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Westinghouse Research Laboratories



**A STATUS REPORT ON CHLORINATED DIPHENYLS,
REGARDING ENVIRONMENTAL POLLUTION**

T. W. Dakin and L. Mandelcorn

Research Report 71-1B8-CAPDI-R1

December 27, 1971

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GBRN003300

Research Report 71-1B8-CAPDI-R1
Proprietary Class 1

A STATUS REPORT ON CHLORINATED DIPHENYLS,
REGARDING ENVIRONMENTAL POLLUTION

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Electrical Performance of Insulating Materials
Research Laboratories

December 27, 1971

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GBRN003301

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A STATUS REPORT ON CHLORINATED DIPHENYLS,
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1. INTRODUCTION

Chlorinated diphenyls, PCB's, during the past two years have been included among possible polluters of the ecology, in association with DDT's. This has raised the question about their continued use in the electrical industry, where they have been serving as insulating fluids for capacitors and transformers for almost forty years.

Monsanto, the sole producer and supplier of these materials in the U.S., has dealt with this problem by:

1. restricting their availability to sealed electrical equipment,
2. making available an incinerator for waste chlorinated diphenyls,
3. studying their interaction with the environment, and effects on animals, and
4. developing new chlorinated diphenyl compositions which they think are less persistent in the environment.

Westinghouse's actions in this area have so far been to:

1. control and use specific production procedures to prevent the release of chlorinated diphenyls from plant areas,
2. determine analytically the presence of chlorinated diphenyls in the vicinity of three plants where they have been used extensively, and
3. develop alternate fluids.

This is a presentation of some of the aspects of the chlorinated diphenyl problem that are relevant to Westinghouse. Here are given the Monsanto views and findings, presented at a meeting on December 16, 1971, and Westinghouse needs and alternatives.

2. STATUS OF PRESENT NEED FOR CHLORINATED DIPHENYLS AND POSSIBLE ALTERNATIVES

1. Chlorinated diphenyls, Aroclor 1242 or MCS 1016, are essential for capacitors and transformers for use indoors, because of the very low flammability of these fluids. Special vaults and fire protection would be needed with mineral oil or similar impregnants.

2. No other insulating liquid, which is satisfactory for these devices, and which has as low flammability as these chlorinated diphenyls, is known. There is a low probability of finding a sufficiently good insulating liquid which is as nonflammable as the chlorinated diphenyls.

*3. Certain fluids were found recently, in a Research project, that are satisfactory electrically and thermally for capacitors, and entail only little decreases in KVAR ratings per unit size; but these are similar in flammability to mineral oil.

*4. These new Research developed liquids could be used for power capacitors, only if they are located outdoors or in fire protected vaults.

5. The present alternative to chlorinated diphenyl filled transformers, for indoors, are the dry type units.

6. The situation with regard to chlorinated diphenyl use in lighting ballast and motor run capacitors is not clear. These units are small, and very numerous and widely scattered. There should be no difficulty with outdoor lighting ballasts. Most indoor lighting ballasts have the units potted in asphalt. Tests to satisfy the Underwriters Laboratories would have to be conducted on the entire ballast with new liquids such as those developed in Research.

* This information should be regarded as especially confidential within Westinghouse.

3. THE MONSANTO POSITION

1. Use of chlorinated diphenyls should be restricted to closed electrical systems.
2. Restriction of use of Aroclors to compounds which have lower percent chlorination less than pentachloro-diphenyl will avoid build up and persistence in the environment from minor amounts released.
3. Waste chlorinated diphenyls should be carefully controlled and destroyed or recovered.
4. They feel that burial of chlorinated diphenyl impregnated paper, etc., or failed or retired capacitors, etc., from which removal of the liquid would be difficult, is a satisfactory procedure - providing the burial site is carefully chosen, preferably dry.
5. They indicated that they intended to stay in the business of supplying chlorinated diphenyls, Aroclors, but only to the electrical industry.
6. They strongly urge that the electrical industry make a more vigorous effort to define and justify the use of chlorinated diphenyls in their apparatus to government and other environmental groups.

4. SUMMARY OF FACTS PRESENTED BY MONSANTO

1. Monsanto has ceased to market Aroclors for all applications other than electrical, but are still supplying some for other applications where there is hardship; but these will be stopped during 1972.
2. Tests by Monsanto and others of chlorinated diphenyls, PCB's, in the environment have shown a concentration of higher chlorinated compounds and a reduced or no presence of compounds with three chlorines or less.

3. Artificially controlled studies of biodegradation using a semi-continuous activated sludge test, SCAS, and also single bacteria culture tests have shown that the lower chlorinated compounds are biodegraded, but the rate of biodegradation decreases as the percent chlorination increases, and is very low or zero for pentachloro compounds and higher. Their scientists state that they do not know the correlation of these artificial biodegradation tests to environmental conditions.

4. Chlorinated diphenyls were first identified in the environment along with DDT's and the controls on the levels set by the FDA are "Action Levels", which are the same as for DDT. They are not levels for which PCB's have shown to be harmful to mammals.

5. Chlorinated diphenyls are considered about 1/13 as toxic as DDT for mammals. White rats fed up to 100 ppm of PCB's in their food steadily over a period of 24 months were healthy. Dogs fed up to 100 ppm of the PCB's over 24 months showed a slowed weight gain with the higher chlorinated compounds, but not with the Aroclor 1242. There were no deaths. The higher chlorinated compounds accumulated in their fatty tissue to an equilibrium level.

6. Chlorinated diphenyls affect the egg shells and hatchability of some birds. Other breeds of birds have not shown any effects. Birds are more susceptible to the lower chlorinated compounds, di and tri chlorinated. Three ppm of PCB in chicken feed affects the hatchability of Leghorn chickens, but not some other breeds of chickens.

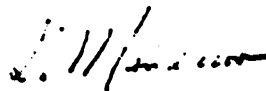
7. One incident of ingestion of PCB's by humans has been reported from Japan. In this case, a rice oil with 2000 ppm of PCB's was consumed by 1000 people. Severe cases of chloracne, nausea, headaches, and weakness were experienced. Some babies of these people were born with brown pigmented skin; but the pigmentation later disappeared. There were no deaths. It is suspected that the PCB involved contained a chlorinated dibenzofurane, a toxic impurity found in some European chlorinated diphenyls.

8. Chlorinated diphenyls appear to diffuse very slowly through soil.

9. Monsanto feels that their new grade of chlorinated diphenyl, MCS 1016, is biodegradable, since it contains only 0.16% of pentachlorinated diphenyls. They recommend its use over MCS 1015, which contains 6.7% penta-chlorodiphenyl, for capacitors or wherever the waste material not strictly controlled.



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5. APPENDIX -
DETAILS OF MEETING WITH MONSANTO

5.1 Makeup of the Meeting

The meeting was held at Monsanto, St. Louis, Missouri, on December 16, 1971.

Representing Monsanto were: Messrs. P. B. Benignus, T. L. Gossage, W. Richards, and W. B. Papageorge, and Drs. R. H. Munch, R. E. Keller, and S. Tucker.

Representing Westinghouse were: D. Sauter and R. D. McClain (Bloomington), D. P. Keiser (South Boston), T. K. Sloat (Sharon), B. Boquist (Headquarters Engineering), T. W. Dakin, L. Mandelcorn, and G. C. Gainer (Research Laboratories), and J. C. R. Kelly and T. O. Munson (Annapolis, Ocean Research).

The Monsanto representatives made specific presentations, which were further discussed by the group.

P. G. Benignus reviewed some of the Monsanto Aroclor activity.

Dr. R. H. Munch discussed the ecological problem, means to minimize release of chlorinated diphenyls, and new alternative liquids of a similar type.

Dr. S. Tucker presented results of biodegradation and animal studies.

W. B. Papageorge dealt with various government (the U.S.A. and others) and committee activities regarding PCB's.

5.2 Monsanto Aroclors - Description and Usage (Tables 1 - 3 incl.)

TABLE 1
Composition of Different Liquid Chlorinated Diphenyls

Components - given as % -	Monsanto Aroclors							
	<u>1221</u>	<u>1232</u>	<u>MCS 1043</u>	<u>1242</u>	<u>MCS 1016</u>	<u>1248</u>	<u>1254</u>	<u>1260</u>
Chlorine	21	32	32	42	42	48	54	60
Diphenyl	14.8		.04	.02	.02			
Mono-chlorodiphenyl	56.5		22.2	.72	.93			
Di-chlorodiphenyl	26.9	~55	74.4	15.6	19.4			
Tri-chlorodiphenyl	1.42		3.3	54.5	64.5			
Tetra-chlorodiphenyl	.06			22.5	15.0	~55		
Penta-chlorodiphenyl				6.7 [*]	.16 [*]		~60	
Hexa-chlorodiphenyl								~70

* Includes higher than penta-chlorinated isomers.

TABLE 2
Monsanto Production and Sales of Aroclors for 1960-1971,
with Breakdown Showing Electrical Usage
(from C&E News, December 6, 1971)

<i>Figures in short tons</i>	<u>U.S. Production</u>	<u>Domestic Sales</u>		<u>Exports</u>
		<u>Insulating Liquids^a</u>	<u>Others^b</u>	
1960	20,786	12,444	5,163	1827
1961	20,333	11,108	7,661	2076
1962	20,986	11,683	7,339	1809
1963	22,367	11,448	7,618	1824
1964	25,417	13,769	8,666	2048
1965	30,240	16,203	9,695	2117
1966	32,925	18,897	10,642	3426
1967	37,655	20,387	10,846	4062
1968	41,427	20,568	11,990	5312
1969	38,194	18,564	15,034	5312
1970	42,527	20,268	16,263	6826
1971 ^c	20,236	14,417	4,401	4938

^a For closed electrical systems - transformers and capacitors.

^b Includes heat-transfer systems, hydraulics/lubricants, and plasticizers.

^c Estimated.

Source: Monsanto

TABLE 3

Aroclors Sold in 1970 for Capacitors and Transformers,
and Corresponding Contents of ≥ 5 Chlorinated Components
(≥ 5 Cl's are more persistent than lower isomers)

<u>Aroclor</u>	<u>Million Lbs Sold</u>	<u>Corresponding</u>
		<u>≥ 5 Cl, Million Lbs</u>
		<u>Capacitor Usage - (about equally divided between power and small capacitors)</u>
1242	26.1	1.83*
1254	.5	.5
		<u>Transformer Usage</u>
1242	6.3	.4
1254	3.5**	3.5
1254 } + Chlorinated Benzene	$\sim 1^\dagger$	~ 1
1260	4.1	4.1

* Would be .07 million lbs for MCS 1016

** GE usage

† as replacement, e.g., to repair sites

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5.3 Highlights of Biodegradability and Animal Studies Reported by Monsanto

TABLE 4

Biodegradability of Different Chlorinated Diphenyls

- Semi Continuous Activated Sludge Test, 2×10^8 cells/cc -
(observations after preconditioning sludge to Aroclor tested)

<u>Aroclor</u>	<u>% Chlorine</u>	<u>% Disappearance in 48 hrs</u>
Mono-chlorodiphenyl	18.5	100
1221	21	88
MCS 1043	30	55
MCS 1016	41	35*
1242	42	25
Distillate of MCS 1016	51	15
1254		15
DDT		<10
Linear Alkyl Sulfonate-Standard		100

* Noted concentrating of 4-, 5-, and 6- chlorinated isomers

- Single Cultures, C-2 and C-3, with specific isomers (Europe) -
Both cultures have approximately the same effect.

<u>Chlorinated Diphenyl</u>	<u>Time for 50% Disappearance</u>
di and tri	~26 days
tetra	~30 days

Monsanto observed, in exposures of animals to Aroclors, that the retained material was richer in the penta and higher chlorinated isomers, and poorer in the lower (tetra and below) isomers. This was shown in:

1. chicken fat of chickens whose feed contained Aroclor 124 (leakage of heat transfer fluid),
2. Mississippi River carp, caught downstream from their Sauget, Illinois plant,
3. milk from a cow exposed to Aroclor 1254 (which was used as a plasticizer),
4. fish exposed to Aroclor 1254, and
5. dogs exposed to Aroclor 1242, in controlled feeding. Their fat had chlorinated diphenyls of a composition resembling that of Aroclor 1260.

TABLE 5
"Storage" of Chlorinated Diphenyls in Albino Rats,
After 24 Months' Exposure in Feed

Note: Concentration in lipid became approximately constant at about 6-12 months; except for Aroclor 1254 and 1260 exposures at higher concentrations, noted by *, where it tended to increase continuously with time, and the liver to brain weight ratio increased.

<u>Aroclor - in Feed</u>	<u>Concentration in Lipid, ppm,</u>			ppm in feed
	at <u>1</u>	<u>10</u>	<u>100</u>	
1242	10	70	200	
1254	50	200	1,500*	
1260	?	?	5,000-10,000*	

TABLE 6
"Storage" of Chlorinated Diphenyls in Dogs,
After 24 Months' Exposure in Feed

<u>Aroclor - in Feed</u>	<u>Concentration in Lipid, ppm,</u>			ppm in feed
	at <u>1</u>	<u>10</u>	<u>100</u>	
1242	3	5	6	
1254	6	18	109*	
1260	13	86*	579*	

* reduced weight gain, increase in liver to brain weight ratio

3.3 Controls of PCB's

U.S.A.

Control of PCB's in the U.S.A. is by individual states, with advice from FDA. Generally, the levels that are permitted are equivalent to those specified for DDT. They are "action" levels, not "regulatory", noting that they are not precedent setting. See Table 7. Certain Federal legislation that would include PCB control is being considered.

Monsanto, the sole producer of chlorinated diphenyls in the U.S.A., has limited their availability to sealed electrical systems, i.e., capacitors and transformers. Availability for other applications is being stopped. This action will cover all non-electrical users sometime in 1972.

United Kingdom

Monsanto's policies there are the same as in the U.S.A.

Sweden, Norway, and Holland

The governments of these countries are planning to set laws to limit usage and levels of PCB's.

Japan

Legislation may be enacted in Japan to control PCB's, following pressure from the news media.

Germany

Bayer, who produces chlorinated diphenyls in Germany, will be controlling its availability starting January 1, 1972.

France, Italy, and Russia

These countries are presently taking the attitude that PCB's do not present any problems.

TABLE 7
Generally Permitted "Action" Levels of PCB's
(same as those issued for DDT)

<u>Medium</u>	<u>Parts per Million PCB Permitted</u>
Water	.5
Butter fat	5
Milk	.2*
Fish	5
Eggs	.5

* for 4% butter fat

TABLE 8
Some Significant Properties of Certain Candidate Insulating Fluids
to Replace Aroclor 1242

Fluid	Dielectric Constant, ϵ'_r , at 100°C	Cleveland Open Cup Flammability		Density	Cost, ¢/lb
		Flash Point	- °C - Fire Point		
Aroclor 1242	4.9	194	333	1.38	18
Aroclor MCS 1016	4.9	191	319	1.36	18
Aroclor MCS 1043 (lower chlorinated diphenyl)	4.8	160	244	1.28	18
Ester Solution (R&D)*	3.7	150	160	.95	20
Wemco C Oil	2.1	145	150	.9	3
(Chlorinated diphenyl oxide)		More toxic than Aroclor (Monsanto)			

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