Lefeuvre

Environment Canada / Environnement Canada

Water Management / Gestion des Eaux

Our File No / Notre dossier 1135-32

Your File No / Votre dossier

March 24, 1970.

I.J.C. Officers, Washington and Ottawa
for Members of the International Joint Commission.

The report of the International Lake Erie Water Pollution Board, the International Lake Ontario-St. Lawrence River Water Pollution Board and the Interconnecting Channels Water Pollution Boards on Polychlorinated Biphenyls (PCB's) is herein forwarded to you for consideration at the Commission meeting April 10 - April 13.

This report is a follow-up to that presented to the Commission in 1970 and was reviewed and approved at the Boards meetings in Detroit, March 7. It covers both some general background information on PCB's and more particularly, a survey of information on the present levels in the Great Lakes environment. This current appraisal of environmental levels has been a joint effort by both the United States and Canadian agencies.

Yours sincerely,

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Environmental Quality Coordinator,
Canada Centre for Inland Waters,
Box 5050, Burlington, Ontario.

cc: Members of the I.J.C. Pollution Boards for Lake Erie, Lake Ontario and the Interconnecting Channels.

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CONFIDENTIAL

REPORT OF

THE INTERNATIONAL LAKE ERIE WATER POLLUTION BOARD,

THE INTERNATIONAL LAKE ONTARIO-ST. LAWRENCE RIVER WATER POLLUTION BOARD

AND

THE INTERCONNECTING CHANNELS WATER POLLUTION BOARDS

TO THE

INTERNATIONAL JOINT COMMISSION

APRIL 1972

POLYCHLORINATED BIPHENYLS

IN

THE GREAT LAKES ENVIRONMENT

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PROLOGUE

Chlorinated hydrocarbons are among the more widespread synthetic organic chemicals which have been found to contaminate the environment. Collectively, these compounds possess physical and chemical characteristics which cause them to persist for extreme lengths of time. Their resistance to degradation is partially due to chlorine polysubstitution; this is true for both straight chain and ring structures. Further, these chemicals have a lipophilic nature. They are virtually insoluble in water, but readily soluble in fats and oils. Consequently, they accumulate in the fatty tissues of both vertebrate and invertebrate organisms. With their affinity for fats, magnification can occur along the food chain - traces of chlorinated hydrocarbons in the parts per billion range in water can result in levels of parts per million in fish.

Considerable effort has been expended in the monitoring of the common chlorinated hydrocarbon pesticides such as dieldrin and DDT, as well as the metabolic intermediates such as DDE and DDD. Except in isolated instances, these organochlorine compounds are found at what is considered to be sublethal concentrations. Accordingly, the major environmental concerns with the presence of chlorinated hydrocarbons have been that of the long term effects, such as adaptability, reproduction, and perhaps extinction. Similarly, from the human health standpoint, concern has been raised about long-term exposure. Unlike the situation with organophosphates or carbamates, the physiological mechanisms of these chlorinated hydrocarbons are not well understood. Yet we are aware that trace amounts are present in various foodstuffs and must establish valid and realistic human food thresholds.

Recently this concern over chlorinated hydrocarbons has developed a new dimension in the environmental contamination by polychlorinated biphenyls. PCB's, like DDT, contain chlorine, hydrogen and carbon; like DDT they are

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insoluble in water, soluble in fat, and extremely persistent in the environment. The chemical similarity of these chlorinated hydrocarbons suggests similar physiological effects in the bodies of fish, birds and perhaps people.

PCB's are extensively used in industry and are ubiquitous in the global ecosystem. Their presence has been frequently reported in the marine environment; recently it has been shown that freshwater ecosystems have also been contaminated. An in-depth survey of this environmental contaminant, polychlorinated biphenyl and its present levels in the Great Lakes is reported herein. This essay should not be viewed as only an examination of the potential hazards of PCB's, but also as further evidence against the entire class of chlorinated hydrocarbons.

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As requested by the International Joint Commission in their meeting of October 6, 1971, a report of the environmental contaminant, polychlorinated biphenyls (PCB's) is here tabled. Its scope is twofold:

(a) to report on the contemporary research findings re PCB's,

(b) to report the assessment of the present levels of this contaminant in fish species of the Great Lakes area.

Present environmental levels reported herein have been compiled by the following agencies: Michigan Water Resources Commission, Michigan Department of Agriculture, Ontario Department of Lands & Forest, Ontario Pesticide Residue Laboratory (Guelph), and the Canada Centre for Inland Waters.

INTRODUCTION

Polychlorinated biphenyls are chemical compounds manufactured in North America solely by the Monsanto Chemical Company. Monsanto distributes these products under the trade name of Aroclor^{R}. The name is followed by four digits to designate its composition. The first two digits indicate the basic structure, 12 indicates biphenyls, 54 indicates terphenyls, and 24 and 44 indicate mixtures of both biphenyls and terphenyls. The last two digits represent the percentage chlorine in the mixture; for example, 21, 42, 54, 60, 62, 68. Additionally, Monsanto markets a 5,000 series of Aroclors, which is an undistilled equivalent of the 5400 products (chlorinated terphenyls). There is also a 6,000 series which are blends of Aroclor 5460 and Aroclor 1221. The last two digits indicate the percentage of Aroclor 5460 in the blend; e.g., Aroclor 6062 is a blend containing 62% Aroclor 5460 and 38% monochlorinated biphenyl (1221).

All Aroclors produced by Monsanto are in fact mixtures of various

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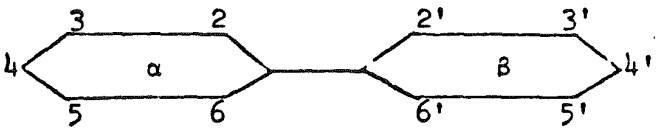
isomers. With a view of the diagram below of the basic structure of a biphenyl



and the positions available for chlorine substitution, the table that follows gives magnitude to the number of possible isomers.

TABLE 1. POSSIBLE ISOMERS OF POLYCHLORINATED BIPHENYLS

Number of chlorines in ring β	Number of chlorines in ring α					
	0	1	2	3	4	5
0	1	3	6	6	3	1
1		6	18	18	9	3
2			21	36	18	6
3				21	18	6
4					6	3
5						1
Total Theoretical No.						210

It should be pointed out that the theoretical number of isomers is not attained because of steric effects of chlorine atoms on a ring which direct subsequent chlorine substitution to ortho or para positions. Also, deactivation of the phenyl ring by chlorine atoms can preclude the formation of those isomers in which the chlorine number on each of the two rings does not differ by more than one. These considerations reduce the number of more probable isomers to approximately 100.

From a commercial standpoint, the individual isomers are of little significance. Further, the separation of polychlorinated biphenyl isomers presents a substantial problem. Thus the commercial PCB products exist as a

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complex mixture of various chlorinated hydrocarbons (biphenyl) and their effect on aquatic communities may be due to single or combined components.

PCB'S - INDUSTRIAL APPLICATIONS* AND AMOUNTS USED

PCB's as a group have had a wide variety of uses because of the following properties: fire resistance, chemical resistance, adhesion, resistance to oxidation, low volatility and resistance to hydrolysis. These properties together with their compatibility with a wide range of material and synthetic polymers and copolymers have made PCB's desirable components in many products and industrial formulations such as natural and syntehtic rubber, electrical products, floor tile, printer's ink, coatings for paper and fabric, brake linings, automobile-body sealants, paints, varnishes, waxes, asphalt and many kinds of adhesives and resins.

Significantly Monsanto, since mid-1970, has taken voluntary unilateral action to restrict its sales of polychlorinated biphenyls into "open systems". That is, areas of application where the ultimate introduction into the environment cannot be predicted and controlled. This would effectively delete Aroclor PCB's from many of the above products such as adhesives, sealants, chlorinated rubber, specialty coatings, etc.

Consequently, major volume uses for PCB's as identified by Monsanto are as fire resistant fluids in closed system applications such as: transformers, capacitors, heat transfer systems, industrial and hydraulic applications. Their excellent dielectric properties, fire resistance, inertness and stability at elevated temperatures have made them key factors in monitoring a high level of safety in many industrial operations.

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* This discussion of the Industrial applications of PCB's is largely a synthesis of material from the early report of the Advisory Boards on PCB's.

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The North American environment is NOT free of PCB's in "open systems". No-one is able to discuss in meaningful terms what amount of open system products have been stockpiled which contain PCB's. Conceivably, there might exist sufficient quantities to maintain the present levels of contamination for years to come. Further, there are no restrictions on the importing of European and/or Asian PCB's for open-system use or European and/or Asian products which contain PCB's. The entry of these foreign products can only act to nullify the effect of Monsanto's action.

Monsanto has revealed that substitutes have been formulated for industrial applications. These new products contain fire-resistant ingredients other than polychlorinated biphenyls. It has been reported that Monsanto has distributed terphenyls, another chlorinated hydrocarbon of a slight variation from a biphenyl, for open systems use. Its toxicity has been investigated and has been found to be similar to PCB's. (This will receive further discussion in a later section) Of the other substitutes being used, there has been only limited discussion by Monsanto.

Until only recently there existed a dearth of information regarding the quantities of PCB's being produced and distributed. This lack of information largely deterred any study of the environmental flow of this contaminant. Recently Dr. N. Nelson[2] stated the situation concisely:

> "It is inexcusable that chemists still have to run around with test tubes analyzing materials suspected of containing PCB's. There is a public responsibility here which would require as a first step that there be an open disclosure of sources and use of these hazardous materials."

In November, 1971, Monsanto released the following production figures: 42,500 tons produced in 1970, 353,000 tons manufactured since 1960. This type of information did not make it clear what quantities were destined for "open" or

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"closed systems" use. Further it failed to give meaningful information of the primary sources of release of PCB's into the environment. Finally last month, February 1972, Monsanto released more extensive data, indicating the quantities for the various PCB applications. These figures are shown in Table 2. The data on sales of PCB are available only for the United States. Sales reached a high of 36,500 tons in 1970. Sales doubled from 1960 - 1970; assuming the same growth rate from 1930 to 1970, about 500,000 tons have been sold in the United States. Monsanto's 1971 sales dropped to half the 1970 level and 1972 sales are expected to be 12 - 15,000 tons. Prior to 1971 when Monsanto curtailed sales for non-closed system use, about 40% was used in plasticizers, hydraulic fluids and lubricants, surface coatings, inks and pesticide extenders - uses that potentially result in environmental contamination.

ANALYTICAL METHODOLOGY

Polychlorinated biphenyls were first detected in the environment as interferences in routine chlorinated pesticide monitoring studies. The more suitable systems for detection of the PCB's are essentially the same as those used in chlorinated pesticide analysis. In particular, electron capture gas chromatographic systems capable of detecting highly chlorinated compounds at the low picogram level and mass spectrometric total-ion-monitoring systems which can detect ions at the 100 to 1000 picogram level have been utilized. These systems are well established in analytical chemistry.

Although the detection of low levels of PCB's is not considered a significant problem, quantitative gas chromatographic analysis is difficult due to the large number of isomers which are present. This difficulty is compounded by mutual interferences which arise because of the chemical similarities between the chlorobiphenyls and other organochlorine compounds such as the chlorinated pesticides.

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Recent research has helped to characterize the numerous isomers of the Aroclor mixtures[3, 4]. It has been shown that the predominant isomer in Aroclor 1254 is a pentachlorobiphenyl, with smaller amounts of tetra- and hexachlorobiphenyls. In Aroclor 1260 it is a hexachlorobiphenyl, with a significant level of heptachlorobiphenyl[5].

To arrive at an absolute measurement of PCB content pure standards of all the isomers of the Aroclor mixtures would be required. At present these are not available. A reasonable estimate is made by relating the peak areas obtained from extracts of PCB's in an electron-capture gas-liquid chromatography chromatogram to the corresponding peak area produced by a known weight of the commercial PCB mixture. Results are reported as being based on the various Aroclor commercial mixtures or combinations of these mixtures.

The interference problem has largely been alleviated. Several liquid-solid chromatography columns have been employed to separate the organochlorine compounds prior to electron capture gas chromatography. The successful use of a Florisil column was reported by L. M. Reynolds[6] and a silicic acid column by Armour and Burke[7]. Both these procedures are now widely quoted in the literature. More recently, G.A.V. Rees[8] has developed a separation procedure using cocoanut charcoal.

The confirmation of the presence of polychlorinated biphenyls with mass spectrometry was first reported by Jensen, Nucci and Widmark[1]. Later Bagley[9] et al. confirmed the identity of PCB in Bald Eagles using mass spectrometry. Confirmation with mass spectrometry is now routinely carried out whenever possible.

In summary then it can be stated that PCB's can be detected at the low picogram level. With the successful separation of the interfering organochlorine pesticides, the quantitative results are accepted as reasonably

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accurate estimates. However, from an analytical point of view, there is need to think in terms of individual isomers rather than commercial mixtures. If it is found that specific isomers are more toxic than others, as was the case with the BHC* isomers, more accurate methods of quantification would have to be developed.

BIOLOGICAL ACTIVITY

The acute toxicity of PCB's to various organisms has been investigated[10, 11, 12, 13]; more recently, however, toxicological experiments have shown that PCB's have the capacity to produce adverse physiological effects, much below these lethal concentrations. This sublethal activity is of major significance from an environmental standpoint. It is the intention of this report to focus on this latter aspect of biological activity.

The investigation of the effect of much reduced levels of PCB's has revealed:

(a) PCB's are oestrogenically active. More specifically, they are instrumental in the breakdown of oestradiol.

(b) PCB's have the ability to inhibit enzyme systems.

D. Peakall (Risebrough et al.)[17] reported that steroid hydroxylase induction by PCB's (Aroclor 1262) was five times that of pp'DDE or technical DDT as determined via oestradiol degradation. Later he reports that the delay in egg laying observed in various bird species has been associated with lower concentrations of oestradiol in the blood early in the breeding cycle and PCB's have been suggested as a primary cause of breeding delay.

Subsequently J. L. Lincer and D. B. Peakall[15] reported that the conversion of oestradiol into a more polar metabolite in Kestrel livers was increased by polychlorinated biphenyls, Aroclor 1254 or 1262, at an equivalent dose of 2 mg/kg orally. The increased enzyme activity responsible for the

*Benzene hexachloride, is in fact a mixture of isomers, of which lindane, (the widely used pesticide) is the γ isomer and the most toxic.

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oestradiol breakdown was correlated with an increased cytoplasmic R.N.A., suggesting that the physiological activity was similar to those of DDT and its metabolite.

Bitman and Cecil[16] used the 18 hour glycogen response of the rat uterus as a measure of oestrogenic activity. It was found that polychlorinated biphenyls plus terphenyls were estrogenically active.

More recently F.S. Pardini[17] reported that in contrast to an earlier report that indicated that out of eleven chlorinated insecticides tested, three inhibited both mitochondrial (NADH - OXIDASE and succinoxidase) enzyme systems, all of the PCB's tested inhibited both systems. Aroclor 5442 (a mixture of terphenyls) was included in the testing.

H. H. Yap et al.[18] investigated (1971) the sensitivity of ATP ases, in the blue gill fish (Lepomis machrochirus), to PCB's. Three polychlorinated biphenyl mixtures, Aroclor 1221, Aroclor 1254, and Aroclor 1268 and one polychlorinated terphenyl Aroclor 5460 were examined. All compounds inhibited ATP ases in low concentrations (less than 1 ppm) with the most pronounced inhibition of Mg^{2+} ATP ase of muscle. The higher sensitivity of muscle Mg^{2+} ATP ase to PCB compounds is consistent with the high sensitivity of this enzyme to DDT, as previously reported.

These studies substantiate the capability of this contaminant to interfere with estrogenic activity, electron transfer and energy releasing enzymes. This fact, in itself is not sufficient. The determination of the critical concentration of PCB's at which these inhibitions occur must follow. Again, there is need to be aware of the possible varying biological activity of individual isomers.

Recently concern has grown about the possible presence of teratogens; namely dibenzofurans, in the Aroclor mixtures. These dibenzofurans are an intermediate of dibenzo-p-dioxins. One may recall that this latter compound was found to be the teratogenic contaminant in 2, 4, 5 - T[19]. The chlorinated

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forms of these compounds are among the most toxic and teratogenic chemicals known.

In 1970, Vos and Koeman[20] reported the finding of tetra- and pentachlorodibenzofurans in Phenoclor and Clophen (European PCB commercial mixtures). They noted that the variation in toxicity among PCB mixtures was related to concentration of teratogenic material present. In light of this discovery, they suggested it was difficult to interpret data of previous experiments.

Current evidence suggests that the Monsanto products are essentially free from these contaminants, which probably accounts for the differing toxicities and effects reported for Aroclors and the European PCB's. In the literature there are, however, two reports of teratogenic effects of Aroclors: McLaughlin et al[21] reported beak deformity and growth retardation in his work with chick embryos; R. W. Risebrough[22], in a productivity study of Common and Roseate terns reports abnormalities which included feather loss in juvenile terns, as well as bill and foot deformities. In any current appraisal of PCB's, this question of teratogenic contamination must be given foremost attention.

HUMAN HEALTH HAZARD

Although from an environmental point of view, a formidable case has been built against PCB's, these compounds are considered to be a potential but not an immediate human health hazard. Levels have been detected in human adipose tissue; but these are very small (mean residue $\sim$1 ppm on a fat basis). It is felt that these PCB's enter the human diet primarily through residues in fish. At present it is not known how long term exposure to PCB's might affect human health.

The only clinical experience with human illness that is directly traceable to PCB consumption occurred in 1968 in southern Japan. More than 1,000 people were affected as a result of rice oil becoming contaminated with PCB's. It was found that patients had consumed an average of 2 grams of PCB's,

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with symptoms appearing at a minimum dose of about 0.5 gm. Generally, these individuals suffered from follicular accentuation pigmentation of the skin, acne form eruptions and a chronic numbness in the limbs. That PCB's can readily cross the placental barrier was shown as several infants were born with the above symptoms, some to apparently unaffected mothers. A recent report indicates that many individuals still are suffering from the above affects, although more than three years time has lapsed.

In regard to this incident, the question has been raised whether these Japanese PCB products were contaminated with dibenzofurans or other teratogens?

PRESENT LEVELS DETECTED IN THE GREAT LAKES ENVIRONMENT

The data presented herein has been the work of the following agencies: Michigan Water Resources Commission, Michigan Department of Agriculture, Ontario Department of Lands & Forests, Ontario Pesticide Residue Laboratory, Guelph, Ontario and the Canada Centre for Inland Waters.

During 1971, 98 water samples (mostly 30-hour composites) from 30 major tributaries to the Great Lakes were analyzed for PCB concentrations by the Michigan Water Resources Commission. Seventy-one per cent of the samples contained detectable concentrations (greater than 0.01 ppb) of PCB's (Table 1). The highest concentration reported was 2.90 ppb in the Saginaw River, tributary to Lake Huron. PCB concentrations exceeded 0.100 ppb in only seven of the thirty streams sampled.

Sampling of Lakes Ontario and Erie was carried out in the spring and fall, 1971, by CCIW. The levels detected are reported in Table 4. The level of detectability was of the order of .02 ppb; thus data in Table 3 and 4 are of similar sensitivity. PCB's were detected in 60 per cent and 63 per cent of the water samples of Lake Ontario and Lake Erie respectively.

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It should be noted that the data in Table 3 pertains to tributaries, and must not be construed as an indicator of the various lake concentrations. Actual sampling of water from the Great Lakes must be carried out to give an accurate determination of PCB levels.

The data in Tables 5, 6 and 7 collectively report a survey of the present PCB contamination of fish species of all the Great Lakes. All concentrations are expressed in parts per million and thus facilitate a comparison of the various lakes and species.

It is known that PCB's accumulate in the fat similarly to DDT. With respect to Table 5, the variation between different species is reduced when comparisons of concentrations of PCB on a fat basis is made. Unfortunately this type of data is not available for the other two sets of sampling.

As a result of recent adulteration of fish with PCB's the U.S. F.D.A. has adopted as a working guideline the level of 5 ppm. This concentration is determined on the basis of the edible portion of the fish and not on the basis of fat. Thus it is imperative to view the detected concentrations of PCB's within the tissues of the various fish species in relation to this tolerance level.

In Lake Michigan this limit has been exceeded by lake trout (9.08), coho (9.73), chinook salmon (13.06), and chub (5.23), and in Lake Huron by walleye (10.0), whitefish (9.17) and catfish (7.18). In Lake Ontario the concentrations in smelt (13.1) and coho salmon (9.4) are above the tolerance level. In Lake Erie, where generally the concentrations in the tissue are well below 5 ppm, white bass have been detected at 5.2 ppm.

During 1971 analyses of various bird species were also carried out by the Ontario Pesticide Residue Laboratory. Table 8 gives magnitude to the levels of PCB detected. It is important to note that the "land bird species" are relatively uncontaminated. In 50% of these species PCB's were undetectable.

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In contrast, the coastal and aquatic species showed high levels of contamination. The range of PCB concentrations in the tissues was .12 - 559 parts per million. A comparison of "main food eaten" indicates that piscivors have the highest residues (A. Mergansser - 559 ppm). Herbivors and "invertebrate eaters" showed levels below 2 ppm.

SUMMARY

Unlike the situation with DDT, PCB's are contaminating particularly the aquatic and not the terrestrial ecosystems in the Great Lakes environment. Their presence has been found in the waters, fish and aquatic bird species. Although PCB have been detected throughout the Great Lakes, residues in fish were higher in Lakes Michigan, Huron and Ontario. In many instances, the levels of PCB's exceeded those of total DDT.

It is of prime importance to relate the concentrations of PCB's in the water to those found in fish, and accordingly those found in bird species. Unfortunately, the data that is available does not facilitate such a comparison. Further investigation of possible magnification along the food chain is required.

The establishment of a water quality criterion for PCB's must firstly consider the following:

(a) the critical concentration at which sublethal activity is initiated;

(b) the presence or absence of teratogenic impurities;

(c) the possible variation in toxicity of the individual isomers;

(d) the lowest concentration from which biological uptake can occur.

As with other chlorinated hydrocarbons, the ability to establish valid food thresholds for PCB's rests on our better understanding of the human physiological effects.

These above areas of concern are as applicable to terphenyls as

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biphenyls. The use of terphenyls in open systems presents somewhat of an urgent problem as the analytical methodology for accurate detection in the environment does not presently exist.

As we are aware that European and suspect that Japanese PCB products may be contaminated with teratogenic compounds, it is exceedingly important that we discover what quantities are entering North America. Possibly these products could be examined for teratogens prior to their admittance into the country. This contamination should prevent their entering the country for either open or closed systems use.

In contrast to DDT, which has been used with intent, PCB's have escaped into the environment by accident. Consequently, whereas the statistics for DDT usage were relatively available, meaningful data of polychlorinated biphenyls has only been recently released and data re terphenyls and other possible substitutes remain unknown. The inability to study the environmental flow of PCB's (because of the lack of only recently released data), prompted the following message to the United Nations Conference on the Human Environment:

> "studies necessary to gain adequate understanding of the behaviour and importance of some pollutants, notably the PCB's, are rendered impossible because information on production and distribution is not made public."[23]

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TABLE 2. PCB MANUFACTURING AND SALES

DATA FROM MONSANTO INDUSTRIAL CHEMICALS CO.

1957 THROUGH 1971

(Thousands of Pounds)

	1957	1958	1959	1960	1961	1962
TOTAL PRODUCTION (For Domestic Sales)(1)				37,919	36,515	38,353
DOMESTIC SALES	32,299	26,061	31,310	35,214	37,538	38,043
DOMESTIC SALES BY CATEGORY						
Heat Transfer	--	--	--	--	--	157
Hydraulics/Lubricants	1,612	1,549	2,685	2,523	4,110	3,915
Misc. Industrial	704	755	1,569	1,559	2,114	1,681
Transformer	12,955	5,719	5,984	7,921	6,281	7,984
Capacitor	17,028	14,099	16,499	16,967	15,935	15,382
Plasticizer Applications(2)		3,939	4,573	6,244	9,098	8,924
Petroleum Additives	--	--	--	--	--	--
Total	32,299	26,061	31,310	35,214	37,538	38,043
DOMESTIC SALES BY PCB GRADE						
Aroclor 1221	23	16	254	103	94	140
Aroclor 1232	196	113	240	155	241	224
Aroclor 1242	18,222	10,484	13,598	18,196	19,827	20,654
Aroclor 1248	1,779	2,559	3,384	2,827	4,023	3,463
Aroclor 1254	4,461	6,691	6,754	6,088	6,294	6,325
Aroclor 1260	7,587	5,932	6,619	7,330	6,540	6,595
Aroclor 1262	31	184	359	326	361	432
Aroclor 1268	--	72	102	189	158	210
Total	32,299	26,061	31,310	35,214	37,538	38,043

NOTE: (1) Production amounts prior to 1960 are not available.

(2) Amounts for plasticizer applications prior to 1958 are not available.

.....Continued

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TABLE 2 (Continued)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	Prospect 1972
TOTAL PRODUCTION	44,734	50,833	60,420	65,849	75,309	62,854	76,387	85,054	40,471	25-30 m
DOMESTIC SALES (LBS.)	38,132	44,869	51,796	59,078	62,466	65,116	67,194	73,061	37,635	25-30 m
TOTAL EXPORT SALES	3,647	4,096	4,234	6,852	8,124	11,231	10,624	13,651	9,876	?
TOTAL DOMESTIC SALES BY CATEGORY										
Heat Transfer	582	929	1,237	1,766	2,262	2,529	3,050	3,958	3,480	--
Hydraulics/Lubricants	3,945	4,374	4,616	4,258	4,643	5,765	8,039	7,403	1,642	--
Misc. Industrial	1,528	1,692	1,841	1,779	1,424	1,283	1,079	1,627	578	--
Transformer	7,290	7,997	8,657	8,910	11,071	11,585	12,105	13,828	11,528	25-30 m
Capacitor	15,606	19,540	23,749	28,884	29,703	29,550	25,022	26,708	17,395	25-30 m
Plasticizer Applications	9,181	10,337	11,696	13,481	13,361	14,404	16,460	19,537	3,102	--
Petroleum Additives	--	--	--	--	--	--	1,439	--	--	--
Total	38,132	44,869	51,796	59,078	62,464	65,116	67,194	73,061	37,635	
TOTAL DOMESTIC SALES BY PCB GRADE										
Aroclor 1221	361	596	369	528	442	136	507	1,476	1,600	300
Aroclor 1232	13	13	7	16	23	90	273	260	211	300
Aroclor 1242	18,510	23,571	31,533	39,557	43,055	44,853	45,491	48,588	21,000	4,000
Aroclor 1248	5,013	5,238	5,565	5,015	4,704	4,894	5,650	4,073	261	--
Aroclor 1254	5,911	6,280	7,737	7,035	6,696	8,891	9,822	12,421	5,800	6,000
Aroclor 1260	7,626	8,535	5,831	5,875	6,417	5,252	4,439	4,890	1,750	600
Aroclor 1262	414	446	558	768	840	720	712	1,023	--	--
Aroclor 1268	284	190	196	284	287	280	300	230	--	--
Total	38,132	44,869	51,796	59,078	62,464	65,116	67,194	72,961*	30,622*	

* These figures may be subject to change by E.P.A., Chicago.

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MICHIGAN WATER RESOURCES COMMISSION

TABLE 3. PCB LEVELS - GREAT LAKES TRIBUTARIES - 1971

Basin	Number of Tributaries Sampled	PCB's Based Upon Aroclor 1254 Standard (Parts per Billion)	
		Range	Mean
Lake Michigan	11	<.01 - 0.097	0.025
Lake Huron	10	<.01 - 2.946	0.209
Lake Superior	3	<.01 - 0.010	0.006
Lake St. Clair	3	<.01 - 0.432	0.085
Lake Erie	4	<.01 - 1.584	0.210

ANALYTICAL METHOD; Separation of organochlorine pesticides carried out on a silicic acid column (Armour, J.A. and J. A. Burke [illegible]), prior to gas-liquid chromatographic - electron capture analysis.

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TABLE 4 PCB AND DDT LEVELS IN LAKE ONTARIO AND LAKE ERIE

(Expressed in parts per billion)

	Mean Values of PCB		Mean Values of Total DDT**	
	*Surface	*Bottom	Surface	Bottom
LAKE ONTARIO				
Western Region	.050	.062	<0.005	<0.005
Central Region	.032	.028	<0.005	<0.005
Eastern Region	.012	.014	<0.005	<0.005
Entire Lake:	.030	.032	<0.005	<0.005
LAKE ERIE				
Western Region	.034	.043	.007	.009
Central Region	.024	.033	.008	.006
Eastern Region	.027	.013	.028	.017
Entire Lake	.027	.025	.015	.009

* Samples taken one metre from surface and bottom

** Total DDT = Sum of op' DDT, pp' DDT, pp' DDE, pp' DDD.

ANALYTICAL METHOD: Separation of organochlorine pesticides carried out on a florisil column (Reynolds, L.M.[6]), prior to gas-liquid chromatographic-electron capture analysis.

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ONTARIO DEPARTMENT OF LANDS AND FORESTS, AND

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TABLE 5 — RESIDUES OF PCB's IN FISH TISSUES FROM THE GREAT LAKES (1970-71)

Location	Species	Number Analysed	Average Weight (g)	Fat (%)	PCB Tissue (ppm)	PCB Fat (ppm)	Ratio DDE/PCB
Lake Huron	Smelts	8	24	6.55	.60	9.2	1.17
	Alewife	13	34	5.52	1.00	18.	1.32
	Chub	19	187	16.47	2.90	18.	1.64
	Salmon - Kokanee	16	503	3.92	0.54	14.	1.66
	Splake	23	705	10.23	1.03	10.	0.96
	Whitefish	3	1183	9.94	9.17	92.	0.20
	Walleye	5	1196	5.27	10.0	190.	0.28
	Salmon - Coho	15	1275	8.44	6.19	73.	0.49
Lake Superior	Chub	3		9.69	0.60	6.2	1.98
Lake Michigan	Chub	4	189	24.4	4.48	18.	2.31
Lake Erie	Shad-Gizzard	6	92	15.5	2.30	15	0.03
	Bass-Rock	1	101	2.30	0.62	25	0.03
	Perch-Yellow	10	116	2.04	0.76	37	0.05
	Ling	1	166	1.90	0.61	32	0.05
	Sheephead	18	178	5.3	1.34	25	0.02
	Bass-White	19	187	5.5	1.52	28	0.07
	Sunfish-Green	2	199	2.3	0.51	22	0.10
	Walleye	4	460	4.0	1.11	28	0.02
	Catfish	2	518	19.3	4.95	26	0.03
	W. Sucker	1	699	3.40	1.10	32	0.07
	Salmon - Coho	3	806	11.53	1.73	15	1.02
Lake Ontario	Salmon - Coho	4	1068	7.12	9.4	132	0.23

ANALYTICAL METHOD: Separation of organochlorine pesticides carried out on a cocoanut charcoal column (G.A.V. Rees[8]) prior to gas-liquid chromatographic electron capture analysis.

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TABLE 6. PCB LEVELS IN LAKE ONTARIO AND LAKE ERIE FISH - 1971

(expressed in mg/kg wet weight)

Location	Species	Range Aroclor 1254	Mean Value	Range Aroclor 1260	Mean Value	Total PCB	Total DDT**
Lake Ontario	Alewives (8)*	5.00 - 23.00	14.32	.72 - 4.16	2.90	17.22	1.20
	Smelt (8)	5.40 - 17.00	10.98	.80 - 3.40	2.20	13.18	.70
	Sculpins (4)	6.65 - 42.00	20.62	1.5 -12.00	5.60	26.22	1.52
Lake Erie	White Bass (2)	4.02 - 5.20	4.61	.38 - .82	.60	5.21	.53
	Yellow Perch (3)	1.40 - 1.90	1.63	.28 - .30	.24	1.87	.25
	Smelt (6)	.95 - 13.00	3.61	.12 - 1.20	.37	3.98	.15
	Drum (2)	.64 - 4.90	2.77	.08 - .61	.35	3.12	.20

\# number of fish analyzed
** mean value

ANALYTICAL METHOD: Separation of organochlorine pesticides carried out on a florisil column (Reynolds, L.M.[6]), prior to gas-chromatographic - electron capture analysis.

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TABLE 7. RESIDUES OF PCB's IN FISH FROM THE GREAT LAKES - 1971

(expressed in parts per million)

Location	Species		% Fat	Total DDT	Total PCB	Ratio DDT/PCB
Lake Huron (Saginaw Bay)	Catfish	(15)**	15.5	3.62	7.18	.50
	Carp	(5)	7.5	1.65	3.89	.42
	Perch	(7)*	1.1	.43	1.12	.38
	Crappie	(1)	2.3	.48	1.14	.42
	Bullhead	(2)*	2.6	.29	.72	.40
	Sucker	(4)*	1.9	.93	2.08	.45
Lake Superior	Lake Trout	(43)	14.2	2.73	2.77	.99
	Whitefish	(6)	11.2	.53	.47	1.13
	Chubs	(1)*	25.39	12.03	4.76	2.53
Lake Michigan	Lake Trout	(6)	11.8	8.27	9.08	.91
	Whitefish	(18)	11.7	1.09	.99	1.10
	Chubs	(106)*	15.0	5.17	5.38	.96
	Coho	(56)	5.3	7.64	10.47	.73
	Salmon Eggs	(12)*	--	7.00	9.47	.74
	Steelhead	(1)	6.0	1.79	2.56	.70
	Brown Trout	(1)	2.4	2.01	2.89	.70
	Chinook	(6)	9.1	9.55	13.06	.73

* Composited samples

** 10 composite samples; 5 samples of individuals

ANALYTICAL METHOD: Separation of organochlorine pesticides carried out on a silicic acid column (Armour, J.A. and J. A. Burke[7]), prior to gas-liquid chromatography - electron capture analysis.

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TABLE 8. Residues of PCB in Body Tissues of Several Species of Birds from Several Habitats in Ontario

Habitat	Main Food	Species	Number	Fat (%)	PCB Tissue (ppm)	PCB Fat (ppm)	Ratio DDT/PCB
Land	Omnivor	Bluejay	1	2.90	.19	6.6	2.4
	Insectivor (Larval)	Chickadee	1	3.45	1.0	29.	0.7
	Carnivor (Mammals)	G. Eagle	1	6.50	9.7	149.	1.1
	Herbivor (Buds & Fruit)	R. Grouse	1	-	ND	-	-
	Seeds and Insects	M. Lark	1	10.1	ND	-	-
	Carnivor (Rodents)	B. Owl	2	4.40	53.	1205.	1.9
	Grain-Invertibrates	R.H. Pheasant	16	2.59	ND	-	-
	Insects-Invertibrates	Snipe	1	12.8	ND	-	-
	Herbivors (Grain)	H. Sparrow	4	8.1	ND	-	-
	Insectivor	Warbler	1	21.5	0.5	2.3	1.6
Coastal & Aquatic	Grain-Invertibrate	Ducks - Mallard, Black	5	8.1	1.7	21.	1.3
	Carnivor	Ducks-Old Squaw	4	11.5	5.2	.45	0.5
	Carnivor	Fulmer	1	2.70	8.0	296.	1.2
	Herbivor (Grain-Plant-Invertebrate)	C. Geese	18	3.19	0.12	3.8	1.2
	Carnivor	Gulls	70	3.65	204.	5589.	0.3
	Frogs, Fish, Invertebrates	Herons	2	3.66	38.	1038.	0.9
	Piscivor	Loons	3	8.43	43.	510.	1.6
	Piscivor	A. Merganser	1	6.19	559.	9031.	0.2
	Herbivor - aquatic, plants & invertebrate	W. Swans	3	7.20	0.21	2.9	1.5
	Invertibrates	Casp. Tern	1	4.43	1.43	32.	0.6

ANALYTICAL METHOD: Separation of organochlorine pesticides carried out on a cocoanut charcoal column (G.A.V. Rees[8]) prior to gas-liquid chromatographic electron capture analysis.

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