EPA
National Conf
on PCBs

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MONS 205160

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PAPER
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TO: PCB Mailing List

FROM: Jim Haney, Chairman, Wisconsin Paper Council,
Government Relstions Committee

SUBJECT: EPA National Conference on PCBs

On November 19-21, 1975, I attended the Environmental Protection Agency's National Conference on Polychlorinated Biphenyls at the Pick Congress Hotel in Chicago. My participation was on behalf of the Wisconsin Paper Council. In addition, other paper industry personnel were in attendance from the following firms: International Paper, Weyerhaeuser, St. Regis, Container Corporation of America, Wisconsin Tissue Mills, John Strange Paper Company, Fort Howard Paper, Kimberly-Clark Corporation, Mead Corporation, Packaging Corporation of America, IPC, BRDA, API and NCASI.

Enclosed with this memorandum are a number of items of intereat to those following the PCB situation:

1. A statement relating to PCBs on behalf of the Wisconsin Paper Council and delivered by Jim Haney, Bergstrom Paper Company.

2. "The view of the paper industry on the occurrence of PCBs in the environment and the need for regulation," delivered by Dr. Paul Trout on behalf of Container Corporation of America and the American Paper Institute.

3. A characterization of PCBs by James P. Mieure, Monsanto.

4. Conference abatracts prepared by the Research Triangle Institute on seven specific papers which were presented at the conference.

5. A summary of conference highlights and impressions prepared by Jim Schedgick, Menasha Corporation.

During the two-and-a-half day conference, almost 90 people presented scientific papers and/or testimony. In addition to the paper industry, spokesmen from the fishing industry, the electrical industry, and a variety of environmental groups supplemented the scientific information being presented.

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EPA Administrator, Russell Train, set the tone of the conference in his keynote address by calling for a "rise in the level of understanding" of the PCB problem as the conference goal. There was not much question that EPA also used the conference as a major publicity effort to gain support for the Toxic Substance Control Act currently pending in the Congress. Train and other EPA spokesmen repeatedly called for the passage of this act to give them additional tools for an effective regulatory program.

The conference was designed to bring together the latest data and best available expertise to help clarify the problems associated with the manufacture, use and disposal of PCBs. Additional objectives included the assessment of the effectiveness of steps taken to reduce the problems associated with PCBs and the clarification of the feasibility and complications of steps to reduce these problems. The conference was also designed to provide a platform for interested parties to present previously neglected data concerning PCBs, and it is in this light that we feel the paper industry's participation was critical.

The conference proceedings will be compiled and distributed by the Environmental Protection Agency. They will include summaries of all of the presentations made in the seven substantive aessions. These sessions included a discussion of the following items:

I. Health effecta and human exposure.

II. Usea, sourcea and identification.

III. Environmental fate and occurrence.

IV. Ecological effects and exposure.

V. Economics and substitutes.

VI. A general session (citizen participation).

VII. Approaches to control.

Firms which will be affected by regulation of the use of PCBs, or of the discharge of PCBs, should obtain copies of the conference proceedings from the Environmental Protection Agency. It would be my recommendation that interested parties contact the Conference Coordinator, Franklin Ayer, at Research Triangle Institute, Research Triangle Park, North Carolina 27709, for additional information.

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STATEMENT RELATING TO POLYCHLORINATED BIPHENYLS
ON BEHALF OF THE WISCONSIN PAPER COUNCIL
MADE AT THE EPA NATIONAL CONFERENCE ON PCBs
CHICAGO, ILLINOIS - NOVEMBER 19-21, 1975

The Paper and Paper Recycling Industries in Wisconsin.

My name is James Haney, and I am Public Affairs Director of the Bergstrom Paper Company, Neenah, Wisconsin. I appear today on behalf of the Wisconsin Paper Council, the trade association for the pulp and paper industry within Wisconsin. I am chairman of the Wisconsin Paper Council's Government Relations Committee.

There are 49 pulp and paper mills in Wisconsin employing 46,000 people who produce in excess of 5 million tons of pulp and paper products annually. Wisconsin manufactures more than 11% of the total production of pulp and paper products in the United States and is the number one paper-producing state in the country.

Not only do we lead the nation in paper making, but we are also the number one state in paper recycling. At least 19 Wisconsin paper firms recycle fibers to some extent and several firms make a specialty of it. A fifth of Wisconsin's annual paper production -- about 780,000 tons -- is made from recycled, post-consumer wastes. Some Wisconsin paper makers, like my own Company, have been producing recycled paper and paperboard since the turn of the century.

What Has The Wisconsin Paper Industry Done For The Environment?

Manufacturing any product is not a clean, tidy process. Generally, it is noisy, usually it is dirty, and often it involves work with large machinery. It normally takes skilled labor, of which Wisconsin is fortunate to have an ample and sufficient supply. The point being, however, that in the manufacturing process certain natural resources are consumed and related by-products are discharged or emitted as a part of the process itself.

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Recognizing this impact on the environment upon which our industry depends, the Wisconsin paper industry had expended approximately $126 million on water pollution abatement equipment prior to 1975. It is estimated by the industry that within the next five years an additional $153 million, at a minimum, will be expended for a total investment of approximately $280 million for water pollution abatement equipment alone -- not one cent of which is attributable to new production equipment.

As to air pollution, prior to 1975, the Wisconsin paper industry had invested approximately $34 million in air pollution abatement equipment and anticipates that between 1975 and 1980 it will invest minimally an additional sum in excess of $60 million. In rough figures, therefore, the paper industry in Wisconsin alone will have spent approximately $375 million by 1980 for air and water pollution abatement equipment -- approximately $8,200 per employee -- on what is very environmentally necessary, but very absolutely unproductive, equipment.

The Issue of Polychlorinated Biphenyls

In light of previous comments at this Conference, I think I need spend little time in identifying polychlorinated biphenyls (PCBs) or their historical uses. One of the many varied uses of PCBs prior to 1971 had been in carbonless copy paper which has accumulated in the files of many businesses and numerous governmental agencies. From time to time, some of this paper is discarded and becomes part of the solid waste chain.

At this time I wish to make one point very clear. Waste paper collectors and recyclers do not manufacture PCBs nor do they use them in their manufacturing process. To the extent that recyclable waste paper does contain traces of PCBs, this contaminant is introduced into the industrial system and becomes part of the industrial waste discharge of recycling facilities.

The only other known PCBs on a paper mill's premises might be PCB containing transformers or capacitors.

The Wisconsin Paper Council is vitally concerned that overly restrictive regulations of PCBs, both in finished paper or paperboard products or in effluent discharges, could destroy the nation's recycling efforts. We strongly urge that those who are drafting regulations concerning PCBs more fully analyze the impact of such regulations on recycling industries.

You must understand, for example, that a very small portion of the total amount of PCBs manufactured domestically by Monsanto Company were used for carbonless paper which is the chief assumed source by which waste paper contains the PCB contaminant. Aroclor 1242, by weight containing relatively lower amounts of chlorine than other domestically produced and sold PCBs, was used in the production of carbonless paper. Between 1958 and 1971, at which time the use of PCBs in the manufacture of carbonless paper was ceased, approximately 48% of Monsanto's PCB production was of Aroclor 1242. However, of its entire domestically sold production during those years, only about 22% was used for "plasticizer applications." Plasticizer applications include not only use for carbonless paper, but also for adhesives, textile and other surface coatings, inks, investment casting wax, and sealants. Therefore, we know that something considerably less than 10% of Monsanto's total PCB production between 1958 and 1971 was used in the manufacture of carbonless paper -- all of it being of the Aroclor 1242 variety.

Aroclor 1242 has significantly different structural constituent characteristics, whereby its stability and persistence are less and its degradeability appears to be significantly higher than its comparatively more highly chlorinated Aroclor relatives. At least 1500 reports in scientific literature have been written relating to PCBs and, whereas most of these deal with only the question

of reporting the presence of PCBs in the environment, invariably these reports describe and relate to Aroclor 1254 and 1260 -- the more highly chlorinated PCBs produced by Monsanto. In fact, a Monsanto spokesman has indicated that it was his opinion that "if we could just turn the clock back" and have produced only Aroclors 1221, 1232 and 1242 and no others, we probably wouldn't be holding hearings today. We are told that the principal Aroclors being found in Wisconsin fish are Aroclor 1254 (Mississippi River) and Aroclor 1248 (lower Green Bay). Predominantly it is Aroclor 1254 that is found in the environment. In terms of degradation and degradeability, there is a definite difference between Aroclors 1242 and 1254.

On the issue of bioconcentration, the EPA has stated that Aroclor 1242 bioaccumulates on the order of 8 times less than the more highly chlorinated Aroclors. On the issue of removal from effluent, the EPA has predicted that we can look forward to significant reductions in discharge concentrations as the program and projected treatment systems required by the NPDES program become effectively operational.

All of the above can be restated concisely as follows -- only a small portion of total PCBs domestically produced were utilized for purposes of manufacturing carbonless paper and, as to those particular Aroclors, they are relatively less stable and persistent, appear to be more degradeable, and are less susceptible to accumulation in fish than are their related, more highly chlorinated Aroclors. As a result, the impact of the waste paper recycling industry on the issue of PCBs, must be put into a more proper and positive perspective.

Concluding Remarks

I think the time has come for us to recognize that we all know less than we would like to know about PCBs. Because of their persistence and because of uncertainties about their impact, the new production of this substance has all

but been eliminated and is now used for only very specific purposes. An inventory must be made of where PCBs are coming from, the type of Aroclors that are being discharged, emitted and landfilled, the best methods of decreasing these discharges, emissions and landfillings and to put some proper perspective on the existence of this substance in our environment. We know of no current practical method by which to separate out of the wastepaper mass that portion of paper that contains PCBs -- particularly since PCBs have been recycled into other paper products other than carbonless paper. PCBs cannot be legislated out of the recycled paper system. The whole concept of recycling wastepaper is at stake in considering the promulgation of regulations particularly at a time when, as a national industry, the pulp and paper industry is expanding its paper making capacity at a faster rate than it is expanding its ability to produce pulp. It simply must be a national priority to encourage recycling.

The Wisconsin Paper Council recognizes that there is a potential problem with the introduction of PCBs into the environment.

We strongly support strict controls on the manufacture, distribution, and use of PCBs and we favor a national ban on the importation of PCBs.

But, the paper industry has not created this problem, it does not use PCBs in its processes, and it finds itself caught in the middle of this controversy merely because of its recycling efforts which would be halted by the adoption of overly restrictive regulations.

For example, proposed regulations in Wisconsin place an incredible burden on our industry, requiring removal of PCBs to levels 1,000 times smaller than the Food & Drug Administration's temporary tolerances as applied to food board.

Our industry has a history of cooperation with government agencies to reduce PCB levels in our finished products. We will continue to co-operate with the Food & Drug Administration, with the EPA, and with our own DNR to find solutions to the PCB problem in effluent. We concurred with Mr. Schweitzer when he testified in Wisconsin that "it is important to clarify the portion of the PCB contamination problem which can be attributed to specific discharges and the practical feasibility of reducing the discharges." We hope that his Department recognizes that there is a difference in terms of environmental acceptance of various forms of PCBs and that this should be taken into account when dealing with any proposed regulations.

But we continue to appeal to you for reason. Let us admit together that we do not know enough, at least at this point, to promulgate reasonable regulations and, ill-conceived rules could mean economic catastrophe for a significant portion of Wisconsin's paper industry. The commitment of this industry is to Wisconsin and to its environmentally pure future. It has invested and will invest over $300 million prior to 1980 to accomplish that goal. We only hope that realistic, reasonable, feasible and responsible regulations will be proposed by the EPA which will bolster its reputation as a defender of the environment while at the same time not place it in a position of ridicule because it has suggested regulations so badly researched that they are either unenforceable or that they destroy recycling -- one of this country's most environmentally considerate industries.

THE VIEW OF THE PAPER INDUSTRY ON THE OCCURRENCE OF PCB'S IN THE ENVIRONMENT AND THE NEED FOR REGULATION

by

Paul E. Trout

National Conference on Polychlorinated Biphenyls

PCB's in the Environment - 1975

November 20, 1975

The Pick-Congress
Chicago, Illinois

MONS 205169

My name is Paul E. Trout. I am Director of Environmental Control for Container Corporation of America and am presenting the following comments on behalf of my company and the American Paper Institute.

The American Paper Institute is a national organization composed of manufacturers of pulp, paper and paperboard. Members utilize both virgin and recycled fiber in the manufacture of paper products. In 1973, the American paper industry and its wastepaper suppliers recycled nearly 15 million tons of wastepaper,[1] an all time high. In the same year, approximately 41% of the fiber used by Container Corporation of America's 13 paperboard mills was derived from wastepaper.

This recycling of wastepaper unwittingly plunged my company and similar recyclers into the morass of the PCB problem in late 1970.

I. THE PAPER INDUSTRY DOES NOT USE OR INTRODUCE PCB'S INTO THE ENVIRONMENT BUT RATHER RECIRCULATES PCB'S ALREADY PRESENT WHICH ARE UNAVOIDABLY INCLUDED IN ITS MANUFACTURING INPUT

PCB's are not a part of the manufacturing process of paper. Consequently the paper industry does not add new PCB's to the environment. PCB's are, however, unavoidably included in certain inputs into the paper manufacturing process. In particular, the water supply used in paper making contains PCB's from other unrelated sources. The paper manufacturing process is not designed to remove PCB's and consequently effluents do contain low levels of this chemical which have entered the mills in the intake waters.

1/ Smith, F.L., Jr. "Wastepaper Recycling: Review of Recent Market Demand & Supply", Pulp & Paper, pg. 148 (Sept. 1975)

The other PCB input to the paper manufacturing process is the raw material used by recycling mills as a fibre source. Until early 1971, NCR paper (carbonless copy paper) used Aroclor 1242 enclosed in microcapsules coated on the paper. Thus business forms made with carbonless copy paper have been a component of office waste paper, a portion of which is recycled in the papermaking process. Inevitably the PCB's present in the office waste have been introduced into the paper recycling process.

Again, no new PCB is added to the environment by paper mills but, rather, existing PCB is simply recirculated. If the paper mills could not recycle the office waste containing PCB-bearing paper, the paper would just as surely enter the environment either through leaching in land fills or volatilization in incinerators which are unable to destroy the PCB's. In either of those events, municipal solid waste systems would have a very substantial new burden added to their normal operating loads and the important national recycling would be significantly injured. Moreover, the PCB present in the old NCR paper still occasionall finding its way into the waste stream is Aroclor 1242, the least chlorinated of the Aroclors and the one not accumulating in the environment. It is this PCB that is found both in paper product and in the effluent of paper mills.

Since 1971, when the use of PCB in the manufacture of carbonless carbon paper was halted, PCB levels in recycled-fiber paperboard used for food packaging have continued to decline. The industry monitoring program showed that, in the third quarter of 1975, 99.63% of such paperboard had a PCB content less than 10 ppm and 91.3% had a PCB content less than 2.5 ppm. These results have been achieved through the most careful selection of the wastepaper used in the recycling process with rejection of all types of wastepaper suspected to contain PCBs.

II. THE PCB RECIRCULATED BY THE PAPER INDUSTRY, AROCLOR 1242, IS NOT FOUND TO ACCUMULATE IN ANIMALS, MAN, OR IN THE ENVIRONMENT

The PCB occasionally detected in paper products and in the effluent of paper manufacturing plants is Aroclor 1242. For the years 1960 through 1971, Aroclor 1242 represented from 48.5 to 68.9% of the total domestic PCB production, reaching this maximum percentage in 1967 and 1968 and decreasing thereafter. Accordingly, it would necessarily be the PCB most widespread in the environment if all PCB's were all equally degradeable. In fact, however, Aroclor 1242 is neither found in the tissues of man or animal nor in the aquatic environment generally. This indicates that the lower chlorinated PCB's such as Aroclor 1242 are either metabolized, decomposed in aqueous environments or degraded by photolysis. If accumulation of PCB in aquatic environments, and thereby in the food chain and man, is perceived to be a potential threat to human health, it is a threat unrelated to Aroclor 1242, the PCB recirculated in the papermaking process. Any PCB regulation based on environmental needs must accomodate this fact.

III. THE CURRENT LEVELS OF DIETARY INTAKE IS MANY ORDERS OF MAGNITUDE LOWER THAN THE ALLOWABLE DAILY INTAKE AS FOUND BY THE FOOD AND DRUG ADMINISTRATION

Evaluation of the need for regulatory controls of the source and distribution of PCB's must begin with the threat PCB's pose to the health of man or other part of the living environment. In the case of PCB's the possible threat to human health is through the food supply. Accordingly, that evaluation should start with the levels of dietary intake of PCB's with reference to the levels posing a threat to man.

As a distinguished committee of the National Academy of Sciences -- National Research Council stated "For every chemical there is some finite level sometimes called the 'safe' level, at or below which it can be present in food without

prejudicing safety."1/ Conversely, as three other NAS committees have recently noted: "There is no substance which under certain circumstances, could not be dangerous and unsafe."2/ The possible need for regulatory controls of PCB's therefore must be assessed in terms not of the conceivable danger posed by some amount of a substance but rather in terms of the available margin of safety between conceivably harmful dosages and actual consumption.

According to the Food and Drug Administration's Director of the Office of Science, Dr. Albert C. Kolbye, Jr., the allowable daily intake of PCB's in the adult human diet is 200 micrograms per day. (Kolbye Testimony, FDA Dkt. No. 75N-0013, p. 6, submitted October 16, 1975). This conclusion is based upon Dr. Kolbye's analysis of available animal toxicity studies including the recent investigations of Dr. Renate Kimbrough "Induction of Liver Tumors in Sherman Strain Female Rats by Polychlorinated Biphenyl Aroclor 1260" as well as upon analysis of human toxicity data arising from the "Yusho" incident in Japan involving massive intoxication by PCB's.

The Food and Drug Administration's "Total Diet Studies" (sometimes referred to as "market basket surveys") demonstrate that PCB average dietary intake levels have never been remotely near this 200 microgram/adult/day figure. On March 18, 1972, FDA stated in a Federal Register notice that its total diet studies indicated an average daily intake of seven micrograms per day per adult or 4.7 ppb in the total diet. (37 Fed. Reg. at 5705). This is 3-1/2% of the amount Dr. Kolbye concluded was plainly safe. That data reflected the period of August 1969 through March 1972 when PCB exposure must have been at its peak since the

1/ "Guidelines for Estimating Toxicologically Insignificant Levels of Chemicals in Food," "Food Protection Committee-Food & Nutrition Board, National Academy of Sciences-National Research Council (Washington, D.C.1969) p. 1.

2/ "Principles for Evaluating Chemicals in the Environment," a joint report of three NAS Committees: Committee for the Working Conference on Principles of Protocols for Evaluating Chemicals in the Environment; Environmental Study Board, National Academy of Sciences-National Academy of Engineering;and Committee on Toxicology,National Research Council.(Wash., D.C.1975), p. 83.

steps taken by Monsanto Company in early 1971 to confine the sale of PCB's to closed systems had not yet had time to be reflected in the data base.

Fifteen months later, on July 6, 1973, FDA announced that the quantitatively measurable residue of PCB's were equivalent to an average dietary intake of 4.2 micrograms/day/adult. (38 Fed. Reg. at 18097). This corresponds to a dietary intake of 2.8 ppb or about 2% of the level Dr. Kolbye identified as safe. According to FDA's total diet studies for fiscal year 1973 (July 1, 1972 through June 30, 1973) the dietary intake of PCB's was one microgram/day/adult or .67 ppb (See FDA's "Compliance Program Evaluation Total Diet Studies: FY 1973" dated January 9, 1975, evaluating the effectiveness of FDA's total diet study program). This is less than 1/2% of the safe amount calculated by Dr. Kolbye. According to these studies for the period of October 1972 to January 1975 the average dietary intake was .178 micrograms/day/adult or .118 ppb (118 ppt), or below 1/10 of 1% of Kolbye's safe level. An examination of the total dietary intake as shown by FDA's total diet studies from January 1, 1974 through June 1975 shows PCB intake has been zero: that is, not a single quantifiable residue of PCB has been detected in the total diet study which would allow any quantitative estimate whatsoever.1/

In short, dietary intake of PCB has been declining rapidly since approximately the time Monsanto implemented its voluntary controls on the distribution of PCB's to its customers. Even during the maximum exposure period the average dietary intake was nowhere near what the Food and Drug Administration states to be an allowable daily intake. At the present time, there is an even vaster gulf -- many orders of magnitude -- between the allowable daily intake and the amount of PCB posing any conceivable hazard to man.

1/ It is also significant that for FY 1975 the total diet studies did not detect a single trace of Aroclor 1242, the PCB associated with the recycled paper manufacturing process.

IV. ANY ADDITIONAL CONTROLS MUST ACHIEVE MAXIMUM ENVIRONMENTAL COST: EFFECTIVENESS

The paper recycling industry has been a participant in the PCB drama through circumstance, not by choice, and our industry is not alone in this. We thus appreciate the need for procedures to prevent similar happenings in the future as well as to correct remaining PCB problems.

Our industry approves the principle of restricting the use of hazardous substances. We do not, however, support far-reaching regulation of the nature of Senate Bill 5776. Such legislation simply would amount to the "Biological and Analytical Chemist's Relief Act of 1975" and would, in addition, open a new Pandora's box of legal mischief. We believe duplication of existing legislation should be avoided and that deficiencies in existing legislation be corrected by specific amendment in order to maximize environmental benefit at minimum cost to the public.

We particularly urge states now considering new regulations to combat the PCB problem to develop rational rather than political solutions. Destruction of the wastepaper recycling industry will benefit neither the public health nor the public purse.

We urge the Environmental Protection Agency to establish a task group to investigate PCB imports, track down specific uses of these materials in the United States and publish this information so that further unknowing use of PCBs can be avoided.

We urge the Environmental Protection Agency to publicize abroad the self-regulatory action taken by Monsanto Co. to minimize further PCB contamination of the environment in hopes that such enlightened action may spread worldwide.

And, finally, we urge the Environmental Protection Agency to implement a program whereby PCB-containing wastepapers issuing from Federal Agencies are disposed of by incineration at a temperature sufficient to destroy PCB. If Aroclor 1242 is an environmental hazard, this procedure would prevent the reservoir of this material now residing in the files of the world's greatest record-keeper from contaminating the environment.

All of these control actions can be initiated immediately, without need for additional legislation and with immediate positive results.

To conclude, I would like to summarize these points:

I. THE PAPER INDUSTRY DOES NOT USE OR INTRODUCE PCB'S INTO THE ENVIRONMENT BUT RATHER RECIRCULATES PCB'S ALREADY PRESENT WHICH ARE UNAVOIDABLY INCLUDED IN ITS MANUFACTURING INPUT.

II. THE PCB RECIRCULATED BY THE PAPER INDUSTRY, AROCLOR 1242, IS NOT FOUND TO ACCUMULATE IN ANIMALS, MAN, OR IN THE ENVIRONMENT.

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IV. ANY ADDITIONAL CONTROLS MUST ACHIEVE MAXIMUM ENVIRONMENTAL COST: EFFECTIVENES

NATIONAL CONFERENCE ON POLYCHLORINATED BIPHENYLS

JAMES P. MIEURE

CHARACTERIZATION OF POLYCHLORINATED BIPHENYLS

November 19 - 21, 1975

Pick - Congress Hotel

Chicago, Illinois

Monsanto

MONS 205177

CHARACTERIZATION OF POLYCHLORINATED BIPHENYLS

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CHEMICAL STRUCTURE

Polychlorinated biphenyls (PCBs) are made by direct chlorination of biphenyl. The biphenyl molecule has ten possible sites at which chlorine atoms can be substituted. The numbering system for the biphenyl structure is shown in Figure 1. By convention, the two rings are numbered identically except the ring with the fewest chlorine substituents or substituted in the highest numerical positions is designated as primed. Examples of nomenclature for a tri- and a tetrachlorobiphenyl are included in Figure 1. An excellent discussion of PCB nomenclature can be found in a recent text by Hutzinger, Safe and Zitko (1).

There are 209 possible chlorobiphenyl isomers distributed as indicated in Table I. However, many of these isomers are not likely to occur at significant levels in commercial PCB mixtures. For example, isomers with four or five chlorine atoms on one ring but none on the other ring are not detectable in PCB products.

TABLE I

209 POSSIBLE PCB ISOMERS

Degree of Substitution	Number of Isomers
Mono	3
Di	12
Tri	24
Tetra	42
Penta	46
Hexa	42
Hepta	24
Octa	12
Nona	3
Deca	1
	209

AROCLOR PRODUCTS

The major producer of PCBs in the United States is Monsanto Company, which markets mixtures for closed electrical system applications under the Aroclor® trademark. Aroclor products are identified by a four digit numbering code in which the first two digits, 12, indicate the parent molecule is biphenyl and the last two digits specify the weight percent of chlorine. The exception is Monsanto's newest product, Aroclor 1016 (41% chlorine), which retained the 1016 designation by which it was known during development. Aroclor products manufactured in the United States are listed in Table II. Production of the materials listed as discontinued was terminated in or prior to 1971.

TABLE II

AROCLOR PRODUCTS MANUFACTURED IN THE U.S.

Current	Discontinued	Percent Chlorine
1221		21
	1232	32
1016		41
1242		42
	1248	48
1254		54
	1260	60
	1262	62
	1268	68

AROCLOR COMPOSITION

The composition of the four Aroclor products currently marketed in the United States is given in Table III. Aroclor 1221 is primarily monochlorobiphenyl while Aroclor 1016 and Aroclor 1242 are primarily trichlorobiphenyls. The major difference between these two products is the lower penta- and hexachlorobiphenyl content of Aroclor 1016. Aroclor 1254 is primarily pentachlorobiphenyl. The values in Table III were calculated from measurements by gas chromatography with flame ionization detection after component identification by gas chromatography/mass spectrometry. All gas chromatographic separations were made with a high resolution capillary column. Average response factors determined for each degree of chlorine substitution were applied to all components.

TABLE III

TYPICAL PERCENT COMPOSITION OF AROCLOR PRODUCTS

# Cl/BIPHENYL HOMOLOG	AROCLOR 1221	AROCLOR 1016	AROCLOR 1242	AROCLOR 1254
0	11	<0.1	<0.1	<0.1
1	51	1	1	<0.1
2	32	20	16	<0.5
3	4	57	49	1
4	2	21	25	21
5	<0.5	1	8	48
6	ND	<0.1	1	23
7	ND	ND	<0.1	6
8	ND	ND	ND	ND

ND = NONE DETECTED, <0.01%

Detailed chromatograms of these four products are illustrated in Figures 2-5. Specific isomer identifications determined by Webb and McCall (2) and Sissons and Welti (3) are listed for the major Aroclor 1242 components in Figure 4. The complexity of these mixtures was emphasized by amplifying the first and last portions of the Aroclor 1254 chromatogram in Figure 5. Eighty-five components were detected in Aroclor 1254. A .32 mm id X 50 m glass capillary column coated with OV-101 was used for these separations. The flow rate was 2 ml/min helium and the column temperature was programmed from 150° to 230°C at 2°C/min.

High resolution chromatographic conditions are very useful for characterizing PCB products. However, for routine monitoring of environmental materials, it is more appropriate to use gas chromatography with packed columns and electron capture detection. Typical chromatograms of this type for Aroclor 1016 and Aroclor 1242 are compared in Figure 6. The chromatograms are essentially identical for retention times less than 70 relative to p,p'-DDE. However, the higher chlorinated components with relative retention times 70 and greater represent a significantly smaller contribution in the Aroclor 1016 chromatogram. These chromatograms illustrate the feasibility of distinguishing these unaltered products. However, in environmental materials the characteristic features of Aroclor 1242 are frequently obscured by interfering compounds or by component alteration so the distinction is less clear or sometimes entirely lacking. These separations were carried out on a 6 ft. X 4 mm id glass column packed with 3% SE-30 on 80/100 mesh Chromosorb W - HP at 190°C.

PHYSICO-CHEMICAL DIFFERENCES

The physical and chemical properties of PCB isomers and commercial mixtures vary greatly depending on the degree and position of chlorine substitution. The effect of chlorine content on several physico-chemical properties is summarized in Table IV. Three of these properties, volatility, water solubility, and biodegradability, are very relevant to the environmental occurrence of PCBs. Volatility and water solubility represent potential mechanisms for introduction into and transport within the ecosystem. Biodegradation represents a mechanism for removing PCBs from the environment. Illustrations of the relative significance of these properties for different PCB isomers are evident from the following three examples.

TABLE IV

PHYSICO-CHEMICAL PROPERTIES FOR PCB PRODUCTS

Property	Percent Chlorine 21	42	54
Density (g/ml)	1.19	1.39	1.50
Distillation Range (°C)	275-320	325-366	365-390
Fire Point (°C)	176	None	None
Vaporization Rate (mg/cm^2/hr @100°C)	1.74	.338	.053
Water Solubility (ppm)	>.2	.2	.04
Biodegradability*	81	26	15

*Percent degradation/48 hr cycle with semi-continuous activated sludge

Relative volatilities for the PCB components in Aroclor 1016 are indicated in Figure 7 by comparing chromatograms of liquid and vapor composition. The higher numbered components make successively less contribution to the total vapor composition.

Water solubility of Aroclor 1016 components is illustrated in similar fashion in Figure 8. Water saturated with Aroclor 1016 was extracted with hexane and the extract compared chromatographically to an Aroclor 1016 standard. The numbers above significant peaks express the percentage contribution of that peak area to the total area. Earlier eluting, lower chlorinated components are more soluble and contribute more to the water saturated composition. A related study has shown that PCBs leaching from Aroclor 1016 impregnated soils after the equivalent of forty years annual rainfall consist of lower chlorinated biphenyls (4) (Figure 9).

Microbial degradation also affects PCB isomers to different degrees. For example, Figure 10 shows chromatograms depicting Aroclor 1016 composition after exposure to a naturally occuring mixed microbial population for 1/2 hour (above) and 14 days (below). The number above each GC peak indicates the percent biodegradation for that component. These percentages range from 17 to >98 and in general are higher for lower chlorobiphenyls. The exposure was carried out with activated sludge from a domestic sewage treatment facility. The sludge was previously acclimated to a mixture of industrial organic compounds before addition of 3 ppm Aroclor 1016. PCB composition was determined by extracting a representative aliquot of mixed liquor with hexane followed by analysis by gas chromatography using a glass capillary column and electron capture detection.

It is apparent from these examples that introduction of PCBs into the ecosystem by volatility or water solubility would enhance the ratio of lower to higher chlorinated biphenyls in the environment. PCB removal from the environment by either of these mechanisms or by microbial degradation would reduce this ratio. These and related factors combine to make assessment of PCB environmental impact a very complex problem.

In view of the recognized complexity in studying commercial PCB mixtures, it would seem expedient to substitute for the mixture a single isomer product having the desired electrical and physical properties. The environmental properties of this isomer would be much simpler to

characterize and control. However, no such PCB isomer exists. Most PCB isomers are solid crystalline materials when isolated at 25°C. Commercial products are liquids only because of the mutual melting point depression exerted by the PCB components of the mixture.

CONCLUSIONS

Commercial PCB products are mixtures of many different isomers with varying chlorine content. The properties of these isomers, and hence the products, are vastly different and are complex to study. The environmental impact for each product must be accurately assessed and compared to the functional benefit.

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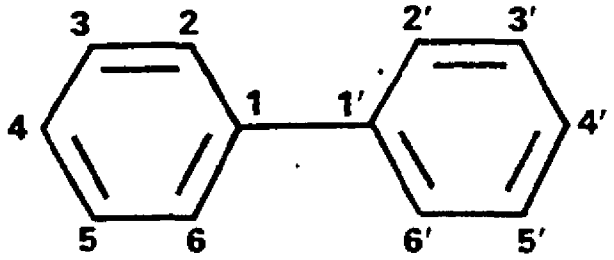
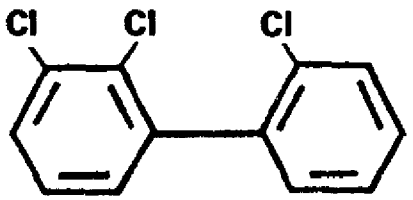
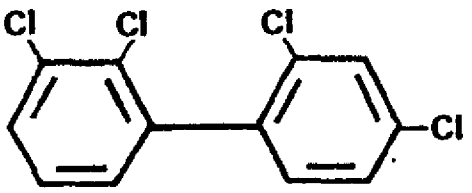


BIPHENYL



2,2',3-TRICHLOROBIPHENYL



2,2',3,4'-TETRACHLOROBIPHENYL

Figure 1

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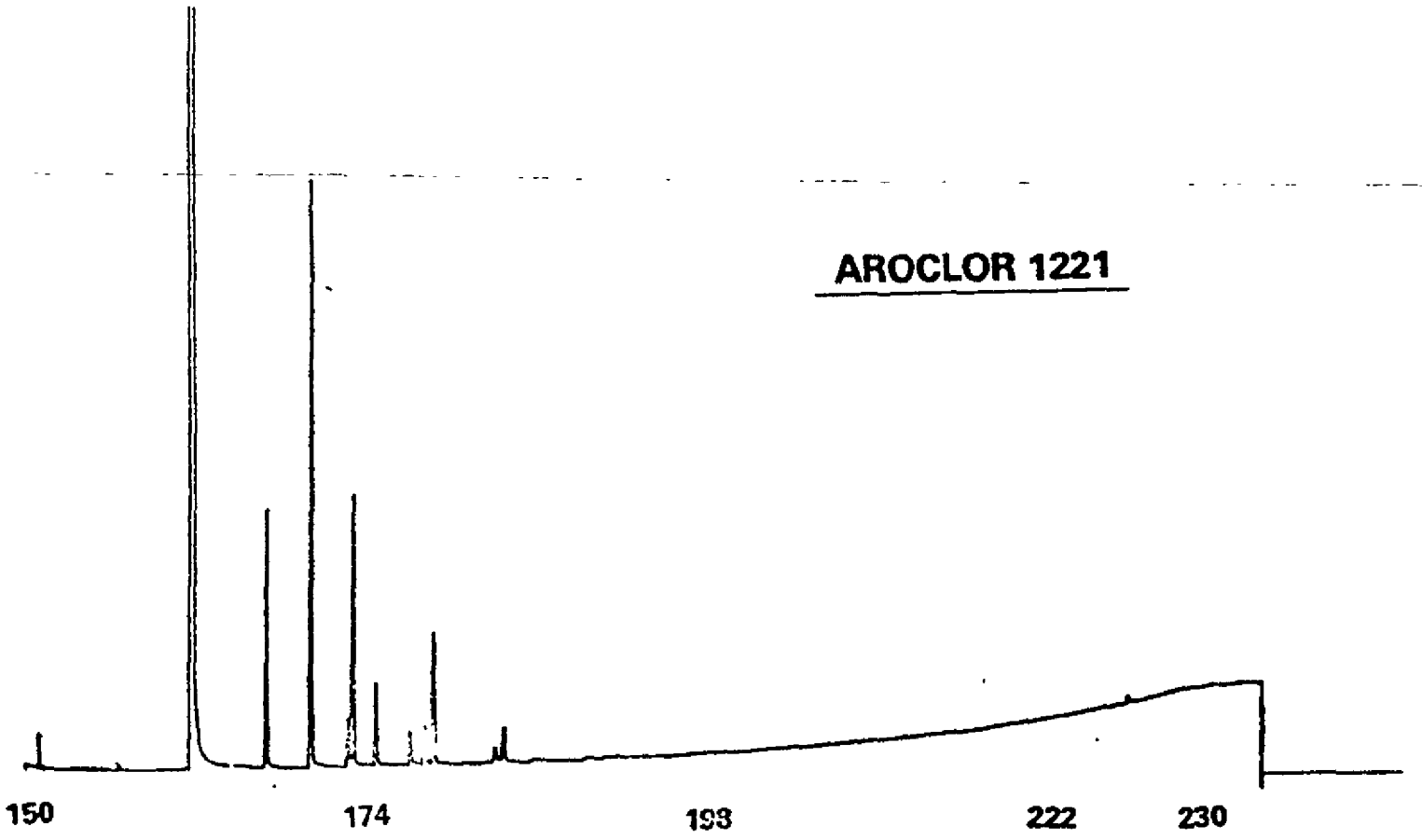

Figure 2

HONS 205188

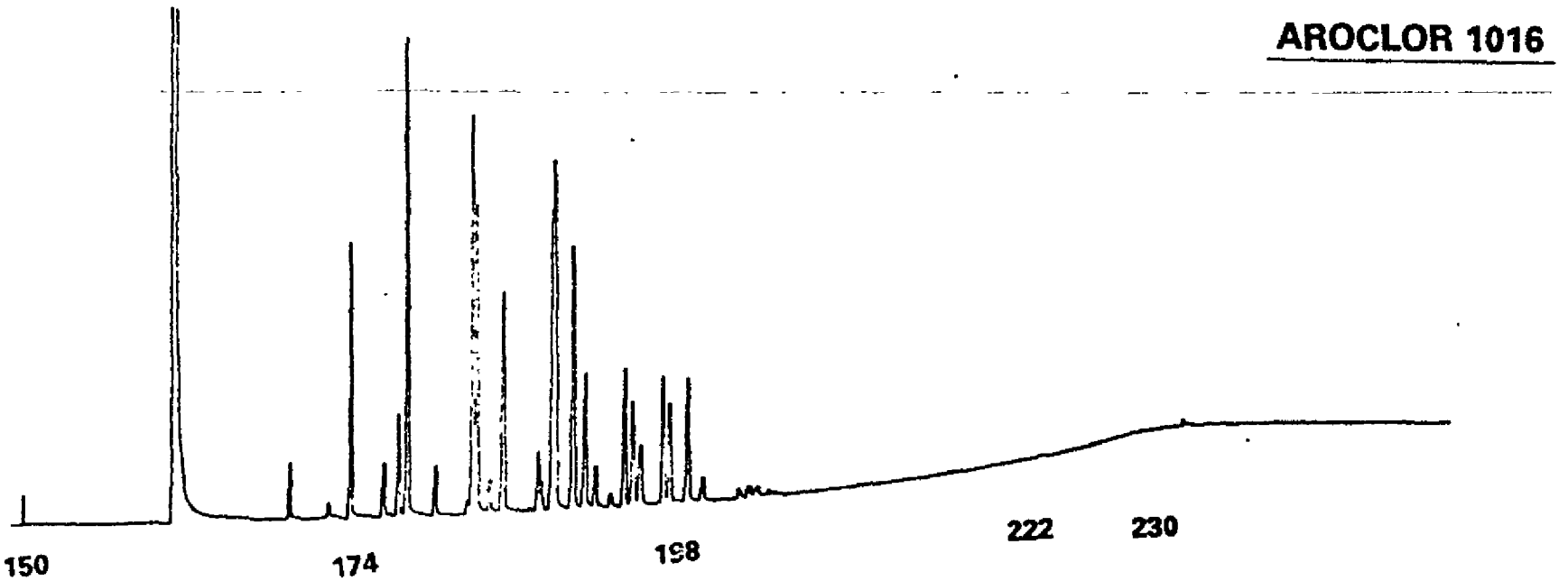

Figure 3

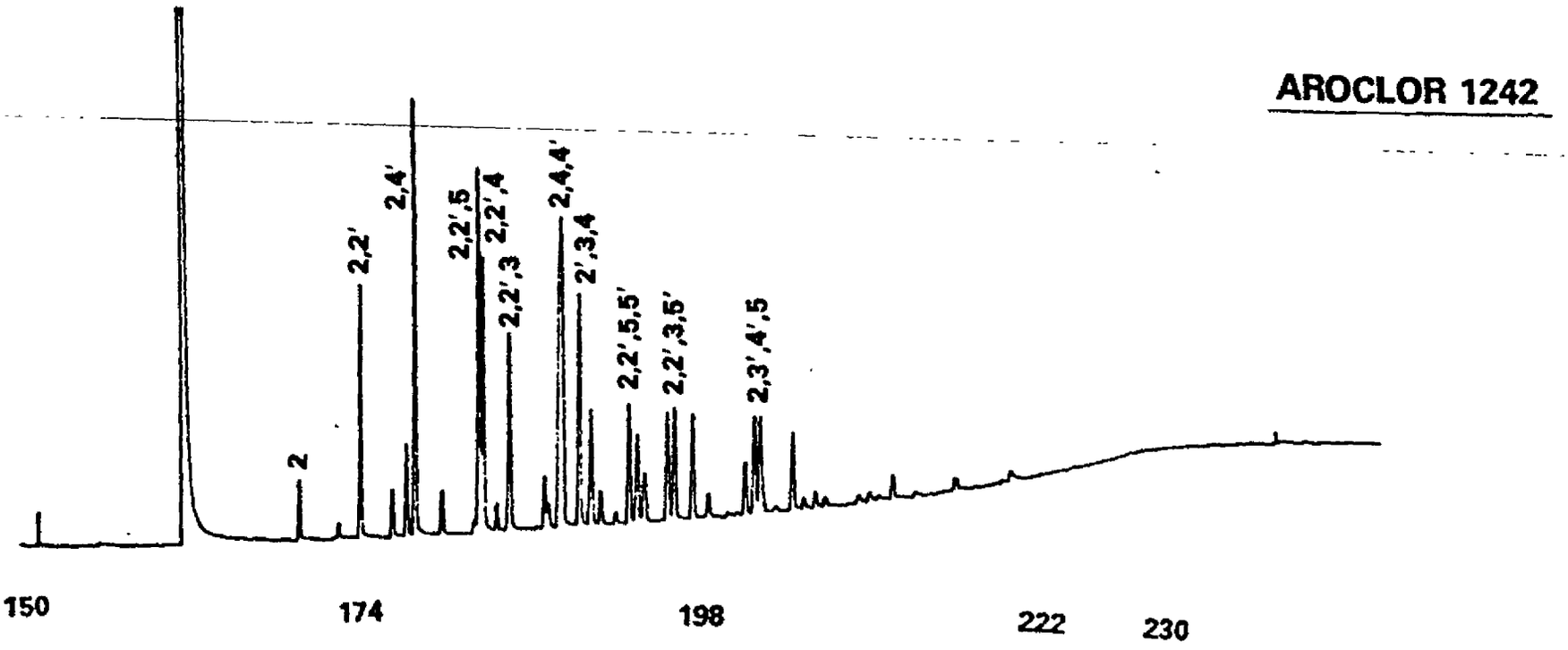

Figure 4

MONS 205190

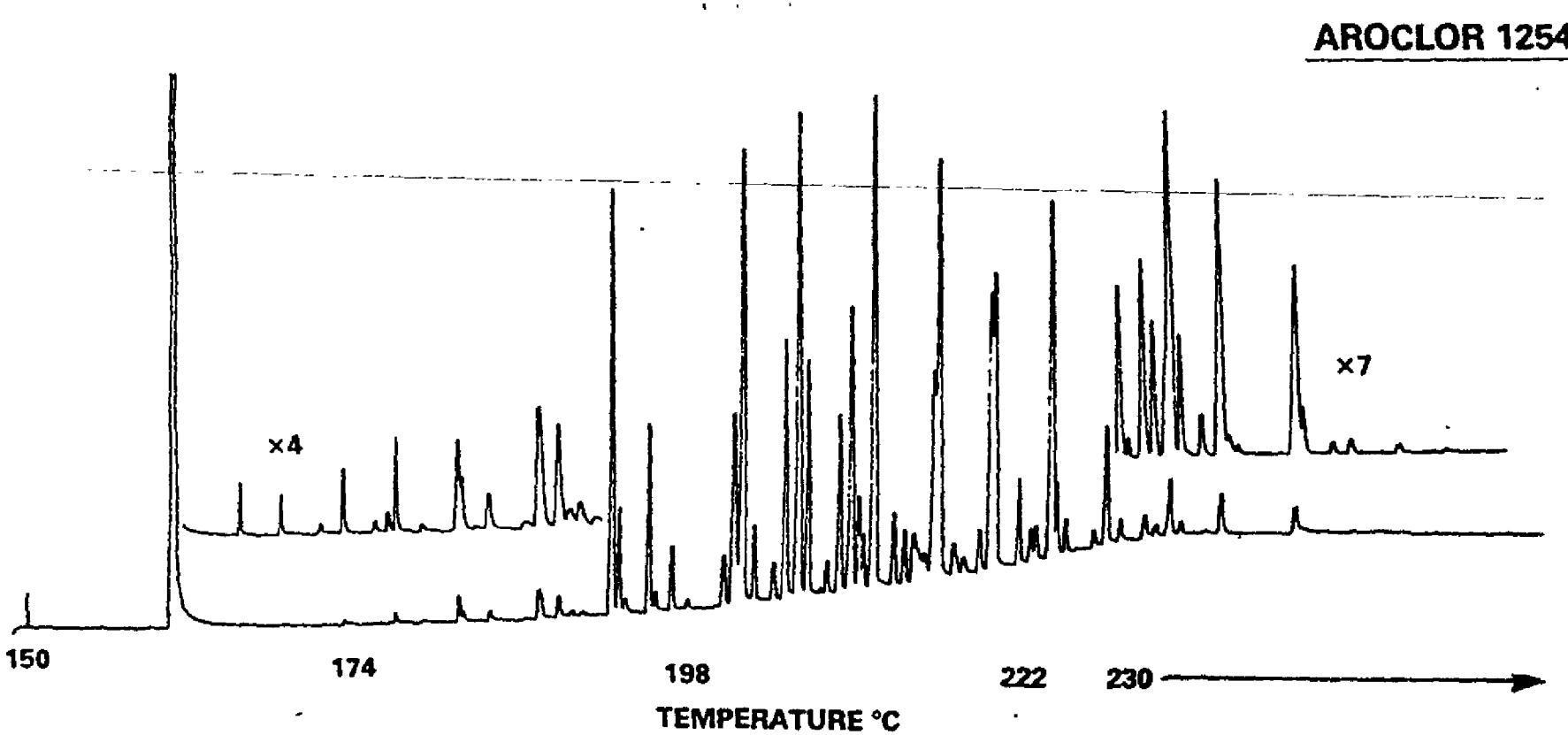

Figure 5

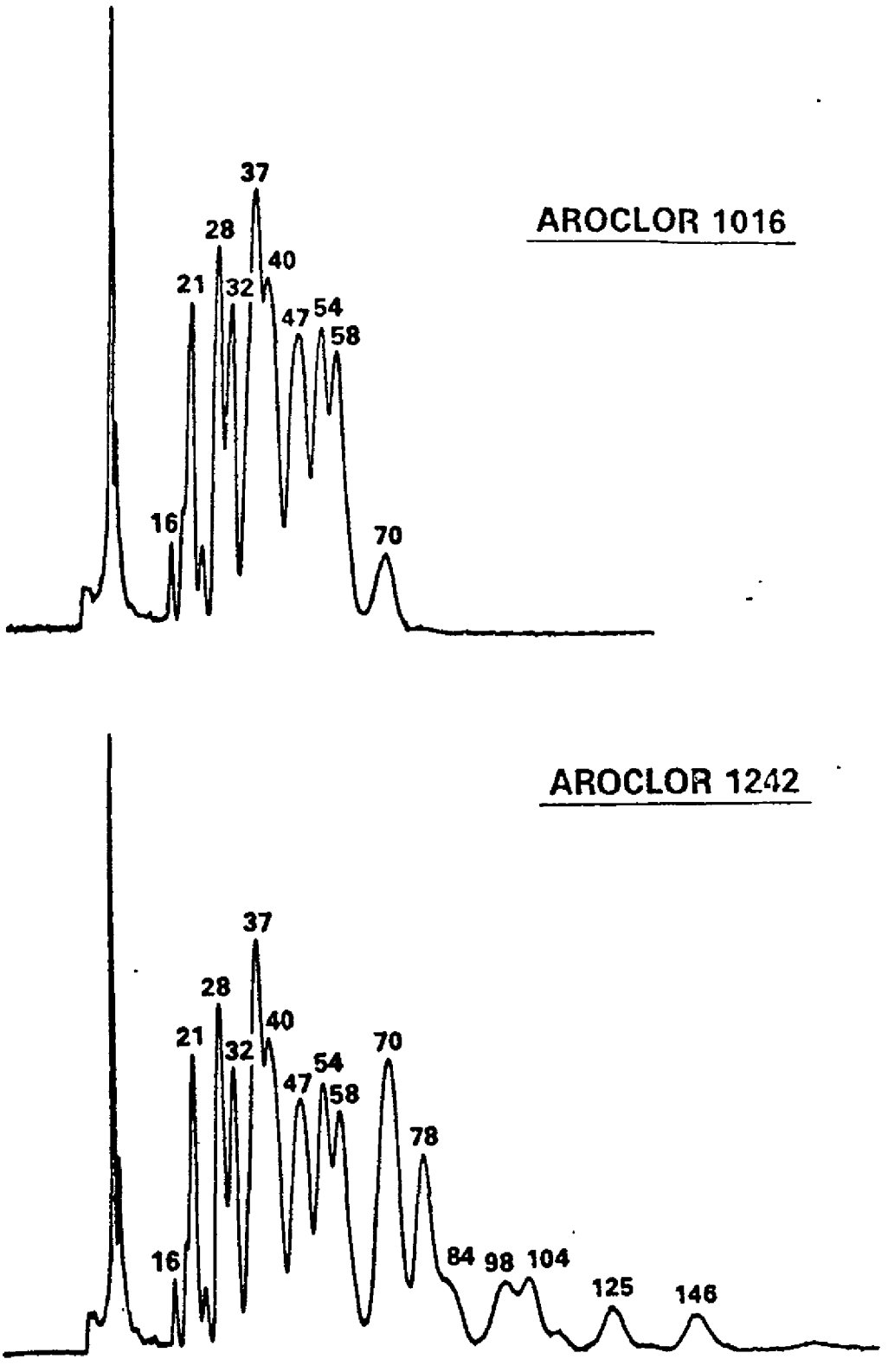

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Figure 6

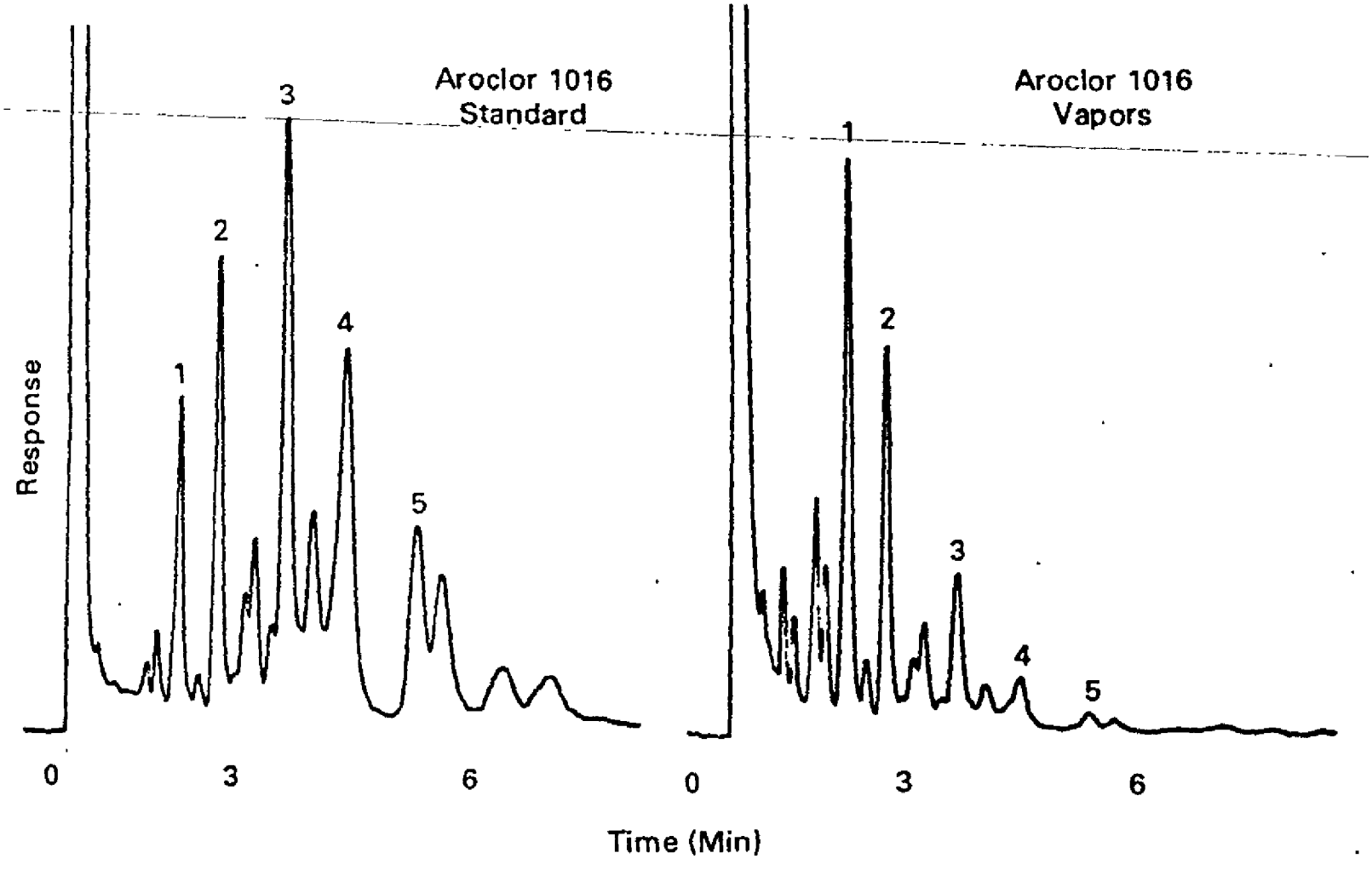
Aroclor 1016
Standard
Aroclor 1016
Vapors
Response
1
2
3
4
5
0
3
6
Time (Min)

Figure 7

AROCLOR 1016

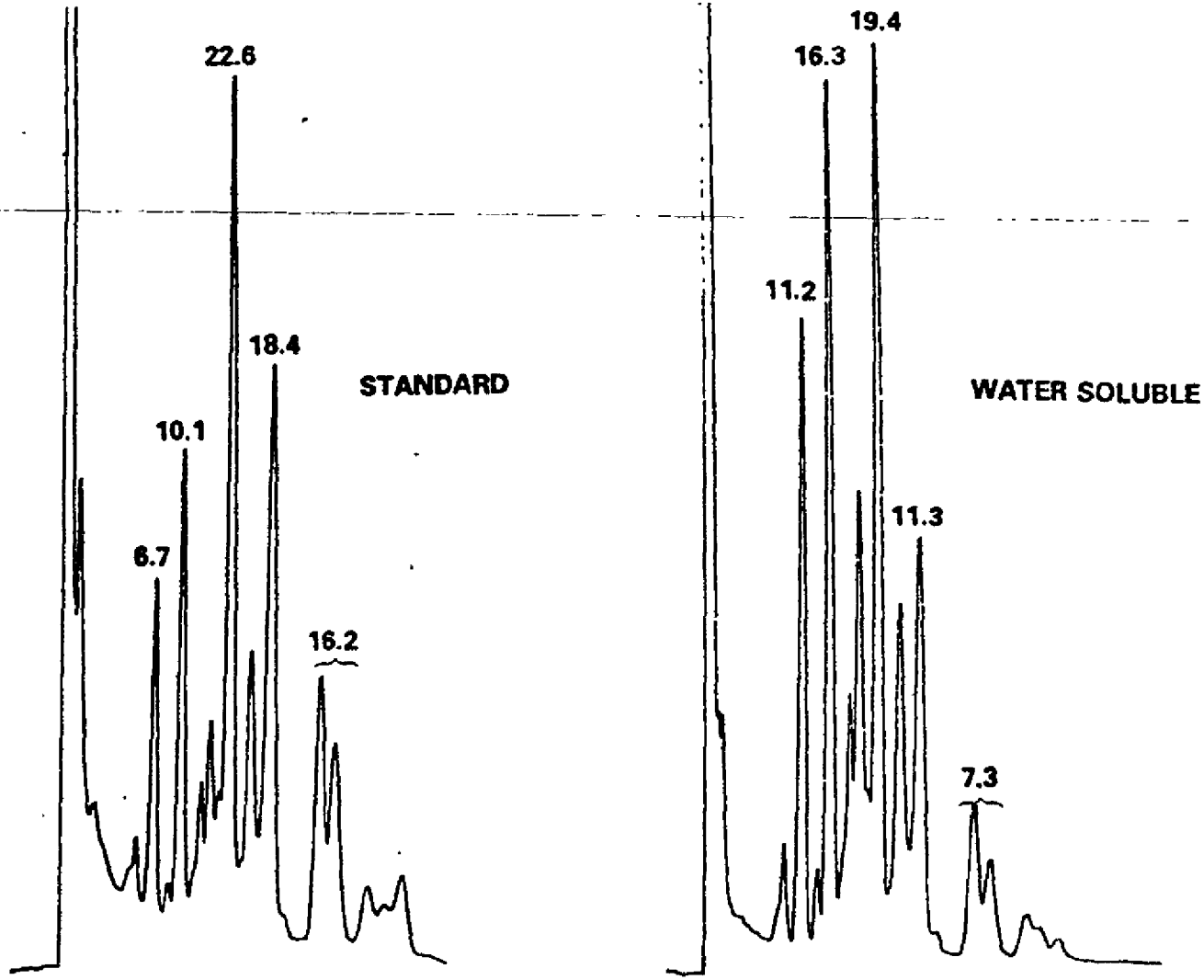

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Figure 8

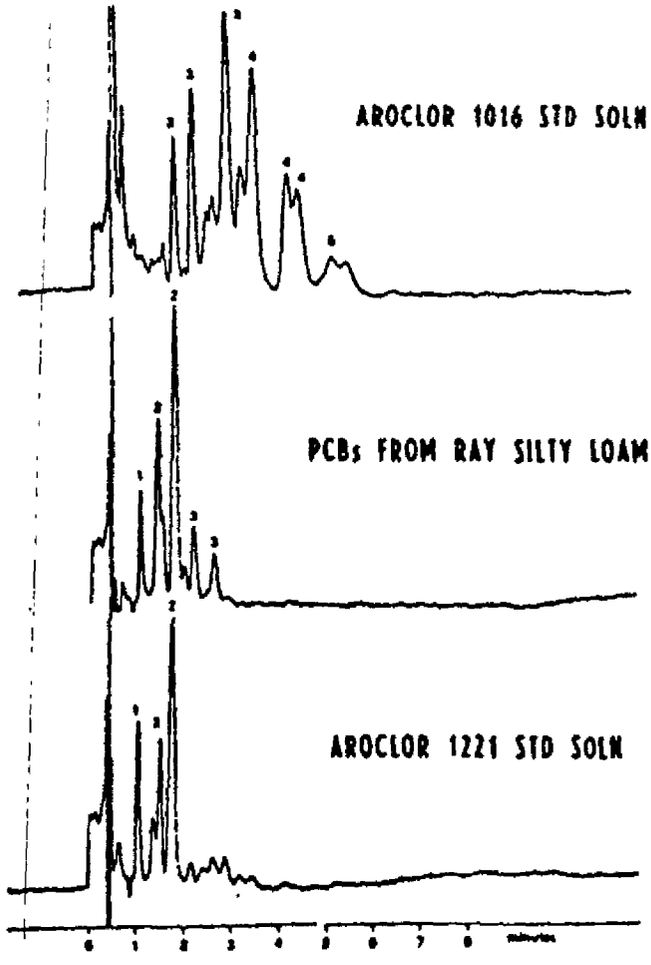
AROCLOR 1016 STD SOLN
PCBs FROM RAY SILTY LOAM
AROCLOR 1221 STD SOLN

Figure 9

AROCLOR 1016 BIODEGRADATION

SEMI-CONTINUOUS ACTIVATED SLUDGE

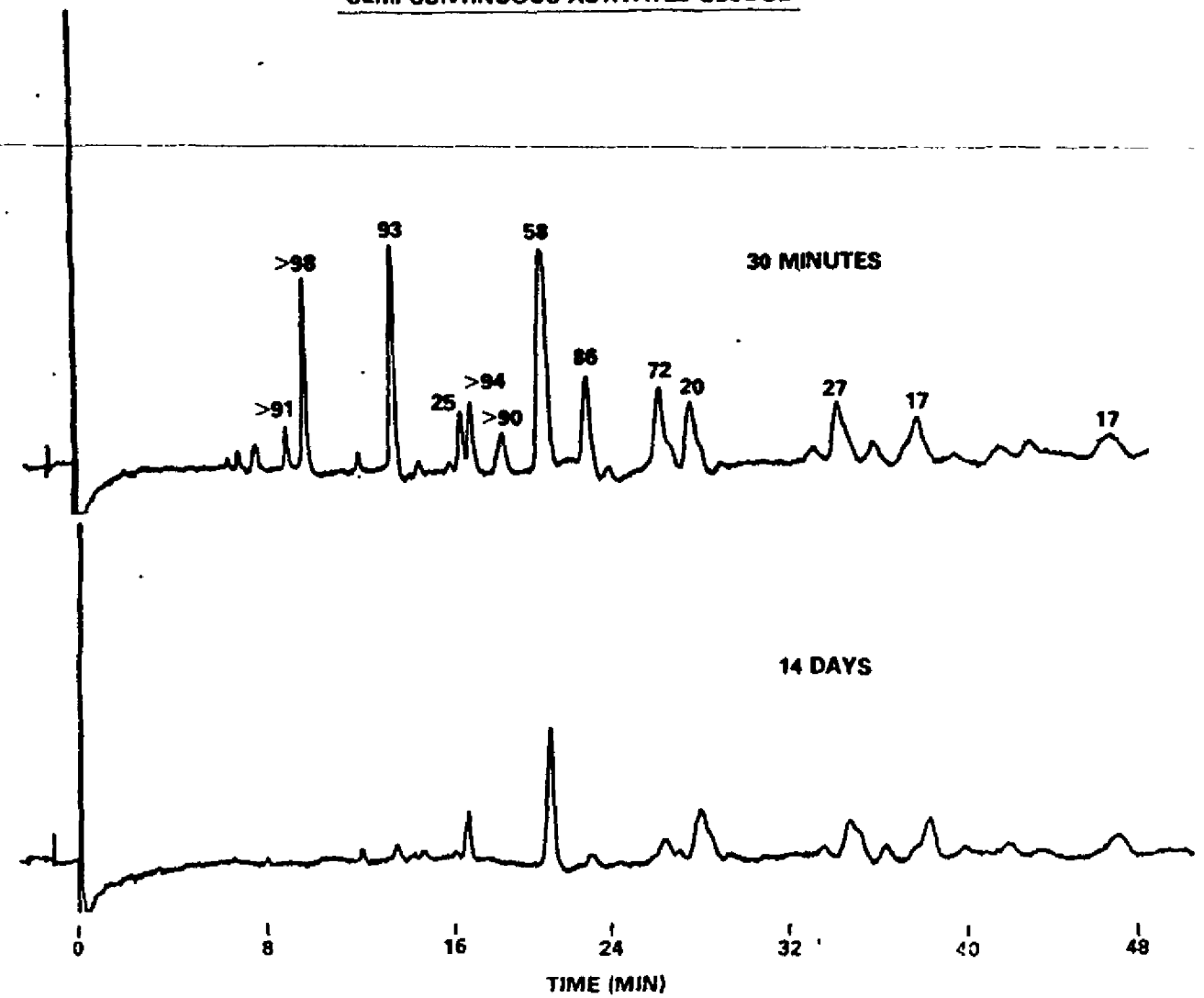

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Figure 10

Conference Abstracts

NATIONAL CONFERENCE ON POLYCHLORINATED BIPHENYLS

(November 19-21, 1975 - Chicago, Illinois)

Compiled by

RESEARCH TRIANGLE INSTITUTE
P. O. Box 12194
Research Triangle Park, North Carolina 27709

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J. R. Allen (continued)

monkeys was absorbed from the gastrointestinal tract and was most highly concentrated in the adipose and hepatic tissues. After one week, 12% of the dose given to a female juvenile monkey was excreted into the bile. Approximately 50% of the biliary material was reabsorbed by the gut as only 6% of the total dose was recovered from the feces during this period. The majority of the biliary material was in the form of a water soluble glucuronic acid conjugate. An additional 8% of the dose was recovered from the urine. Urinary metabolites consisted of monohydroxylated and dihydroxylated tetrachlorobiphenyls, trans-3,4-dihydro-3,4-dihydroxytetrachlorobiphenyl and hydroxy-3,4-dihydro-3,4-dihydroxy tetrachlorobiphenyl.

Single doses of tritiated 2,4,5,2',4',5'-hexachlorobiphenyl administered to juvenile monkeys were concentrated in adipose and hepatic tissues. The material was excreted at a much lower rate than that for the tetrachlorobiphenyl.

(This research was supported in part by U.S. Public Health Service grants ES-00472, ES-00958, and RR-00167 from the National Institutes of Health and the University of Wisconsin Sea Grant Program.)

ABSTRACT: TOXICOLOGY OF SELECTED SYMMETRICAL HEXACHLOROBIPHENYL ISOMERS: BIOLOGICAL RESPONSES IN CHICKS AND MICE

AUTHOR: Marco Biocca, M.D., Department of Environment, Ottawa, Ontario, Canada

One-day-old cockerals were fed: (I) 3,10,30,100, and 300 ppm of 3,4,5,3',4',5'-hexachlorobiphenyl (HCB); (II) 400 ppm of 2,3,4,2', 3',4'-HCB; (III) 400 ppm of 2,4,5,2',4',5'-HCB; (IV) 400 ppm of 2,3,6,2',3',6'-HCB; and (V) 400 ppm of 2,4,6,2',4',6'-HCB. Surviving chicks were sacrificed at 21 days. Male mice were fed 10, 30, 100, and 300 ppm of three of the above isomers (I, III, V), and survivors were sacrificed at 28 days. HCB's levels in adipose tissue and liver were determined. There were variations among the isomers as to dose and pathologic effects. Isomer (I) showed the greatest effect of those studied on mortality, body weight gain, liver, thymus, and spleen; it also attained the highest tissue concentration. It was the only isomer which produced porphyrin accumulation; and, in the chicks, produced hydropericardium, ascites, and edema. The decreasing order of overall toxicity was I >> V > II, III, IV. A general similarity of response was observed in both chicks and mice.

ABSTRACT: PATHOBIOLOGICAL RESPONSES OF PRIMATES TO POLYCHLORINATED BIPHENYL EXPOSURE

AUTHORS: D. H. Norback and J. R. Allen, Department of Pathology, University of Wisconsin, Madison, Wisconsin

Male and female rhesus monkeys received varying levels of polychlorinated biphenyls (PCBs), and were evaluated for toxic effects, reproductive dysfunctions and metabolism of the compounds. Female rhesus monkeys exposed to PCBs (Aroclor 1248) at doses ranging from 25 to 300 ppm of the diet developed facial acne, erythema, subcutaneous edema, conjunctivitis and loss of eyelashes. Within 2 to 3 months, the majority of the animals had died or were moribund. Terminally, they developed anemia, anorexia, hyproteinemia, and hypolipidemia. Severe gastric mucosal hyperplasia and ulceration were present at autopsy. Surviving animals from the group that received 25 ppm for 2 months continued to have detectable levels of PCBs within their tissues, were devoid of eyelashes, and manifested facial erythema two years following the exposure period.

Female rhesus monkeys exposed to dietary levels of 2.5 and 5.0 ppm of PCB developed facial lesions within 2 months. Irregularities of the menstrual cycles were noted within 4 months. After 6 months exposure the animals were mated with control males. Six of the eight females on the 5.0 ppm diet conceived; the remaining two animals continued to cycle and were mated five times without conceiving. Five of the six animals that conceived aborted or experienced early-fetal resorption. Eight out of eight females on the 2.5 ppm diet conceived; however, 3 of the 8 females did not carry their infants to term. The six infants born to the PCB-fed females were small (350 g vs. 475 g) and displayed areas of cutaneous hyperpigmentation. Skin biopsies obtained shortly after birth contained PCBs. As a result of exposure to PCBs through the lactating mothers, the PCB levels of the infant tissues increased rapidly. Within 2 months the infants developed conjunctivitis, periorbital edema, loss of eyelashes and acne. Three infants expired within 4 months following birth. The surviving 3 animals were weaned and showed decreased severity of symptoms after 4 months on a milk supplement diet free of PCBs.

In contrast to the severe effects of low PCB exposure experienced by female rhesus monkeys, male monkeys tolerated 5.0 ppm PCBs as a dietary additive for one year without showing signs of severe intoxication. In addition, these males demonstrated no reproductive abnormalities.

Dietary PCBs (Aroclor 1248) were absorbed from the gut and distributed in the body tissues of the rhesus monkeys with highest concentrations being in the adipose tissue and liver. The levels in the adipose tissue of males receiving 5 ppm and of females receiving 2.5 ppm continued to increase through 14 months of exposure. Levels in the adipose tissue of females receiving 5ppm reached a maximum level of 75 to 100 ug per g at 9 months. Following removal of the PCBs from the diet, the concentration of the material decreased from the adipose tissue with a half-life varying between three and four months. Gas chromatographic patterns of the adipose and hepatic tissues demonstrated the persistence of the more highly chlorinated PCB isomers and near absence of the lower chlorinated isomers.

Over 90% of an oral dose of a single PCB isomer labeled with tritium (^{3}H 2,5,2',5'-tetrachlorobiphenyl) administered to infant or juvenile rhesus

ABSTRACT: INPUTS AND DISTRIBUTIONS OF POLYCHLORINATED BIPHENYLS IN THE SOUTHERN CALIFORNIA MARINE ENVIRONMENT

AUTHORS: T. C. Heesen, D. R. Young, Deirdre J. McDermott, Assistant Environmental Specialist, Southern California Coastal Water Research Project, El Segundo, California

A number of potential anthropogenic sources of polychlorinated biphenyls (PCBs) were identified and their inputs quantified. Submarine discharge of municipal wastewater has been the dominant source of PCB to the marine environment off southern California. However, the level of input from this source has steadily decreased during the period 1972 (> 19,000 kg/yr) to 1975 (2,600 kg/yr). Dry aerial fallout also appears to be an important source, and if wastewater inputs continue to decrease, fallout will probably become the dominant input [illegible] of the future. Surface runoff is of secondary importance, and inputs from direct industrial discharges and vessel antifouling paints are insignificant.

Despite the significant decrease in the municipal wastewater input, no significant decrease was observed over the 3 year period 1971-72 to 1974-75 in the level of PCB in muscle tissue of Dover sole, Microstomus pacificus, collected from throughout the Southern California Bight. In contrast, similar surveys of the intertidal mussel, Mytilus californianus, indicated that the PCB levels in this marine organism has significantly decreased over the same time period.

Bight-wide surveys of M. californianus and the yellow rock crab, Cancer anthonyi, indicate that PCB contamination of these marine animals is low but widespread. Levels of PCB in the harbor mussel, M. edulis, were highest in specimens collected from areas of intense vessel activity.

ABSTRACT: TOXICOLOGY OF SELECTED SYMMETRICAL HEXACHLOROBIPHENYL ISOMERS: CORRELATING BIOLOGICAL EFFECTS WITH CHEMICAL STRUCTURE

AUTHOR: James D. McKinney, Ph.D., National Institute of Environmental Health Science, Environmental Protection Agency, Research Triangle Park, N. C.

The symmetrical hexachlorobiphenyls (HCBs) represent model PCBs with high and constant chlorine content permitting unequivocal study of a given substitution pattern. These isomers show separate and distinct biological responses which can be related to chemical structure via effects on compound lipophilicity and metabolism. Compound purity must also be assured. Relative molecular polarizability can be correlated with lipophilicity and biological activity and is measurable by chromatographic and spectroscopic techniques. These parameters were highest in HCBs with planar symmetry and 4,4'-substitution. The rates of metabolism of these isomers are considered of lesser importance than the potentially highly toxic nature of some of the intermediary and terminal metabolites such as chlorinated dibenzofurans.

ABSTRACT: PRODUCTION AND USAGE OF PCBs IN THE UNITED STATES

AUTHOR: Robert Durfee, Ph.D., Consultant Vice President, Versar Incorporated, Springfield, Virginia

About 99 percent of the PCBs used in U.S. industry are produced by Monsanto in a single facility at Sauget, Illinois. These materials, termed Aroclors^{R}, are used in the production of capacitors (70 percent) and transformers (30 percent). Imported PCBs, comprising slightly over one percent of U.S. usage, are used in investment casting operations (80-90 percent; decachlorobiphenyl) and semi-closed heat transfer applications (10-20 percent). Capacitor and transformer production processes are similar in that process steps involving PCBs include filtration, flood or individual filling of the products, and removal of excess PCBs prior to sealing and individual testing of the products. Most losses occur from pump leaks to cooling water, spills, personal hygiene practice, and the like. Many of the discharges containing PCBs are to municipal sewers.

ABSTRACT: PCB CHLORINATION VERSUS PCB DISTRIBUTION AND EXCRETION

AUTHORS: M. Anderson and H. B. Matthews, Ph.D., National Institute of Environmental Health Sciences, Research Triangle Park, N. C.

The distribution and excretion of selected ^{14}C-labeled polychlorinated biphenyls (PCBs) were studied in the male rat. The distribution and excretion of each of the PCBs was studied after either i.v. or oral administration. Following administration, each of the PCBs was rapidly removed from the blood and stored in the liver and muscle. The rates of PCB redistribution from liver and muscle to skin and adipose tissue and/or elimination in urine was related to the degree of chlorination. The subsequent rates of PCB removal from skin and adipose tissue, excretion in urine and total excretion were related to the degree and position of chlorination of the biphenyl molecule. None of the PCBs studied were excreted to a significant extent prior to metabolism to more polar compounds. It appears as if the degree and position of chlorination controls the rate of metabolism. The limiting factor may be the facility of arene oxide formation as metabolic intermediates. The toxicologic implications of arene oxide formation versus PCB accumulation in animal tissues are discussed.

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ABSTRACT: TRANSPORT OF CHLORINATED HYDROCARBONS THROUGH THE UPPER CHESAPEAKE BAY

AUTHORS: H. D. Palmer, J. M. Forns, and T. O. Munson, Fellow Biochemist,
Westinghouse Electric Corporation, Ocean Research Laboratory
Annapolis, Maryland

Under contract to the Maryland State Department of Natural Resources, the staff of the Westinghouse Ocean Research laboratory (together with subcontractors at Johns Hopkins University and the University of Maryland) recently completed the Upper Bay Survey - a program having as the central task the study of the routes, rates, sources, sinks and reservoirs of chlorinated hydrocarbons (CHC's) in the upper Chesapeake Bay. Data from the field portion of this program will be presented; in particular, the levels of PCB's, chlordane and DDTR found in bottom sediments, suspended particulates, zooplankton, and shellfish will be summarized. The discussion will include the role of sediment deposits as traps for CHC's; suspended particulates as transport vehicles for CHC's; movement of CHC's from the suspended particulate reservoir into the biological system, particularly shellfish and zooplankton; and the sources of CHC's in the upper Chesapeake Bay.

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