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Current Intelligence

Polychlorinated Biphenyls

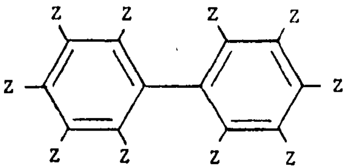
J. William Lloyd, Sc.D.; Roscoe M. Moore, Jr., D.V.M.; Barbara S. Woolf, M.S.; and Harvey P. Stein, Ph.D.

Reports of adverse health effects in humans and the demonstration of carcinogenic effects in certain animal species have led to the reexamination of the distribution of polychlorinated biphenyls (PCBs) in the environment and the potential health effects of human exposure.

Because the industrial environment represents the major source of potentially high exposures to PCBs, the National Institute for Occupational Safety and Health (NIOSH) has gathered pertinent information on the manufacture, uses, and reported deleterious effects of polychlorinated biphenyls and is advising the occupational health community of these hazards.

Background

Polychlorinated biphenyls (PCBs) describe a group of synthetic chlorinated organic compounds having the following structure:



where each of the ten Z's can represent either a hydrogen or a chlorine atom. There are 209 different chlorinated biphenyls and they are collectively referred to as PCBs although many are not actually *poly*chlorinated. Approximately half of these compounds have been synthesized and characterized.

Mixtures of polychlorinated biphenyls are important industrial products. The most common tradenames for these mixtures are Aroclor,* Inerteen,† Kanechlor‡ and Pyranol.¶ Other known tradenames for PCB-containing products are listed in Table 1. PCB-containing dielectrics (electrical insulators) are generally referred to as "askarels" in the electrical industry.

Mixtures of polychlorinated biphenyls are very resistant to degradation, are thermally stable, and resistant to oxidation, acids, bases, and other chemical agents. They are soluble in most of the common organic solvents and lipids, but only slightly soluble in water, glycerol, and glycols. PCBs are good electrical insulators. Although most individual polychlorinated biphenyls are solids at room temperatures, the mixtures vary in consistency from mobile oils to viscous liquids or sticky resins.

PCBs are generally prepared industrially by the chlorination of biphenyl with anhydrous chlorine in the presence of iron filings or a ferric chloride catalyst. Trace quantities of chlorinated naphthalenes and chlorinated dibenzofurans have been reported in some commercial samples of PCBs and it has been suggested that the presence of these impurities may be of toxicological significance.[1,2,3]

Commercial PCBs are generally mixtures of many different chlorinated biphenyls, as shown in Table 2, manufactured to meet operational specifications (such as dielectric constant, flash point, fire point, density, percent chlorine, and color); these commercial mixtures may vary chemically from batch to batch.

Table 1. — Tradenames for Known PCB Containing Products.

Tradename	Tradename Owner
Aroclor	Monsanto Company St. Louis, MO
Chlorextol	Allis-Chalmers Milwaukee, WI
Clophen	Farbenfabriken Bayer GmbH Germany
Dykanol	Federal Pacific Electric Co. Newark, NJ
Fenclor	Caffaro S.P.A. Italy
Inerteen	Westinghouse Electric Corp. Pittsburgh, PA
Kanechlor	Kanegafuchi Chemical Industry Co., Ltd. Japan
Noflamol	Wagner Electric Corporation Newark, NJ
Phenoclor	Prodelec France
Pyralene	Prodelec France
Pyranol	General Electric Co. Schenectady, NY
Santotherm	Mitsubishi-Monsanto Japan
Therminol*	Monsanto Co. St. Louis, MO

*Therminol products now formulated in the U.S. do not contain PCBs

From the Office of Occupational Health Surveillance and Biometrics, National Institute for Occupational Safety and Health, 5600 Fishers Lane, Rockville, MD 20852

PCBs have found wide use in industry and have been manufactured in the United States since 1929. The major domestic manufacturer, Monsanto Company, produces PCBs at Sauget, Illinois and reports manufacturing 40 million pounds of PCBs in the United States during 1974 (down from 85 million pounds in 1970).[4] Monsanto's domestic production and sales of PCBs by grade and category from 1957 through the first quarter of 1975 are shown in Table 3.

Uses

PCBs are employed in capacitors and transformers because they combine attractive dielectric properties with chemical stability and fire resistance. Approximately twice as many pounds of PCBs are used in the manufacture of capacitors as in the manufacture of transformers.

Prior to the environmental concern surrounding the persistence and ubiquitousness of PCBs,[5] they were more widely used in industry as fluids for heat transfer systems, hydraulic systems, gas turbines, and vacuum pumps, as fire retardants, and as plasticizers in adhesives, textiles, surface coatings, sealants, printing, and carbonless copy paper.

Beginning in 1971, Monsanto voluntarily restricted its domestic sales of PCBs to closed system dielectric applications in capacitors and transformers.[6] Other current domestic applications of PCBs include use in investment casting processes, as heat exchange fluids, and as hydraulic fluids. Imports of PCBs have been estimated to exceed 375,000 pounds for 1974. Reclaimed PCBs also are reported to be available.[7]

More than 95% of all power capacitors contain PCBs. Among their applications are use on electric utility lines, in air conditioners, and in the ballast of fluorescent lamp fixtures. PCBs are employed for safety, reliability, and long life, as well as to achieve size compatibility with equipment and installation requirements. However, non-PCB power capacitors are being manufactured (e.g., General Electric's Econol line and Sprague's Eccol line) which may serve as alternatives.[8,9]

PCBs are employed in transformers at locations where their proximity to people and/or property demand a fire resistant dielectric. Approximately 5% of transformers are PCB filled and each of the transformers so filled contains between 40 and 500 gallons of PCBs (about 235 gallons is average). Possible alternatives to PCB filled transformers may include dry transformers (which are larger) as well as transformers filled with silicone fluids or other materials under evaluation.[8,9]

Chlorinated terphenyls, as well as PCBs, are used in some formulations of wax for investment casting processes.[6] The chemical structure of chlorinated terphenyls resembles that of PCBs. Chlorinated terphenyls have been reported to have toxicological effects similar to those of PCBs.[10]

Approximately 330,000 pounds of chlorinated terphenyls were imported into the United States during 1974[11] and 125,532 pounds during 1973.[12]

Toxicity

PCBs are poorly metabolized and tend to accumulate in animal tissues, including humans.[13-17] The accumulation, particularly in tissues and organs rich in lipids, appears to be higher in the case of *penta* and more highly chlorinated biphenyls.[18]

Studies have revealed PCBs in human fat tissue and blood plasma. PCBs, in amounts greater than 2 parts per million, were reported in 198 of 637 (31%) samples of human fat tissue taken from the general population of 18 states and the District of Columbia.[14] PCB residues ranging up to 29 parts per billion have also been found in 43% of 616 plasma samples collected from volunteers in a southeastern U.S. county.[15]

Human

The known toxic effects of PCBs in humans include an acnelike skin eruption (chloracne), pigmentation of the skin and nails, excessive eye discharge, swelling of eyelids, and distinctive hair follicles.[19]

For a number of years, chloracne of the face and neck has been reported among workers exposed to chlorinated hydrocarbons. Workers exposed to PCBs in the process of insulating cables,[20] in the production of condensers[21] and in the manufacture of chlorobiphenyls[22] have reported these skin lesions along with systemic effects such as digestive distur-

Table 2. — Description of PCB Mixtures.

	Aroclor® 1221*	Aroclor 1016*	Aroclor 1242*	Aroclor 1254*	Aroclor 1260†	Kanechlor® 300‡	Kanechlor 400‡	Kanechlor 500‡
Approximate Chlorine Content	21%	42%	42%	54%	60%	42%	48%	53%
Components								
Biphenyl	11	<0.1	<0.1	<0.1				
Monochlorobiphenyls	51	1	1	<0.1				
Dichlorobiphenyls	32	20	16	0.5		17	3	
Trichlorobiphenyls	4	57	49	1		60	33	5
Tetrachlorobiphenyls	2	21	25	21		23	44	27
Pentachlorobiphenyls	<0.5	1	8	48	12	0.6	16	55
Hexachlorobiphenyls	none detected	<0.1	1	23	38		5	13
Heptachlorobiphenyls	none detected	none detected	<0.1	6	41			
Octachlorobiphenyls	none detected	none detected	none detected	none detected	8			
Nonachlorobiphenyls					1			

It must be emphasized that these are approximate compositions of the PCB mixtures and that a particular product may vary in chemical composition from batch to batch.
* Weight-weight percent. None detected = less than 0.01%. Source of component compositions: Monsanto Company, quoted in Hutzinger, O., et al., op. cit., p. 23
‡ Percent. Source of component compositions: Thruston, A., PCB Newsletter, No. 3, July 1971, quoted in Hutzinger, O., et al., op. cit., p. 23
† Percent. Source of component compositions: Ito, N., et al., op. cit., p. 1637

bances, edema of the face and hands, burning of the eyes, impotence, and hematuria.[16-22]

The toxic effects of PCBs in humans are further illustrated by a 1968 outbreak of poisoning in Japan that involved over 1,000 people who ingested PCB contaminated rice bran oil for a period of several months. The contamination of the oil (estimated 1,500 to 2,000 ppm) occurred when heat transfer pipes immersed in the oil during processing developed pin-sized holes. The clinical aspects of the poisoning included chloracne, brown pigmentation of the skin and nails, distinctive hair follicles, increased eye discharge, swelling of eyelids, transient visual disturbance, and systemic gastrointestinal symptoms with jaundice.[19] In some patients, symptoms persisted three years after PCB exposure was discontinued. Infants

Table 3. — PCB Manufacture and Sales Monsanto Industrial Chemicals Company. 1965 Through 1975 (Thousands of Pounds)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	(1st quarter) 1975
U.S. Production	60480	65849	75309	87854	76389	85054	34994	38600	42178	40466	8532
Domestic Sales	51798	59078	62466	65116	67194	73061	34301	26408	37742	34406	7966
U.S. Export Sales	4234	5852	8124	11231	10624	13651		6388	8346	5395	1538
Domestic Sales by Category											
Heat Transfer	1237	1766	2262	2529	3050	3958	3060	752			
Hydraulics/ Lubricants	4616	4256	4643	5766	8030	7403	1562	0			
Misc. Industrial	1841	1779	1426	1283	1079	1627	1155	0			
Transformer	9657	8910	11071	11585	12105	13828	11134	25656	37742	34406	7966
Capacitor	23749	28884	29703	29554	25022	28708	14141				
Plasticizer Applications	11696	13481	13381	14404	16400	19537	3259	0			
Petroleum Additives	—	—	—	—	1439	—	—	0			
Domestic Sales by PCB Grade											
Aroclor 1221	309	528	442	136	507	1476	2215	171	35	57	10*
Aroclor 1232	7	16	25	90	273	260	171	0	0	0	0
Aroclor 1242	31533	30957	43055	44853	45491	40500	21901	726	6200	6207	2201†
Aroclor 1248	5569	5015	4704	4894	5650	4073	213	807	0	0	0
Aroclor 1254	7737	7035	8096	8091	9022	12421	4061	3495	7976	6188	2115†
Aroclor 1260	5831	5875	6417	5252	4439	4890	1729	305	0	0	0
Aroclor 1262	558	768	840	729	712	1023	1	0	0	0	0
Aroclor 1268	196	284	287	200	300	330	0	0	0	0	0
Aroclor 1016	0	0	0	0	0	0	3334	20002	23531	21955	3660*

*Used primarily in capacitors

†Used primarily in transformers

1957 Through 1964

	1957	1958	1959	1960	1961	1962	1963	1964
U.S. Production	(1)	(1)	(1)	37919	38515	38353	44734	50833
Domestic Sales	32290	20081	31310	35214	37538	38043	38132	44888
U.S. Export Sales	(2)	(2)	(2)	(2)	(2)	(2)	3647	6096
Domestic Sales by Category								
Heat Transfer	—	—	—	—	—	157	582	929
Hydraulics/Lubricants	1632	1640	2688	2923	4110	3919	3946	4374
Miscellaneous Industrial	704	796	1509	1850	2114	1681	1520	1692
Transformer	12966	5719	9004	7921	6282	7984	7290	7997
Capacitor	17028	14000	16400	16067	19030	19302	15006	19040
Plasticizer Applications	(1)	3939	4973	6244	9098	8924	9101	10337
Petroleum Additives	—	—	—	—	—	—	—	—
Domestic Sales by PCB Grade								
Aroclor 1221	23	16	254	103	94	140	301	506
Aroclor 1232	186	113	240	156	241	224	13	13
Aroclor 1242	18222	10444	13990	18196	19027	20054	18610	23571
Aroclor 1248	1779	2598	3304	2827	4023	3403	5013	5238
Aroclor 1254	4461	6091	6784	6089	6294	6325	5911	6200
Aroclor 1260	7587	5982	6619	7330	6540	6596	7626	8636
Aroclor 1262	31	104	380	326	361	432	414	448
Aroclor 1268	—	72	102	100	150	210	204	190
Aroclor 1016	—	—	—	—	—	—	—	—

(1) Production figures and Plasticizer Applications figures unavailable during year indicated.

(2) U.S. Export Sales figures unavailable during year indicated.

Source: Monsanto Industrial Chemicals Company, St. Louis, Missouri, September, 1975.

born to poisoned mothers had decreased birth weights, and showed skin discoloration due to PCB placental passage. Two stillbirths to PCB exposed women were also reported.[23]

Animal

The toxic effects of PCBs in animals have been studied extensively. Reports of malignant, nonmalignant, and reproductive effects are shown in Tables 4, 5, 6.

Occupational Exposure

It is estimated that 12,000 people are occupationally exposed to polychlorinated biphenyls. The majority of these exposures are in capacitor production and in investment casting processes.

Permissible Occupational Exposure

The current Occupational Safety and Health Administration, Department of Labor standards for chlorinated biphenyls are 1 mg/cubic meter for 42% chlorine mixtures and 5 mg/cubic meter for 54% chlorine mixtures. These are based on the Threshold Limit Values (TLV) established by the American Conference of Governmental Industrial Hygienists.[15]

Table 4. — Malignant Pathologic Effects Induced by PCBs in Animals.

PCB Mixture	Treatment	Animal	Effects
Kanechlor 500[24] Kanechlor 400 Kanechlor 300	500 ppm, 250 ppm and 100 ppm in diet for 32 weeks	Mice	Liver weight increased with percent chlorine and dosage. Kanechlor 400 and 500 produced liver cell hypertrophy. 500 ppm of Kanechlor 500 produced hyperplastic nodules in 7 of 12 mice and hepatocellular carcinomas in 5 of 12 mice No nodules or carcinomas in controls
Aroclor 1254[25]	300 ppm in diet for 6 & 11 months	Mice	Increased liver weight. Adenofibrosis in all mice fed for 11 months. Nine of 22 mice fed for 11 months had hepatomas. One of 24 mice fed for 6 months had a hepatoma. No hepatomas in control mice.
Aroclor 1260[26]	100 ppm in diet for 21 months	Rats	Hepatocellular alteration in 182 of 184 rats fed PCBs and in 28 of 173 control rats. Neoplastic nodules in 144 of 184 PCB fed rats and none in control rats. Hepatocellular carcinomas in 26 of 184 rats fed PCBs and in 1 of 173 control rats.

Table 5. — Nonmalignant Pathologic Effects Induced by PCBs in Animals.

PCB Mixture	Animal	Route of Administration	Effects
Acute Effects			
Unspecified Product Containing 42% Chlorine[27]	Guinea pigs Rats Rabbits	Subcutaneous injection Skin application Feeding	Fatty degeneration and central atrophy of the liver.
Aroclor 1242[28] Aroclor 1254	Guinea pigs Rats Mice Rabbits Cat	Inhalation	Aroclor 1242 produced no ill effects on basis of mortality, growth, pathology, organ enlargement, liver function, or hematological changes. Aroclor 1254 produced no harmful effects regarding growth or mortality, but did produce enlarged livers with microscopic evidence of hepatic cellular injury.
Aroclor 1260[29]	Monkeys	Feeding	Weight loss, hair loss, mouth and eyelid edema, acneform lesions, decreased hemoglobin and hematocrit, severe gastric mucosal ulceration and extreme hypertrophy of the liver.
Chronic Effects			
Aroclor 1254[30] Aroclor 1260	Rats	Feeding	Hypertrophy of the liver cells, a brown pigment in the Kupffer cells, lipid accumulation in the cytoplasm of hepatocytes and adenofibrosis.

Table 6. — Reproductive Effects of PCBs in Animals.

PCB Mixture	Animal	Route of Administration	Effects
Aroclor 1242[31] Aroclor 1254 Aroclor 1260	Chickens	Feeding	Aroclor 1242 and 1254 reduced egg production and hatchability and caused thin eggshells. Aroclor 1260 produced no harmful effects.
Aroclor 1254[32]	Mallards Bobwhites	Feeding	No adverse effects.
Aroclor 1254[33]	Pheasant	Feeding	Reduced egg production and hatchability.
Aroclor 1254[34]	Mink	Feeding	Severely affected reproduction.
Aroclor 1248[29]	Female monkeys	Feeding	Reduced ability to become pregnant. Pregnancies produced small infants with PCBs in tissues.

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*Aroclor is a registered trademark of the Monsanto Company.

†Inerteen is a registered trademark of the Westinghouse Electric Corporation for its brand of PCB containing dielectric fluids.

‡Kanechlor is a registered trademark of the Kanegafuchi Chemical Industry Company, Ltd.

¶Pyranol is a registered trademark of the General Electric Company for its brand of PCB containing dielectric fluids.

§In December, 1975, The Dow Chemical Company and McGraw Edison Company announced the development of a substitute for PCBs in high voltage capacitors, butylated monochlorodiphenyl oxide.

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CLINICAL TOXICOLOGY

Mercury in Dental Offices: A Professional Hazard (Le mercure dans les cabinets dentaires: un risque professionnel). J. P. Magnaval, R. F. Magnaval and L. R. Karhausen. *Rev Epidém, Méd soc et Santé Publ* 23:53-62, 1975. F 34 Montpellier, 16, rue de Sceaux, F 92290 Châtenay-Malabry

French authors reviewed the literature of 16 papers or documents in English and three in French concerning the possible occupational risk of dental personnel. They reached the following opinions or cited others' conclusions. (1) The environment is being constantly polluted with mercury at an increasing rate (no reference given). (2) Dental personnel are exposed to a variable low level of mercury primarily from amalgams that may pose a possible long-term risk. (3) The routes of entry of vapors, particles, and larger masses were skin absorption, ingestion, and respiration. (4) There were positive correlations of mercury levels in the air with offices where amalgams were prepared but must less so in waiting and entry rooms. (5) The mercury levels in hair, fingernails and toenails of 66 dentists and 74 assistants were much above those of "unexposed" dental personnel. (6) Hair levels for mercury of some both increased and decreased with years of occupational exposure. About half of dentists never developed levels above that found in the general population. (7) Man is suggested in one study as able to methylate mercury like certain other animals.

Ancillary epidemiologic studies will be needed according to the authors to more succinctly evaluate the hazard. Meanwhile, authors recommend five preventive actions to reduce the exposure of dental personnel.

—G.E.Q.

Data on the Status of the Specific Female Functions of the Organism in Female Workers Exposed to Hexachlorocyclohexane. V. I. Il'ina and N.A. Blekherman. *Pediat Akush Ginekol* 36:46-49, 1974 (Ukrainian). All-Union Sci. Res. Inst. Hyg. Toxicol. Pesticides Polymers and Plastic Materials, Kiev, USSR.

The sexual functions were studied in women occupationally exposed to hexachlorocyclohexane (BHC), benzene, and chlorine for 2 to 11 years. Ovarian-menstrual disturbances (hypermenorrhea,