to completely ban an existing product following the procedures outlined in the proposed bill. We use the case study for following reasons. It provides an example of the complete analysis required to assess the impact of a ban; it illustrates the direct and secondary impact on industry; and it enables us to estimate the economic consequences of a ban on one specific product. In our study, we also highlighted the unquantifiable factors.

In our methodology, and again this was done in the early part of the year, we assume all the steps in the proposed Toxic Substance Control Act as illustrated by Senate Bill S776 are taken. The end result of this is a total ban on PCB manufacture and use. We selected PCB's for illustrative purposes only. Our discussion was not intended to reflect on the actual health or environmental aspects of the example product.

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The scenario for banning the product is estimated to require about 76 months for complete phaseout of product use. Thirty-eight months were estimated for publications of the rules, testing, hearings, and so forth. The key element in this period is the 24-month period that we estimated would be required for testing. The key element in months 39 through 76 is phasing out the sale of some manufactured goods, particularly appliances. We also assumed that no legal action would be taken by industry until publication of the final ban on substances occurring after the 38 months of testing and hearings.

A possibility in the scenario of the second 38 months is that industry requests a judicial review but complies with the review. We estimated the judicial review takes 2 years and results in a complete product ban. In the second 38-month period the following types of activity would go on: documentation for control purposes; monitoring of shipments; limitation of stockpiling of PCB products; refining methods to prevent PCB's from entering the environment, such as controlled use and control proposal; stopping the production and import of PCB's or equipment containing PCB's, and finally banning the manufacture and sale of PCB-containing products.

In the analysis of our PCB's we have tried to consider the complete life cycle of the product. PCB's are produced by one manufacturer in the United States—the trade name is Aroclor—and about 40.5 million pounds were produced in 1974. The sale of PCB's is currently restricted to electrical use and casting waxes. In the past they were used as transfer fluids from heat exchangers, hydraulic fluids, and so forth. However, as you know, to avoid potential adverse environmental impact, Monsanto restricted domestic and export sales in 1972 to electric installation equipment applications in which the product is enclosed in a relatively well-maintained container throughout its use. Monsanto and others offer PCB disposal service.

We found that PCB applications are characterized by their long-term utilization with the majority controlled by utilities. Transformers, for example, were reported to last 20 to 30 years, and capacitors to last 7 to 10 years.

The number of transformer manufacturers vary; anywhere from 2 to 10 have produced PCB-containing transformers. Primary use is as nonflammable electric insulating oil. Previous estimates report approximately 5,000 transformers were produced per year with an aver-

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age PCB amount of about 5,000 pounds per transformer. Value of shipments (1974 data) is estimated at $35 to $45 million.

The number of people using capacitors varies. Estimates range from 16 up to 50 capacitor manufacturers. There are approximately 90 to 100 million units per year produced with a value about $105 to $147 million. There are primarily two types: large utility capacitors, using about 9 to 13 million pounds of PCB's per year, and small industrial capacitors, using about 17 million pounds per year.

In the case of casting wax, there is only one manufacturer in the United States. PCB's represent 30 percent of the components of the wax. The annual usage is about half a million pounds. Primarily, it is imported. We also found another indirect importation of PCB's—in capacitors in electrical equipment.

The primary transformer users are utilities; others include manufacturers of and users of electrically powered rail equipment, furnace equipment, and electrostatic precipitators. About 85 percent of PCB transformers are used as network transformers by the utilities, and we estimate that approximately 90 percent of the transformer uses are controlled by the utilities, either through ownership or service contracts.

With respect to the capacitor users, electric utilities use large capacitors and manufacturers and consumers of goods use small capacitors. Electric utilities use them primarily for power factor correction, and smaller units are used for starting and other uses such as fluorescent lighting. We estimate that about 2 to 3 percent of large capacitors are consumed as replacements and about 5 to 10 percent of the small capacitors were consumed as replacements.

With respect to the casting wax, approximately 98 percent of that is now recycled and the people in the business maintain that the remaining 2 percent that is left in the mold is destroyed when the mold is prepared at high temperatures.

The final step is disposal. Monsanto and others have specialized incincerator facilities for PCB liquids, primarily for large uses such as transformers and capacitors used by utilities.

The ban of PCB's was estimated to result in a one-time cost of $13.7 million. There would be additional expenditures of $110 million annually. The ban would also affect regulatory codes, public safety, and other intangible areas, and, as always, the net result would be an increase in consumer costs.

The primary impact, which is on the manufacturer and users, is estimated at $8.8 billion for one-time costs and approximately $16 milllion for annual costs. Key elements in this, surprisingly enough, were "red tape" required by Senate Bill S776. There are also disposal costs, plant rebuild costs, and salary costs.

Secondary impact on users of PCB's, PCB-containing products or services, and disposal organizations is estimated at $4.9 billion for one-time costs and $93 billion for annual costs. Elements of secondary impacts are primarily new plant rebuilds for increasing the capacitor output of the United States, disposal, and the increased cost of substitutes.

The annual costs reflect the forecasted increased costs of electrical equipment manufacture and use, including replacements of existing equipment. Since the lifetime of large transformers and capacitors is 20 to 30 years, the additional annual cost, over $110 million, was forecast for the same period.

In the proposed 38-month time period, industry representatives indicated that for primary and secondary transformer use, there would essentially be a shift to mineral oil as a replacement for PCB's, since the environment and performance characteristics of other substitutes are not thoroughly researched. Major technological breakthroughs, such as development of substitute fluids, were not forecast.

We did use minimum cost estimates. The cost of replacing a PCB transformer, for example—not necessarily the transformer but the vault which is surrounded by the building—has been estimated as varying anywhere from $5,000 to $50,000. We used a figure of about $10,000, which we consider low and very conservative.

The economic impact of changing the regulatory codes cannot be accurately quantified without a detailed survey. However, the impact of the changeover for those localities with regulations was estimated not to cause major dislocation in building activities. We do know that many cities permit only nonflammable, essentially PCB, electrical equipment to be installed in tall buildings; however, others do permit non-PCB transformers with a vault.

Intangible issues include public safety, which would be impacted by a ban on PCB's. Analysis would require a detailed analysis of the tradeoffs between the benefits of the product versus the benefits of the ban. Electrically driven trains use PCB transformers and it has been reported that the flammable liquid in the transformer would be a potential hazard. Uses of other transformers in rail cars, if possible, would require redesign and overhaul of existing equipment. Use of large quantities—over 20 gallons of liquid—in buildings would present a potential danger even in walls. Insurance underwriters have reportedly studied the problem but nothing has been presented as a request to change rates.

Other intangible areas are in replacements for all types of equipment. Dry transformers, for example, are

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reported to have a low reliability. There are also specific areas, such as replacement capacitors for compact equipment in which the capacitors cannot be replaced with a non-PCB-containing unit similar in size and characteristics, forcing either salvage or scrappage of the equipment.

In assessing all these costs, we forecasted pass-through to the consumer.

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THE USE OF DOW CORNING® Q2-1090 DIELECTRIC LIQUID IN POWER TRANSFORMERS

Richard H. Montgomery*

Abstract

Dow Corning has developed Q2-1090 Dielectric Liquid to replace askarels in transformers. Five years of laboratory and field testing have shown it to be both efficient and safe. It is now being sold in commercial quantities both for new transformers and for retrofilling old transformers. With some redesign, competitive entries, and further restrictions on PCB use anticipated, it is expected to have favorable economics. A 3- to 5- year phase-in to completely commercially qualify the liquid in all applications is planned.

Thank you for the opportunity to come here today to represent the silicone industry, which in the United States consists of the Dow Corning Corporation, the General Electric Corporation, Union Carbide, and Stauffer Chemical. The global silicone industry is now 5 years into a program to qualify dielectric fluid replacements in both transformers and capacitors. The Japanese silicone industry and Dow Corning Corporation have led this effort to date. As a result of this extremely large effort by the industry, I am very pleased today to make two major announcements.

First, the technology to commercially manufacture a capacitor dielectric fluid with superior dielectric properties is being developed. This material appears to withstand any of the high electrical stresses the material would normally be used for in the industry. We plan to make this product commercially available during 1976. At its present state of development, we know of no environmental problems with this particular product. No chemistry would indicate there should be any. But this will be continually studied, as have other products from the silicone industry.

Second, Dow Corning now has commercial production available to manufacture silicone transformer liquids in sufficient capacity to handle the global transformer market, and that is a very large investment. So let me now turn in some detail to the transformer industry and the role silicones can play.

We must remember that today three environmentally safe transformer systems are available to replace transformers filled with PCB liquids. Gas-cooled, air-cooled dry types, and liquid-silicone-filled transformers will meet almost every need where PCB-containing transformer fluids are used.

The silicone industry has produced insulating materials for transformers for 25 years. The industry's newest material, a silicone transformer liquid, is now in use in Japan as a direct replacement for PCB-containing transformer oils. In the United States, extensive field testing has been under way for 4 years and at the present time this material is being examined for inclusion in the U.S. National Electrical Code.

Now, to underscore Dow Corning's personal assurance in the safety, the efficacy, and the efficiency of this liquid, Dow Corning has notified its vendors that we will be specifying silicone-filled transformers for all the new transformers in our production plants around the world. Our existing askarel transformers, in which we have a very heavy investment, are being phased out rapidly through a silicone retrofit program. Over 6 transformers have been installed new or retrofitted in the past year, and this program will accelerate in the spring. It is, of course, not possible in Michigan during the winter months to drain the PCB's satisfactorily and replace these materials with a silicone fluid.

The material that we are talking about is known today as Q2-1090 dielectric liquid. Basically, Q2-1090 transformer liquid is a dimethyl silicone that has been specially formulated and qualified for use in electrical applications. The technical feasibility of using the silicone in transformers has been shown in over 20 years of experience in military transformers, in several years of use on the Japanese National Railway, and in a number of power transformers in the Midland, Michigan, area; several other areas around the United States will also test silicone transformers in the next few months.

In addition to these actual applications, which today are well known and have worked out nicely, support for the use of a silicone dielectric fluid in power transformers is contained in over 30 years of accumulated data on dielectric properties and compatibility with the common materials of transformer construction.

The present concern for fire, explosion, health, and environmental hazards are all strong reasons for an evolutionary approach to using silicones and qualifying them in this application for all major power transformer uses over the next few years.

The silicone liquids of this type are much less

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flammable than typical mineral oils. They actually have a higher flash point than many PCB-containing transformer fluids. Although they will burn, they have an extremely low heat of combustion, extremely high flashpoints and firepoints, and they have been shown in catastrophic testing to be self-extinguishing. They appear to offer a level of fire safety greatly superior to mineral oils.

The silicone that we are now recommending, a dimethyl silicone, has been evaluated by Underwriters Laboratory, and has received an extremely low flammability classification number. In Japan and the United States, transformer cases containing PCB's, silicones, and mineral oil were subjected to catastrophic failure testing. In both tests, all liquids exploded. Most important, following this test, only the mineral oil continued to burn. Both the polychlorinated biphenyl materials and the silicone fluid self-extinguished. Normally, in a test of this type you would fuse the circuit cutout. The fault in the silicone fluid self-cleared, thereby extinguishing the arc. With the other materials, the backup fuse blew and extinguished the arc.

Following the review of some very extensive data (which is available to all of you by writing to me at Dow Corning, provided you are willing to put in 4 or 5 hours in reading it), the major insurance companies have given their permission to use silicone fluid in indoor transformers. Because it is a new material and since no general policy has been established, the insurers have indicated that they will evaluate each application on an individual basis; this is a conservative approach which we highly applaud.

Dow Corning feels that we should look at a 3- to 5-year evolutionary approach of gradually putting a larger and larger number of transformers into operation. We are offering financial inducements to companies who do this in order to collect a large body of case history data that can be used to convince ourselves and the industry that there are no fatal flaws that have been overlooked. It's an extremely conservative approach.

Silicones are often used in small concentrations in the preparation of certain foods. Any time you eat a jam or jelly or drink a glass of some of that good old Milwaukee beer, you are eating a food-grade dimethyl silicone. And if you have an ulcer and you eat Di-Gel, you are also eating it. They are excellent deflaccuants.

The toxicity of dimethyl silicones to mammals, aquatic life, and plants has been very thoroughly investigated. The extremely low toxicity of silicones has made it difficult to detect any toxic reactions in test subjects. Studies directed toward determining the tendency of silicone to bioconcentrate have been negative. It has not been possible to date to show that any bioaccumulation was occurring.

It has been often stated that silicones are persistent in the environment because they do not biodegrade, under the evidence available at the present time. However, there is considerable evidence that silicones do chemically degrade in the environment. Contact with soil and water causes the liquid to depolymerize to low-molecular-weight species, and known chemistry definitely suggests that these degrade in water or in the atmosphere.

Silicones cost more money than the current liquids being used in transformers, but they are not outrageously expensive. Referring to the entire market of capacitors and transformers, and making some assumptions which would include the shipment of present products such as PCB's to the manufacturer's site, if we include the shipping costs, my estimate is that the industry PCB purchases would be about $19.2 million.

If good engineering practices are followed to reduce the amount of fluid needed, which has never been a design criteria in the major manufacturer's mind, as mineral oil, of course, is cheap, those costs would probably rise with the use of silicone to an industry figure of $25 million.

So the total increased cost to the electrical and electronics market would be about $5.8 million or 29 percent. If we made the assumption that the dielectric fluids cost is 20 percent of the total material cost going into a transformer or capacitor, we are talking about an average cost increase of about 5.8 to 6 percent at the manufacturing level on new equipment.

I feel that this slightly higher initial cost of silicone liquid-filled transformers is more than offset by the cost of monitoring and controlling of PCB-filled transformers over their lifetimes. And with silicone, no known environmental hazards are incurred.

PCB-filled transformers currently in service can be changed over to Q2-1090 transformer liquid without undue problems. I think the work we have done over the past 4 years—some of it in conjunction with Dow Chemical, a lot of it in conjunction with leading transformer manufacturers—shows this.

I think you will be hearing not only from Dow Corning in more detail on this subject. I highly suspect that our worthy competitors, who can manufacture dimethyl silicones to the same specifications once they learn what they are, will go into the market. At that particular time, the law of supply and demand will come into effect. The silicone industry at the present time has more capacity than it can sell. I anticipate the economics will be extremely favorable for further consideration of this product in both transformers and capacitors over the next three years.

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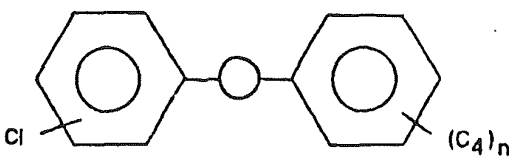
DOW XFS-4169L: AN ENVIRONMENTALLY ACCEPTABLE CAPACITOR FLUID

Dean Branson, Ph.D.*

Abstract

Dow and McGraw-Edison Companies have developed a new capacitor fluid which is electrically, ecologically, and economically acceptable. Chemically, the new fluid can be described as butylated monochlorodiphenyl oxide.



n = 0, 1, 2, 3

Dow XFS-4169L capacitor fluid

Dow XFS-4169L capacitor fluid performs equal to or better than Aroclor 1016 in power capacitors. This conclusion is based on dielectric losses, discharge inception voltages, capacitor size, fire hazard, reliability, economics, and availability. Dow XFS-4169L capacitor fluid and its components are acceptable in terms of health and environment according to an assessment of biodegradability, bioconcentration in fish, toxicity to animals, and toxicity to fish. Other capacitor manufacturers are currently evaluating XFS-4169L for applicability in their respective companies. Field trails have been started with utility companies across the country.

The contents of this presentation represent 4 years of joint research between Dow and McGraw-Edison Company which has culminated in the development of an environmentally and electrically acceptable capacitor fluid.

When PCB's replaced mineral oils some 40 years ago in power capacitors, this represented another step forward in the electrical industry's continuing effort to provide the public with low-cost electrical power and safer electrical equipment. As a result of the use of PCB's, there has been a downward trend in the cost per kilovar of power factor correction.

In 1971, Monsanto limited the sale of PCB's for dielectric uses where acceptable alternatives were not yet available. Since then, industry has been searching for alternatives which were ecologically, electrically, and economically acceptable.

Today, we want to report to you that Dow and McGraw-Edison have developed a butylated monochlorodiphenyl oxide known as XFS 4169L. It meets all the above criteria and can be used in high-voltage capacitors.

Initially, over 50 fluids representing several chemical families were selected as possible dielectric fluids on the basis of their chemical and physical properties. These fluids were then screened for both electrical performance in miniature capacitors and for potential hazard to the health and the environment in a battery of indicative tests.

The conclusion of these screenings was that the most promising chemical family was the alkylated monochlorodiphenyl oxides.

Electrically, several members of this family performed equal to or better than Aroclor 1016. It was the health and environmental data that demonstrated the significant advantages of the butylated monochlorodiphenyl oxides.

Electrical Performance

The confidence that McGraw-Edison Company has in high-voltage capacitors made with the XFS fluid is based on the following assessment of these six key electrical performances.

1. *Dielectrical losses*. The dielectric losses are as low or slightly lower than for capacitors with a PCB known as Aroclor 1016. This is true for both paper-film and all-film high-voltage power capacitors. This means that the capacitors will operate under normal temperatures and that the operating costs will be minimal. This is one of the same significant advantages that PCB's have relative to mineral oil.
2. *Discharge inception voltages*. Discharge inception voltage is significantly higher than for Aroclor 1016 in both paper-film and all-film capacitors. This means that operating voltages may surge at least 20 to 30 percent higher without resulting in temporary malfunction due to electrical discharges known as corona.
3. *System size*. The size or volume per unit of high-voltage power capacitor correction known as kilovar is

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the same as for comparative capacitors impregnated with Aroclor 1016. This means that it will not be necessary to redesign capacitors, the capacitor manufacturing, or the application of capacitors.

4. *Fire hazards*. As indicated with PCB's, there is a low risk of explosion and fires from power capacitors impregnated with XFS 4169L. A major problem associated with a failure in a paper-film power capacitor is the decomposition of the paper and, to a lesser degree, the film. The resulting pressure of the gases formed is a major cause of tank rupture. After failure, the flammability of the fluid may contribute to a fire only if the paper, the film, and the fluid, are above the ignition or flash temperatures.

Under normal operating conditions, a capacitor will operate between 40° and 80° C. At a time of failure, this temperature will have to exceed the flashpoint of the capacitor fluid before this fluid becomes contributive to the explosiveness or the flammability of the system. In this regard, the flash temperature for the existing dielectric fluids for mineral oil is 154° C; for Aroclor 1016, 166° C; and for XFS 4169L, 174° C. The fire temperature for mineral oil, 167 PCB, is greater than 316° C; for XFL 4169L, it is 199° C. This clearly shows that the flash and fire points are substantially above the operating temperatures.

The National Electric Code allows the installation of the electrical devices without a vault if they contain less than 3 gallons of burnable liquid. The most common size of our capacitor used today is a 200-kilovar unit. These units contain less than 3 gallons of fluid, and are installed predominantly outdoors.

5. *Capacitor reliability*. Power capacitors impregnated with XFS are more reliable than the same type of capacitors impregnated with Aroclor 1016. This conclusion is based on results of comparative evaluations. The following tests have been completed. Three years of accelerated life tests, more than 18 million kilovar hours in full-sized units without failures. Hundreds of sample capacitors operating up to 200 percent of the rated voltages for a wide range of temperatures, minus 60° to plus 125° C.

6. *Economics and availability*. The long-range price of power capacitors impregnated with XFS 4169L will be reasonable. The increased price or expense attributed to the fluid is expected to be less than $20 for a 200-kilovar unit.

Dow has assured the electrical industry that it will have the manufacturing capabilities to produce XFS at a million pounds per year rate during the first quarter of 1976. Should this fluid prove to be acceptable to the industry, Dow is willing to make the commitment to produce the fluid in multimillion pound quantities per year by the end of 1976.

Health and Environmental Assessment

The Dow Chemical Company's assessment of the health and environmental acceptability of XFS 4169L as a dielectric fluid in capacitors is based on the following criteria.

1. *Biodegradability*. The components in XFS 4169L are significantly more biodegradable than the components of Aroclor 1016. With micro-organisms, the rates of formation of radioactive carbon dioxide from radiolabeled components of XFS 4169L are much faster than for 2,5,2′ trichloro biphenyl, a major component of Aroclor 1016. The major component in 4169L is 45 times more biodegradable than the representative PCB isomer. This rate of biodegradability is comparable to several nonpersistent industrial chemicals.

2. *Bioconcentration*. The bioconcentration factors in fish of the components of XFS 4169L are low relative to the components of Aroclor 1016. The environmentally significant components in each fluid show a factor 30 times less bioconcentratable in trout muscle for XFS.

3. *Toxicity to animals*. In both acute and 90-day toxicity tests with animals, XFS shows very little toxicity. For example, in rats, a dose of 10 grams per kilogram of XFS 4169L was administered orally and had no observable effect on rats.

The levels of the components of XFS that accumulated in the fat of rats fed the XFS in the diet for 150 days were significantly lower than for the comparable dietary tests with Aroclor 1016. For example, the accumulation in the fat was 22 times less for XFS; the apparent plateau level was achieved in 1 to 2 months compared to 6 to 7 months for the PCB, and the estimated half-life of the rat was 7 days with XFS compared to 60 days for the PCB. This indicates the relatively low degree of toxicity associated with XFS 4169L in animals.

4. *Toxicities to fish*. The XFS material is only moderately toxic to fish compared to capacitor-grade PCB, which is extremely toxic. The concentration of XFS that was toxic to fathead minnows was 15 milligrams per liter compared to 0.76 milligrams per liter of Aroclor 1016, which is a factor of 20 times less toxic to the fathead minnow.

Dow and McGraw-Edison Companies have determined that XFS 4169L is an acceptable alternative to capacitor-grade PCB in high-voltage power capacitors. This is based on the electrical performance and its low potential impact on health and the environment.

Today, McGraw-Edison is proceeding with field trials of capacitors at utility companies across the

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country. Other U.S. manufacturers of power capacitors are currently evaluating XFS for applicability in their respective companies.

The information about XFS in this discussion is only a very brief summary of the toxicological and ecological data which have been generated.

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CHLORINATED BIPHENYL DIELECTRICS— THEIR UTILITY AND POTENTIAL SUBSTITUTES

David Wood*

Abstract

The paper describes the major reasons for the use of chlorinated biphenyl in capacitors and transformers. These lead to establishment of objectives for research into potential substitutes. MCS-1238, a non-PCB capacitor fluid developed by Monsanto, is discussed and areas where further development work is required are indicated. The particular problems associated with definition of "fire resistance" relative to transformer fluids is raised.

I. INTRODUCTION

In 1970, Monsanto voluntarily began its program of terminating sales of chlorinated biphenyls to open applications—those which could result in losses to the environment. By late 1972, this program was fully implemented and Monsanto was selling these products only to manufacturers of sealed electric equipment such as transformers and capacitors.

Major applications affected by our withdrawal were carbonless paper, fire-resistant hydraulic fluids, heat transfer fluids, and plasticizers. Sales for other miscellaneous minor applications were discontinued during the same period. This action resulted in a reduction of some 45 million pounds per year in the use of chlorinated biphenyl in areas where entry to the environment was less controllable.

We decided at that time to continue supply to closed electrical applications because we believed that:

1. Entry of chlorinated biphenyl to the environment was limited and controllable;
2. A more biodegradable, lower chlorinated homolog had been developed which the capacitor industry could use;
3. Withdrawal would have brought to a halt production of equipment essential to the safe and efficient distribution and use of electrical energy because there was no known satisfactory replacement for chlorinated biphenyl dielectrics.

Today we continue to sell chlorinated biphenyl, observing the following policy:

1. We supply only to manufacturers of *sealed* electrical equipment such as capacitors and transformers.
2. We supply lower chlorinated homologs, Aroclor 1016, to the capacitor industry.
3. We offer an incineration service for liquid PCB wastes.
4. We continue to work with ANSI Committee C107 and other bodies to establish appropriate handling and control procedures for equipment containing chlorinated biphenyl.
5. We allocated increased research resources in 1969 to seek and develop effective replacements; this program continues.
6. In seeking possible replacements, we will insure that differences between Aroclor and candidate fluids from our program are widely reviewed in order that the potential impact of any compromises is fully evaluated.

The implementation of these and other programs both by ourselves and electrical equipment manufacturers was prompted by the utility of this dielectric family and the difficulties inherent in developing substitutes to effectively and fully replace it.

II. UTILITY OF CHLORINATED BIPHENYL IN CAPACITORS

1. *Fire Resistance*

The adoption of chlorinated biphenyls in 1929 as capacitor dielectrics stemmed from their superior dielectric properties compared to mineral oil. However, recognition of the fire-resistant character of the fluids influenced system and equipment design and standards over the subsequent 45 years. It is probably true that today many people find it difficult to assess potential capacitor fire hazard purely because Aroclor has been used for 45 years.

Particular examples where fire resistance in a capacitor is of benefit include:

a. fluorescent lighting ballasts,
b. air-conditioner motor capacitors,
c. television capacitors,
d. large power capacitors where high fault currents can cause rupture and ejection of fluid from pole-mounted units close to people and buildings,
e. industrial furnace capacitors.

2. *Stability*

The persistence of chlorinated biphenyl in the environment is associated with the high degree of thermal, chemical, oxidative, and hydrolytic stability which permits capacitor manufacturers to fulfill the exacting reliability requirements that exist today.

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3. *Dielectric Constant/Dielectric Strengths*

These properties are important in determining the size of a capacitor. In a mixed dielectric system, e.g., paper/Aroclor or paper/polypropylene/Aroclor, the dielectric properties of Aroclor permit optimization of stress distribution between the components making up the dielectric layer. This has enabled capacitor manufacturers to reduce paper and film volumes for a given capacitance. I shall discuss under the heading of "potential substitutes" the impact that this could have on:

a. paper/film availability and usage;
b. design of equipment containing capacitors.

III. UTILITY IN TRANSFORMERS

Chlorinated biphenyl transformers represent less than 15 percent of transformers in service. Their use is associated with the need to limit fire hazard in installations.

1. *Railroad Transformers*

Multiple unit cars as used in rapid transit systems have transformers mounted beneath each car. By nature of the type of service, involving high passenger density, safety is essential.

2. *Urban Power Substations* (e.g., Underground Vaults)

These designs need to take into account city center space limitations and also the safety of the public and maintenance crews. Fire-resistant liquid transformers are helpful to all these objectives.

3. *Industrial Load Centers*

Efficient system designs for large, power intensive, manufacturing plants (e.g., automotive assembly, steel production) often incorporate transformers close to the electrical load centers. The use of Aroclor transformers at these centers, in the heart of the plants, or overhead in roof structures, protects both employees and plant.

4. *Transformer/Rectifiers*

Programs to reduce the emission of particulate matter from stack gases, for example in fossil fuel generating plants, include installation of electrostatic precipitators. The transformer/rectifiers energizing the precipitator field must be located close to the electrodes. In many designs, the multiple transformers are located in a penthouse above the precipitator. A fire in the penthouse could lead to shutdown of the precipitator, and thus the generating plant, if pollution control is to be maintained. A fire-resistant fluid is of obvious benefit in this application.

In each of these applications, Aroclor protects the system from:

a. initiation of a transformer fluid fire by an electrical fault beneath the liquid level,
b. electrical breakdown of the fluid causing emission of flammable gases,
c. propagation of fire if the transformer liquid content is involved in an external fire.

IV. POTENTIAL SUBSTITUTES IN CAPACITORS

1. *Research Objectives*

In seeking potential substitutes, our research objectives of necessity involved keeping those properties that gave Aroclor its value. We equally recognized the need that an Aroclor replacement should eliminate environmental concerns. A replacement should ideally operate across the full range of current Aroclor capacitor applications while requiring minimum changes in design of capacitors and equipment utilizing capacitors.

The use of chlorinated biphenyl is worldwide. Monsanto manufactures chlorinated biphenyls both in America and Great Britain. We supply to the capacitor industry of many countries. We sought potential replacement products that could be made available with the consistent quality control applied to Aroclor on a worldwide basis.

We referred earlier to availability of codielectric components in capacitors. A solution requiring substantial changes in availability of polypropylene film (quantity or quality) or a major increase in short-term availability or capacitor paper, we considered unsatisfactory. If in 1974 such increased quantities had been required, they would not have been available. Capacitor production would have fallen short of demand, further jeopardizing efficient power supply.

Our research objectives can be broadly summarized in table 1.

2. *Non-PCB Candidates*

The capacitor industry is currently examining two Monsanto non-PCB (candidate) dielectrics. These contain no chlorinated biphenyl and are not chlorinated products. The two fluids are designated MCS 1238 and MCS 1588. Both of these products are blends of synthetic hydrocarbons with a high dielectric constant additive to give a dielectric constant equivalent to Aroclor 1016. Table 2 lists some of the properties of MCS 1238 and MCS 1588 compared to Aroclor 1016.

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Table 1. Research objectives in seeking potential substitutes for capacitors

1.	Match or exceed Aroclor 1016 capability:	
	a. Dielectric constant Dielectric strength	- Usage of other components - Convertability
	b. Stability Power factor	- Reliability
	c. Fire resistance	- Safety
2.	Good environmental compatibility:	
3.	a. Span existing applications	- Complete solution.
	b. Internationally available	- Not solely U.S.A. situation.

Table 2. Some properties of MCS 1238 and MCS 1588 compared to Aroclor 1016

Property	Aroclor 1016	MCS 1238	MCS 1588
DK 25° C	5.9	6.0	6.1
100° C	4.85	5.1	5.1
Corona IV/EV[a]	-	-	-
Hydrolysis stability[a] (neutralization number)	0.00	0.00	0.00
Dissipation factor fluid tan δ 60 Hz. 100° C	0.0025	0.05	0.05
Dissipation factor model paper capacitor at 90° C	0.0032	0.0039	0.0035

[a]See text explanation, section IV 2.

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Corona inception and extinction voltages are more a function of capacitor design than of the liquid itself. Preliminary industry results demonstrate functioning in capacitors equivalent to Aroclor 1016. Further full-scale work is required before final conclusions can be drawn.

Dielectric constants relate closely to those of Aroclor 1016 over the temperature range of capacitor operation. Hydrolysis stability is mentioned because of work carried out on earlier candidates based on esters, which gave concern because of hydrolysis instability. Hydrolysis was assessed by measuring the neutralization number of a sample with 0.5 percent water added, which had been heated for 168 hours at 210° F in a stainless steel bomb along with an aluminum and a mild steel coupon.

3. *Fire Resistance*

Neither MCS 1238 or 1588 is fire resistant. This deficiency versus Aroclor 1016 must be closely considered.

4. *Environmental Considerations*

The environmental/health evaluation of capacitor replacement fluids must be related to:

a. Degradation—If some quantity enters the environment, at what rate and through which mechanism will it degrade?
b. Tissue accumulation
c. Toxicity—Occupational safety
   Environmental compatability

5. *Degradation*

Biodegradation has been studied using a semicontinuous activated sludge technique. Forty-eight-hour exposure of Aroclor 1254, Aroclor 1016, and MCS 1238 dielectric fluids to activated sludge using a semicontinuous procedure resulted in the percent biodegradation rates and 95 percent confidence limits shown in table 3.

For the polychlorinated biphenyl (PCB) materials, the level of chlorination appears to be the most significant factor in their relative biodegradability. The rate of biodegradation decreases as the number of chlorine atoms per biphenyl molecule increases. Chromatograms representing samples after exposure to activated sludge show significant alteration in the Aroclor 1016 isomer distribution, but little for Aroclor 1254. Degradation of the nonhalogenated fluid, MCS 1238, proceeds much more rapidly than for the halogenated PCB fluids with no evidence of resistant components. The methodology for this technique is described in appendix B.

6. *Tissue Accumulation*

Figure 1 depicts the results of rat tissue residue level studies vs. time and compares Aroclor 1242, Aroclor 1016, and MCS 1238. A fraction of the ingested Aroclor 1242 and Aroclor 1016 was stored in rats' lipid reservoirs. However, most of this residue was depleted after the rats had been on the basal laboratory diet for several weeks. During the course of the feeding study, residues of Aroclor 1016 accumulated more slowly and to a significantly lesser extent than those of Aroclor 1242. During the recovery period, these PCB residues decreased to lower values for Aroclor 1016.

The residue concentrations of MCS 1238 quickly reached a stable level well below the concentration in the feed. The residues did not increase with continued exposure. After feeding of the treated chow was ceased, the MCS 1238 residues were rapidly metabolized and/or excreted. The tissue residue accumulation and depuration profile of MCS 1238 shown in figure 1 is markedly different than those of the Aroclor fluids, especially that of Aroclor 1242. Methodology is given in appendix A.

Table 3. Results of biodegradation using a semicontinuous activated sludge technique

Material	48-Hour percent biodegradation	Feed concentration, ppm
Aroclor 1254	15 ± 38	1
Aroclor 1016	33 ± 14	1
MCS 1238	70 ± 10	3

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25 PPM FEED LEVEL FOR RATS

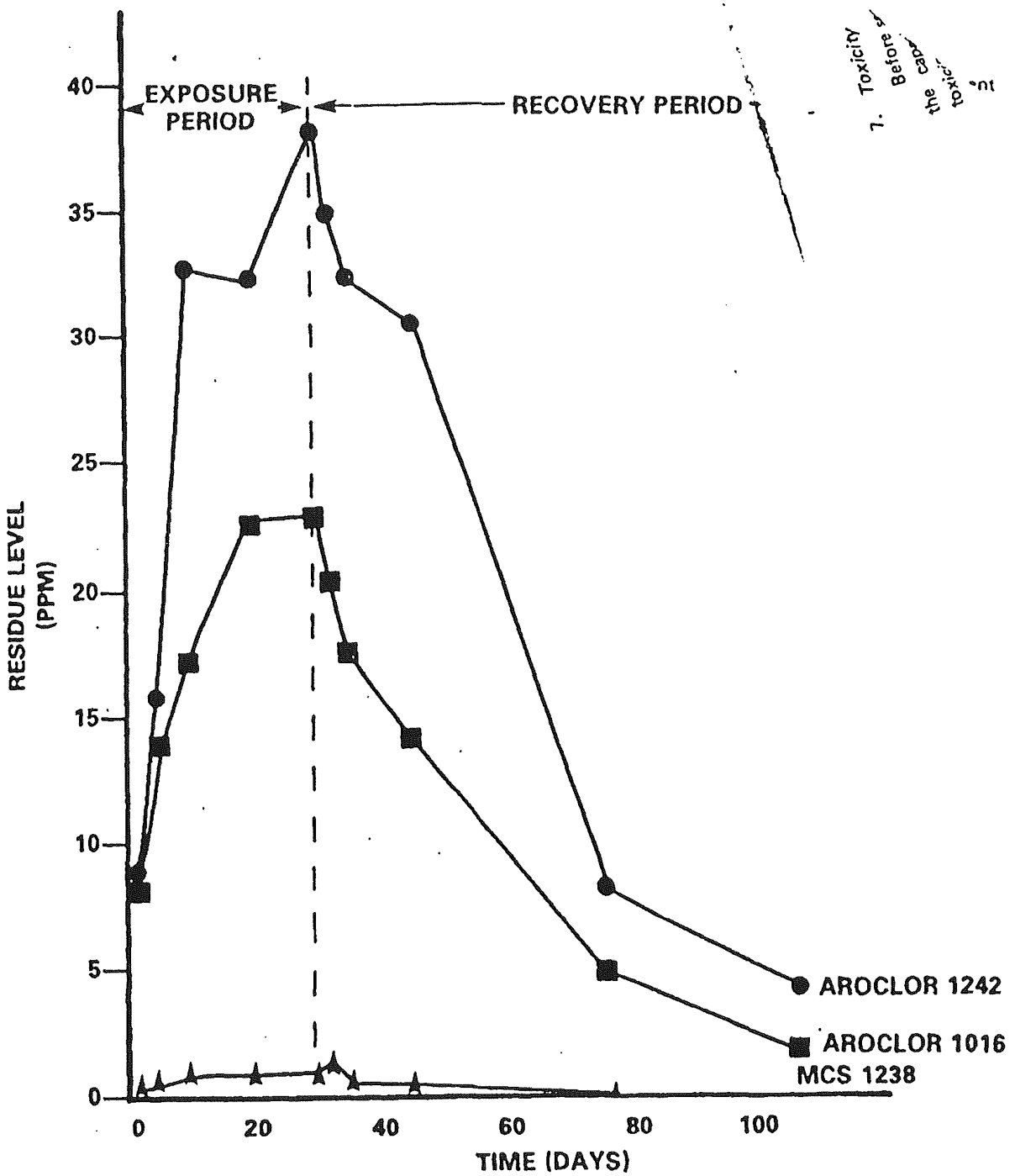

Figure 1. Results of rat tissue residue level studies vs. time, comparing Aroclor 1242, Aroclor 1016 and MCS 1238.

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7. *Toxicity*

Before samples of MCS 1238 could be evaluated in the capacitor industry and within Monsanto, acute toxicity data was gathered:

a. Rat—Acute single oral dose LD_{50}: 3,800 mg/kg.
b. Rabbit—Dermal LD_{50}: 5,000-8,000 mg/kg.
c. Rabbit—Potential eye irritation: A slight degree of irritation resulted when 0.1 ml of undiluted MCS 1238 was placed in the conjunctival sac of the rabbit eye. The average maximum score recorded at one and again at 24 hours after treatment was 12.0 on a scale of 110.0. All eyes had regained normal appearance 72 hours after dosing.
d. Rabbit—Potential skin irritation: When undiluted, MCS 1238 was held in continuous 24-hour contact with intact rabbit skin, a moderate degree of irritation resulted. The maximum average score was 3.6 on a scale of 8.0.

Further programs are in process, or scheduled, to study the following:

a. vapor inhalation,
b. ultimate degradation,
c. 90-day pilot feeding study,
d. long-term (2-year) feeding studies, and
e. fish tissue residues.

8. *Conclusions*

To summarize Monsanto research activities:

- A large number of single compounds and mixtures have been evaluated in terms of physical property data, environmental compatability, fire resistance, and model capacitor life testing.
- These have led us to conclude that:
  a. Aroclor 1016 may well be sufficiently degradable to remain in controlled use,
  b. MCS 1238 is a potentially acceptable replacement with the qualification that it is not fire resistant.
- Further programs must be completed with MCS 1238 in order to:
  a. deepen our knowledge of its environmental compatibility,
  b. permit complete evaluation by the capacitor industry across their range of applications,
  c. enable utilities, capacitor users, and agencies to evaluate the significance of decreased fire resistance.

As a closing thought to this section, I would like to comment that since 1929 when Aroclor was first developed as a capacitor dielectric, normal commercial pressures have spurred efforts to find superior replacements. The awareness of environmental accumulation of chlorinated biphenyls from other applications added further impetus for more intensive research in the chemical and electrical industries. Aroclor has defied 45 years of search for a superior replacement.

V. SUBSTITUTE TRANSFORMER FLUIDS

Neither Monsanto nor any other company, to our knowledge, has developed a transformer dielectric with equivalent fire resistance to that of Aroclor. The difficulties that we face in common with other workers in this field are twofold:

1. Aroclor has become the reference standard for fire resistance in transformers because it works and has worked for 45 years. To establish standards to guide research effort, there is a need for objective evaluation of the fire hazard associated with the major sectors of *transformer use.*
2. The chemistry which imparts fire resistance tends also to produce stable molecules. Monsanto seeks replacement products that will provide protection against:
   a. fire from transformer faults under the liquid surface,
   b. fire from secondary ignition of gaseous arc decomposition products,
   c. fire propagation if the transformer is involved in an externally initiated conflagration.

We strive to accomplish this and produce an environmentally compatible product. We have four candidates which are currently being evaluated by the transformer industry. These materials are in a sufficiently early stage of development that it would be premature to give detailed property data at this meeting.

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APPENDIX A

METHODOLOGY FOR FEEDING STUDY

Feeding and Sampling

Rat chow containing 25 ppm Aroclor 1242, Aroclor 1016, or MCB 1238 was prepared by mixing the products into Ralston Purina rat chow. The treated chow was fed ad libitum to adult albino rats for an exposure period of 30 days. Following the 30-day exposure period, all remaining rats were placed on the basal laboratory diet. At predetermined intervals during the exposure and recovery periods, five rats from each exposed set and a control set were sacrificed. Fat tissue was excised for analysis and composited for each group. Samples were quick-frozen and stored in glass containers with aluminum foil-lined caps to minimize risk of contamination.

Isolation

The dielectric fluid residues were isolated from the fat by solvent extraction. A weighed amount of fat was placed in an Erlenmeyer flask and homogenized three times with 25 ml of pesticide-grade hexanes and anhydrous sodium sulfate using an ultrasonic homogenizer. The combined supernatants and washings were filtered through anhydrous sodium sulfate and diluted to 100 ml with hexane.

Lipid Weight Determination

A 5 ml-aliquot of the extract solution was pipetted into a tared 50-ml beaker. After evaporation of the solvent under a stream of nitrogen, the beaker and residue were reweighed to obtain the lipid weight of the aliquot. All residue levels are reported as ppm on a lipid weight basis.

PCB Cleanup And Measurement

Sample cleanup for the extracts containing Aroclor 1242 and Aroclor 1016 residues was accomplished by pipetting an aliquot of the extract onto a 5 percent deactivated alumina column and eluting with 125 ml of hexanes. The column eluate was collected in a Kuderna-Danish evaporative concentrator, a 3-ball Snyder condenser was attached, and the solution was concentrated to 5 ml. The residue levels in the extracts were measured by gas chromatography using an electron capture detector.

Non-PCB Cleanup And Measurement

Sample cleanup for the extracts containing MCS 1238 residues required separation of the residues from the lipid by preparative scale gel permeation chromatography. Following the GPC separation, the extracts were further cleaned up on an alumina column, collected, and concentrated as above. The residue levels in these extracts were measured by gas chromatography using a flame ionization detector.

Calculations

Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected. Residue levels in the samples were determined by summation of the total area of peaks corresponding to peaks in the standard and use of the appropriate calibration curve. The calculations were done as follows:

$$\text{Residue (ppm)} = \frac{(N)(V_F)}{(V_I)(W)}$$

where N = Amount of product from calibration curve (ng),
V_F = Volume of final concentrate (ml),
V_I = Volume injected (ul),
W = Lipid weight of original sample (g).

APPENDIX B

TECHNIQUE FOR BIODEGRADATION METHOD

Biodegradation Method

Since activated sludge is one of the most important agents for sewage treatment, test procedures evaluating its action are of great importance.

The semicontinuous activated sludge (SCAS) method has been extensively utilized in the development of biodegradable detergents. In our SCAS procedure, patterned after the Soap and Detergents Association's

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standard method (1,2) mixed liquor (activated sludge and supernatant) from a local domestic sewage treatment plant is charged to magnetically stirred glass vessels of 1.5-l capacity. Means for aeration and sampling are provided. The SCAS unit is generally operated using a retention or aeration time cycle of 24 to 72 hours. At the beginning of each cycle, synthetic sewage (300 mg glucose, 200 mg nutrient broth, and 130 mg K_2HPO_4) and the appropriate test material in ethanol solution are added to the mixed liquor (2,500 mg/l suspended solids concentration). Aeration is maintained until the end of the cycle, at which time the sludge is settled and 1 l of supernatant drained. The cycle is then reinitiated by the addition of tap water, synthetic sewage, and test material. Operation of the units can be continued for an indefinite period of time until consistent degradation rates are observed.

Sample Analysis

Biodegradation of the test material was determined during one cycle each week by analyzing 20 to 50 ml mixed liquor samples withdrawn after feeding and at the end of the aeration cycle. The mixed liquor analytical procedure involved extraction with three successive 25-ml portions of hexane, and drying combined extracts with anhydrous sodium sulfate. Extracts were concentrated in a Kuderna-Danish evaporative concentrator equipped with a 3-ball Snyder condenser, and measured by electron capture or flame ionization gas chromatography. Calibration curves for each product were prepared by plotting detector response (total peak area) versus nanograms of standard injected.

The percent biodegradation was calculated from the following equation:

$$\text{percent biodegradation} = (C_o - C_n)/C_o \times 100$$

where C_o and C_n use the initial and final concentration of test material, respectively, on the mixed liquor.

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SOME COMMENTS ON ALTERNATIVES TO PCB's

Bruno Rey Coquais*

Abstract

In the transformer industry, the benefit of a nonflammable liquid seems to exceed the risks of pollution by polychlorinated biphenyls; however, to minimize eventual contamination of the environment, it is suggested to use, when possible, a mixture of chlorobenzene and trichlorobiphenyl or even chlorobenzene alone.

For the impregnation of capacitors, most of the substitutes which can be imagined are not very attractive, though they are useful for certain applications. It is proposed to use a mixture of pure dichlorobiphenyls and their alkylated derivatives. This impregnant, named chloralkylene, has dielectric properties very similar to the industrial trichlorobiphenyl.

The tests in progress already show that chloralkylene is easily biodegradable and has a low toxicity. This compound seems to be quite acceptable for the environment and should be a perfect substitute for polychlorinated biphenyls in capacitors.

To begin with, I would insist on the fact that heavy chlorinated biphenyls have been used for a long time in dispersive applications as plasticizers and for other uses. Although these types of applications have been stopped in accordance with the OECD recommendations of the February 14, 1973, it is not surprising to continue to find these persistent, highly chlorinated PCB's everywhere in the environment. It is therefore very difficult to know if the electrical uses of PCB's for transformers and for capacitors have a significant contribution to the pollution of our environment.

TRANSFORMERS

PCB's are used in transformers only when the fire hazard is high (department stores, theatres, movies, skyscrapers, factories); otherwise oilfilled transformers, which are cheaper, are always preferred. We do not think dry-type transformers would be a competitive alternative in spite of the fact that silicone and epoxy belong to the range of products we market. They may be very attractive in some cases, but in addition to certain economical and technical disadvantages, dry transformers do not offer a perfectly safe solution wherever flammable vapors (solvents, oil, gas) may be present accidentally.

We believe a nonflammable dielectric liquid is absolutely necessary to prevent the risk of fire in transformers. In table 1 we have listed the different possible solutions. In the United States, at this time, transformers are filled with Inerteen 70-30, which is based on pentachlorobiphenyl, or with Inerteen 100-42. To minimize the pollution risk, a mixture of trichlorobiphenyl and chlorobenzene or even the chlorobenzene alone could be used in spite of some technological problems.

In any case, the systematic recovery of used PCB's will further limit pollution hazards; our company Prodelec has organized this practice throughout France since 1968, as soon as this pollution problem became known. This systematic recovery has now been enforced in France by the French law of July 8, 1975, on PCB's.

CAPACITORS

For capacitor impregnation, we have examined various possible solutions. We think that the performances of such compounds as silicone; sulfone or synthetic oil (alkylbenzene, polybutene); phthalate; and sebacate—which we are indeed selling ourselves for certain applications—are not really satisfactory enough for generalized or widespread use.

In our opinion, a substitute to PCB's should be characterized by:

- High permittivity;
- Nonflammability, at least not sustaining combustion;
- Compatibility with polypropylene film;
- Being a permanent liquid with no crystallization until -25°;
- Good thermal and electric subfield stability;
- Regarding its effect on the environment, being fairly easily biodegradable, to eliminate the risk of accumulation, and by having low toxicity.

To get a good and nonflammable dielectric fluid means in practice that the compound must be a chlorinated aromatic hydrocarbon. We have studied, for instance, new structures, as shown in figure 1. With chlorobiphenyl oxide, we are afraid of the risk of metabolization in highly toxic dioxins and we feel that products of the family of the chlorobiphenylethane are technically and environmentally much more promising. Actually, introducing a totally new compound would require a long and expensive testing program and it seems better to take advantage of the huge amount of knowledge gathered about PCB's and to see how it may be possible to improve the present situation.

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Table 1. Possible solutions for dielectric liquid

IEC type	Chloro-biphenyl	Chloro-benzene	Pour Point (°C)	Viscosity Cst at 20° C	ε at 20° C	Hydrogen index[a]	Askarels for transformer
T_1	60% hexa	40% tri	<-33	21	4.5	<0 excess Cl	Pyralene T_1 Pyroclor
T_2	45% hexa	55% tri and tetra	<-40	11	5	<0 excess Cl	
T_4	70% penta	30% tri	<-30	20	5	0	Inerteen 70-30 Pyralene T_4
	45% penta	55% tri and tetra	<-40	10		<0 excess Cl	Pyralene T_2
T_3	100% tri		<-18	65	6	16	Pyralene T_3 Inerteen 100-42
	60% tri	40% tri	<-50	7	6	10	Pyralene 1460
	40% tri	60% tri and tetra	<-20			4	
		100% tri and tetra	Chrys-tallize -9		6	<0 excess Cl	

[a]Hydrogen index = $\frac{\text{No. hydrogen - No. chlorine}}{\text{Molecular weight}}$.

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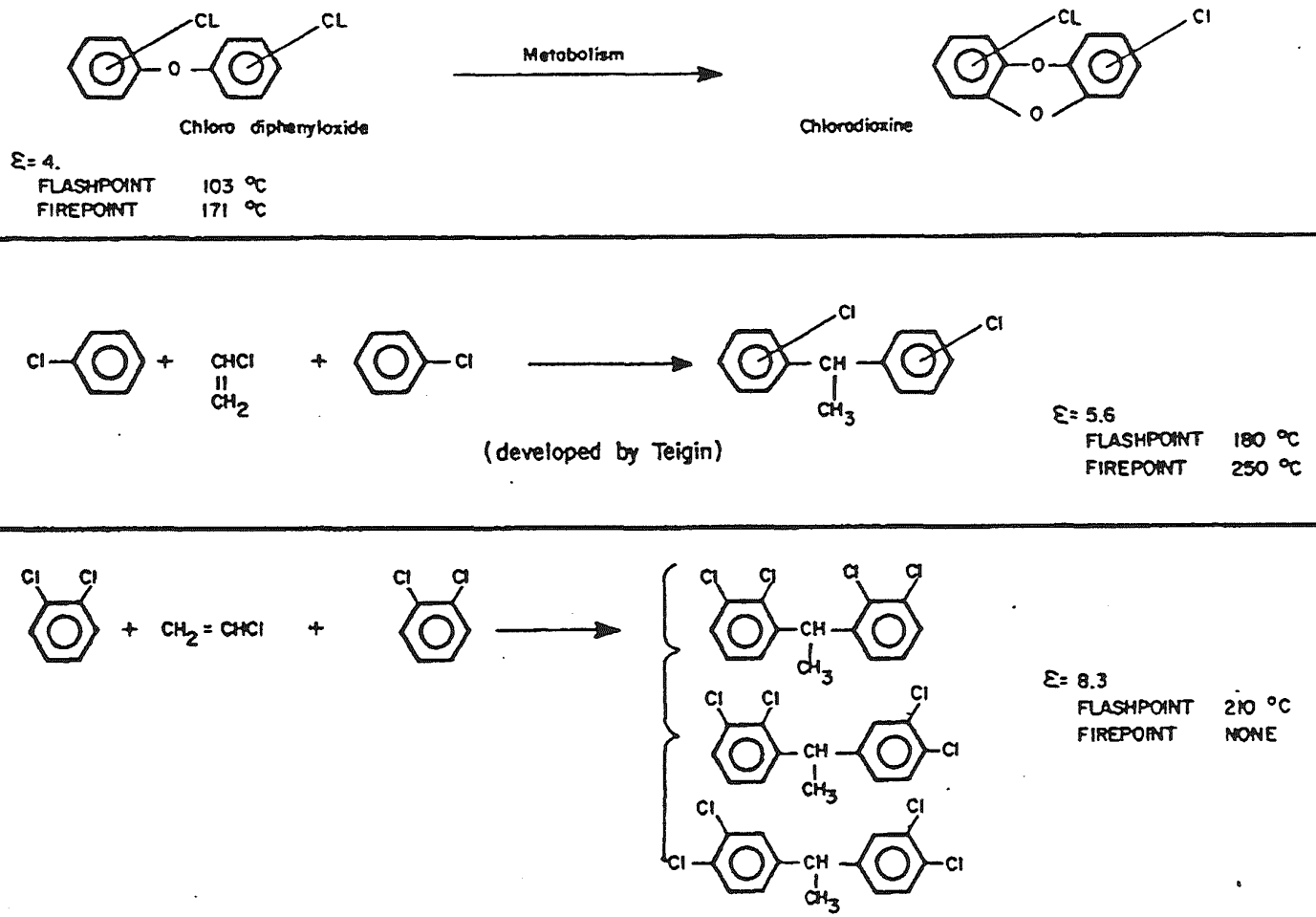

Figure 1. New structures for nonflammable dielectric fluids.

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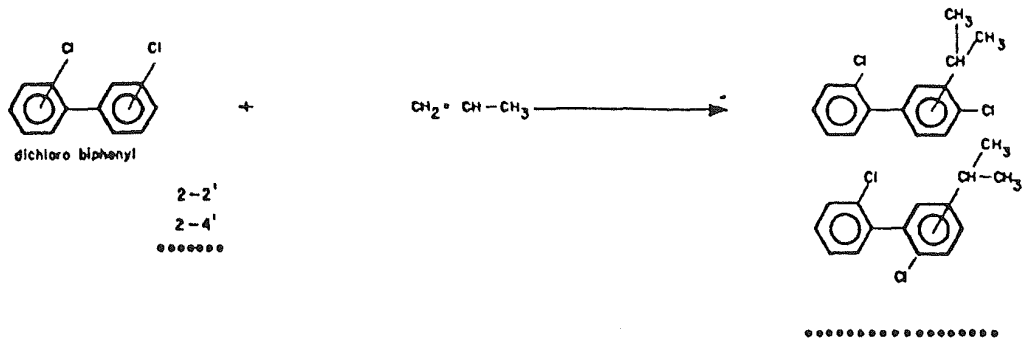

Figure 2. Structure of chloralkylene.

Table 2. Composition of various impregnants

Composition, percent	Chloralkylene 12	Pyralene 3010 (trichloro-biphenyl)	Pyralene 1500	Pyralene 2000
Biphenyl	0	0	0	1.6
Monochlorobiphenyl	0	0	0.5	18.4
Dichlorobiphenyl	20	11.4	37.5	44.0
Trichlorobiphenyl	0	57.1	40.0	23.4
Tetrachlorobiphenyl	0	29.4	20.5	11.7
Pentachlorobiphenyl	0	2.2	1.5	0.9
Alkylchlorobiphenyl isomers	80	-	-	-
Chlorine content, percent	25.8	42.	38.5	33.5

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Table 3. Comparison of chloralkylene to commercial trichlorobiphenyls

Characteristics	Chloralkylene 12	Pyralene 3010 (trichlorodiphenyl)
Specific gravity at 20° C	1.163	1.391
100° C	1.097	1.319
Coefficient of expansion	7.5×10^{-4}	6.8×10^{-4}
Viscosity Cst. at 20° C	135	65
100° C	3.2	2.3
Pour point (ASTM D 97)	-25° C	-23° C
Firepoint (Cleveland)	258° C	none until boiling
Permitivity at 20° C	6.00	5.93
100° C	4.86	4.80
Resistivity 100° C - 500 V - 1 mn	$>3000 \times 10^9$	$>3000 \times 10^9$
Dissipation factor +gδ 100° C - 50 cps	<0.02	<0.02

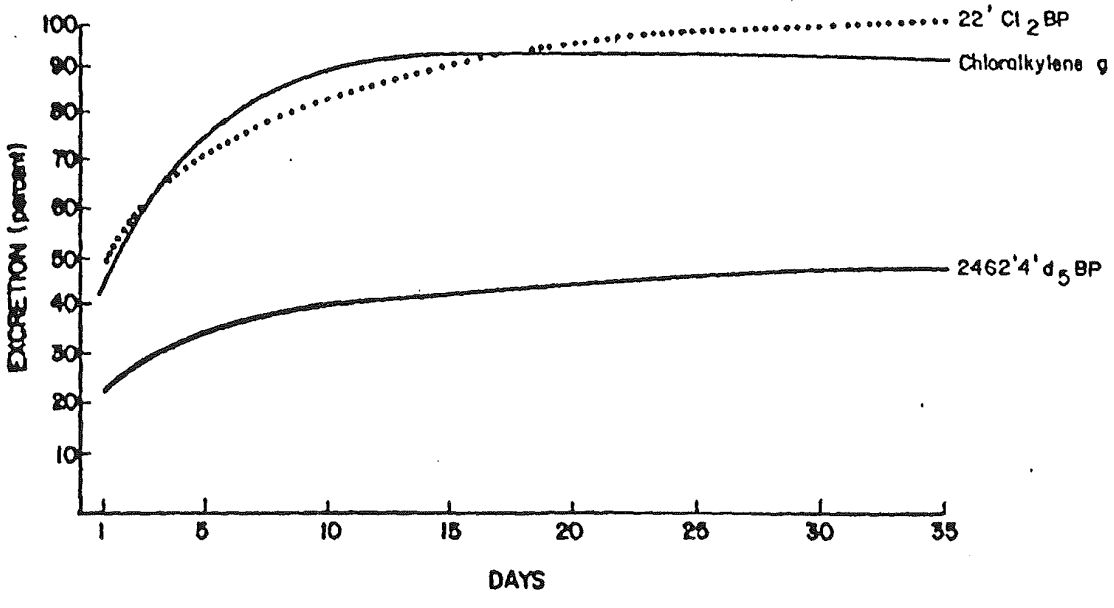

Figure 3. Excretion by rats, with diet of 2 ppm/day for 5 weeks.

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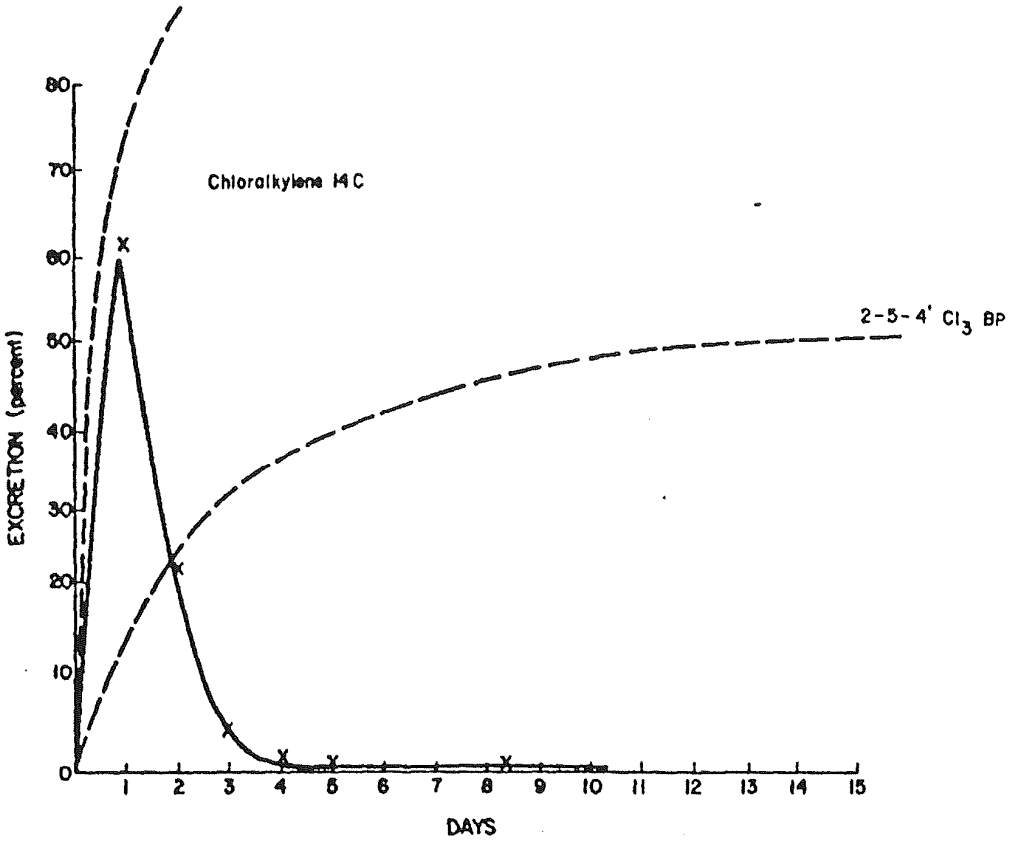

Figure 4. Excretion by rhesus monkey; single oral dose 1 mg/kg.

The studies carried on, in particular by Prof. Korte and Dr. Klein in Germany, seem to prove the easy biodegradability of PCB's when they have a very low chlorine content; therefore, pure mono- or dichlorobiphenyls could be quite acceptable for the environment.

As an impregnant consisting only of mono- and dichlorobiphenyls would crystallize at room temperature, it is necessary to produce a more complicated mixture to get a permanent liquid at all temperatures. We have therefore developed a product named "chloralkylene," obtained by addition of an alkyl chain, actually an isopropyl group, on a mixture of nearly pure dichlorobiphenyl isomers (figure 2).

As shown on table 2, chloralkylene contains no penta- nor tetrachlorobiphenyl and the trichlorobiphenyl content can be extremely low. Technically, for its dielectric and physical properties, the chloralkylene is a perfect substitute to the commercial trichlorobiphenyls (Pyralene 3010, Arochlor 1016), as shown in table 3 and as checked by some major capacitor manufacturers here and abroad.

To assess its impact on the environment, we have given chloralkylene to the Institute for Ecological Chemistry in Bonn, Germany, Prof. Korte. This institute is engaged in an extensive investigation on "PCB's in the Environment." We therefore hope to have next spring the final results on the fate of chloralkylene in comparison with PCB isomers.

Tests on environmental acceptability are actually being carried out with chloralkylene based on 2-4' dichlorobiphenyl labeled with 14c. The tests consist of a study of the balance of the excretion, the storage, and the metabolism in rats and in monkeys (figures 3 and 4); the monkey studies are being completed at the Institute of Experimental Pathology and Toxicology, Albany Medical College, Albany, New York. These tests also examine the fate of chloralkylene in a soil plant ecosystem and in an aquatic ecosystem, as well as its behavior under atmospheric conditions, upon waste composting, and in sewage treatments. The results so far obtained prove that

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chloralkylene does not accumulate, is metabolized quickly, and behaves generally like the dichlorobiphenyls isomers themselves.

Chloralkylene is two times less toxic than trichlorobiphenyl when one compares the acute toxicity values. At this time, there is no real reason to consider PCB's dangerous for the labor manufacturing capacitors, if the necessary precautions are taken. We think that with an easily biodegradable compound such as chloralkylene, long-term effects due to accumulation along the food chain do not need to be feared.

The chloralkylene price is presently twice that of the currently commercially available polychlorobiphenyls, which would result in an increase of the capacitor costs of about 5/10 percent. However, by substituting mineral oil or other substitutes with less outstanding characteristics, the increase of the cost of capacitors would be much higher. We hope to improve its economy and are quite confident that chloralkylene could thus be an excellent substitute for trichlorobiphenyls.

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PCB's AND THEIR SUBSTITUTES – A BRIEF LOOK AT SOME EXAMPLES OF PAST TRADEOFFS

Dale Hattis, Ph.D., and Albert Murray, Ph.D.*

Abstract

Some aspects are described of a study of the economic, health, legal, and other impacts of the past voluntary restriction on PCB sales. Examples illustrate the importance of examining the effects of substitute technologies in assessing regulatory policy by showing the potential for surprises in this regard. In the PCB case, substitutes may be producing both unanticipated economic benefits and unappreciated health and safety risks.

I am Dale Hattis of the Center for Policy Alternatives at M.I.T. My colleague at the center, Dr. Albert Murray, who was originally scheduled to speak here—and who would be the most appropriate speaker on this subject—was unfortunately taken ill about a week and a half ago and he is now still recuperating in the hospital. What I have done in his place for presentation today is to extract some particular examples of tradeoffs from Al's work on PCB's, which illustrate some occasionally surprising features of the technological changes that arise out of environmental/health concerns.

For context, I would like to say that our project, sponsored by the Council on Environmental Quality and EPA, and under the direction of Dr. Nicholas A. Ashford, has for the past year been exploring ways to analyze the economic, environmental health, legal, and other impacts of regulatory decisions related to environmental chemicals. In this exploration, we are now in the process of completing eight experiments in the analysis of the impacts of particular regulatory actions, primarily drawn from the past 5 years of history. The first of our eight experiments, though not strictly resulting from a mandatory governmental action, was the restriction a few years ago of the sale of PCB's for particular uses. Because our case studies are experiments to explore the practical use of methods, and because the resources we could devote to each case were relatively small, we could not perform as comprehensive an elucidation of effects as we would have wished. Nevertheless, we do think that our analyses have revealed important types of questions, similar to those referred to yesterday by Mr. Train, which are difficult to deal with in the single chemical reactive context of most current regulatory authorities.

My initial two examples of such questions on PCB's illustrate the fact that it is sometimes difficult to be sure that technological changes introduced with the intent of reducing environmental health risks accomplish their purpose on balance, when the risks of substitute practices are considered. Sometimes there appear to be legitimate reasons for concern that particular changes—especially in the absence of continuing regulatory followup—might create environmental health hazards as dangerous or more dangerous than the ones that are eliminated.

As a first example, the substitutes for PCB's in some large heat exchangers and in some special hydraulic fluids for high-fire-risk uses are flammable at elevated temperatures. Concern for the lack of fire protection previously provided by PCB's in these situations has reportedly caused a substantial increase, as much as a doubling in some cases, in fire insurance rates on some industrial facilities employing high-temperature heat exchangers. In our case study, Al Murray estimated the total increase in premiums at possibly in the tens of millions of dollars annually. This, of course, reflects mainly property damage and not the human cost. However, if our information on the increased premiums is correct, and if the apparent perception of the insurance companies is correct as to the size of the added chance of catastrophic fires, then we must consider that such events would be likely to be accompanied by appreciable human casualties. The rise in insurance rates, of course, may not reflect an actual change in risk, and in that case the increased insurance cost is simply a transfer payment to the benefit of the insurance companies, but the matter seems to deserve further exploration with the aid of hard statistics on actual fire-risk experience. If the data confirm that appreciable human impact may be expected to occur, alternative means for reducing this risk might be productively evaluated.

Another, although probably less important, example of potential risk of substitute technology arises in the case of the former use of PCB's as a dye-solvent for carbonless carbon paper. It may be recalled that at some frequency PCB's from this source found their way into recycled paperboard products for food contact use, and this was a source of concern for the FDA. Now the PCB's formerly used for this purpose have been replaced, but unfortunately it is not public information what exactly has replaced them. The barrier of trade secrecy

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in this instance, as in many others, can frustrate attempts to assess the difference in environmental health risk produced by the change in technology.

Two other examples illustrate the potential for a different category of surprises—those in the economic area.

Formerly, PCB's costing on the order of 25 cents per pound were used in many paints and coatings, sometimes as a major ingredient. In this application PCB's were a chemically stable blender and conferred resistance to fire, impacts, water, and weathering. Our inquiries with paint manufacturers indicate that chlorinated paraffins now perform essentially all the technical functions of PCB's at about half the former cost. Our industry informants mention some increased problems in a few of their products with lowered stability to dechlorination—causing occasional discoloration and loss of weathering resistance—but over the great bulk of their product lines, the industry perception appears to be that the change has been economically beneficial. PCB's had evidently become established as paint additives before the availability and advantages of the chlorinated paraffins became widely appreciated. Later, when approximate technical equality and lower prices might have tempted paint manufacturers to substitute, the usual inertial resistance to any change appears to have caused this opportunity to be generally neglected. The real world and the economists' ideal one occasionally behave differently.

Another example of a surprise (at least to us) in the economic area is the potential importance of even small adverse impacts on sport fishing. A U.S. Department of Interior survey (ref. 1) indicates that in 1970 a total of about 700 million person-days and five billion dollars were spent in pursuit of this pastime – mainly in fresh water. The five billion dollars must, of course, be considered an underestimate of the actual "value" of that activity to people. If PCB's had continued to be used as they were in the past, we might speculate that additional concern of people about residues (such as that now publicly in evidence), or possibly some declines in fish populations might have led to small fractional declines in participation or enjoyment of fishing by some portion of the population. If this were to occur, the loss of value to society of even less than a fraction of a percent of national sport fishing activities might be appraised at tens of millions of dollars annually—depending on the "value" realized by former fishers in substitute recreational activities.

The importance of examining subtle and uncertain effects, including the effects of substitute technologies, is illustrated by such occasional insights into their potential magnitude.

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ENJ-2065—AN ELECTRICAL INSULATING FLUID

E. J. Inchalik, Ph.D.*

Abstract

The need for an electrical insulating fluid whose use would avoid the adverse toxicological and ecological effects associated with polychlorinated biphenyls prompted a study of organic esters as possible substitutes. The study culminated in the identification of diisononyl phthalate (ENJ-2065) as a dielectric fluid of potential interest to the capacitor industry. ENJ-2065 has been made available to that industry and it is now being used in some commercial capacitors.

In late 1970, a study was begun at Exxon Research and Engineering Company by Drs. A. J. Rutkowski and E. O. Forster to develop an electrical insulating fluid whose use would avoid the adverse toxicological and ecological effects associated with polychlorinated biphenyls. This study culminated in the identification of diisononyl phthalate (ENJ-2065) as a dielectric fluid of potential interest to the capacitor industry. Exxon Chemical Company U.S.A. has made ENJ-2065 available to the industry for its evaluation and it is now being used in some commercial capacitors.

In the preliminary phases of this study, the dielectric properties of a significant number of mono- and dibasic acid esters were determined in order to obtain a general understanding of the interrelation between molecular structure and dielectric properties. From these data it was concluded that major attention ought to be directed at the esters of phthalic acid. The phthalates that we tested all had dielectric constants of 4-6, close enough to the desired level for fluids for the widely used paper-based capacitors to justify further evaluation. The optimum dielectric constant for these capacitor fluids is one which closely matches the dielectric constant of the paper. A close match reduces electric field inhomogeneities, increases dielectric strength and lifetime, and decreases capacitor size. Other important property criteria for a paper dielectric fluid include a low dissipation factor, to reduce energy loss and destructive heat buildup; a high dielectric strength, to reduce capacitor size and improve service life by permitting short-term exposure of the fluid to abnormally high stresses without breakdown; a low gassing tendency, to avoid production of gases that could lead to pressure buildup in sealed units; stability at elevated temperatures, to prevent capacitor breakdown and stabilize performance; low viscosity, to allow for easier impregnation and filling of capacitors and elimination of air pockets; a low order of toxicity; and compatibility with the environment.

Consideration of these factors as well as availability and cost resulted in narrowing the choice of potential candidates to those shown in table 1. From this list, diisononyl phthalate (ENJ-2065) was selected as the most promising for additional study. ENJ-2065 was chosen on the basis that it has (1) a higher dielectric constant than the phthalates of higher molecular weight, (2) an advantage in its loss characteristics relative to the lower molecular weight dihexyl and dioctyl phthalates, (3) a relatively high flash point of 430° F, (4) a more highly branched molecular structure than dihexyl and dioctyl phthalates with the potential for improved hydrolytic stability and (5) a good balance of other physical and electrical properties. ENJ-2065 is manufactured in the United States by Exxon Chemical Company U.S.A. from phthalic anhydride and a mixture of branched isomeric alcohols in which C_9 alcohols predominate.

Electrical insulating fluids have to remain essentially unchanged chemically when subjected to temperature cycles. Once having chosen ENJ-2065 for further evaluation, it was desirable to know what effect certain contaminants might have on its stability, how these contaminants might be removed, and what additives, if any, might be useful in enhancing its stability.

The effects of small amounts of two potential contaminants, alcohol and water, on conductivity of ENJ-2065 are shown in tables 2 and 3. The results show that alcohol levels of less than about 1,000 ppm and water levels of less than about 100 ppm can probably be tolerated without affecting performance seriously. To remove small quantities of these impurities as well as any acids or catalyst residues from the production of ENJ-2065, we found percolation through a packed column of activated Attapulgus clay to be effective, but we did not carry out extensive studies to optimize a purification system. It is our feeling that systems now being used in the industry for purification of PCB's prior to use in capacitors, or slight modifications of them, will prove to be satisfactory for ENJ-2065.

Although the most widely used capacitors today are of the all-paper type, newer types based on polypropylene film and paper or on all-polypropylene film are growing in importance. With capacitors of this type, the dielectric constant of the fluid is less important.

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Table 1. Electrical and physical properties of phthalate esters

Phthalate Ester	Dihexyl	Di-2-ethylhexyl	Diisooctyl	ENJ-2065	Diisodecyl	Ditridecyl
Dielectric constant	5.64	5.33	4.97	4.66	4.45	4.08
Tan delta	--	0.14	0.30	0.05	0.02	0.01
AC conductivity, 10^{-11} $(ohm\text{-}cm)^{-1}$	9.0	2.1	1.3	0.29	0.20	0.04
Breakdown voltage (KV/0.1 in.)	--	28	27	30	36	29
Boiling point--mid @ 5 mmHg, °C	210	230	235	252	256	286
Pour point, °C	-33	-50	-45	-48	-50	-37
Viscosity, cps., 20° C	50	81	83	95	110	230
Flashpoint, COC, °F	380	425	430	430	452	470
Firepoint, COC, °F	420	475	485	495	515	555

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Table 2. Effect of residual alcohol on conductivity of ENJ-2065

Temperature cycle (1,000 V, 60 Hz)	Conductivity (10^{-12} ohm-cm)$^{-1}$ Wt. percent alcohol added		
	0	0.01	0.1
25° C	0.78	1.97	1.98
90° C	40	65	320
25° C	3	4	12

Table 3. Effect of residual water on conductivity of ENJ-2065

Temperature cycle (1,000 V, 60 Hz)	Conductivity (10^{-12} ohm-cm)$^{-1}$ Wt. percent water added			
	0	0.001	0.01	0.1
25° C	0.78	2.7	3.7	135
90° C	40	165	>400	>400
25° C	3	10	25	70

Table 4. Weight gain of PP film in contact with dielectric fluid

Fluid	Run number		
	1	2	3
ENJ-2065	11.0	10.9	13.8
Arochlor 1242	18.8	18.2	22.8

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impregnation of the polypropylene film with the fluid, however, is of great importance and prompted a brief study, summarized on table 4. These data show that ENJ-2065 swells polypropylene capacitor-grade films satisfactorily, as measured by the film weight gain after 2 days at 60° C, so that film impregnation should not be a serious problem. The next generation of capacitors may well be based on metallized polypropylene film. Polychlorinated biphenyls cannot be used for this type of capacitor since they generate hydrogen chloride, which can lead to premature breakdown.

In summary, we believe that ENJ-2065 has a balance of properties such that it will find a niche in the capacitor fluid field.

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CHAIRMAN MUIR: All right. I see that we have reached our scheduled departure hour. I think it's only fair to entertain a few questions from the audience and given the diversity, I would request that people raise a question from the floor and then address their questions to the individual they would like an answer from.

MR. BEN KININGHAM (Illinois Lung Association, Springfield, Illinois): I do not have any particular gentleman on the panel to address. I just want to refer to the breakdown of the film, if anyone could elaborate on how that comes about, and if so, is there any research that is being carried on now in development of films that would be any more stable.

MR. RICHARD ROLLINS (Jard Corporation, Bennington, Vermont): Are you talking about a biological breakdown?

MR. KININGHAM: Biological or chemical or both breakdowns.

MR. ROLLINS: It is a reduction type atmosphere in the capacitor so it does not see the oxygen that would normally be considered. The basic problem is not one of the degradation as much as it is an inherent characteristic of not being able to survive voltage levels or stresses in an AC application.

MR. KININGHAM: Would it be feasible to develop an alternative program?

MR. ROLLINS: The organic type films have been used or have been attempted to be used in AC capacitors. The basic problem is one of corona exception and corona distinction voltages, and this is inherently low and goes down to initiation of points 250 to 275 volts and the extinction voltage is extremely low. The meaning of the corona is that the capacitor slowly deteriorates by this ionic device which is the definition of corona. The interpretations of corona I am not going to get into today because every capacitor designer has his own opinion, but every capacitor designer is completely aware of what the corona problems can do. So essentially what we are saying is that organic films have the basic problem of not being able to withstand high AC voltages, especially in the dry system.

On an impregnated system, the circumstances are still there, so you are not really changing the circumstances a great deal in all polypropylene film or any organic film when you impregnate it.

VOICE: I have a question for Dave Wood. We heard a number of things about environmental factors. How about a still lower chlorinated material than 1016 that might be a more desirable material? I believe Monsanto has passed a given developmental material such as 1043, which is a lower chlorinated material.

MR. DAVID WOOD (Monsanto Industrial Chemicals Company, St. Louis, Missouri): We have done considerable work with MCS 1043, but at the present time commercialization of such a product must hang in the balance pending further conclusions being drawn about the true significance in the differences observed between the trichlorinated materials and bichlorinated materials. Aroclor 1016 was itself a reduction in materials from the Aroclor 1042 widely used by the industry.

In order to carry through development of the dichlorinated material, I think we need some approvals from the community that they recognize a movement in that direction as one that should be taken.

So yes, some data are already available. Acceleration or stopping of that program depends largely, on some of the things that we hope will come out of this conference this week.

MS. NANCY STROUP (Environmental Defense Foundation, Washington, D.C.): I apologize for the openhandedness of my question, but I hope that the panel members will respond as concisely as possible.

One of the speakers mentioned that his concern was that we not jump from the frying pan into the fire, and I am sure it's the concern of everyone at this meeting. To that end I would like to know when the four or five compounds that are now being developed to replace PCB's will be tested for the health and safety of these compounds, including carcinogenic, immunogenic, and teratogenic tests before your marketing. And whether this information will be available for independent review.

DR. MUIR: Essentially, as I already outlined in my talk, we developed a date for the work and the work is going forward and we recognize the biphenyl problem and that replacing the product inevitably is going to have to satisfy the most thorough and rigorous testing.

DR. DEAN BRANSON (Dow Chemical, Inc., Midland, Michigan): In the case of methosilicones additional data will be published very shortly and will be publicly available. I think this is most in the minds of all manufacturers when they consider substitutes

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for the material which is dielectrically one of the best ever developed. This will seem to solve the problem when it comes out.

DR. E. J. INCHALIK (Exxon Chemical Company, Linden, New Jersey): A great deal of information is already available. You may recall in 1972 a program sponsored by the National Foundation of Health Sciences and one subject made by Dr. Tapper, what he observed at comparison of PCB and mercury, it was like an ideology searching for a disease, and that's a quote.

The recent study by Dr. Hartung of the University of Michigan has concluded that no problems attributable to polyesters have been noted due to the constant low level exposure of the general population, and that occupationally, only mild skin irritation has been observed at high exposures. But he did point out that ecological work should be continued. And I might add that Dr. Tapper suggested the same.

To help answer these questions, particularly related to these items, a research grant has been made by the University of Missouri to the Manufacturing Chemists Association, and they are starting tests. I think we can hope within the next year or so results will be coming from this study obviously available to all which will help answer these questions.

MR. DUNCAN MacARUTHUR (Booze Allen and Hamilton, Inc., New York, New York): Well, some of the things that you have asked for are in progress and when these things are available, they will also be made available to the general public.

MR. DAVID C. MORRIS (Weyerhauser Company, Tacoma, Washington): You stated, sir, that a cost of $4.9 million would be necessary for I guess you would call them secondary market users like my company, to replace our PCB with some substitute.

Did I understand you correctly, Mr. MacArthur?

MR. MacARTHUR: Yes.

MR. MOSS: Just for my own sake, I just believe in it very strongly, the cost alone is estimated at $2 million and we are right in the midst of investing. And I think somewhere along the line the investing might not take into account the factors that we initially have to face. I would guess it's at least 50 times over.

CHAIRMAN MUIR: Yes, sir.

VOICE: There are three experimental items coming on the market. Will someone label these transformers--

MR. ROLLINS: Well, I'm not too sure, but there have been requests that major capacitors manufacturers now conform by labeling all capacitors that have greater than I believe 5 pounds of Aroclor—I may be wrong, but on small capacitors, the basic problem is the label gets hidden because this is placed into another piece of equipment.

MR. STEVE NUMUS (Environmental Protection Agency): I have a question for Richard Montgomery regarding the use of silicone which was approved by Underwriters Lab for indoor use. Do you know the reasons why it was approved for indoor use and why it was not approved for outdoor use?

And secondly, can somebody give me an idea of the percent of transformers in the United States used for outdoor purposes as opposed to indoor purposes?

MR. RICHARD H. MONTGOMERY (Dow Corning Corporation, Midland, Michigan): First of all, Underwriters Laboratory does not approve of any particular material for any given use—once you exceed 600 volts in a transformer, Underwriter's Laboratories has no certification. The only certification received from Underwriters' Laboratories is as to the fire hazard of your particular material on a scale which ranges from 0 to 100, with the burnability of water as 0, and gasoline as 100. Therefore, Underwriter's Laboratory does not approve silicone material for indoor use.

In respect to the use of dielectric fluids in transformers, the electric code for outdoor uses does not specify nonflammable material. It does in subsection 450, paragraph 23 approve the use for the indoors. These are the only materials approved for use.

MR. NUMUS: I want to know the percentage as opposed to indoor use.

MR. MONTGOMERY: Well, my research seems to indicate 85 to 90 percent of the transformers sold in the United States are currently outdoor applications, and the other 10 to 15 percent are indoor applications, for safety is of paramount importance.

MR. WOOD: Essentially the figure that he is using is pretty accurate. Very large power transformers are filled with mineral oil because, if they're out in the field, there is not a substantial hazard, they can be screened out. In the medium voltage range the use of askarel is something under 15 percent of the transformers used in that medium voltage area.

MR. CLIFFORD H. TUTTLE (Aerovox Industries, Inc., New Bedford, Massachusetts): I really have two questions—another alternative mentioned up there, the capacitor for getting the high voltage can consume 20 to 50 million pounds a year. How long

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would it take fluid to be available in that type of quantity; 1 year, 2 years, 3 years, or what? I don't want to pressure you, I just want to determine.

The second question is a third of that market is lighting, fluorescence. If you have an application at 100° C, are any of these fluids or alternatives capable of operating at that temperature without breaking?

MR. MONTGOMERY: Let me answer your second question first. The answer is yes. The answer to the first question is we do have the productive capabilities capable to handle that market. It could be accomplished very quickly. It would probably be faster than the industry takes to evaluate and qualify new material.

MR. WOOD: In terms of Monsanto, alternatives could be made available on a production basis in calendar year 1976, in relationship to the stability of these materials at 100° in the HIB and the fluorescent lighting capacitors, those are test sequences which are going on under our test programs. And the results will be forthcoming. We are in a period now of collective work. We are not ready to go tomorrow.

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PROPOSED REVISION TO ANSI C-107.1(1974)

1. SCOPE

This standard establishes guidelines for the safe transport, use, maintenance, and disposal of askarel and askarel-soaked material used in capacitors and transformers.

2. GENERAL INFORMATION

2.1 General. The term "askarel" generally describes a broad class of nonflammable synthetic chlorinated hydrocarbon insulating liquids widely used in capacitors, transformers, reactors, and accessory equipment operated at power frequencies.

Askarels consisting of or containing polychlorinated biphenyls (PCBs) have been used in many applications since the early 1930's, but only recently was it discovered that PCBs are widely dispersed in the environment. Systematic investigations of the biological effects of PCBs have been undertaken within the past few years to establish the effects of specific formulations on specific species. Studies have shown that PCBs are an environmental contaminant. Significant steps have been taken by U.S. industry to limit further releases of PCBs to the environment.

PCBs have been used in three broad types of applications as follows:

(1) "Open-ended" applications; for example, in paints, speciality inks, paper coatings, plastics, etc.

(2) "Nominally closed" applications; For example, as the working fluid in hydraulic and heat transfer systems.

(3) "Closed electrical system" applications, specifically as the insulating fluid in certain kinds of transformers and capacitors.

Effective January 15, 1972, the Monsanto Company, sole domestic producer of PCBs discontinued supplying PCBs to all except manufacturers of electrical transformers and capacitors.

Evaluations of the benefits, risks, and alternatives involved in the continued use of PCBs in closed electrical systems are summarized in 2.2 through 2.4.

2.2 Benefits. Askarel-filled transformers are used where fire-resistant properties are important. Askarel-filled power and industrial capacitors are significantly smaller, more reliable, more durable, and safer than oil-filled capacitors. As a result, askarels have supplanted mineral oils in more than 90% of the power and industrial capacitors made today. Over the past few decades most of the equipment that incorporates such capacitors has been designed to take particular advantage of the size, safety, and reliability benefits of askarel capacitors (for example, many types are today less than 14% of the size of equivalent oil capacitors and have a life expectancy of 10 to more than 20 years).

Various federal, state, and local codes dictate the present use of askarel-containing equipment in or adjacent to public, commercial, and industrial buildings, which locations present the greatest potential danger to life and property.

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2.3 Risks. In the United States, medical records since the early 1930's show that the only adverse health effects experienced by U.S. workers exposed to askarels, either during the manufacture of these liquids or of electrical equipment containing these liquids, have been limited to occasional cases of monochronic chloracne or other temporary skin lesions or irritations.

Askarel-filled transformers and capacitors are delivered to customers as sealed units from which there is no escape of askarel under normal operation. Although certain types of equipment failures can result in loss of some askarel to the environment, transformer failures are limited to approximately 0.02% of the units in service per year. With respect to capacitors, such losses are limited to approximately 0.04% of the units in service per year. In addition, limited amounts of PCBs can get into the environment during the manufacture, delivery, improper use, maintenance, repair, and disposal of transformers and capacitors.

Specific control measures have been instituted by individual manufacturers and users and are supplemented and strengthened by national standards and procedures such as this standard, which provides information to prevent the inadvertent loss of PCBs to the environment at all stages from initial askarel manufacture through ultimate disposal.

2.4 Alternatives. For technical and local and national code reasons, it would be impossible to replace most askarel-filled transformers now in service with oil-filled units of equivalent ratings without major construction changes that would be required to compensate for the fire resistance of the askarel-filled units. For certain applications and locations, dry-type transformers may replace askarel-filled transformers.

For new installations, although many of the foregoing limitations would still apply, building and installation design provisions could be made to accommodate the use of oil-filled, open dry-type or sealed dry-type transformers, provided that necessary technical, code, physical size, and cost considerations are properly evaluated.

Several potential alternative transformer fluids are under intensive investigation to determine if they will have satisfactory electrical and operating performance characteristics. Such liquids must be acceptable environmentally, to the users, and from the fire risk standpoint.

The principal alternatives to askarels for capacitors are either mineral oil or various types of synthetic fluids. The latter types are under intensive investigation by the industry. Mineral oil and these newer fluids are flammable. The use of mineral oil would return capacitor technology to its pre-1932 level and would necessitate the redesign and replacement of such widely used equipment as flourescent light fixtures and racks for power and induction-heating capacitors, which could not now accommodate the increased size of oil capacitors while maintaining their present ratings. For the newer types of synthetic fluids under investigation it must be determined if they will yield satisfactory operating performance, are environmentally acceptable and that liquid non-flammability is not required.

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Long before there were any environmental concerns about PCBs, there was a strong economic incentive to find other less expensive insulating liquids with the desirable characteristics of askarels. Omitting economic considerations there are no technically equivalent fluids available today.

3. CAPACITOR GUIDELINES

3.1 General. The environmental effects of askarels are under in-depth study by governmental and other agencies. Askarels have been considered relatively harmless to humans based on safe industrial usage, since the 1930's, except for minor skin and eye irritation. There have been no known instance of human injuries when they were used under the normally accepted precautions and conditions of handling in both manufacturing and user applications.

Askarels are being found in the environment and in fish and bird life. The long-term genetic and ecological effects are not yet completely understood. For these reasons, care should be taken to contain askarels and minimize their entry into the environment.

There are two general classes of askarels used by the electrical industry. The higher chlorinated grades are the more persistent in nature. Because of their higher degree of resistance to burning, they are used in transformers where personnel safety is of paramount importance.

Capacitor-grade askarel has a lower degree of chlorination (composed primarily of the 3-chlorine isomers of biphenyl) and a higher degree of biodegradability. Generally, it has not been found in animal life. It is used in capacitors, where the extreme resistance to burning required in transformers is of less importance.

Although capacitor-and transformer-grade askarels both contain members of the PCB family, they do differ in composition, degree of biodegradability, persistance in nature, electrical stability, chemical stability, and degree of flammability (both are recognized as highly resistant to burning. It is for those reasons that Section 3 of this standard is intended to apply to capacitor-grade askarel.

3.2 Capacitor Grade Askarel. In September 1971, a new grade of capacitor impregnant, Aroclor 1016, was made available to the industry. This new grade contains a typical concentration of 0.4% or less by weight of the higher boiling homologues of the chlorinated biphenyls. [See ASTMD3303 -74(1)[1]] Aroclor 1016 replaces Aroclor 1242, which previously was the major capacitor impregnant and contained around 7% of the higher-boiling homologues (the more persistent in nature). This 0.4% level of the higher-boiling homologues should be the maximum concentration acceptable in any capacitor impregnant. Aroclor 1242 and 1254, previously used as impregnants, do not meet this requirement and should no longer be used in capacitors designed and manufactured for alternating-current applications.

Aroclor 1016 has the same Underwriters' Laboratories, Inc. flammability rating as Aroclor 1242.

Commonly used solvents for clean-up purposes, include benzene, kerosene, acetone, trichloroethane, trichloroethylene, and perchloroethylene. Typical vapor pressure data for Aroclor 1016 are:

0°C	=	0.001	mmHG
25°C	=	0.006	mmHG
150°C	=	4.3	mmHG
200°C	=	29.0	mmHG

At 25°C and 760 mmHG pressure, saturated air contains approximately 0.09 mg/l.

NOTE: 1 mg/l = 90.0 ppm (v/v)
1 ppm (v/v) = 0.011 mg/l

[1] Numbers in brackets refer to corresponding numbers in 7.1, References to the Text.

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3.3 Employee Safety and Plant Housekeeping. The procedures and limits given in 3.3 are intended to be minimum requirements to be met by manufacturers and users of capacitors containing askarel. Handling, control, and disposal procedures are given, together with exposure limits and indicated antidotes and clean-up procedures.

3.3.1 General Safety Precautions. Although it is generally accepted that exposure to capacitor-grade askarel is not hazardous provided that simple precautions are taken, exposure should still be avoided.

3.3.1.1. Vapors. The odor of askarel is noticeable well below the maximum air concentrations considered safe. Up to 1.0 milligram per cubic metre of air has been determined to be the maximum safe level of exposure during an 8-hour workday. (See reference 19)

The procedure for performing the necessary analyses of vapors is referenced in Section B3 of Appendix B. This procedure or its equivalent should be used.

Breathing vapor or fumes from heated askarel should be avoided. Provisions should be made for adequate ventilation and regulation of manufacturing operations to avoid open exposure to askarel (especially at temperatures of 55°C or higher). The gases produced when askarel is decomposed by very high temperatures (such as that of an electric arc) in the presence of air or organic insulating materials contain a very high percentage of hydrogen chloride, and small percentages of carbon dioxide, carbon monoxide, and oxygen. Minute concentrations of this combination of gases are very unpleasant and irritating, thus giving ample warning of their presence. If exposure to high concentrations of askarel is necessary under emergency conditions, an approved gas mask or self-contained breathing apparatus should be worn. Such exposure should be under the surveillance of other personnel capable of effecting rescue in case of an accident. If the odor of askarel is detected by the person wearing protective equipment, he should immediately go into fresh air. All gas masks, respirators, and replacement parts should have U.S. Bureau of Mines approval and be maintained on a regular schedule in accordance with the manufacturer's recommendation.

3.3.1.2 Liquid. In contrast to the situation in which mineral insulating oils are handled, there is virtually no fire hazard in handling askarel. A limited solvent action (similar to that for paint thinner) on the fats and oils of the skin with prolonged contact may lead to drying and chapping of the skin. As with insulating oil, some people are allergic to askarel, and continued exposure may result in skin irritation. Both the liquid and vapor are moderately irritating to eye tissue.

Operating procedures should be such as to minimize or eliminate contact with askarels. The use of porous gloves that can absorb and retain askarel is to be avoided. Resistant gloves[2] should be used if contact is unavoidable. Use of enclosed transfer and handling equipment, processing equipment, and mechanical washers reduces direct contact.

[2] For example, Edmont-Solvit 5-352 (Mersick of Bridgeport, Bridgeport, Conn), or the equivalent.

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Medicinal washes or mild detergents followed by the application of cold cream will reduce the irritation resulting from the contact of an open cut or abrasion with askarel.

Safety glasses with side shields or a face shield should be worn when handling askarels. If liquid askarel contacts the eyes, the eyes should be irrigated immediately with large quantities of running water for approximately 15 minutes and then examined by a physician (A drop of (U.S.P.) castor oil has been found to reduce irritation).

Persons developing a skin irritation or respiratory tract irritation while working with askarels should be placed under the supervision of a physician. Ingestion or swallowing of askarels is not generally regarded as a problem of the industry; However, should accidental ingestion occur, a physician should be consulted.

Hands should be cleaned of askarel before eating, drinking, smoking, or using toilet facilities by means of waterless hand cleaners[3] and wipe towels which should then be properly disposed of.

3.3.2 Bulk Fluid Shipment; Receiving and Transfer. Shipment of askarel from point of manufacturing to point of receiving should be done in closed containers such as rail tank cars, truck tanks, marine or barge tanks, or sealed drums. In case of an askarel spill during bulk fluid shipment, reference should be made to paragraph 6.0 which provides procedures for control and listed authorities to be notified. Containers should be labeled as to contents and carry a label cautioning against loss of fluid to the open environment (See section 3.6). Containers used to transport askarel should not be used for storage or to transport other material without being completely cleaned of all traces of askarel. (Cleaning procedures must take cognizance of precautions against excessive exposure and of the need for proper disposal of contaminated cleansing solvents and materials as set forth in 3.5) Transfer from shipping containers to processing systems should be through closed piping or tubing with appropriate valves, pumps, etc. Provision should be made for trapping and disposing of fluid lost by leakage or spills from the transfer system and from the storage containers.

Drums to be retired from use should be cleaned before crushing, delivery to scrap dealers, or other disposal. Contaminated cleaning fluids and materials should be disposed of as indicated in 3.5.

3.3.3 Manufacturing Housekeeping. Manufacturing equipment and operating procedures should safeguard against loss of askarels to the environment through proper containment and disposal procedures.

3.3.3.1 Processing Area Control. Enclosed systems of sealed piping, properly gasketed joints, valves, containers, and processing chambers should be used for all operations where askarel temperatures may exceed 55°C. Enclosure should preferably extend to all other portions of the system insofar as practicable.

Establish containment methods and/or procedures for all askarel processing areas to prevent loss to sewer systems by spillage, leakage or other uncontrolled conditions or events.

[3] For example, Pow'r Kleen Handcleaner, (Woodbine Chemical and Research, Inc., Medina, Ohio or Man's Hands, Oak Industries, Inc., Moosick Falls, New York)

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3.3.3.2 Types and Control of Liquid Askarel Wastes. Askarel-containing liquid wastes may occur in manufacturing from sources such as the following: 1) Liquid askarel contaminated during processing which is unsuitable for reclaiming as a dielectric fluid, 2) liquid askarel from solvent operations or water and detergent type washers, 3) vacuum pump oils contaminated with askarel, 4) steam jet vacuum system condensates contaminated with askarels, and 5) askarel containing materials from laboratory samples.

Waste fluids containing askarel should be collected (by means of traps, drip pans, trays, etc) and disposal should be in accordance with 3.5.

Spills of askarels should be contained and cleaned up promptly by means of absorptive material, such as sawdust, or trapped and removed by pumping or other suitable means. Disposal should be per 3.5.

3.3.3.3 Types and Control of Other Askarel Containing Wastes. Saturation of materials with askarels may occur in manufacturing from the following sources: 1) Saturated earth or other absorbent media from filtering operations or from cleaning up spills, 2) saturated filters from vapor control devices and other filters, 3) saturated wastes such as paper, rags, etc. 4) saturated spent gasket materials and 5) capacitors failing tests or otherwise designated for disposal.

All of the above items should be collected for proper disposal. Wiper rags, protective clothing[4] and other extraneous materials which are likely to be soiled should preferably be made of disposable materials. Other materials should be collected within the containment area for properly controlled laundering.

3.4 Control of Plant Effluents.

3.4.1 Water Effluents. The industry goal is to eliminate askarel in plant water effluent streams. However, it is recognized that existing drain systems in capacitor manufacturing plants are probably contaminated as a result of past practices, and askarel traces may continue to decrease with the proper containment of askarel wastes and no further discharges into drain systems. Other sections of this standard provide that no askarel wastes of any kind be disposed of in any water effluent streams and that accidental spills be prevented from getting into such streams.

3.4.1.2 Concentration Limits. The EPA has proposed water quality criteria to maintain PCB concentration in rivers and lakes below detection level. Requirements under Sections 307(a), 307(b) and 311 of the 1972 Amendments to the Federal Water Pollution Control Act are under review (1976-77) and the latest revisions will apply. State and municipal requirements must also be met.

Further information may be obtained from an Environmental Protection Agency Regional Office. A listing of these offices is contained in Appendix D.

3.4.1.3 Monitoring Streams. On a regular basis consistent with plant situations, all effluent streams should be analyzed. The procedure for performing the necessary analyses is per ASTM Method D3304. This procedure or its equivalent should be used.

4 For example, Edmont-Wilson, 1294 Walnut St., Coshocton, Ohio 43812, or Slosman Corp., P.O. Box 3014, Asheville, N.C. 28802

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3.4.1.4 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to isolate totally all effluents that could be contaminated with askarels during manufacturing processes and prevent them from being discharged from the plant. Carbon absorption, limestone beds, and solvent extraction are techniques that could be applied to reduce the askarel content of effluent streams. These techniques may be most useful in cleaning up water used in plant processing and to permit recycling.

3.4.2 Air Effluents. The industry goal is to eliminate askarel vapors in plant air effluents. Plant operations involving askarels at elevated temperatures in excess of 55°C should be performed, wherever possible, within closed systems. Filtration of plant air effluents, to minimize PCBs entry into the environment, should be accomplished where envolvement of air borne PCBs may occur from open operations.

3.4.2.1 Monitoring. All plant air effluents should be sampled and analyzed on a routine basis consistent with plant situations. The procedure for performing the analysis is per ASTM Method D3304 (See Appendix B3).

3.5 Scrap-Disposal Procedures. The manufacture and use of capacitors involves processes which produce askarel-saturated solids and liquids containing or composed entirely of askarel, which should be disposed of as wastes. Specific sources of these materials are described throughout this standard. They may be placed into three categories:

1) Capacitor units impregnated with askarel, production and field rejects

2) Manufacturing process liquid wastes containing askarel

3) Solid waste purposely or accidentally saturated with askarel

Disposal should be done in a manner which is consistent with proper concern for the environment and minimizes any release of askarels to the environment.

3.5.1 Disposal of Capacitor Units. Scrap capacitor units can be generated during manufacturing processes or during field service. Production rejects are those capacitors that are rejected after the impregnation process in the course of production by the capacitor manufacturer. They may be rejected for mechanical or electrical reasons.

Field rejects are those units that are rejected or, for other reasons, are to be scrapped after shipment from the plant where they were manufactured.

Capacitor units should be disposed of intact, or if leaking, in sealed drums. The small amount of liquid to be drained, the integrity of intact units and the necessity for complex control over drainage procedures make intact disposal preferable.

3.5.1.1 Production Rejects. Rejected capacitors in capacitor manufacturing plants represent a concentration of askarel. It is, therefore, important that disposition be made in a manner consistent with proper concern for the environment. Preference should be given to disposal of capacitors in sites approved for hazardous waste disposal (See Appendix A). Another alternative, but less desirable, would be disposal in approved landfill sites.

Care should be exercised to insure that no loss of liquid will occur during transportation to the disposal site.

Incineration of scrap capacitors in facilities designed to accept such solids would provide a preferential alternative to approved landfill sites when such services become available.

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3.5.1.1 Plant Process. Wherever practical, all askarel containing capacitors should be removed prior to disposal of equipment. This precaution will enhance environmental control procedures and insure that by removing these capacitors they do not ultimately disperse their askarel contents into an unapproved landfill site.

After removal from equipment, capacitors should be disposed in accordance with the procedures for production rejects (3.5.1.1). Where removal of askarel-containing capacitors from equipment is not practical, that equipment should be disposed of only in approved landfill sites.

3.5.2 Disposal of Liquid Wastes. All waste askarel or liquid wastes containing askarel should be disposed of in accordance with one of the procedures given in 3.5.2.1 or 3.5.2.2. However, preference should be given incineration, 3.5.2.1.

3.5.2.1 Incineration. Proper incineration must involve a suitable balance between dwell time and temperature in the incinerator plus oxygen availability, and finally, suitable scrubbers to remove the HCL that will be formed; for example, 2-second dwell time at 2000°F and 3% excess oxygen in stack gas, or 1.5 second dwell time at 2700°F and 2% excess oxygen in stack gas.

These facilities should meet the applicable state requirements and should control effluents within the limits set forth in this standard.

3.5.2.2 Chemical Waste Disposal. Where incineration is not feasible, sites which have been classified by state agencies as suitable for disposal of chemical waste liquids should be used (See Appendix A).

3.5.3 Disposal of Solid Wastes (See 3.5.1 for scrap capacitors). All solid wastes which have been saturated with askarel should be placed in leak proof containers and preferably transported for disposal by incineration. A less preferable disposal procedure is an approved landfill site. See Appendix A for listing of Facilities.

3.5.4 Packaging and Shipment.

3.5.4.1 Transportation to the disposal facility should be in containers that will prevent leakage and accidental loss of askarel to the environment.

3.5.4.2 Containers should be labeled as to contents and precautions relative to loss to the environment per 3.3.2.

3.5.4.3 Containers for this purpose cannot be used for any other materials or they should be retired from service until they are completely cleaned. Any solvents used in cleaning these containers will be contaminated with askarel and should be disposed of according to the same procedures described in 3.5.2.

3.6 Labeling. Capacitor units vary greatly in size and in end use or application. Small capacitor units are frequently applied as a component of another piece of equipment, such as a fluorescent lighting ballast, a roadway of area lighting luminaire, a motor, etc. In such applications a label on the capacitor unit referencing approved disposal procedure would not normally be visible when the piece of equipment is disposed of.

For the foregoing reasons the methods of labeling for small capacitors and large capacitors are treated separately in 3.6.1 and 3.6.2, respectively

3.6.1 Small Units. Small capacitors are defined as those that contain askarel in quantities up to about 2 pounds each and in which the free liquid does not exceed 0.4 pounds. They are hermetically sealed in metalic cases. It is recommended that shipping containers from capacitor manufacturers should be labeled as to contents and that transporters be given instructions, in accordance with paragraph 6.12 as to procedures in the event of a spill.

If, however, a label of the capacitor is required by statute or by specific manufacturers, the following is suggested:

Contains PCBs. Use care in disposal.

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The shipping container label, yellow on black, should contain the following information:

"CAUTION" Contains PCBs (Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-424-8802) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with NIOSH C-107 Guidelines or applicable state and Federal statutes."

Small unit capacitors are applied as a component of a large piece of equipment. Manufacturers utilizing askarel-filled capacitors should affix a label referencing this standard or describing disposal procedures consistent with it.

3.6.2 Large Units. Large capacitor units are defined as those which contain more than 2 pounds of askarel. The manufacturer should affix a label in a conspicous place on the capacitor, referencing this standard or describing disposal procedures consistent with it. As a minimum, the label should contain information listed in 3.6.1.

3.7 Information for Users of Large Capacitors

3.7.1 General. Large Askarel-filled capacitors contain more than 2 pounds of askarel and delivered to customers as sealed units from which there is no escape of askarel under normal operation. Although certain types of equipment failures can permit loss of some askarel to the environment, such cases are extremely rare.

3.7.2 Transportation and Receiving. Immediately upon receipt of a shipment and following any transportation or handling accident that could affect the integrity of the capacitor enclosure, the transportation vehicle, enclosure, and fittings should be examined for any leakage or spillage that may have occurred in shipping. If leakage is evident, the cause should be corrected and the spillage soaked up with absorbent materials such as sawdust, followed by a cleanup of the affected area with kerosene or other approved solvent such as perchloroethylene. All materials used should be collected for proper disposition as described in 3.5.

3.7.3 Installation and Periodic Inspection. Large capacitors should be installed in new facilities such that if a leak should develop, askarels can be restrained from reaching the environment. Depending upon the type of installation, consideration may be given to pans, dams, traps, standpipes, dry wells, absorbing agents, etc.

Following installation, the unit should again be inspected for any damage or leakage. It is recommended that periodic in-service inspections be made for leaks.

4. Transformer Guidlines.

4.1 General.

4.1.1 Askarels of various compositional types are currently in use (for the general properties and types, see ASTM D2283-73a(20)). The trademark designations used by manufacturers for liquids containing PCBs are given in Appendix C.

Under arcing conditions, the gases produced, though predominantly consisting of noncombustible hydrogen chloride, can contain varying amounts of combustible gases depending upon the askarel type.

4.1.2 Safety Precautions. Based on about 40 years of safe industrial usage, askarels have been considered as relatively harmless materials to humans There has been no known instance of human injury when askarels are used under the normally prescribed conditions of precaution and handling.

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[illegible] generally thought that exposure to askarels is not hazardous provided that simple precautions are taken, exposure should still be avoided or minimized.

4.1.2.1 Vapors. The odor of askarel is noticeable well below the maximum safe air concentrations. Depending upon the composition of the askarel used, from 0.5 to 1.0 milligram per cubic metre of air has been determined to be the upper safe level of exposure during an 8-hour workday. (See reference (19)).

The procedure for performing the necessary analysis is contained in ASTM Method D3304 (See Appendix B).

Breathing vapor or fumes from heated askarels should be avoided. High concentrations of vapors can cause irritation of the eyes, nose, throat, and upper respiratory tract. Provisions shall be made for adequate ventilation to avoid open exposure of hot askarels (55°C or higher). The gases produced when askarel is decomposed by very high temperatures (such as that of an electric arc) in the presence of air or organic insulating materials contain a high percentage of hydrogen chloride which is highly toxic, and small percentages of other gases. Minute concentrations of this combination of gases are very unpleasant and irritating, thus giving ample warning of their presence. If exposure to high concentrations of askarels or its arced products is necessary under emergency conditions, an approved gas mask of the organic canister type, or self-contained breathing apparatus, must be worn. Such exposure should be under the surveillance of other personnel capable of effecting rescue in case of accident. If the odor of askarel or its arced products is detected by the person wearing protective equipment, he should immediately go into fresh air. All gas masks, respirators, and replacement parts should have U.S. Bureau of Mines approval and be maintained on a regular schedule in accordance with the manufacturer's recommendation.

4.1.2.2 Liquid. In contrast to the situation in which mineral insulating oils are handled, there is no fire hazard in handling askarels. A limited solvent action (similar to that for paint thinner) on the fats and oils of the skin with prolonged contact may lead to drying and chapping of the skin. As with insulating oil, some people are allergic to askarel, and continued exposure may result in skin irritation. Both the liquid and vapor are moderately irritating to eye tissue.

Operating procedures should require avoidance of contact with any askarels. The use of porous gloves that can absorb and retain askarels is to be avoided. Resistant gloves and aprons such as the polyethylene or fluoro elastomer* type should be used if contact is unavoidable. For some operations, it has been found advantageous to use non-porous, disposable aprons and gloves. In case of spillage on clothing, the clothing should be removed as soon as practical, the skin cleaned with waterless cleaners or solvents such as kerosene, and wiped dry with disposable towels. These towels should be disposed of as PCB contaminated solid wastes. See Section 4.1.6.2.2. Clothing and shoes saturated with askarel should be discarded (burnable waste). Contaminated clothing may be reused providing that

*For example "VITON"

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as has been thoroughly cleaned using segregated solvents or a segregated degreaser, then followed by normal laundering. (Laundering alone is not sufficient.)

Medicinal washes or mild detergents followed by the application of cold cream will reduce the irritation resulting from the contact of an open cut or abrasion with askarel.

Safety glasses with side shields or a face shield should be worn when handling askarels. Eyes that have been exposed to liquid askarel should be irrigated immediately with large quantities of running water for approximately 15 minutes and then examined by a physician. (A drop of (U.S.P.) castor oil has been found to reduce irritation.)

Ingestion or swallowing of askarels is not generally regarded as a problem of the industry; however, should accidental ingestion occur, a physician should be consulted.

Hands should be cleaned as noted above before eating, drinking, smoking or using toilet facilities.

4.1.3 Liquid Transport Containers.

4.1.3.1 Transport Container Marking. Any container, such as tank cars, tank trucks, drums, cans, etc., used to transport transformer askarels, new or used, should be labeled with the following(yellow on black):

"CAUTION" Contains PCBs(Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-424-8802) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with ANSI C-107 Guidelines or applicable state and Federal statutes."

4.1.3.2 Spill Procedures - Bulk liquid shipments. See Section 6.

4.1.4 Receiving, Handling, and Storage of Askarels.

Askarels are shipped in tank cars, tank trucks, steel drums, metal cans, and test-sample containers. When received, all containers should be inspected for leaks.

4.1.4.1 Storage Tanks. Storage tanks should be erected so that inspection can be made for leaks or spills. Construction should be such that inadvertent leakage or spills are prevented from reaching streams and sanitary or storm sewers.

4.1.4.2 Tank Cars and Tank Trucks. All bulk shipment equipment should be inspected for leaks immediately upon receipt. Drain pans should be provided to prevent spillage from unloading hoses and connections. Askarel liquid collected in drain pans should be placed in drums labeled "Scrap Askarel" for disposition in accordance with 4.1.6.2.1.

4.1.4.3 Steel Drums, Cans, and Test Sample Containers. On delivery, all such shipments should be carefully inspected for leaks. The containers should be stored indoors in an area especially selected for this purpose. A curb should enclose the area to provide a basin for containing the askarel from one or more containers should the containers be damaged. The area should not have a drain that is connected to a sanitary or storm sewer.

If an indoor storage area is not possible, the containers should be stored under a lean-to with similar containment capabilities.

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4.1.5 Control of Water Effluents. The industry goal is to eliminate askarel in water effluent streams. However, it is recognized that existing drain systems from manufacturing plants, repair shops, and installation sites may be contaminated as a result of past practices. Other sections of this standard provide that no askarel wastes of any kind be disposed of in any water effluent streams and that accidental spills be prevented from getting into such streams.

4.1.5.1 Concentration limits. The EPA has proposed water quality criteria to maintain PCB concentration in rivers and lakes below detection level. Requirements under Sections 307(a), 307(b), and 311 of the 1972 Amendments to the Federal Water Pollution Control Act are under review (1976-77) and the latest revisions will apply. State and municipal requirements must also be met.

Further information may be obtained from the Environmental Protection Agency Regional Office. A listing of these offices is contained in Appendix D.

4.1.5.2 Monitoring Streams. All plant effluent streams should be monitored on a regular basis. The procedure for performing the necessary analysis is contained in ASTM Method D3304 (See Appendix B).

4.1.5.3 Methods for Minimizing Effluent Stream Contamination. The ideal approach is to totally isolate all effluents that could be contaminated with askarels during manufacturing processes and prevent them from being discharged from the plant.

4.1.6 Disposal procedures and Services.

4.1.6.1 Sources of Materials Requiring Special Handling and Disposal Procedures. Liquids containing PCBs and solids containing or contaminated with PCBs may come from many sources including transport containers, transformer manufacturing processes, in-test failures, liquids contaminated beyond reclamation, in-service transformer leaks and failures, askarel-filled transformers scrapped for any reason, sample containers and handling equipment.

4.1.6.2 Classification for Disposal of Materials Containing PCBs. In general, there are four types of materials requiring disposal: burnable liquids contaminated with PCBs; nonburnable liquids contaminated with PCBs; burnable solids contaminated with PCBs; and nonburnable solids contaminated with PCBs.

4.1.6.2.1 Burnable Liquids. Liquids containing PCBs requiring disposal by high-temperature incineration may consist of the following:

(1) PCBs contaminated with mineral oil.

(2) Mineral oil contaminated with PCBs.

(3) Nonreclaimable contaminated transformer askarels, arced askarels, askarels from manufacturing spills, sump accumulation, askarels from holding basins, drip and drain pans, washings, sample jars and containers, etc.

4.1.6.2.2 Nonburnable Liquids (Water) Contaminated with PCBs. Water contaminated with PCBs may be treated by such means as activated carbon filtration or by a reductive dechlorination process, providing that the effluent meets Federal and State water effluent standards. Such liquids may also be disposed of, packed in suitable containers, in approved landfills. See Appendix A.

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4.1.6.2.3 Burnable Solid Waste Materials Contaminated with PCBs. These materials can be disposed of by high-temperature incineration and consist of cellulosic materials, rags, pressboard, wood, sawdust, fuller's earth in bulk or in cloth bags, blotter papers, nitrile or cork gaskets, etc.

4.1.6.2.4 Nonburnable Solid Waste Materials Containing or Contaminated with PCBs. These materials may consist of steel, copper, aluminum, filter units of the steel mesh construction type, askarel drums, cans, etc.

Materials of this nature should be allowed to drain with liquids collected in drip pans, etc. Further removal of adhering PCBs should be accomplished by vapor degreasing, washing or solvent extraction with kerosene or other approved washing liquids such as perchloroethylene. Accumulated liquids should be disposed of as indicated in 4.1.6.2.1. Solid materials as cleaned above may be handled as normal scrap.

Coil structures may be dismantled with burnable material removed. Metals should be treated as noted above, and burnable solids disposed of in accordance with Section 4.1.6.2.3. An alternative but less desirable procedure for disposal of coils, cores, burnable waste, etc., is to suitably package and bury in an approved landfill site. See Appendix A.

4.1.6.3 Shipment of Scrap Liquids For Disposal. All liquid scrap material should be placed in appropriate metal transport containers, properly labeled (Section 4.1.3.1) for shipment to a company offering an acceptable disposal service (Appendix A).

4.1.6.4 Shipment of Burnable Solid Waste Material Containing PCBs for Disposal. Material of this type should be placed in a liquid-tight container meeting Federal and State transportation requirements, and acceptable to the disposal organization. The container should be properly labeled (Section 4.1.3.1) for shipment to a company offering an acceptable disposal service (Appendix A).

4.1.6.5 Liquid and Solid Waste Disposal Service Organizations. These facilities should meet the applicable requirements of the state in which they are located and should control effluents within the limits referred to in Section 4.1.5.1.

4.2 Guidelines for Original Manufacture, Service and Repair Shops.

4.2.1 Plant Housekeeping It is necessary to assume that in filling equipment with askarel, and during further handling of this equipment, an askarel spill may occur. Therefore, it is necessary to provide facilities and a procedure for cleanup to prevent contamination.

4.2.1.1 Askarel Filling Area.

4.2.1.1.1 It is desirable that the askarel filling area be adjacent to the test area and final shipping area to minimize the danger of damage to units during handling.

4.2.1.1.2 The main manufacturing area for filling equipment with askarel should be provided with impervious surface floors or suitable basins so constructed that any inadvertent leakage or spills are prevented from reaching streams, sanitary sewers, or storm sewers. All askarel-handling equipment, such as pumps, hoses, etc., shall be of the askarel-resistent type.

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4.2.1.1.3 Drip pans shall be provided for hose connections and filling valves.

4.2.1.2 Special Containers for Scrap Materials.

4.2.1.2.1 Drums labeled "SCRAP ASKAREL" should be available for handling all spilled and waste askarel from sumps, failed units, drip pans, sample jars, etc.

4.2.1.2.2 Open-head drums with suitable closures and labeled "SCRAP BURNABLE ASKAREL WASTE" should be available for handling contaminated cellulose insulation, rags, paper, pressboard, wood, gaskets, sawdust, etc.

4.2.1.2.3 Separate containers for handling steel, copper, and aluminum, each adequately marked, shall be provided for the components of contaminated core and coil assemblies. These containers are required for the various materials when repairing or scrapping assemblies.

4.2.1.2.4 Containers for supplies of materials for absorbing small askarel spills or cleanup of larger spills should be provided.

4.2.1.3 Conditioning of Askarels.

4.2.1.3.1 Askarel Conditioning Equipment. The conditioning unit should be located either in the storage tank area or in the main transformer manufacturing area for filling with askarel.

4.2.1.3.2 Fuller's Earth. Conditioning of new askarel or recycled askarel requires fuller's earth treatment. The spent fuller's earth in cartridges or bags, when replaced, should be allowed to drain thoroughly over drip pans to remove as much liquid askarel as possible. The cartridge units of steel mesh construction should be placed in the "STEEL CONTAMINATED WITH ASKAREL" container for disposition. Cloth bags filled with fuller's earth should be placed in the "SCRAP BURNABLE ASKAREL WASTE" container for disposition.

4.2.1.4 Teardown of Units for Repair or Scrap.

4.2.1.4.1 Drain all askarel from the unit either into a holding tank for reuse or into the drum labeled "SCRAP ASKAREL" for disposition, allowing sufficient time for all of the askarel to drain from the core and coils.

4.2.1.4.2 Remove the core and coil assembly from the transformer tank and place over a suitable drip pan.

4.2.1.4.3 Place all materials in the appropriate salvage containers during dismantling for later disposition.

4.2.1.4.4 All used materials, including rags, sawdust, tape, etc., regardless of quantity, shall be put into the appropriate containers for disposition.

4.2.2 Transformer Labeling and Shipment

4.2.2.1 New and Rebuilt Transformers. All new and rebuilt transformers that contain PCBs shall have a label of adequate durability, permanently and prominently attached to the tank by the manufacturer, giving adequate warning and instructions. A suggested label, yellow on black, includes the following:

"CAUTION" Contains PCBs (Polychlorinated Biphenyls) that are environmental contaminants. In case of leaks or spills, restrain discharge and consult manufacturer. In transportation emergencies, call National Response Center (800-424-8802) and Chemtrec (800-424-9300). Avoid prolonged breathing of vapors or mists, contact with eyes or skin. Disposal should be in accordance with ANSI C-107 Guidelines or applicable state and Federal statutes."

4.2.2.2 In-Service Transformers. The Transformer manufacturer should make available suitable labels with similar warning as shown in 4.2.2.1 for use on existing transformers.

4.2.2.3 Shipping papers should contain the warning

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4.2.3 Information for Transformer Users

4.2.3.1 General. Askarel-filled transformers are delivered to customers as sealed units from which there is no escape of askarel under normal operation. Although certain types of equipment failures can permit loss of some askarel to the environment, such cases are extremely rare.

4.2.3.2 Transportation and Receiving. Immediately upon receipt of the equipment and following any transportation or handling accident that could affect the integrity of the tank, bushings, or radiators, the transportation vehicle, tank, and fittings should be examined for any leakage or spillage that may have occurred in shipping. If leakage is evident, the cause should be corrected and the spillage soaked up with absorbent materials such as sawdust, followed by a cleanup of the affected area with rags soaked with kerosene or other approved solvent such as perchloroethylene. All materials used should be collected for proper disposition as described in 4.1.6.

4.2.3.3 Installation and Periodic Inspection. Transformers should be installed so that if a leak should develop, askarels can be restrained from reaching the environment. Depending upon the type of installation, consideration may be given to pans, dams, traps, standpipes, dry walls, absorbing agents, etc.

Following installation, the unit should again be inspected for any damage or leakage. It is recommended that periodic in-service inspections be made for any leaks.

4.2.3.4 Filling, Filtering, or Drying Askarel. Most askarel units are shipped with the proper amount of askarel, but if it becomes necessary to top off a unit, the manufacturers's instructions should be followed.

If it is necessary to dry an askarel unit or to treat an askarel unit with fuller's earth, instructions should be followed. When filtering or conditioning askarel, all of the precautions previously described for drip pans, proper disposal of filter media, etc. apply.

4.2.3.5 Sampling. It is common practice to sample askarel from a transformer for periodic maintenance testing. As previously described, such samples should be taken in a manner to avoid any contamination of the environment. Washings should be collected for proper disposal. Field and laboratory test samples, washings, etc., should also be collected for proper disposal.(See Section 5).

4.2.3.6 Transformers Installed in Moving Vehicles. In the event of a leak or accidental spill, the procedures outlined in Section 6 should be followed.

4.3 Retrofilling Apparatus Containing Askarels. It is not recommended that apparatus containing PCB liquids be changed to other liquids. It is recognized that the best possible change-out procedures will still leave appreciable PCBs in the apparatus. Apparatus that has contained PCBs which has been replaced with another fluid should be labeled as indicated below, and the disposal ultimately should follow the same disposal procedures as those recommended for PCB liquids and PCB-filled apparatus.

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Label (yellow on black)

CAUTION: Contains liquid contaminated with PCBs an environmental contaminant. Changed to (describe liquid) on (give date).

4.4 Transformer Disposal.

The ultimate disposal of a PCB-containing transformer may be accomplished by the following procedures:

1. Contract with a qualified organization for disposal of the complete transformer.

2. Where acceptable facilities are available, the following alternative procedures are recommended:

(a) Always drain the liquid and dispose of it by approved incineration.

(b) For the solid components or for the entire structure, either of the following procedures are recommended:

i. Dismantle, wash and dispose in accordance with Section 4.1.6.

ii. Ship entire solid structure to acceptable organization for disposal.

iii. Ship to acceptable landfill disposal site. (See Appendix A).

5. Disposal of Laboratory Samples Containing PCBs.

The disposal of laboratory samples and materials used for testing and experimental purposes which contain, are impregnated with, or contaminated by PCBs (askarels) must be carefully controlled. Their disposition should be made in a manner consistent with procedures in 3.5.2 and 3.5.3 (Capacitors) and 4.1.6 (Transformers).

6. Spill Notification and Control Plan

Polychlorinated Biphenyl (PCBs)

The immediate actions needed are to contain or restrain liquid spills with the best means available and to notify "CHEMTREC" and "The National Response Center."

"The basis for this spill notification and control plan relies on Chemtrec to advise on the immediate actions needed to contain or restrain the liquid spill with the best means available based on listed instructions. The National Response Center will notify all interested parties, i.e. Federal and State authorities and the manufacturers involved, as well as give guidance on action to be taken."

FAILURE TO REPORT SPILLS TO PROPER AUTHORITIES MAY RESULT IN CRIMINAL PENALTIES.

6.1 Chemtrec

6.1.1 What is it. - Chemtrec stands for Chemical Transportation Emergency Center, a public service of the Manufacturing Chemists Association at its offices in Washington, D.C.

Chemtrec provides immediate advice for those at the scene of emergencies, then promptly contacts the shipper of the chemicals involved for more detailed assistance and appropriate follow-up.

Chemtrec operates around the clock - 24 hours a day, seven days a week - to receive direct-dial toll-free calls from any point in the continental United States through a wide area telephone service (WATS) number, 800-424-9300 (483-7616 for calls originating within the District of Columbia; 202-483-7616 for calls originating outside the continental U.S.).

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6.1.2 It is recommended that all past and present manufacturersof PCBs and PCB-containing equipment be listed with Chemtrec.

Contact "CHEMTREC" at the manufacturing Chemists Association, 1825 Connecticut Ave., N.W., Washington, D.C. 20009.

6.2 National Response Center.

6.2.1 What is it -

Location: U.S. Coast Guard Headquarters, Nassif Building, 400 7th Street, S.W. Washington, D.C. 20590.

Purpose: To coordinate pollution emergencies when national involvement is required. A Standard Reporting Network for receiving pollution reports. The basis of this network is a well publicized toll-free telephone number (800-424-8802) which anyone may use to call the National Response Center reporting pollution incidents or accidents which may result in pollution.

Relay of Pollution Reports to the local representatives of the Federal Agency responsible for action when a pollution discharge has occurred. When necessary, other specific local, regional, or national representatives for the various agencies will also be notified.

6.3 Shipment of Liquids and Equipment Containing PCBs.

6.3.1 Labeling: All containers and equipment containing PCBs shall be labeled in accordance with sections 3.6, 4.1.3, 4.2.2.1 and 4.3.

6.3.2 Shipping Papers. Shipping papers should contain the following warning statement:

CAUTION: Contains PCBs(askarel) that are environmental contaminants. In case of leaks, or spills, restrain discharge, DO NOT WASH. For further instructions call Chemtrec (800-424-9300) and the manufac- [illegible] National Response

6.4 Accidents Involving Equipment

It is recommended that all users should have an on-site spill prevention counter-measure and control plan which should be followed in the event of an accident.

6.4.1 Capacitors

Capacitors should be installed in accordance with 3.7.3.

6.4.2 Transformers

Transformers should be installed in accordance with Section 4.2.3.3.

6.4.3 Spills

In case of liquid spills due to leaks or equipment failures, the procedures outlined in sections 3.7.2 for capacitors and 4.2.3.2 for transformers should be followed.

7. REFERENCES

7.1 References to Text

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(2) American National Standard Method of Test for Specific Gravity of Askarels, C59.1965 (R1973) [ASTM D 1810-63 (1973)].

(3) American National Standard Method of Test for Neutralization Number by Color-Indicator Titration, Z11.131-1964 (R1974) [ASTM D 976-64 (1973), IP 139/65].

(4) American National Standard Method of Test for Neutralization Number by Potentiometric Titration, Z11.59-1958 (R1971) [ASTM D664-58 (1968), IP 177/64].

(5) Standard Method of Test for Density of Rubber Chemicals,[ASTM D 1817-66 (1972)].

(6) American National Standard Method of Test for Inorganic Chlorides in Askarels, C59.55-1963 (R1973)[ASTM D 1821-63 (1973)].

(7) American National Standard Method of Test for Pour Point of Petroleum Oils, Z11.5-1966 (R1972) [ASTM D 97-66 (1971), IP 15/67)].

(8) American National Standard Method of Test for Power Factor and Dielectric Constant of Electrical Insulating Liquids, C59.22-1967 (R1973)[ASTM D 924-65 (1973)].

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(9) American National Standard Method of Test for Specific Resistance (resistivity) of Electrical Insulating Liquids, C59.52-1965 (R1973) [ASTM D 1169-64 (1973)].

(10) American National Standard Method of Test for Hydrolyzable Chlorine Compounds in Chlorinated Aromatic Hydrocarbons (Askarel) C59.106-1970 [ASTM D 1820-65 (1971)].

(11) American National Standard Method of Test for Thermal Stability of Chlorinated Aromatic Hydrocarbons (Askarels), C59.111-1970 [ASTM D 1934-64 (1971)].

(12) American National Standard Method of Test for Distillation of Road Tars, A37.9-1974 [ASTM D20-72].

(13) American National Standard Methods of Testing Electrical Insulating Oils, C59.2-1974 ASTM D 117-71 (1973)

(14) American National Standard Method of Test for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes, C59.19-1968 (R1973) [ASTM D 877-67 (1971)].

(15) American National Standard Method of Test for Flash and Fire Points by Cleveland Open Cup, Z11.6-1973 [ASTM D 92-74, IP 36/67].

(16) American National Standard Method of Test for Saybolt Viscosity, Z11.2-1956 (R1971) [ASTM D 88-56 (1973)].

(17) American National Standard Method of Test for Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels, C59. 57-1963 (1973) [ASTM D 1903-65 (1973)].

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7.2 General References

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8. REVISION OF AMERICAN NATIONAL STANDARDS REFERRED TO IN THIS DOCUMENT.

When the American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply.

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APPENDIXES

(These Appendixes are not a part of American National Standard Guidelines for Handling and Disposal of Capacitor - and Transformer-Grade Askarels Containing Polychlorinated Biphenyls, C107.1 -197__, but are included for information purposes only.

APPENDIX A

Disposal Services

In addition to the supervised dry land fill sites that may be used for the disposal of askarel-containing scrap, the following additional known facilities and services have been established. For other facilities, call your regional Environmental Protection Agency Office. (See Appendix D).

The firms listed below (not all-inclusive) will accept PCBs for treatment or disposal, as noted. The Environmental Protection Agency does not endorse any of these firms nor accept vouch for the environmental soundness of their operations. Each of these firms has been contacted and reports having the required technical characteristics to adequately handle PCBs, in accordance with Recommended Procedures for the Disposal of PCB-Containing Waste (Industrial Facilities) as published by EPA in the Federal Register. The appropriate State or EPA Regional Office should be contacted for environmental suitability of the firm/site.

1. California Class I Landfills

(a) Casmalia Disposal Site
Santa Barbara, California (800-969-4703)
Bulk liquids and drummed materials.

(b) BKK Corporation
Wilmington, California (213-775-3607)
All forms.

(c) Environmental Protection Corporation
Bakersfield, California
All forms.

(d) County of Los Angeles
Whittier, California (213-699-7411)
Facilities: Palos Verdes Calabasas
All forms.

(e) San Diego County
San Diego, California (714-565-5703)
All forms

(f) Ventura County Dept. of Public Works
Ventura, California (805-648-2717)
All forms.

(g) Richmond Sanitary Service
Richmond, California (415-234-3304)
All forms.

2. Chemical Waste Disposal Co.
Elizabeth, N.J. (201-351-5460)
Disposal by incineration.

3. Chem-Trol Pollution Services, Inc.
P.O. Box 200
1550 Balmor Road
Model City, N.Y. 14107
Phone; 716-754-8231

Can handle solids and liquids by incineration or land disposal.

This organization has facilities and services capable of handling:

(1) Liquids. Askarels alone or mixed with solvents or oils. Disposal by High-temperature incineration.

(2) Solids (software). Askarel-soaked compounds, rags, cartons, absorbing earths, etc. Disposal by incineration or scientific landfill.

(3) Solids (hardware). Capacitors, transformer tanks, cores, askarel-soaked metals. Disposal by scientific landfill. Has solvent extraction capability.

4. Wyon Waste Management Services, Inc.
Chicago, Ill. (312-646-0016)

Can handle solids and liquids by incineration.

5. Monsanto Company
800 North Lindbergh Boulevard
St. Louis, Missouri 63166
Phone: 314-694-3352

Handles only liquid askarels manufactured by Monsanto. Disposal is by incineration.

This organization has facilities and services capable of handling askarel liquids alone or mixed with other oils or solvents by high-temperature incineration. Liquid is pumped through a gun with atomizing steam into incinerator.

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Temperatures are maintained at 2000°F with auxiliary natural gas. Exit gases are quenched to 180°F by contact with water. Gas is then passed through a high-energy venturi scrubber for removal of particulates. Before exhausting to air (110°F, gases are passed through a packed column scrubber to remove HCl. Askarel liquids containing more than 1% water, or any phosphate esters cannot be accepted.

6. Nucleus Engineering Co., Inc.
Louisville, KY. (502-426-7160)

Facilities: Sheffield, Ill.
Beatty, Nev.

Disposal by landfill; Can handle drummed liquids and solids.

Nucleus Engineering Company
Eastern Division
P.O. Box 240
Morehead, Ky. 40351
Phone: 606-784-6011

Nucleus Engineering Company
Disposal Division
Sheffield, Ill. 61341
Phone: 815-454-2524

The organization provides containerization, transportation, and disposal services of all liquids and solids (including hardware). Disposal is in controlled chemical and scientific landfill area. Licensed by Atomic Energy Commission for radioactive waste disposal. The organization also has two West Coast locations, in the states of California and Washington.

7. Rollins Environmental Services, Inc.
P.O. Box 2349
Wilmington, Delaware 19899
Phone: 320-655-0541

This organization has facilities and services capable of handling;

(1) Liquids. Askarel alone or mixed with solvents or oils. Disposal is by high-temperature incineration.

(2) Solids (software). Askarel-soaked compounds, rags, cartons, absorbing earths, etc. Disposal is by incineration at combustion temperatures up to 2500°F. Incineration gases are scrubbed, and entrained solids are removed before exhausting to air.

Rollins Environmental Services maintains disposal facilities in the following areas:

Philadelphia/Camden:
Rollins Environmental Services, Inc.
Route 322
Logan Township
Bridgeport, New Jersey 08014

Baton Rouge:
Rollins Environmental Services, Inc.
Scenic Highway & West Cheatham Lane
Scotlandville
East Baton Rouge Parish, La. 70807

Houston:
Rollins Environmental Services, Inc.
Tidal Road & Highway 134
Deer Park, Texas 77536

8. Texas Ecologists, Inc.
Robstown, Texas
Phone: 512-387-3518
Disposal by landfill..

9. Wes Con, Inc.
Twin Falls, Idaho (208-733-0897)

Receive packaged materials for disposal in missile silos.

10. Godcor Environmental Protection Corp.
1313 Newburgh Rd.
Westland, Michigan 48185
Phone: 313-326-0600

Will accept transformers, capacitors and PCBs solidified in Imbiber* beads.

APPENDIX B

ANALYTICAL PROCEDURES AND LABORATORY SERVICE ORGANIZATIONS.

B1. General

Analysis for PCB in environmental samples is a tedious process due to the very low levels (ppb or ppt) which are of interest and due to the high sensitivity of the electron capture chromatographic procedure. It cannot be overemphasized that extreme care must be taken to ensure first that the sample is representative and second that sufficient numbers of blanks,

*Dow Chemical Corp.

and sample replicates are tested to define detectability limits and precision of the particular equipment and procedure being used. Cleanliness of sampling devices and containers and their extraction is also important. Analytical procedures for the determination of PCBs in air, water and sediments are given in section D3.

D2. Laboratories

For a listing of laboratories offering services for PCB analysis refer to Directory of Testing Laboratories publication STP333A available from the American Society for Testing and Materials (ASTM) 1916 Race Street, Philadelphia, Pa. 19103. If an outside laboratory is used, a verification of capability is recommended.

D3. Analytical Procedures

See ASTM D3304-74, "Analysis of Environmental Materials for Polychlorinated Biphenyls".

APPENDIX C

TRADENAME DESIGNATIONS USED BY MANUFACTURERS FOR LIQUIDS CONTAINING PCBs.

Capacitors or transformers in service and liquid shipments showing the following trademark designations contain PCBs. These have been or are in use and usually the designation appears on the nameplate or the warning label.

DOMESTIC

NAME	MANUFACTURER
Aroclor	Monsanto
Aroclor B	Mallory
Asbestol	American Corporation
Askarel*	Hevi-Duty Corporation
Askarel*	Ferranti-Packard Ltd.

DOMESTIC

NAME	MANUFACTURER
Askarel*	Universal Mfg. Company
Chlorextol	Allis-Chalmers
Clorinol	Sprague Electric
Clorphen	JARD Company, Inc.
Diaclor	Sangamo Electric
Dykanol	Cornell Dubilier
Elemex	McGraw Edison
Eucarel	Electric Utilities Corp.
Nyvol	Aerovox
Inerteen	Westinghouse Electric
No-Flamol	Wagner Electric
Pyranol	General Electric
Saf-T-Kuhl	Kuhlman Electric

OFFSHORE

Clophen	Bayer (Germany)
Fenclor	Caffaro (Italy)
Kennechlor	Kennoclor (Japan)
Phenoclor	Prodelec (France)
DK	Caffaro (Italy)
Pyralene	Prodelec (France)
Pyroclor	Monsanto (UK)
Solvol	USSR

*World-Wide generic name used for insulating liquids in capacitors and transformers that usually contain PCB's.

APPENDIX D

ENVIRONMENTAL PROTECTION AGENCY REGIONAL OFFICES.

Environmental Protection Agency
Region I, Room 2303
John F. Kennedy Federal Building
Boston, Massachusetts 02203
Telephone: 617-223-7265

Environmental Protection Agency
Region II, Room 909
26 Federal Plaza
New York, New York 10007
Telephone: 201-548-8730

Environmental Protection Agency
Region II
Curtis Bldg., 6th & Walnut Sts.
Philadelphia, Pa. 19106
Telephone: 215-597-9898

Environmental Protection Agency
Region IV
1421 Peachtree Street, N.E.
Atlanta, Georgia 30909
Telephone: 404-526-5062

Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604
Telephone: 312-896-7591

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Environmental Protection Agency
Region VI, Suite 1000
1600 Patterson Street
Dallas, Texas 75201

Environmental Protection Agency
Region VII
1735 Baltimore Avenue
Kansas City, Missouri 64108
Telephone: 816-374-5770

Environmental Protection Agency
Region VIII, Suite 900
1860 Lincoln Street
Denver, Colorado 80203
Telephone: 303-837-3880

Environmental Protection Agency
Region IX
100 California Street
San Francisco, California 94111

Environmental Protection Agency
Region X
1200 Sixth Avenue
Seattle, Washington 98101
Telephone: 206-442-1263

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ABSTRACT

This document presents the findings of a study of available wastewater management and treatment technology for the purpose of determining toxic pollutant effluents concentrations and daily load achievable in three industrial categories: polychlorinated biphenyls (PCBs) manufacturing; capacitor manufacturing; and transformer manufacturing.

All plants in the above categories have PCB discharges to either waterways or sewage treatment plants, under normal operating conditions. All plants have discharges to storm sewers or directly to waterways under heavy rainfall conditions.

Extensive survey of wastewater treatment technologies and cooperative laboratory work with several suppliers of treatment equipment and research facilities has confirmed that carbon adsorption technology is the best current candidate for successful removal of PCBs from the wastewaters. As an alternative uv-ozonation was considered. This technology is still in the research stage; however, it offers potential of complete destruction of PCBs all the way to CO_2, water and HCl.

Another adsorbent technology now in the development stage, AMBERLITE polymeric adsorbents, has demonstrated a PCBs removal efficiency roughly equivalent to carbon during laboratory tests. Further testing is needed with this adsorbent to accurately assess its potentiality.

For scrap oils and burnable solid wastes generated at these plants, high temperature, controlled incineration offers a straightforward method of destruction, whereas scientific landfilling appears to be the best suited mode of disposal for nonburnable contaminated solids.

Zero discharge objectives can be best achieved by eliminating discharge streams and developing recycle systems. All non-contact cooling water would be segregated, cooled, and recycled. All other wastewater streams would be pretreated. The portion of the pretreated water which would be used in the plant would be treated with carbon, while the excess water would be

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incinerated in a specially designed system which would allow for energy recovery.

Supporting data, rationale for the selection of above recommended treatment technologies and associated costs are contained in this report.

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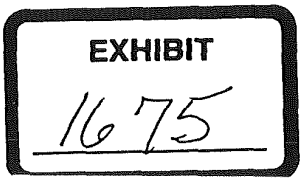

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