

SUBMISSION TO  
THE SUBCOMMITTEE ON OVERSIGHT AND INVESTIGATIONS  
OF  
THE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

U. S. HOUSE OF REPRESENTATIVES

By

Monsanto Company  
800 N. Lindbergh Blvd.  
St. Louis, MO 63166

November 16, 1979

MONS 010394

1. HISTORY OF MONSANTO PRODUCTION AND SALES OF CHLORINATED BIPHENYLS

Monsanto entered the chlorinated biphenyls business in 1935, when it purchased the Swann Chemical Company. Production and distribution increased until the early 1970s, when, in response to reports of its presence in the environment, Monsanto restricted sales of chlorinated biphenyls. In 1977, the company ceased production and distribution of chlorinated biphenyls in cooperation with the electrical industry. Chlorinated biphenyls were banned (except for certain applications) in the U.S. in 1979.

Sales and Distribution

The chemical structure of the polychlorinated biphenyls has been known for nearly 100 years. Commercial production of these materials was initiated in 1929 by the Swann Chemical Company in response to the electrical industry's need for improved dielectric insulating fluids which would also provide increased fire resistance when used in transformers and capacitors. (See para. 2, page 2 of the Interdepartmental Task Force on PCBs report, "Polychlorinated Biphenyls and the Environment," May 1972 - Attachment 1-1.)

As the unique functional characteristics of these materials became more fully understood, additional uses were found. Their fire resistance made them an excellent choice in high pressure hydraulic applications associated with high risk of fire such as die casting and steel production. Their thermal stability and fire resistance were valuable in heat transfer systems.

Their stability, low water solubility, low vapor pressure and solvency power made them attractive in carbon-less paper systems. Their fire resistance, thermal stability and viscosity characteristics made their use desirable in hot melt adhesives and other plasticizer applications.

Chlorinated biphenyls, therefore, evolved as a unique class of chemicals which met important needs for both industry and society. In some instances, fire and building codes required the protection of life and property offered by chlorinated biphenyls. It was within this framework that Monsanto and other producers developed a growing worldwide business for these versatile products. For a retrospective discussion of the benefits of chlorinated biphenyls, see Attachment 1-2.

The following charts show the data for chlorinated biphenyls through Monsanto's voluntary phaseout program to termination of production and sales in 1977. Significant points in these charts are:

- a. Heat Transfer -- Between 1970 and 1972, a task force of Monsanto engineers worked closely with customers to replace chlorinated biphenyl fluids with materials of equivalent thermal stability but with unavoidable lower fire resistance. Phaseout was completed in 1972.
- b. Hydraulic Fluid -- Development of replacement fluids began in 1970, and sales of chlorinated biphenyl-based fluids were discontinued in 1971.

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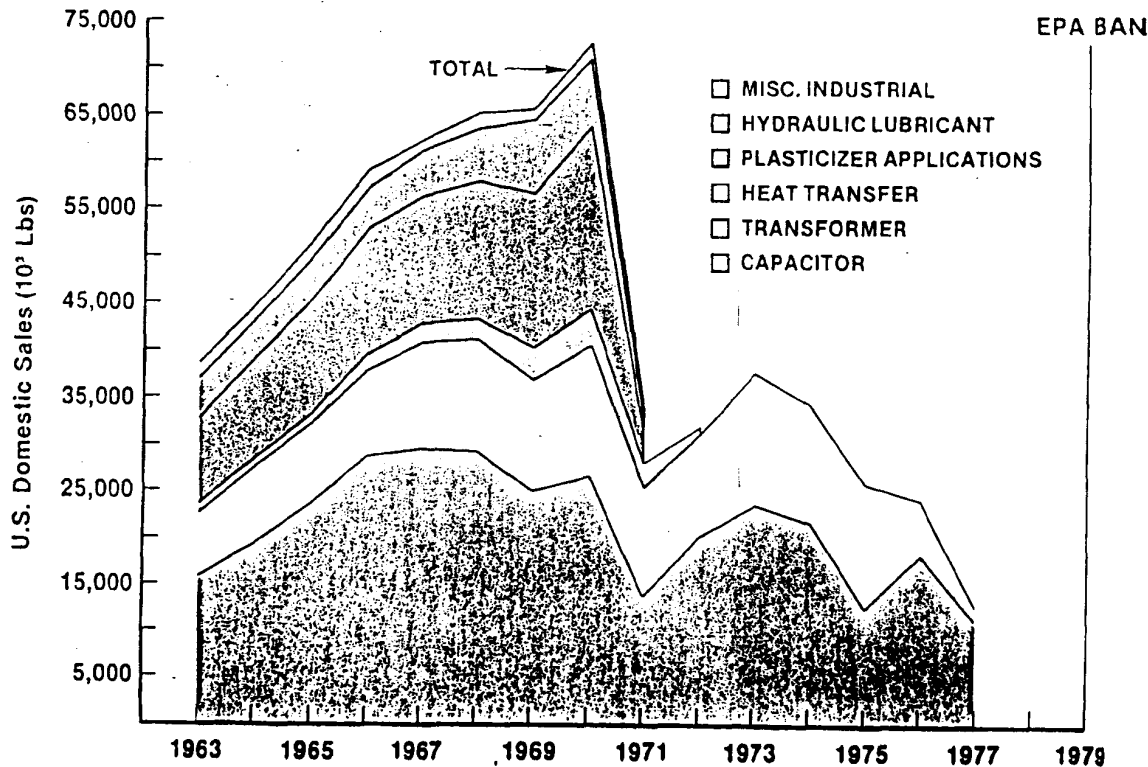
| U.S. PRODUCTION<br>(1) | 1957<br>(2) | 1958<br>(3) | 1959<br>(4) | 1960<br>(5) | 1961<br>(6) | 1962<br>(7) | 1963<br>(8) | 1964<br>(9) | 1965<br>(10) | 1966<br>(11) | 1967<br>(12) | 1968<br>(13) | 1969<br>(14) | 1970<br>(15) | 1971<br>(16) | 1972<br>(17) | 1973<br>(18) | 1974<br>(19) | 1975<br>(20) | 1976<br>(21) | 1977<br>(22) | 1978<br>(23) | 1979<br>(24) | 1980<br>(25) | 1981<br>(26) | 1982<br>(27) | 1983<br>(28) | 1984<br>(29) | 1985<br>(30) | 1986<br>(31) | 1987<br>(32) | 1988<br>(33) | 1989<br>(34) | 1990<br>(35) | 1991<br>(36) | 1992<br>(37) | 1993<br>(38) | 1994<br>(39) | 1995<br>(40) | 1996<br>(41) | 1997<br>(42) | 1998<br>(43) | 1999<br>(44) | 2000<br>(45) | 2001<br>(46) | 2002<br>(47) | 2003<br>(48) | 2004<br>(49) | 2005<br>(50) | 2006<br>(51) | 2007<br>(52) | 2008<br>(53) | 2009<br>(54) | 2010<br>(55) | 2011<br>(56) | 2012<br>(57) | 2013<br>(58) | 2014<br>(59) | 2015<br>(60) | 2016<br>(61) | 2017<br>(62) | 2018<br>(63) | 2019<br>(64) | 2020<br>(65) | 2021<br>(66) | 2022<br>(67) | 2023<br>(68) | 2024<br>(69) | 2025<br>(70) | 2026<br>(71) | 2027<br>(72) | 2028<br>(73) | 2029<br>(74) | 2030<br>(75) | 2031<br>(76) | 2032<br>(77) | 2033<br>(78) | 2034<br>(79) | 2035<br>(80) | 2036<br>(81) | 2037<br>(82) | 2038<br>(83) | 2039<br>(84) | 2040<br>(85) | 2041<br>(86) | 2042<br>(87) | 2043<br>(88) | 2044<br>(89) | 2045<br>(90) | 2046<br>(91) | 2047<br>(92) | 2048<br>(93) | 2049<br>(94) | 2050<br>(95) | 2051<br>(96) | 2052<br>(97) | 2053<br>(98) | 2054<br>(99) | 2055<br>(100) |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------|
| U.S. PRODUCTION<br>(1) | 1957<br>(2) | 1958<br>(3) | 1959<br>(4) | 1960<br>(5) | 1961<br>(6) | 1962<br>(7) | 1963<br>(8) | 1964<br>(9) | 1965<br>(10) | 1966<br>(11) | 1967<br>(12) | 1968<br>(13) | 1969<br>(14) | 1970<br>(15) | 1971<br>(16) | 1972<br>(17) | 1973<br>(18) | 1974<br>(19) | 1975<br>(20) | 1976<br>(21) | 1977<br>(22) | 1978<br>(23) | 1979<br>(24) | 1980<br>(25) | 1981<br>(26) | 1982<br>(27) | 1983<br>(28) | 1984<br>(29) | 1985<br>(30) | 1986<br>(31) | 1987<br>(32) | 1988<br>(33) | 1989<br>(34) | 1990<br>(35) | 1991<br>(36) | 1992<br>(37) | 1993<br>(38) | 1994<br>(39) | 1995<br>(40) | 1996<br>(41) | 1997<br>(42) | 1998<br>(43) | 1999<br>(44) | 2000<br>(45) | 2001<br>(46) | 2002<br>(47) | 2003<br>(48) | 2004<br>(49) | 2005<br>(50) | 2006<br>(51) | 2007<br>(52) | 2008<br>(53) | 2009<br>(54) | 2010<br>(55) | 2011<br>(56) | 2012<br>(57) | 2013<br>(58) | 2014<br>(59) | 2015<br>(60) | 2016<br>(61) | 2017<br>(62) | 2018<br>(63) | 2019<br>(64) | 2020<br>(65) | 2021<br>(66) | 2022<br>(67) | 2023<br>(68) | 2024<br>(69) | 2025<br>(70) | 2026<br>(71) | 2027<br>(72) | 2028<br>(73) | 2029<br>(74) | 2030<br>(75) | 2031<br>(76) | 2032<br>(77) | 2033<br>(78) | 2034<br>(79) | 2035<br>(80) | 2036<br>(81) | 2037<br>(82) | 2038<br>(83) | 2039<br>(84) | 2040<br>(85) | 2041<br>(86) | 2042<br>(87) | 2043<br>(88) | 2044<br>(89) | 2045<br>(90) | 2046<br>(91) | 2047<br>(92) | 2048<br>(93) | 2049<br>(94) | 2050<br>(95) | 2051<br>(96) | 2052<br>(97) | 2053<br>(98) | 2054<br>(99) | 2055<br>(100) |
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69. Production values and marketing applications shown separately above are estimates.

(9) U.S. Export Sales figures attributable during your business

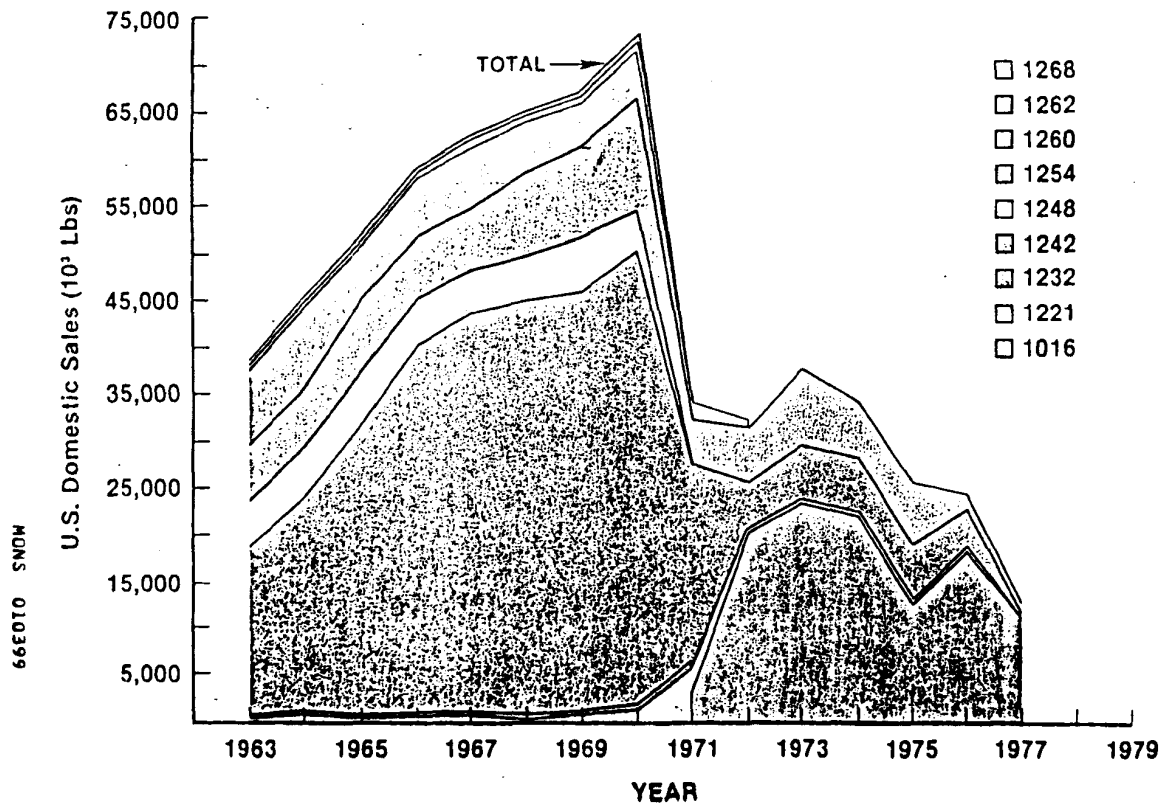
# U.S. DOMESTIC SALES OF PCBs BY CATEGORY

(The Uppermost Curve Represents The Total Sales.)



(The Uppermost Curve Represents The Total Sale)

**(The Uppermost Curve Represents The Total Sale)**



c. Plasticizer Applications -- Sales of most chlorinated biphenyl plasticizers were terminated in 1970, with phaseout completed in 1971.

d. Miscellaneous Industrial Uses (such as vacuum pump fluids) -- Sales ended by 1971.

These voluntary restrictions resulted in a 64 percent reduction in Monsanto sales of chlorinated biphenyls from 1970 to 1972.

However, termination of sales for dielectric uses would have resulted in severe economic and social dislocation. This was recognized by the federal Interdepartmental Task Force on PCBs which concluded in 1972 that "Their continued use for transformers and capacitors in the near future is considered necessary because of the significantly increased risk of fire and explosion and the disruption of electrical service which would result from a ban on PCB use." (See para. 6, page 4, of Attachment 1-1).

Therefore, Monsanto agreed to continue supplying the products to manufacturers of electrical power distribution equipment who use chlorinated biphenyls only in sealed systems such as capacitors and transformers. In continuing to sell to such customers, however, Monsanto required assurances that the materials would be safely handled and properly disposed of.

In making this decision Monsanto believed 1) that entry of chlorinated biphenyls to the environment could

be effectively limited and controlled by users (see Attachment 1-3, Westinghouse report presented at the January 3, 1972, meeting of the National Industrial Pollution Control Council), 2) proper maintenance and decommissioning practices could limit fluid escape from transformer operations, and 3) withdrawal from production for these applications would have stopped production of equipment essential to the safe and efficient distribution and use of electrical energy. In addition, a more biodegradable lower chlorinated product (AROCOR®1016) had been developed by Monsanto for use by the capacitor industry (see Attachment 1-4).

Steps Taken in Labeling and Transport Practices for Ongoing Dielectric Sales, 1972-1977

Monsanto shipped PCB fluids in both bulk carriers and in drums. Bulk shipments were made in Monsanto-owned railroad tank cars, which were used exclusively for that service, or in customer-owned tank trucks. Drum shipments were made in special reinforced drums. A multilingual warning label was affixed to each package giving a brief description of the nature of the contents and appropriate actions to be taken in the event of a spill or leak. We also supplied a label to be used on return shipments for incineration, which gave similar information.

Industry Guidelines

In June, 1970, the Board of Directors of the Power Equipment Division of the National Electrical Manufacturers Association appointed a committee to review the chlorinated

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AROCOR® is a trademark of Monsanto Company

biphenyl situation as it affected electrical usage. As a result, in April, 1971, American National Standards Committee C107 was established to develop guidelines for the safe use, maintenance and disposal of askarel\* and askarel-soaked materials used in electrical equipment. Monsanto participated in this committee. A final draft was completed by November, 1972, and the Standard Guideline was published in 1974 as ANSI C107.1-1974 (Attachment 1-5).

Monsanto's Withdrawal from the Chlorinated Biphenyl Business

When Monsanto decided in 1970 to restrict sales of chlorinated biphenyls, there were no satisfactory alternate materials for closed-system dielectric uses. This view was later affirmed by the EPA. At least as late as a 1975 press conference, the EPA reiterated it would not ask Monsanto to stop production because that would shut down the electrical power industry and the railroads in short order. The EPA objective was to find a way to proceed without shutting down the country. That was precisely the objective to which Monsanto had been committed since 1970.

The problems encountered in replacing chlorinated biphenyls were rooted in their unique fire resistant and dielectric characteristics and in their role in electrical and industrial applications for 45 years. The challenge facing the electrical industry was to replace chlorinated

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\* "Askarel" is a generic name for fire resistant dielectric fluids, including those which contained polychlorinated biphenyls, made to meet specifications set by transformers and capacitor manufacturers.

biphenyls in an orderly manner, without creating other hazards of equal or potentially greater magnitude, and at the same time avoiding serious power and transportation disruptions.

Monsanto expended considerable effort and money in major research programs aimed at developing environmentally compatible replacement fluids for the electrical industry. The level of this research was greatly reduced in 1976 when the electrical industry developed the technology to adapt other compounds to its needs. It now appears the ongoing demand for liquid-cooled transformers will be satisfied by using silicone compounds. In the capacitor industry, the trend has been toward materials such as phthalate esters.

In adopting these substitutes, the electrical industry has been forced to accept lower fire resistance. New safety devices have been required to ensure that replacement equipment will not lead to increased risk to society from fire hazards.

In our press statement of October 5, 1976, Monsanto said we would complete distribution of all inventories and withdraw from the chlorinated biphenyl dielectric business by October 31, 1977. In making the announcement, Monsanto said the company would have targeted an even earlier shutdown date had transformer and capacitor manufacturers' conversion timetables permitted. All chlorinated biphenyl production was halted by Monsanto in July, 1977, and all customer shipments were completed by September, 1977.

At the time we stopped PCB production, Monsanto established policies which precluded licensing of chlorinated biphenyl technology and restricted sales of biphenyl to uses which would not involve halogenation.

PCBs continue to be manufactured by other firms in Germany, France, Spain, Italy and certain eastern European countries. They continue to be widely used throughout the world.

#### Reasons for Monsanto Phaseout

Scientific knowledge about the presence of PCBs in the environment, and about its possible significance, began to evolve during the late 1960s (see, e.g., Attachment 1-6). That evolutionary process, which is still incomplete, began with two events--one in Japan and the other in Sweden.

In 1968, about 1,000 people in Japan became ill from eating rice oil heavily contaminated with Japanese-produced PCBs as a result of an industrial accident which has come to be known as the Yusho incident. The level of PCB contamination in the rice oil was 2000 to 3000 parts per million, extremely high concentrations. Conclusions about that incident have been clouded by the unknown impact of impurities in the Japanese PCB concerned (see pages 160-167, Attachment 1-7). However, the incident sounded a cautionary signal.

In Sweden, Soren Jensen, using new analytical technology to investigate DDT residues in the environment, reported the possible presence of PCBs in fish tissue. Monsanto and others began immediately to study the Swedish work, following preliminary news media reports in late 1966.

Before the findings could be confirmed or duplicated in the U.S., analytical methods had to be refined in order to definitively separate PCBs from other chlorinated hydrocarbons that were known to be present in the environment. New techniques were required to enable researchers to detect these chemicals in the low parts per billion ranges being reported.

The presence of PCBs in the environment in the U.S. was confirmed by 1970, but little was known about their potential impact. Because PCBs were reported in the environment and tests indicated they could accumulate in the food chain, Monsanto voluntarily decided to terminate sales of chlorinated biphenyls to open applications -- those which could result in losses to the environment. Plasticizer and carbonless paper applications fell into this category.

Because of the contamination of rice oil in Japan, food processors using Monsanto's chlorinated biphenyl heat transfer fluids were advised to change to alternative heating methods and Monsanto reemphasized the need for improved monitoring of finished food products to preclude contamination by any heat transfer fluid. The decision was made in 1971 to terminate all heat transfer fluid sales of chlorinated biphenyls, substituting other products with equivalent thermal stability.

High operating pressures cause hydraulic systems to leak. Monsanto therefore alerted users to manage wastes

to eliminate PCB discharge to the environment. As new hydraulic fluids were developed in 1971, we terminated sales of those containing PCBs.

As described earlier, Monsanto agreed with the electrical industry and government that the benefits to society of continued chlorinated biphenyl dielectric use outweighed the low risk of uncontrolled release from these sealed applications. The key to managing the risk was sound maintenance practice and disposal control.

With particular reference to the use of PCBs in human food and animal feed processing facilities, the FDA proposed usage regulations in 1972, which were adopted in 1973, and continue in force today (21 CFR §§109.15; 110.40(b); 500.45).

Although a variety of effects of PCBs has been postulated from research of widely varying quality, there is no evidence of environmental levels of PCBs being a major human health hazard. However, it became apparent that the public perceived risks associated with continued PCB dielectric use and preferred to forego its undoubted functional benefits. Therefore, in October of 1976, we advised dielectric customers that it was our intent, consistent with their progress with substitute products, to terminate chlorinated biphenyl production and sale by October, 1977. Each of them forecast how much product would be required to effect an orderly technical transition. In 1977, we made sufficient dielectric chlorinated biphenyl to satisfy the forecast transition demand and made final

shipments in September. The small residual inventory was incinerated in our pyrolysis unit, bringing to a close our chlorinated biphenyl business.

In summary, Monsanto's decision to withdraw from the PCB business was based on concerns about environmental presence rather than health effects.

## 2. INFORMATION ON HEALTH EFFECTS

Chlorinated biphenyls range from liquid to solid, depending upon the degree of chlorination. On the basis of single dose animal tests commonly used to identify and label hazardous materials, they would be considered to be relatively harmless substances. Monsanto has conducted such acute toxicity and irritation tests on several chlorinated biphenyls over the years (1).

Questions have been raised in four areas of possible health effects of chlorinated biphenyls. These have been related to 1) skin (reddening, chloracne), 2) systemic effects (liver damage, respiratory effects), 3) environmental exposure, and 4) potential carcinogenicity.

A review of the literature from the 1930s and 1940s on the health effects of chlorinated biphenyls contains statements such as "Much of the literature that refers to chlorinated diphenyls is referring to the mixture of chlorinated diphenyl with chlorinated naphthalene." and "A number of the references recorded under chlorinated naphthalenes also discussed chlorinated diphenyl. It is difficult to determine the role played by the chlorinated diphenyls, as, in most instances, they were mixed with chlorinated naphthalene" (2). A parallel situation occurred during the late 1960s when reports of the detection of polychlorinated biphenyls in the environment

began to appear. There was confusion and disagreement as to whether polychlorinated biphenyls or other halogenated hydrocarbons such as DDT were being measured, since the latter had already been identified as environmental contaminants.

#### Skin

Sometime before 1934, Swann Chemical Co. observed dermatological symptoms in workers exposed to chlorinated biphenyls. In May, 1934, Swann Research, Inc., requested Dr. F. B. Flinn of Columbia University's College of Physicians and Surgeons to conduct an investigation "to determine whether or not the various chlorinated diphenyl compounds submitted or some impurities contained therein might be the causative agent producing the dermatitis which had developed among some of the workmen in the plant." He commented on these studies as follows:

"One is impressed with the fact that each of the Aroclors giving a positive reaction were of a fluid nature. Attempts were made to expose the animals to vapors but observations made us conclude that the only difference was that the animal would be exposed to the hot material and it was well-known that the reaction where such an exposure is given is more severe.

"One cannot but feel that any styrene compound which may be found to be present as an impurity is the cause of your trouble. I was rather surprised that more of the compounds submitted did not show or give reactions with the skin. It has been shown in some investigations that chlorine did not produce a dermatitis when metallic electrodes were used but did if the metallic electrodes were replaced by carbon electrodes. The theory was advanced that some organic chlorine compounds were produced in the latter case.

"I would suggest that you study your ventilation system in places where fumes are given off. That means be provided for the men to take a bath with soap and water if they come in contact with the type of material found to be positive. By this I mean if a leak or spillage occurs. The immediate bathing under these circumstances should be insisted on. I found that where I had gotten the material on my hands if I washed them thoroughly no trouble arose."

In his transmittal letter to Dr. J. N. Carothers of Swann Research, Inc., Anniston, Alabama, Dr. Flinn stated:

"It may interest you to know that the dermatitis which was produced by your materials in the case of rabbits cleared up in a couple of weeks, indicating that unless there are repeated exposures the effects are only of a temporary nature. As I said before, I believe that if washing facilities are present and the men are instructed to use them it will do much to supplement the increased ventilation which you have installed." (3)

In the published literature, "the first observations on the development of acnelike lesions among workers in the United States coming in contact with chloronaphthalenes and chlorodiphenyls as well as acute yellow atrophy of the liver occurring among such workers were reported in 1935" (4). Results of Swann studies were published in 1936 (5).

There is a letter report dated December 22, 1949, to Dr. R. E. Kelly (Monsanto) from Dr. L. K. Halpern of the Barnard Free Skin and Cancer Hospital (St. Louis) describing a human patch study. This consisted of applying film treated with 11.5 percent AROCLOR and gauze moistened with 100 percent AROCLOR to skin of the upper arm of 213 volunteers using the

technique developed by Dr. Louis Schwartz, Medical Director of the United States Public Health Service. Dr. Halpern reported "If the procedure recommended by the United States Public Health Service is sufficient to distinguish between chemical compounds that are innocuous when applied to the skin and other compounds that are primary irritants or sensitizers, then it would seem that Aroclor has no primary irritant effect nor is it a sensitizer of high potency." (6) Monsanto records show that this study was conducted with AROCLOR 1254.

In 1963, Monsanto received reports of subacute rabbit dermal studies it had sponsored on several chlorinated diphenyls. Salient features of these studies, conducted according to then-currently acceptable procedures, are summarized below (1).

| <u>AROCLOR</u>      | <u>1221</u> | <u>1242</u> | <u>1248</u>     | <u>1254</u>     | <u>1268</u>     |
|---------------------|-------------|-------------|-----------------|-----------------|-----------------|
| No effect level*    | 150         | 50          | 10              | 10              | 500             |
| LD <sub>50</sub> ** | 250         | 75          | 50              | 75              | 1250            |
| Local skin effects  | none        | none        | none            | yes             | yes             |
| Systemic injury     | none        | none        | liver<br>injury | liver<br>injury | liver<br>injury |

\* All dosages in mg/kg/day

\*\* Based on 20-day dosing and 14-day observation periods

These studies showed that repeated and prolonged skin contact with the higher chlorinated biphenyls could produce skin irritation and that harmful amounts could be absorbed under such conditions. They also demonstrated that there was a safe level of exposure for each material, and that they could be handled safely if the earlier precautions to avoid excessive skin contact were observed.

#### Systemic Effects

On June 30, 1937, a symposium on systemic effects resulting from inhalation of chlorinated hydrocarbons was held at the Harvard School of Public Health. Dr. R. E. Kelly of Monsanto participated in the sessions at which results of investigations requested by manufacturers of chlorinated hydrocarbons were presented. Subsequently, three papers summarizing the results of those studies appeared in the scientific literature (7,8,9). With respect to chlorodiphenyls, the Harvard group concluded that "...it appears safe and it is certainly easily attained, to ventilate so that the air breathed does not contain more than 0.5 mgm. per cu.m. of any of these compounds...". In a separate unpublished report to Monsanto Company (10) Dr. C. E. Drinker of Harvard described the results of inhalation studies conducted with compound #1268, having a chlorine content of 68 percent. He concluded, "#1268, if handled with ordinary precautions as to ventilation, should be entirely harmless to workmen."

Monsanto sponsored a study at the University of Cincinnati's Kettering Laboratory on "The Toxicity of the Vapors of AROCLOR 1242<sup>R</sup> and AROCLOR 1254<sup>R</sup>." A report of those studies (11), presented at the 1956 meeting of the American Industrial Hygiene Association, stated that the investigation "...was undertaken because in the earlier literature dealing with the toxic effects of Aroclors, no distinction has been drawn between the toxic effects of chlorinated biphenyls and those of chlorinated naphthalenes..."

No injury was observed after prolonged intermittent exposure of several species of animals to AROCLOR 1242 at air concentrations of 1.90 to 8.63 micrograms per liter. Animals subjected to comparable exposures of AROCLOR 1254 showed signs of apparently reversible liver cell injury. The authors concluded their observations by saying "It should be noted that it was necessary to heat these Aroclors in order to increase the rate of volatilization sufficiently to attain the concentrations maintained in these experiments. To the extent that their industrial usage is carried out at ordinary temperatures, the hazard of their inhalation may well be slight or entirely absent."

These studies confirmed earlier work which indicated that no harmful effects were to be expected if these materials were used with adequate ventilation since it was necessary to heat the substances to generate sufficiently high air concentrations to injure the test animals.

Prior to 1956, the American Conference of Governmental Industrial Hygienists (ACGIH) had established a Threshold Limit Value (TLV) of  $1 \text{ mg/m}^3$  for chlorodiphenyl. In 1956, the listing was changed to read chlorodiphenyl (42% chlorine) as  $1 \text{ mg/m}^3$ . The 1957 list showed chlorodiphenyl (42% chlorine) as  $1 \text{ mg/m}^3$  and an added TLV of  $0.5 \text{ mg/m}^3$  for chlorodiphenyl (54% chlorine). The latter two values have been unchanged since then (12). Results of the Monsanto-sponsored study (11) contributed to the decision of the ACGIH to lower the TLV for the more highly chlorinated biphenyls (13).

#### Environmental Exposure

In response to reports of the presence of some PCBs in the environment, Monsanto, in 1969, initiated preliminary toxicity studies which led to a series of long-term tests. These tests, on the three predominant commercial polychlorinated biphenyls (AROCLOR 1242, AROCLOR 1254, AROCLOR 1260), consisted of 2-year (lifetime) feeding to rats, 2-year feeding to dogs, 3-generation rat reproduction studies with 2 litters cast per generation, rat teratology studies and dominant lethal mutagenic studies in mice. Toxicity and reproduction studies in chickens were performed to evaluate possible untoward effects in birds such as decreases in eggshell thickness. This series of studies (1) represented the most comprehensive safety tests of the time, and was similar to the tests required for food additives, although Monsanto certainly had no intention of applying for a food additive permit.

The highest dietary level (100 ppm) in the lifetime rat feeding studies produced a weight depression at 24 months in females fed AROCLOR 1254 and liver weight increases in all groups except males fed AROCLOR 1242. As with other halogenated hydrocarbons, the important histopathologic changes were present in the livers of animals sacrificed at the end of the study. These consisted of hepatocellular (liver) alterations such as focal hypertrophy (localized enlargement), cytoplasmic lipid changes and in some animals from the 100 ppm groups, hepatomas or cholangiohepatomas (benign tumors). There was no evidence of hepatocellular carcinogenicity with any of the AROCLOR products.

In the dog 2-year studies, some slight decreases in body weight gain were noted. At the highest feeding level (100 ppm) of AROCLOR 1260, there was evidence of gastrointestinal inflammatory lesions and ulcerations.

In the rat reproduction studies, none of the AROCLOR products produced adverse effects in the 2 litters of the first generation. In the second and third generations, there was a reduction in the mating index and a decrease in the incidence of pregnancy at the 2 highest feeding levels (10 ppm and 100 ppm). The ability of females to carry pups to delivery, once conception had occurred, and to successfully nourish the young was not affected by the three AROCLOR products. No changes were produced in the reproductive tracts of either male or female rats by any of the 3 AROCLOR products.

There was no evidence of teratogenic or mutagenic changes with any of the chlorinated biphenyls at maximally tolerated dose levels in rats and mice.

In the chicken toxicity/reproduction study, AROCLOR 1260 was without effect at all test levels. AROCLOR 1242 and AROCLOR 1254 at 100 ppm in the diet decreased egg hatchability. Poor hatchability of eggs was found from hens fed 8 ppm of AROCLOR 1242. AROCLOR 1242 at 10 and 100 ppm and AROCLOR 1254 at 100 ppm were associated with reduced eggshell thickness. Chick viability was affected by both substances at a dietary level of 10 ppm.

Data developed by Monsanto and information gained from the Yusho incident in Japan were cited by the Food and Drug Administration (FDA) as a basis for establishing tolerances for chlorinated biphenyls in various foods in 1973 (14). Subsequently, the FDA proposed a reduction in those tolerances (15).

In 1976 it was reported that AROCLOR 1248 in the diet of monkeys, at or below FDA tolerance levels for chlorinated biphenyls, adversely affected reproduction (16). FDA limits on PCBs in the human diet are related to a safe level of 1  $\mu\text{g}/\text{kg}$  body weight/day (14). The studies carried out by Allen and coworkers (16) were at dosage levels of approximately 89 and 183  $\mu\text{g}/\text{kg}/\text{day}$ . Their work suggested that there could be a previously unknown effect on reproduction in primates and they failed to define a no-effect level. Monsanto, therefore, undertook a detailed monkey reproduction study with carefully administered dosages at and below those previously studied.

In the Monsanto study, 32 female and 16 male rhesus monkeys, divided into 4 groups each consisting of 8 females and 4 males, were given daily dosages of 0, 5 µg/kg, 25 µg/kg or 100 µg/kg of AROCLOR 1254. The in-life portion of that study, which lasted about 14 months, has been completed.

At Monsanto's highest dosage (100 µg/kg/day), which corresponded to the low level in the Allen study, we find that AROCLOR 1254 has similar effects to those reported earlier for AROCLOR 1248. The results at the lower levels are not completely evaluated.

#### Potential Carcinogenicity - Animal Studies

In 1975, Dr. Renate Kimbrough reported the induction of liver carcinomas in female rats fed AROCLOR 1260 for two years (17). The same lot of AROCLOR 1260 was used in her study as in Monsanto's earlier test. Monsanto's study showed that AROCLOR 1260 as well as AROCLOR 1242 and AROCLOR 1254, produced liver injury, but no cancers. Therefore, an extensive reevaluation was made of the original liver slides from the Monsanto studies as well as additional liver sections from all rats in the Monsanto two-year feeding studies. These slides were examined independently by Dr. D. Gordon of Industrial BIO-TEST Laboratories, by Professor W. Richter of the University of Chicago and by Professor Parvis Pour of the Eppley Institute for Research in Cancer. In addition, Dr. Pour evaluated sections of liver from rats in Dr. Kimbrough's study.

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No carcinomas were seen in the livers of rats from the Monsanto studies, and Dr. Pour did not concur with Dr. Kimbrough's diagnosis of liver cancer in rats from her study (18) (see Attachment 2-2). The different criteria by which pathologists diagnose cancer, and the reported findings of cancer induced by polychlorinated biphenyls in various animal species, have been discussed by Dr. J. C. Calandra (19) (Attachment 2-3).

In 1977, the National Cancer Institute reported results of a bioassay for possible carcinogenicity of AROCLOR 1254. That report stated that AROCLOR 1254 was not carcinogenic under the test conditions (20).

#### Human Epidemiology Studies

The toxicity testing described above has provided a foundation for understanding the potential effects of chlorinated biphenyls. However, firm conclusions cannot be drawn without human epidemiological data drawn from exposed populations.

"The view that human health risks resulting from exposure to chemicals may be determined experimentally by testing laboratory animals is one that is widely accepted in the scientific community and has been adopted by EPA. Because experimentation on human beings raises ethical questions and because epidemiological studies often provide incomplete information, toxicology studies on laboratory animals are often necessary. However, because the extrapolation from animals to man is subject to some uncertainty, corroboration

of laboratory test data with sound epidemiological information is desirable." (U.S. EPA, Support Document/Draft Voluntary Environmental Impact Statement for Polychlorinated Biphenyls, 1978). Such epidemiological data on PCBs is now becoming available.

Monsanto is aware of seven epidemiological studies done in the U.S. of persons exposed to PCBs. They include persons with occupational as well as community exposure, and the effects studied range from deviations in biological parameters, through reported symptoms and illnesses, to the occurrence of death from various causes.

Selikoff and colleagues studied 326 volunteers who were occupationally exposed to PCBs. They report the percentage of those workers with various dermatological, gastrointestinal, neurological and other symptoms, as well as the percentage with abnormal values of clinical chemistry parameters and of pulmonary function. They concluded that reported symptoms and abnormal findings in physical examinations were not related to duration of employment or level of PCBs in the blood, except for abnormal dermatological findings and abnormal levels of some indicators of liver function. Although the authors claim to have found an unusual impairment of pulmonary function in their study population, no effort was apparently made to determine whether this impairment was related to the other findings (see Attachments 2-4 and 2-5).

In spite of a correlation of some liver function parameters with PCB exposure, the prevalence of abnormal liver function was low. The authors state, "The paucity of other abnormalities on physical examination was striking; this included a very low prevalence of abnormal liver findings." (emphasis in original).

The Center for Disease Control examined liver function and blood levels of chlorinated biphenyls in a sample of PCB workers, their families, and exposed persons in the community, in Bloomington, Indiana. This study found very mild liver dysfunction (increased levels of the enzyme GGTP) and increased blood levels of a cholesterol-like substance in persons with higher blood levels of PCBs. It is not clear if these findings have any relationship to actual illness (see Attachment 2-6).

The Michigan Department of Public Health conducted a study of 182 persons who regularly consumed sports fish, a source of PCB, and classified as "exposed", "intermediate" and "controls" according to the amount of fish consumed. A direct relationship was found between the amount of fish consumed and blood level of PCB. However, no significant difference was found between the controls and the exposed in the incidence of 18 health conditions, many of which described the symptoms reported for Yusho disease. Furthermore, in 12 of the 18 conditions, people with the condition had lower blood

PCB levels than those without the condition. The authors conclude, "As a group, the exposed participants had no health problems or medical conditions that could be correlated with PCB levels, exposure to Lake Michigan fish, or known symptoms of PCB poisoning" (see Attachment 2-7).

NIOSH has completed a study of mortality rates in workers in a transformer plant where there was exposure to PCBs, but Monsanto is unable to comment because a report of the study is not yet available.

The South Carolina State Department of Health and Environmental Control recently completed a study of 32 workers in a capacitor plant, 10 of whom were regularly exposed to PCBs. Details of the study available to Monsanto are limited to those contained in newspaper reports, but the study apparently involved a medical examination and a determination of blood PCB level. The authors state that the study "clearly shows that at present there is no evidence of physical harm resulting from working with PCBs." (See Attachment 2-8)

These four recent studies appear to constitute the most extensive epidemiological work yet done on chlorinated biphenyls. They each indicate an absence of morbidity (ill health) associated with significant exposure to PCBs.

The Mobil Corporation carried out a study of the occurrence of cases of cancer in a population exposed for varying lengths of time between 1949 and 1957. Plant medical

records were used to determine the occurrence of cancer in this group between 1958 and 1975. However, records were not available for about 20 percent of the eligible study group. The 41 men who were actually studied differed from the populations described above in that they were employed in a chemical plant which manufactured a number of different materials to which they might have been exposed during their working careers. The study found an excess of skin cancer (melanoma) based on three cases. After a preliminary report of these findings was made, the Mobil Corporation informed NIOSH that there had been "a substantial change" in the definition of the cohort, and that an analysis of the changed cohort might show quite different results. As far as Monsanto is aware, that analysis has not yet been completed.

In 1975, independent of the Mobil effort, Monsanto began to gather information for a mortality study of employees exposed to PCBs at its W. G. Krummrich plant in Sauget, Illinois. Because the plant had manufactured a number of chemicals those persons exposed to PCBs typically had a mixed exposure to other substances as they moved from job to job. Because the work histories of past employees were not computerized, it would have been necessary to identify those who had worked with PCBs by a manual search through 6,000 records. A preliminary identification was made of 50 deaths from various causes among past workers with PCB exposure, and a

review of these suggested a possible excess of lung cancer, but not of skin or pancreatic cancer. This preliminary finding was announced in 1976.

A further attempt to identify a cohort yielded 89 men who had been exposed for at least six months in the period 1945-1965, who were then followed to determine their vital status as of the end of 1977. There were no excess deaths from pancreatic cancer, but 4 lung cancer deaths were found where about 1.5 would be expected. Smoking histories were not available. The accuracy of the determination of this cohort was limited by the necessity of conducting a manual search of the records.

At the present time, computerization of the Krummrich work histories is underway, and should be completed early in 1980. At that time it will be possible to better define the exposed population, and to better determine the other substances to which the population was exposed. However, because of the mixed nature of exposures in a chemical plant, it is unlikely that the Monsanto study can ever be as specifically related to PCBs as those conducted by Dr. Selikoff, CDC, the Michigan DOH, and the South Carolina DOH.

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### 3. MONSANTO ACTIONS RESULTING FROM HEALTH DATA

Monsanto has been responsive to health questions about chlorinated biphenyls over the years. Those responses have been consistent with "state of the art" procedures available at the time the questions were raised. It should be noted that Monsanto's decision to leave the PCB business was based on concerns over environmental presence, not health effects.

#### Skin and Systemic Effects

When first reported in 1935 (1,2), the occurrence of skin and systemic effects from chloronaphthalenes and chlorodiphenyls constituted a new occupational health problem. It rapidly became of concern to federal and state occupational health personnel and to their industrial counterparts. Monsanto was among the sponsors of and a participant in the studies and the subsequent symposium held on this subject at Harvard University (3). In addition, Monsanto conducted its own studies on various polychlorinated biphenyls (4,5,6,7). Earlier, Swann Research, Inc. had conducted human patch tests on these materials (8). Results of these efforts suggested that controlling skin contact and vapor inhalation would permit safe industrial use of these substances.

In 1936, Monsanto began developing a corporate medical program. From the start, Monsanto's Medical Director ensured that chlorinated biphenyl workers at Anniston were included in this program. This consisted of periodic physical examinations, good work practices to ensure personal

cleanliness of employees, adequate ventilation of the work areas, and overall good industrial hygiene practices. The buildings at the Anniston plant were relatively open and most of the processing was done in closed equipment. Therefore, employee exposure was relatively low. However, since some customers were using chlorinated biphenyls at elevated temperatures, with a greater potential for exposure, precautionary statements for handling them were prepared for customer use as early as 1937 (9) (see Attachment 3-1, 3-2, 3-3). As additional information developed, it was incorporated into Monsanto work practices and distributed to customers by way of correspondence, technical bulletins, and other corporate publications (see Attachment 3-4). In addition, upon request, Monsanto technical and medical personnel visited customer plants to advise them on safe handling of polychlorinated biphenyls. Finally, the Monsanto-sponsored studies on AROCLOR 1242 and AROCLOR 1254 led the American Conference of Governmental Industrial Hygienists (ACGIH) to lower the Threshold Limit Value (TLV) for the higher chlorinated biphenyls in 1957 (10).

#### Environmental Presence

In late 1966, Soren Jensen of the Karolinska Institute in Sweden reported the detection of polychlorinated biphenyls in the environment. This was confirmed by 1970. In the interim, Monsanto's European office had entered into discussions with the Karolinska Institute in an attempt to obtain details of the findings. In early 1969, representatives

of Monsanto went from St. Louis to Sweden to meet with Jensen. He was not available, and discussions were held with his professor, Dr. Widmark. At about the same time, Monsanto decided to develop data on the chronic oral toxicity of chlorinated biphenyls. Although there was no intention of petitioning for such use, the extent of these tests was typical of those designed for the evaluation and establishment of the safety of direct and indirect food additives. This series of tests was undertaken because it represented the most comprehensive requirement of safety at that time (11). FDA was informed of the voluntary testing program in October, 1969 (12). Subsequently, as evidence of environmental presence increased, those studies were expanded in scope. Chicken studies to determine the effects of chlorinated biphenyls on avian species were completed in 1970 and 1971. Results of all these studies have been distributed to the FDA and other regulatory agencies. During this time period, Monsanto expanded the warnings on its product labels to include cautions against allowing escape to the environment (Attachment 3-5).

When, in 1976, reproductive disorders were reported in monkeys fed chlorinated biphenyls (13), Monsanto undertook a study to determine the validity of those findings. The Monsanto study is being conducted with AROCLOR 1254, a large volume material, instead of the relatively low volume AROCLOR 1248 used by the earlier investigators.

#### Potential Carcinogenicity

In 1975, after Dr. Kimbrough reported that AROCLOR 1260 produced liver cancer in rats (14), Monsanto undertook a

review of liver sections from its earlier studies on AROCLOR 1242, AROCLOR 1254, and AROCLOR 1260. In addition, it retained Dr. Pour of the Eppley Institute for Research in Cancer to review all liver sections from all of the AROCLOR studies, i.e., Monsanto's and Dr. Kimbrough's (15). That review showed no occurrence of liver cancers. Finally, Dr. Calandra was retained to review and comment on available literature dealing with carcinogenicity of polychlorinated biphenyls (16). Results of those evaluations have been made available to regulatory agencies.

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15. "Histopathological Re-evaluation of Livers from Rats Treated with AROCLOR." /Industrial BIO-TEST Laboratories, Inc. Reports and Eppley Institute Reports, 7
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#### 4. CUSTOMER RECORDS

Over the years, Monsanto developed the normal commercial records on its sales of chlorinated biphenyls. They were useful for sales and service calls, accounting, production forecasting, and, when decisions were reached to limit chlorinated biphenyls, customer lists served as the basis for our notification visits, telephone calls, letters, and publication mailings in the period 1970-1972, as we phased out all but dielectric chlorinated biphenyl sales.

## 5. COMMUNICATING WITH CUSTOMERS

### Notification Procedures

Beginning in February, 1970, Monsanto notified its customers of the early reports that PCBs had been detected in the environment. Additional information was transmitted to customers as it became available, along with details of Monsanto's phaseout. The notification letters included as Attachment 5-1 indicate the priority given to terminating applications that seemed relatively likely to lead to environmental release, were food related, or used the more highly chlorinated products. We cooperated with users of hydraulic fluids and heat transfer fluids to discontinue PCB use.

Simultaneously we introduced AROCLOR 1016, a lower chlorinated product for capacitor use, and restricted transformer fluid sales to equipment manufacturers only. In the case of both capacitor and transformer producers, we emphasized the need for control of PCBs. In 1974, Monsanto revised its dielectric literature to conform to the ANSI guideline (Attachments 5-2, 5-3, 5-4) which resulted from the industry work with ANSI referred to earlier. In 1976 the ANSI committee was reconvened to consider the need for revision of the guidelines. Completion of this task has been deferred pending issuance of EPA regulations on PCBs.

### Monsanto Provided PCB Disposal Assistance to Customers

In 1969 Monsanto started testing the efficiency of PCB destruction by high temperature pyrolysis and constructed

a 6 million pounds/year unit which was completed in May, 1971. This incinerator was designed, and was demonstrated, to destroy PCB wastes at 99.9998 percent efficiency (Attachment 5-5).

By September, 1971, this unit was in continuous operation and was destroying both waste from our production and PCBs returned by customers as they converted to non-PCB replacements. When phaseout from nonelectrical applications was complete, the incinerator was used to destroy waste PCB which collected from ongoing dielectric use.

A system was developed to properly handle customer return of wastes (Attachment 5-6). When some customers did not follow our suggested procedures, Monsanto reemphasized the need for proper packaging (Attachment 5-7). To assist in proper handling, posters were prepared and distributed to further educate those responsible for collection and handling of PCB wastes (Attachment 5-8).

In the period 1975-1976, large (approximately 80 million pounds/year) commercial facilities became available which could handle controlled PCB incineration more efficiently and economically than Monsanto's small prototype unit. Those units incinerated PCBs until their operations were curtailed by the need for a specific permit under the EPA disposal regulations for PCBs, which became effective on April 18, 1978. The first permit has yet to be issued. The potential risks of accidental PCB contamination have undoubtedly increased because of the delay in EPA implementation of its incineration policy.

Label Warnings

In 1970 Monsanto modified the labeling of PCB packages to emphasize the need to keep it from the environment (Attachment 5-9). Subsequently, labels on drums were written in seven languages (Attachment 5-10).

Assistance with Identification of PCBs

Because of the changes in composition of PCB dielectric fluids since their introduction, Monsanto worked with the IEC to document such changes. This led to ASTM standard D2283, which lists the composition of all transformer askarels used at various times since 1932 (Attachment 5-11).

Monsanto researchers worked within ASTM to develop refined technology for determination of PCBs in the environment. This resulted in approval of ASTM D3304 (Attachment 5-12) which has become standard methodology for PCB quantification. While many laboratories have the necessary equipment, proficiency in the methodology varies widely. Monsanto's Applied Sciences group regularly consults with laboratories as they gain experience in testing for PCBs. Regulations require many such tests to be performed. The testing load has been greatly increased by the policy EPA adopted in controlling PCB-contaminated oils at the 50-500 ppm level. This is causing serious delays in reporting of test results.

We recognized that after Monsanto terminated production of chlorinated biphenyls small samples of products which had previous commercial significance would be required for research and standardization of detection equipment.

Arrangements were concluded with a laboratory supply house to take custody of a limited drum quantity and to supply such samples.

Continuing Research

Monsanto is funding studies at two major universities which are directed at finding innovative approaches to reducing PCB levels in the environment.

#### 6. PCB DISPOSAL

During the years Monsanto made chlorinated biphenyls, the quantity of waste produced was relatively low and consisted chiefly of distillation residues, after separation of the useful product mix. Until 1971 these residues were landfilled. From 1971 to 1977 production waste was incinerated.

POLYCHLORINATED BIPHENYLS 1929-1979 :

FINAL REPORT

Final Report

Submitted to:

U.S. Environmental Protection Agency  
Office of Toxic Substances  
Washington, D.C. 20460

Attention: Mr. Thomas E. Kopp  
Project Officer

Contract No. 68-01-3259

Submitted by:

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May 16, 1979

MONS 010439

This report has been reviewed by the Office of Toxic Substances, U. S. Environmental Protection Agency, and approved for publication: Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Agency, nor does mention of tradenames or commercial products constitute endorsement or recommendation for use.

## PREFACE

This report summarizes the work on Polychlorinated Biphenyls (PCBs) that Versar performed for the U.S. Environmental Protection Agency under Contract No. 68-01-3259. Mr. Thomas E. Kopp was the Program Manager for the EPA throughout the performance of this work, and his patient support is gratefully acknowledged.

PCBs were first manufactured in commercial quantities in the U.S. in 1930, and during the next 40 years they were widely used as solvents, resins, and electrical dielectric liquids. Recognition of their environmental persistence and toxicity in the late 1960's eventually led to a ban on the manufacture and use of PCBs in the Toxic Substances Control Act of 1976. This report summarizes the use of PCBs and much of the early literature on the uses and toxicity of this material. In addition, the report reviews the regulatory actions that have been taken to limit the hazards to health and the environment resulting from the accumulation of PCBs in the environment and from their continued use in certain electrical equipment. The report is primarily a summary of the reports that Versar has prepared in support of the EPA's regulatory activities involving PCBs.

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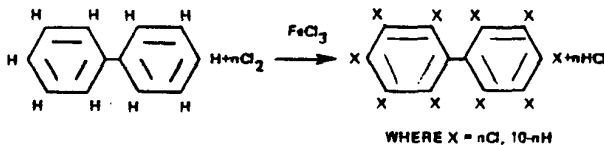
## 1.0 INTRODUCTION

On June 26, 1975, the U.S. Environmental Protection Agency awarded contract no. 68-01-3259 to Versar, Inc. Under this contract, it was anticipated that Versar would be assigned a number of tasks to assess the micro-economic impacts of regulatory alternatives which the EPA would consider for various toxic substances. The first task assigned under this contract required Versar to review and summarize the existing data on the use of polychlorinated biphenyls and to identify the industrial segments that might be impacted by regulations limiting the use of PCBs.

Before this task was completed, PCBs became a major issue within EPA, and the scope of the work assigned to Versar was increased as the agency required additional support. This report summarizes the work that Versar performed over the next four years for the EPA under the subject contract and a follow-on contract that was closely related to this work. All of this work supported regulatory activities involving PCBs, so the description of the work performed necessarily includes a history of the use of PCBs, a summary of regulatory development, and references to related research and reports.

## 2.0 POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls are a group of related compounds formed by the addition of chlorine to the aromatic hydrocarbon "biphenyl." The reaction can be described by the following equation:



### 2.1 History of PCB Usage:

PCBs were first synthesized and described in 1881 (Schmidt, 1881). Commercial production of PCBs did not become possible until after an economical method was developed during the 1920s for the manufacture of biphenyl from benzene.

Biphenyls were first produced in commercial quantities in the U. S. by Swann Research, Inc., of Anniston, Alabama. Shortly after they started manufacturing biphenyls, Swann Research described the manufacturing process (Jenkins, 1930) and the properties of the PCBs they were marketing under the tradename Aroclor (Penning, 1930). The various Aroclors were described as mixtures of chlorinated diphenyls with a wide range of properties from a light oil to a hard resin depending on the degree of chlorination. A number of commercial applications were suggested, including use in varnish, as a fireproofing agent for wood, in electrical equipment as a liquid dielectric and as a component of electrical insulation, as an ingredient in adhesives, as a replacement for Canada Balsam in microscopy, as a substitute for chicle in chewing gum, and in miscellaneous uses including printing inks and textile finishing (Penning 1930). A separate technical article described the compatibility of PCBs in nitrocellulose lacquer resins (Jenkins, 1931). The first major use of PCBs was apparently as a liquid dielectric in capacitors manufactured by General Electric Co. starting in 1930 (Clark, 1962). General Electric also developed the use of PCBs in other electrical applications as described in articles published during the 1930s (Clark, 1934; Clark, 1937).

PCBs were manufactured at the Anniston, Alabama, plant by Swann Research, Inc. and its corporate successor, Monsanto Chemicals Co., until the plant was shut down in 1971. Monsanto also manufactured PCBs at its plant at Sauget, Illinois, until 1977. The only other known U. S. manufacturer of PCBs was Geneva Industries of Houston, Texas, which manufactured PCBs for heat transfer applications from 1972 through 1974.

Most of the applications of PCBs that had been suggested in 1930 proved to be successful. PCBs were used as heat transfer liquids in critical applications such as food processing (Smith, 1955; Coulson, 1957), in various electrical applications (Clark, 1962), in sealants (Skrentny, 1971), in carbonless copy papers (Masuda, 1972; Lister, 1972), and in paint (Young, 1974). Polychlorinated terphenyls were suggested as a carrier for insecticides (Tsao, 1953; Sullivan, 1953). A Monsanto marketing guide to PCBs which was published in the late 1960s also described their possible use as expansion media in temperature sensing bellows devices, as liquid sealants for furnace roofs, as sealers for

gaskets, as dedusting agents, in insecticides, in casting waxes, in abrasives, in lubricants and cutting oils, in adhesives, in polishing waxes and impregnating compounds, in coatings, in inks, in mastics, in sealing and caulking compounds, in tack coatings, and as plasticizers in plastics, paint, varnish, and lacquer. (Monsanto, undated). In addition, a number of other uses of PCBs had been patented over the years (for a list of patents see: Interdepartmental Task Force on PCBs, 1972, pp. 70-74).

The available data on the toxicity of PCBs was first summarized in an article published in 1931 (Smyth, 1931). Skin problems attributed to PCB exposure were later reported to be associated with various industrial processes including PCB manufacturing (Jones, 1936), capacitor manufacturing (Mayers, 1936), industrial painting (Birmingham, 1942), and electrical cable insulating (Good, 1943). Systemic effects of exposure to mixtures of chlorinated organic compounds including PCBs were also noted during the 1930s (Drinker, 1937) and were evaluated by animal exposure studies (Bennett, 1938; von Wedel, 1943; Miller, 1944.) In much of this early work, the toxicity studies used commercial mixtures which included chlorinated naphthalenes, and the effects of PCBs were not conclusively demonstrated (Drinker, 1939). Animal exposure tests eventually defined the toxicity of PCBs (Treon, 1946; McLaughlin, 1963; American Industrial Hygiene Assoc., 1965), and reports of worker health problems became limited to unusual situations (i.e., Meigs, 1954). Information on the toxicity of PCBs led the investigation of PCBs as a possible cause of chick edema disease (McCune, 1962; Flick, 1965) which was later demonstrated to be caused by contamination of feed with chlorinated dibenzodioxins.

During the early 1960s interest increased concerning the biological effects of environmental levels of chlorinated pesticide residues such as DDT and chlordane. Measurement of low levels of these compounds in biological samples required the development of sensitive analytical procedures that could both separate the pesticides from each other and from similar compounds and measure the amount of each compound present. The technique that was developed to perform this analysis was gas chromatography. In this method, a small amount of sample is introduced into a long heated tube which is packed with a material that has

different adsorption characteristics for the different compounds in the sample. The tube is then flushed with an inert gas, and the different compounds are swept out of the tube at different times past a detector that is sensitive to the presence of chlorinated organic compounds and that gives a response proportional to the amount of chlorinated material in the stream of inert gas. The time required for each compound to move through the tube depends on the temperature, the type of packing, the rate of flushing with inert gas, and the characteristics of the particular compound. Therefore, the identification of the compounds in the environmental sample depends on knowing the retention time of the compounds and the response of the detector to each compound. This requires that known compounds be run through the column and detector, and as a result, only known compounds can be identified. Gas chromatography proved to be a very useful method for determining the concentrations of low levels of pesticides in environmental samples, but the detector usually recorded the presence of a number of chemicals that could not be identified by comparison with known pesticide chemicals.

In 1966, Soren Jensen attempted to identify the unknown compounds that were being recorded during routine pesticide analyses. In order to determine when the unknown compounds first appeared in biological samples, he analyzed feathers, from eagles that had been taken for museum collections. He found the unknown materials in feathers collected as early as 1944, before the widespread use of chlorinated pesticides, and so concluded that the unknown materials were not pesticides or degradation products of pesticides (Jensen, 1972). By testing chlorinated materials that were in wide use before 1944, he eventually identified commercial PCBs as the source of the unknown compounds, and published this finding in late 1966 (Jensen, 1966).

A full discussion of the presence of PCBs in pesticide analyses was published in 1967 (Widmark, 1967), and this set off a number of investigations to determine the extent of environmental contamination by PCBs. The discovery that PCBs were common in the environment in sufficient concentrations to affect the reproduction of wild birds was published in 1968 (Risebrough, 1968). This article was picked up in the press which started the widespread concern about possible human health effects from PCBs in the environment.

The Yusho incident that occurred in Japan during the summer of 1968 added to the public concern over the toxicity of PCBs. This was a case of widespread PCB poisoning caused by contamination of cooking oil. The PCBs were used as a heat transfer liquid on the high temperature side of a heat exchanger used to pasteurize the oil. Over 1000 people were seriously affected by eating contaminated oil (Kuratsune, 1971). The resulting concern over PCBs led to regulatory activity and increased research throughout the world. In July of 1971, a similar incident in the United States contaminated a considerable quantity of chicken feed as the result of leakage of PCB heat transfer fluid. The U.S. Food and Drug Administration eventually destroyed thousands of chickens and eggs that were fed this contaminated feed (Pichirrallo, 1971). Starting in 1970, Monsanto voluntarily limited sales of PCBs to closed electrical equipment applications (Wood, 1975) and recommended that existing PCB-filled heat transfer systems be drained and refilled with non-PCB fluid (Monsanto, 1972). This voluntary ban was completed by the end of 1973. Monsanto closed the Anniston, Alabama, manufacturing plant at this time.

By 1972, a great deal of research had been completed on PCBs and was summarized in various review articles covering their toxicity (Kinbrough, 1972; Kinbrough, 1974), environmental impact (Peakall, 1972; Hammond, 1972), environmental distribution (Nisbet, 1972), uses (Broadhurst, 1972), presence in food (Fries, 1972) and chemical analysis (Reynolds, 1971). The basic information on PCBs was later compiled in the monograph "The Chemistry of PCBs" (Hutzinger, 1974). The amount of published information on PCBs has continued to grow rapidly since the early 1970s and is now most accessible through published literature surveys (Fuller, 1976; Kornreich, 1976) and annotated bibliographies (Quinby, 1972; Office of Water Resources Research, 1973; Office of Water Research and Technology, 1975; Cavagnaro, 1978).

## 2.2 PCB Use Restrictions and Government Regulations

The Yusho incident created considerable concern in the U. S. over possible contamination of food by PCBs. The U. S. Food and Drug Administration started routine sampling of foods for PCBs in 1969, and soon found that PCBs

were present in fish from the Great Lakes, that there was PCB contamination of milk caused by use of PCBs as a solvent in pesticide sprays and as a component of sealants used in farm silos, and that there was contamination of chickens resulting from PCBs introduced into the feed as a component of ground bread cartons and wrappers. It has since become apparent that the presence of PCBs in fish is a problem that has existed since at least 1964 (Hartsough, 1965), although PCBs were not identified as the cause of the problem until 1971 (Aulerich, 1971; Aulerich, 1973).

From 1969 through 1971, the FDA established action levels for PCBs in food at 0.2 ppm in milk, 5 ppm in edible flesh of fish, 5 ppm in poultry, and 0.5 ppm in eggs. In 1970, the FDA prepared a summary of the available information on the chemistry and toxicity of PCBs (U. S. Department of Health, Education, and Welfare, 1970). In 1972, the FDA published a notice of proposed rulemaking (Federal Register, 37FR 5705). The U. S. Department of Agriculture also prepared a report on ways that it could act to limit PCB contamination of food (U. S. Department of Agriculture Ad Hoc Group on PCBs, 1972.) In 1973, the FDA formally established limits for PCBs in food and animal feed (Federal Register, 38FR 18096). The FDA proposed a revision of these limits in 1977 (Federal Register, 42FR 17487), but no action has yet been taken on this proposal.

During 1970, the Council on Environmental Quality (CEQ) studied regulatory approaches to the problem of toxic chemicals in the environment. In its report "Toxic Substances" published in 1971, CEQ identified PCBs as a major problem (Council on Environmental Quality, 1971). The initial response of the responsible agencies was to establish a task force to review the available information on PCBs and recommend regulatory alternatives (Interdepartmental Task Force on PCBs, 1972).

During 1973 and 1974, the EPA proposed the establishment of water quality criteria for PCBs in industrial discharges as part of a program for establishing such criteria for a larger group of pesticides. However, PCBs were not covered in the effluent standards that were eventually promulgated.

The Occupational Safety and Health Administration adopted the standards for PCB exposure in industrial air that had previously been established by the American Industrial Hygiene Association. The National Institute of Occupational Safety and Health conducted a major review of available data and an extensive program of industry assessment in the mid 1970s, and the final report recommended that the allowable concentration of PCBs in the work place be reduced (NIOSH, 1977). However, OSHA has not yet taken action on this recommendation.

Government actions restricting the use of PCBs were not limited to the United States. Japan banned the manufacture and use of PCBs in the early 1970s because of public pressure following the Yusho incident. Sweden banned the use of PCBs at about the same time. International actions were also taken to reduce the risk of food contamination by PCBs during the early 1970s (OECD, 1973; OECD Council, 1973; The Council of the European Communities, 1976).

### 3.0 CONTRACT SUPPORT OF EPA ACTIONS ON PCBs

#### 3.1 Support of Office of Toxic Substances

During 1974 and 1975, the Office of Toxic Substances sponsored a series of review studies to identify regulatory alternatives for various specified toxic substances. Contract 68-01-3259 was awarded by the EPA to Versar on June 26, 1975, to support similar work on additional chemicals. The first task on this new contract was assigned by the EPA Technical Project Officer, Mr. David Garrett, on June 27, 1975. This task required the contractor to study the role of PCBs in the U.S. economy and prepare a draft report by October 31, 1975, identifying and screening alternative regulatory and non-regulatory control options: Study of Regulatory Alternatives for PCBs: Draft Interim Report - Task I, October 31. (Unpublished - Superseded by "PCBs in the United States...")

As part of the review of PCBs, the Office of Toxic Substances sponsored a national conference on PCBs in Chicago on November 19 thru 21, 1975.

The Technical Coordinator of this conference was Mr. Thomas Kopp of the Office of Toxic Substances. Several major articles on the environmental effects of PCBs that appeared in the popular press shortly before the conference (Boyle, 1975a; Boyle, 1975b) caused considerable public interest in the conference and a number of demands that EPA regulate PCBs. Dr. Robert Durfee of Versar participated in this conference and presented a paper summarizing the background on PCBs as presented in the draft report (Durfee, 1975).

Because of the increasing importance of PCBs to the activities of the Office of Toxic Substances after the conference, the EPA assigned Mr. Kopp as Technical Project Officer on the contract and had the contractor expand the draft interim report and prepare four special reports under Task I.

The Versar Program Manager in charge of this work was Dr. Robert Durfee. The following reports were submitted in response to this directive:

- The Handling and Disposal of Electric Transformers: Special Report, Task I (December 5, 1975). Non-proprietary sections included in "PCBs in the United States...."
- Results from Review and Analysis of 308 Letter Responses on PCB Manufacturing, Usage, and Disposal in United States Industry: Special Report (December, 1975).
- \* Toxicological Studies Conducted Under Task I: Special Report (February 19, 1976). Incorporated in "PCBs in the United States..." as Appendix F.
- \* Development of an Economic Analysis Methodology for Evaluating Regulatory Alternatives for PCBs: Special Report, Task I (March 9, 1976). Unpublished.
- \* PCBs in the United States: Industrial Use and Environmental Distribution - Final Report, Task I (February 25, 1976). EPA 560/6-76-005. NTIS PB 252 012.

At about the same time that Task I was expanded, the EPA directed the contractor to perform two additional tasks. Task II was a study of wastewater treatment technology that could be used to reduce the concentration of PCBs in industrial effluents. This work was supported by Clark, Dietz Associates who performed the industrial economic analysis under subcontract from Versar as provided by Modification 1 to the contract. Task III was a plan for an assessment of the use of PCBs

\*See summary of report in Appendix C.

in the investment casting industry and the resulting environmental impacts. Versar program managers were Mr. Donald Sargent on Task II and Dr. Robert Durfee on Task III. The following reports were submitted in response to these work directives:

- \* Assessment of Wastewater Management, Treatment Technology, and Associated Cost for Abatement of PCBs Concentration in Industrial Effluents: Final Report, Task II. (February 3, 1976). EPA 560/6-76-006. NTIS PB 251-433/AS.
- \* Development of a Study Plan for Definition of PCBs Usage, Wastes, and Potential Substitution in the Investment Casting Industry: Final Report, Task III. (January, 1976) EPA 560/6-76-007. NTIS PB 251-842.

Based on these three tasks and on other work performed within the Environmental Protection Agency, the EPA published recommended disposal procedures for PCBs (Federal Register, 41 FR 14134) and proposed effluent standards for PCBs in the water discharges from PCB manufacturers and from capacitor and transformer manufacturers that used PCBs (Federal Register, 41 FR 30468).

Senator Gaylord Nelson introduced an amendment to the Toxic Substances Control Act (TSCA) on March 26, 1976. This amendment required the EPA to establish labeling and disposal requirements for PCBs and mandated an eventual ban on the manufacture and processing of PCBs. This amendment was incorporated into TSCA as Section 6(e) and became a legislated requirement when TSCA was signed into law on October 11, 1976. The effective date of TSCA was January 1, 1977.

On July 15, 1976, EPA modified the contract to support additional studies on several aspects of PCBs. EPA technical supervision of this work was the responsibility of Mr. Kopp. Under this contract modification (Mod. 4), four formal tasks were established and two additional reports were prepared for internal EPA use. The Versar program manager for this work was Mr. Robert Westin, with each report being the responsibility of a Versar Task Manager who was as the principal author of the report. The following reports were submitted in response to the requirements of this contract modification:

\*See summary of report in Appendix C.

- \* PCBs Involvement in the Pulp and Paper Industry: Final Report, Task IV. EPA 560/6-77-005, NTIS PB 271-071/6WP. February 25, 1977.
- \* A First Order Mass Balance Model for the Sources, Distribution, and Fate of PCBs in the Environment: Final Report, Task V. EPA 560/6-77-006, NTIS PB 270-220. July, 1977.
- \* Assessment of the Environmental and Economic Impacts of the Ban on Imports of PCBs: Final Report, Task VI. EPA 560/6-77-007, NTIS PB 270-225. July 1977.
- \* Assessment of the Use of Selected Replacement Fluids for PCBs in Electrical Equipment: Final Report, Task VII. EPA 560/6-77-008, NTIS No. forthcoming. April, 1979.

Environmental Discharges of PCBs Associated with the Manufacture and Use of PCBs and PCB-Containing Equipment. (Contains EPA proprietary information, submitted to EPA Enforcement Division.) October 29, 1976.

Usage of PCBs in Open and Semi-Closed Systems and the Resulting Losses of PCBs to the Environment. (Contains EPA proprietary information, submitted to EPA Enforcement Division). September 30, 1976.

### 3.2 Support of the Criteria and Standards Division

Versar provided support to the Criteria and Standards Division of EPA under three separate contract modifications. All of the work involved support of the effluent standards for PCBs by performing additional technical and economic analysis of the feasibility and costs of various pollution abatement technologies. The EPA Technical Program Manager on this work was Mr. Thomas Kopp, and the EPA Task Manager was Mr. Ralph Holtje of the Criteria and Standards Division. The Versar Program Manager was Mr. Donald Sargent. The contract modification requirements and the reports submitted were as follows:

Modification 2 (Feb. 27, 1976): Provided for the analysis of the economic impacts of the proposed regulation by Jack Faucett Associates under subcontract from Versar and for the review of the Final Task II report by Versar.

\*See summary of report in Appendix C.

- \* PCBs Water Elimination/Reduction Technology and Associated Costs: Manufacturers of Electrical Capacitors and Transformers: Addendum to Final Report, Task II. EPA 440/9-76-020. July 2, 1976.

Recommendations as to PCB Sampling Sites and Sampling Points at Industrial Sources: Special Report. August 17, 1976.

- \* Economic Analysis of Proposed Toxic Pollutant Effluent Standards for Polychlorinated Biphenyls: Transformer, Capacitor, and PCB Manufacturing. (Prepared by Jack Faucett Associates) EPA 230/T-76-068. October, 1976.

Modification 3 (June 10, 1976): Provided for additional assessment of wastewater management and treatment technology and support of EPA during formal hearings and rulemaking proceedings.

- \* Costs for U.V. - Ozonation Process: Addendum to Final Report, Task II. September 27, 1976. Unpublished.
- \* Detailed Cost Estimates for Alternative PCBs Treatment Technologies Applied to Hypothetical Large and Medium Sized PCB Capacitor and Transformer Manufacturing Plants. Addendum to Final Report, Task II. October 15, 1976. Unpublished.
- \* Cost for Equalization Basin Based on Bentonite Clay Liner Special Report, October, 1976. Unpublished.
- \* Impacts of Substitutes for PCBs on Fire Hazards in Commercial and Residential Buildings: (Draft) Special Report. October, 1976. Unpublished.
- \* Recent Advances in PCBs Detoxification in Wastewater: Supplement to Final Report, Task II. January 18, 1977. Unpublished.
- \* PCB Levels in Non-Contact Cooling Waters and Other Effluents from Capacitor and Transformer Production Facilities: Supplement to Final Report, Task II. January 18, 1977. Unpublished.
- \* Refinement of Alternative Technologies and Estimated Costs for Reduction of PCBs in Industrial Wastewaters from the Capacitor and Transformer Manufacturing Categories. January 19, 1977. Unpublished.
- \* Costs Associated with Installing Production Equipment for Use of Non-PCB Dielectric Fluids in Transformer and Capacitor Manufacture: Supplement to Final Report, Task II. January 19, 1977. Unpublished.

\*See summary of report in Appendix C.

On February 2, 1977, the EPA promulgated effluent standards restricting any discharges of PCBs in the wastewaters from manufacturers of PCBs or from capacitor and transformer manufacturing plants that used PCBs after February 2, 1978 (Federal Register, 42 FR6531).

### 3.3 Support of PCB Work Group - Disposal and Marking Regulations

Section 6(e)(1) of the Toxic Substances Control Act required the EPA to regulate the labeling and disposal of PCBs by July 1, 1977. On December 8, 1976, the EPA announced the formation of a PCB Work Group to write the proposed rules. The contractor provided staff support to this work group, providing a number of special reports as requested, performing the economic impact analysis of the proposed regulation, and providing testimony at the rulemaking hearing. The contract was modified on March 25, 1977, (Mod. 6) to authorize this additional technical and economic support. The EPA Project Officer for this work was Mr. David Wagner, and Mr. Thomas Kopp remained the Technical Project Officer in charge of the total contract. The Versar Program Manager was Mr. Robert Westin. The following reports were submitted in support of the development of the PCB Marking and Disposal Regulations:

Assessment Methodology for Labeling and Education to Assure the Proper Disposal of PCBs: Special Report. November, 1976.

Analysis of the Economic and Technological Constraints on the Disposal of PCBs: Special Report. November 22, 1976.

PCB Disposal Regulations: Problem Areas and Regulatory Alternatives: Special Report. December 10, 1976.

Estimated Usage of Electrical Equipment Containing PCBs: Special Report. December 23, 1976.

Recommended Label Requirements and Suggested Label Formats: Special Report. January 12, 1977.

Draft Notice of Public Meeting - PCBs. January 10, 1977.

Comments on PCB Definitions to Subcommittee on Manufacturing Bans. January 14, 1977.

\*See summary in Appendix C.

Draft Notice of Proposed Rulemaking, Preamble, and Labeling and Disposal Regulations: Special Report. January 21, 1977; revised February 4, 1977.

Labeling and Disposal Regulations: Revised Draft. January 27, 1977.

Draft Preamble to PCB Disposal Regulation. December 29, 1976; revised January 12, 1977; revised February 4, 1977.

Economic Impact - Summary and Conclusions: Special Report. March 14, 1977.

Statement of Economic Consequences of the Rule: Special Report. April 12, 1977.

- \* Microeconomic Impacts of the Proposed Marking and Disposal Regulations for PCBs. April, 1977. EPA 560/6-77-013, NTIS PB 267-933.

EPA formally proposed the rules for marking and disposal of PCBs on May 24, 1977 (Federal Register, 42 FR 26564). Rulemaking hearings were held on June 24, 27, 28, and 29. Mr. Westin of Versar presented testimony on the economic impacts of the proposed regulation at the hearings on June 29. The EPA promulgated the PCB Disposal and Marking Regulations on February 17, 1978 (Federal Register, 43 FR 7150) and issued corrections on August 2, 1978 (Federal Register, 43 FR 33918). The effective date of the regulations was April 18, 1978.

### 3.4 Support of PCB Work Group - PCB Ban Regulations

Sections 6(e)(2) and 6(e)(3) of the Toxic Substances Control Act banned the manufacturing, processing, distribution, and use of PCBs after January 1, 1978, except in a totally enclosed manner; completely banned the manufacture of PCBs after January 1, 1979; and completely banned the processing and distribution in commerce of PCBs after July 1, 1979. However, the Act also authorized the EPA to exempt those activities involving PCBs that did not present an unreasonable risk of injury to health or the environment provided

\*See summary in Appendix C.

that good faith efforts were made to develop an adequate substitute for PCBs in that use. On June 27, 1977, the EPA announced the formation of a PCB work group to develop proposed regulations implementing these provisions of the act, and announced public meetings on the subject to be held in Washington, D.C. on July 19, 1977 (Federal Register, 42 FR 32555).

EPA modified the contract on June 26, 1977, (Mod. 7) to provide for support during the development of the proposed ban regulations. EPA Project Officers continued to be Mr. Wagner and Mr. Kopp. Versar's work was supervised by Mr. Westin. Versar prepared briefing papers for the work group prior to the public meetings and submitted them to the work group as the special report: Potential Impacts of the Bans on PCB Manufacturing, Processing, and Use: PCB Activity Analysis Papers (July 11, 1977).<sup>\*</sup> Following the public meetings, the work group prepared a draft of the proposed regulations (August 30, 1977), and the contractor submitted a formal report on the economic impacts of these regulations: Microeconomic Impacts of the Draft "PCB Ban Regulations": Draft Report (September 18, 1977). Formal proposal of the ban regulations was delayed while the Work Group prepared the final version of the Disposal and Marking Regulations, and on December 30, 1977, EPA announced that it would not enforce the January 1, 1978 ban on open system activities involving PCBs until after formal ban regulations were promulgated (Federal Register, 42 FR 65264).

The work group continued to revise the draft proposed regulation, and Versar submitted a major revision of the economic impact analysis reflecting the changes in the proposed regulation and including appendices characterizing the U.S. waste oil industry and presenting a formal microeconomic analysis of the supply and demand effects of the PCB Ban on the electric equipment industry: Microeconomic Impacts of the Draft "PCB Ban Regulations": Revised Draft Report (March 8, 1978).<sup>\*</sup>

### 3.5 Support of EPA Office of Planning and Management - PCB Ban Regulations

In early 1978, the EPA transferred responsibility for the analysis of the economic impacts of the PCB ban regulations from the PCB Work Group to the

<sup>\*</sup>See summary in Appendix C.

Office of Planning and Management. On April 19, 1978, the EPA awarded contract number 68-01-4771 to Versar for additional economic analysis, preparation of a revision of the previously submitted draft economic impact report, and support during the public hearings on the proposed regulations. The EPA Technical Project Officer was Mr. Steven B. Malkensen, Office of Planning and Management. The Versar Program Manager was Mr. Robert Westin. In May, 1978, the contractor submitted the revised report: Microeconomic Impacts of the Proposed "PCB Ban Regulations"\* that was issued in support of the proposed regulations as EPA Report No. EPA-560/6-77-035.

The EPA formally proposed the PCB Ban Regulations on June 7, 1978 (Federal Register, 43 FR 24801). Public hearings were held in Washington, D. C., from August 21 through September 1, 1978. Mr. Westin of Versar presented testimony on the economic impacts of the proposed regulations on September 26, 1978.

Following the hearings, EPA continued to revise the ban regulations. On November 1, 1978, EPA published interim procedural rules for filing and processing petitions for exemptions from the January 1, 1979 bans on manufacturing of PCBs (Federal Register, 43 FR 50905). On January 2, 1979, EPA announced that it would not enforce the prohibitions on PCB manufacturing, processing, distribution in commerce, and use until after formal promulgation of the PCB Ban Regulations (Federal Register, 44 FR 109).

On November 15, 1978, Versar submitted a draft report on the economic impacts of the draft ban regulations: PCB Manufacturing, Processing, Distribution in Commerce, and Use Ban Regulation: Economic Impact Analysis: Draft Final Report. A major revision of this report was submitted on December 22, 1978. On December 27, 1978, EPA modified contract 68-01-4771 to extend the duration of the contract and to fund further revisions of the economic impact analyses as required by additional changes to the draft regulation. Mr. Stephen Weil was assigned to be the EPA Technical Project Officer for this contract modification. The contractor submitted the final revision of this

\*See summary in Appendix C.

report on March 30, 1979.\* EPA issued the final regulations on April 19, 1979. Formal promulgation of the regulations through the Federal Register was expected to occur by the end of May, 1979.

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\*See summary in Appendix C.

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MONS 010464

APPENDIX A

FEDERAL REGISTER NOTICES REGARDING PCBs

MONS 010465

Environmental Protection AgencyEffluent Limitations (§ 307a Clean Water Act)

| <u>Date</u>  | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                                           |
|--------------|-------------|--------------|----------------------------------------------------------|
| July 6, 1973 | 38          | 18044-5      | Proposed List of Toxic Pollutants,<br>Including PCBs.    |
| Sept 7, 1973 | 38          | 24342-4      | Promulgated List of Toxic Pollutants,<br>Including PCBs. |
| Dec 27, 1973 | 38          | 35388-95     | Proposed Water Effluent Standards,<br>Including PCBs.    |
| Mar 5, 1974  | 39          | 8325-6       | Public Hearings on Effluent Standards.                   |
| Mar 21, 1974 | 39          | 10603-4      | Correction - Effluent Standards.                         |
| Jul 23, 1976 | 41          | 30468-77     | Proposed Effluent Standards.                             |
| Feb 2, 1977  | 42          | 6531-55      | Effluent Standard Regulations.                           |

Spill Reporting Requirements (§ 311, Clean Water Act)

| <u>Date</u>  | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                                                                                        |
|--------------|-------------|--------------|-------------------------------------------------------------------------------------------------------|
| Feb 16, 1979 | 44          | 10266        | Definition of "Discharge" under Clean<br>Water Act.                                                   |
| Feb 16, 1979 | 44          | 10271-84     | Defines Reportable Quantities of PCBs<br>Spilled into Waterways, Reporting<br>Requirements and Fines. |

Disposal and Marking Regulations (§ 6el) Toxic Substances Control Act

| <u>Date</u>  | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                                                                                                              |
|--------------|-------------|--------------|-----------------------------------------------------------------------------------------------------------------------------|
| Apr 1, 1976  | 41          | 14134-36     | Recommended Disposal Procedures.                                                                                            |
| Dec 8, 1976  | 41          | 53692        | Panel Discussion/Formation of PCB Work Group.                                                                               |
| Jan 5, 1977  | 42          | 1067         | Rescheduling of Meeting.                                                                                                    |
| Jan 19, 1977 | 42          | 3701-2       | Notice of Jan. 24, 1977 Public Meeting.                                                                                     |
| Apr 21, 1977 | 42          | 20640-44     | Proposed Procedures for Rule-Making under Sect. 6 of TSCA.                                                                  |
| May 24, 1977 | 42          | 26564-77     | Proposed Marking and Disposal Regulations.                                                                                  |
| Jul 15, 1977 | 42          | 36484-85     | Deadline for Reply Comment Period.                                                                                          |
| Feb 17, 1978 | 43          | 7150-64      | Promulgated Marking and Disposal Regulations.                                                                               |
| Jul 18, 1978 | 43          | 30882-3      | List of Approved PCB Disposal Facilities.                                                                                   |
| Aug 2, 1978  | 43          | 33918-20     | Corrections to Marking & Disposal Regulations.                                                                              |
| Aug 25, 1978 | 43          | 38087-88     | List of Approved PCB Disposal Facilities.                                                                                   |
| Oct 26, 1978 | 43          | 50041        | List of Approved PCB Disposal Facilities.                                                                                   |
| Dec 20, 1978 | 43          | 59432-3      | List of Approved PCB Disposal Facilities.                                                                                   |
| Mar 12, 1979 | 44          | 13575        | Request for Comments on Citizens' Petition to Give Regional Administrators Authority to Approve Alternate Disposal Methods. |

Ban Regulations (§ 6e2, 6e3, etc.) Toxic Substances Control Act

| <u>Date</u>   | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                                                                                        |
|---------------|-------------|--------------|-------------------------------------------------------------------------------------------------------|
| Jun 27, 1977  | 42          | 32555        | Notice of July 19 Chicago Hearing.                                                                    |
| Dec 30, 1977  | 42          | 65264        | Notice that EPA Would Not Enforce Ban on Uses in "Other Than a Totally Enclosed Manner."              |
| Jun 7, 1978   | 43          | 24802-17     | Proposed Ban Regulations.                                                                             |
| Jun 7, 1978   | 43          | 24818        | Requires Notification of Intent to Export.                                                            |
| Aug 25, 1978  | 43          | 38057        | Incorporates Hearing Record of Effluent Standard Regulations into Hearing Record for Ban Regulations. |
| Sept 22, 1978 | 43          | 43048        | Notice of Cross-Examination of Versar.                                                                |
| Nov 1, 1978   | 43          | 50905-07     | Interim Rules: Applications for Exemption from PCB manufacturing ban.                                 |
| Jan 2, 1979   | 44          | 108-109      | Notice that enforcement is postponed until regulations are promulgated.                               |
| May , 1979    | 44          |              | Promulgated Ban Regulations                                                                           |

Food and Drug Administration

| <u>Date</u> | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                                        |
|-------------|-------------|--------------|-------------------------------------------------------|
| 1972        | 37          | 5705-5707    | Notice of Proposed Rule-Making.                       |
| Jul 6, 1973 | 38          | 18096-103    | Limits of PCBs in Foods, etc., Aug. 8<br>Corrections. |
| 1975        | 40          | 11563-66     | PCBs in Paper/Food Packaging Material.                |
| Apr 1, 1977 | 42          | 17487-94     | PCBs in Food - Proposed Changes.                      |

National Cancer Institute

| <u>Date</u>  | <u>Vol.</u> | <u>Pages</u> | <u>Subject</u>                   |
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| Apr 21, 1978 | 43          | 17060        | Carcinogenicity of Aroclor 1254. |

APPENDIX B  
VERSAR REPORTS TO EPA RELATED TO PCBs

MONS 010470

Contract 68-01-3259 - EPA: Mr. Thomas Kopp, EPA Technical Project Officer

Office of Toxic Substances

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Contract 68-01-4771

Office of Planning and Management: Mr. Steven Malkenson, Mr. Stephen Weil,  
EPA Technical Project Officers

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APPENDIX C  
SUMMARY OF MAJOR VERSAR REPORTS REGARDING PCBs

MONS 010476

## TOXICOLOGICAL STUDIES CONDUCTED UNDER TASK I

Special Report February 19, 1976  
(Included in "PCBs in the United States..." as Appendix F)

This study presents the results of two general areas of effort concerned with PCBs: the toxicology of PCBs and the testing of potential substitutes for PCBs.

The toxicological aspects of PCBs are summarized, with emphasis placed on potential human health hazards caused by widespread use of PCBs in the United States. Tests have been conducted on the toxicity and carcinogenicity of PCBs in a variety of animals including rats, dogs, rabbits, and monkeys. In addition, there was an incident in Japan where approximately 1,000 people consumed rice oil that was contaminated with PCBs.

Reviewing the results of these studies led to several important conclusions. PCBs tend to localize in certain tissues and do not break down easily in the body, leading to cumulative or chronic toxicity. Early toxicological evidence concerning the chronic adverse health effects of PCBs from experimental animals such as mice and rats and from observational data in humans has more recently been supplemented by additional experimental findings in monkeys. A close correlation exists for PCBs between the symptoms noted in humans and those noted in monkeys, suggesting that the dose/response relationships and metabolic and excretion phenomena in humans are similar to those in monkeys. According to some pathologists, PCB exposure can cause cancerous liver lesions. Evidence from short-term (several months) exposure and chronic exposure in animals and humans demonstrates that PCBs are a significant health hazard.

Following the review of the toxicological potential of PCBs, a study was made of the procedures necessary for evaluating the potential hazards from possible PCB substitutes. Preliminary information necessary for a thorough investigation of a substance includes:

- 1) Physical and chemical properties
- 2) Manufacturing processes and possible losses
- 3) Chemodynamics, environmental alteration, and bioaccumulation.

PCBs IN THE UNITED STATES:  
INDUSTRIAL USE AND ENVIRONMENTAL DISTRIBUTION  
FINAL REPORT, TASK I  
February 25, 1976

EPA 560/6-76-005

NTIS PB-252-012

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This report summarizes the production, use, and distribution of polychlorinated biphenyls (PCBs) in the United States. The information was obtained by detailed studies of the production of PCBs, the use of PCBs by first tier user industries, the past and present generation and disposition of PCB-containing wastes, environmental transport and cumulative loads, potential alternatives to PCB usage, inadvertent losses to and potential formation of PCBs in the environment, and current regulatory authorities for PCBs control.

It is estimated that approximately 1.5 billion pounds of PCBs have been sold for industrial use in the U. S. since initiation of production around 1930. Of this amount, at least 95 per cent is still in existence; most is in service in capacitors and transformers, but about 290 million pounds are believed to reside in landfills and dumps and about 150 million pounds are believed to be "free" in the environment. The magnitude of these values indicates that there is a strong future threat from PCBs in land disposal sites.

In 1974, U. S. use of PCBs sold by Monsanto, the sole domestic producer, was distributed between capacitor manufacture (22 million pounds) and transformer manufacture (12 million pounds). Imported materials amounted to about one per cent of U. S. industrial purchases of PCBs in 1974; about 400,000 pounds (of decachlorobiphenyl) were used in investment casting, and an estimated 50,000 pounds of new material were used in specialized heat transfer systems.

Although PCB content in industrial wastes can be reduced through various approaches (treatment, substitution, etc.), the large amounts of PCBs already contained in land disposal sites present a severe hazard for the future. Further study of this and other aspects of the PCBs problem, and determination of ways to minimize the hazard, are recommended.

Monsanto and portions of the electrical equipment industry which use PCBs have greatly reduced PCB releases to water and land over the past few years, primarily through improvement of plant housekeeping, improved waste collection and handling, and disposal of liquid wastes through incineration. Waterborne effluents from PCBs production and first-tier use currently release amounts to the environment which are very small in comparison to the amounts entering land

disposal sites from these industries. However, these effluents can have severe local impacts, as evidenced by the current PCB problem in the Hudson River.

There is no plant-scale process used at present for the specific purpose of removing PCBs from industrial wastewater. The best available treatment technology for removal of PCBs from wastewater is carbon adsorption after removal of solids, oil, and grease. Carbon treatment can produce end-of-pipe PCBs concentrations of one ppb or less. Other adsorbents, such as resins, also appear effective to this extent. The most promising method of those water treatment technologies under development for PCBs destruction is ultraviolet-catalyzed ozonation. "Zero discharge" to water of PCBs from production and first-tier use is available only through extensive water reuse plus extensive incineration of lightly contaminated wastewaters.

Incineration is an effective method of disposal for liquid PCBs. Land-filling is the only generally available disposal method for PCBs-contaminated solid wastes, but incineration of these wastes is technically feasible.

Significant amounts of solid PCB (decachlorobiphenyl, or deka) wastes are stored or disposed of on land by the investment casting industry. Air emissions of deka may also be significant in amount, but no evidence of potential health hazards from this material has been reported.

The total present use of PCBs for open and semi-closed applications is not known but is believed to be small in comparison to closed electrical system use. A few capacitor manufacturing plants report recent use of PCBs in vacuum pumps, and a significant amount of carbonless copy paper containing PCBs must still be in inventory and in files.

PCBs are uniquely suited to the requirements of capacitors for A. C. service. Although a number of potential substitutes for this application are under development and test, they are all more flammable than Aroclor 1016 and neither their performance in service nor their potential toxicity to man and other species have been evaluated sufficiently to allow a definitive comparison with 1016.

Alternatives to PCB use in new transformers are available. In addition, testing of promising substitute fluids (termed "self-extinguishing") is under way; these fluids may gain industry-wide acceptance within three years as substitutes for PCB fluids. At present, choice of PCB-filled transformers appears to be based primarily on cost considerations.

No technical barriers to substitution for PCBs (deka) in investment casting waxes are apparent. Several potential alternatives have been previously used by this industry.

Atmospheric fallout is a major source of PCB input to freshwater systems. In Lake Michigan, the PCB contribution at present appears to be much larger than the total PCB inputs from point sources such as municipal sewage treatment and paper recycling.

The importance of atmospheric transport of PCBs relative to other potential inputs to water indicates that the availability of environmental sinks from PCBs is limited, possibly due to short residence times to evaporation in sea water.

Chlorination of waste biphenyl in industrial wastewaters discharged into municipal sewers is a potential mechanism for inadvertent production of PCBs.

At present, regulatory authority over PCBs in the United States is not sufficient to significantly reduce future PCB inputs to the environment, although inputs directly to the waterways from industrial sources can be reduced from their present level. Current disposal practices, except for incineration, tend to delay instead of prevent the PCB entry into the "free" (available to the biota) state, and these practices are regulated only minimally.

DEVELOPMENT OF AN ECONOMIC ANALYSIS METHODOLOGY  
FOR EVALUATING REGULATORY ALTERNATIVES FOR PCBs

Task I, Special Report March 9, 1976

(Prepared by Jack Faucett Associates under Subcontract to Versar)  
Unpublished

This report presents factors to be taken into account when evaluating alternatives to PCBs to arrive at fair and reasonable time restrictions on the use of PCBs. Also included are a critique of previous estimates of the cost of regulating PCBs, suggestions for improving such estimates, and a survey of the technological aspects of PCB controls.

The following regulatory alternatives are considered:

- 1) Regulation based primarily on chlorine content of Aroclor
- 2) Regulation based primarily on type of use
- 3) Regulation based on responsibility of user
- 4) Regulation of new PCBs
- 5) Regulation of phase-out for PCBs currently in use
- 6) Regulation oriented toward control of waste
- 7) Regulation oriented toward protection of population from exposure to PCBs

After possible regulatory options were identified, a study was made of the information required to evaluate the various alternatives. It was decided that comprehensive information in each of the following areas was needed:

- 1) Present manufacturing and use
- 2) Future substitutions and product changes
- 3) Methods of release to the environment and transport and fate in the environment
- 4) Toxicity, including exposure levels and results of past incidents
- 5) Effect, legality, and options for regulation

Covered under the study of technological aspects of PCB controls are:

- 1) Current and suggested regulations for reducing exposure to PCBs currently in the environment

- 2) Waste disposal control
- 3) Effects of phasing out PCB use
- 4) Limitations on the use of new PCBs in investment casting wax, small capacitors, large power factor capacitors, and electrical transformers

Factors that were analyzed for each of the products above are:

- 1) Risks from continued use
- 2) Present alternatives
- 3) Effect that timing of a ban would have on cost and availability of alternatives
- 4) Benefits from use of alternatives
- 5) Cost of ban of PCBs

This report reaches the following conclusions:

- 1) A total ban on PCBs will have only a minor effect on the current environmental problem but will be necessary in the long run.
- 2) The smooth transition to PCB alternatives is unlikely because of uncertainty about the rationale for and probability of a PCB ban.
- 3) Many of the opinions and cost estimates uncovered in this research indicate that there has been more preparation for debate than for orderly changeover
- 4) Estimates of costs and benefits should be clearly explained to provide incentive for every accurate data supply.

ASSESSMENT OF WASTEWATER MANAGEMENT, TREATMENT TECHNOLOGY,  
AND ASSOCIATED COSTS FOR ABATEMENT OF PCBs CONCENTRATIONS  
IN INDUSTRIAL EFFLUENTS

FINAL REPORT, TASK II

February 3, 1976

EPA 560/6-76-006

NTIS 251-433/AS

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This report presents the findings of a study of available wastewater management and treatment technology for the purpose of determining toxic pollutant effluent concentrations and daily load achievable in three industrial categories: polychlorinated biphenyls (PCBs) manufacturing; capacitor manufacturing; and transformer manufacturing. All plants in these categories have PCB discharges to either waterways or sewage treatment plants, under normal operating conditions. All plants have discharges to storm sewers or directly to waterways under heavy rainfall conditions.

Extensive survey of wastewater treatment technologies and cooperative laboratory work with several suppliers of treatment equipment and research facilities confirmed that carbon adsorption technology is the best current candidate for successful removal of PCBs from the wastewaters. Uv-ozonation was considered as an alternative. This technology is still in the research stage; however, it offers potential of complete destruction of PCBs all the way to CO<sub>2</sub>, water, and HCl.

Another adsorbent technology now in the development stage, AMBERLITE polymeric adsorbents, has demonstrated a PCBs removal efficiency that was roughly equivalent to carbon during laboratory tests. Further testing is needed with this adsorbent to accurately assess its potential.

For scrap oils and burnable solid wastes generated at these plants, high temperature, controlled incineration offers a straightforward method of destruction, whereas scientific landfilling appears to be the best suited mode of disposal for nonburnable contaminated solids.

Zero discharge objectives can be best achieved by eliminating discharge streams and developing recycle systems. All non-contact cooling water would be pretreated. The portion of the pretreated water which would be used in the plant would be treated with carbon, while the excess water would be incinerated in a specially designed system which would allow for energy recovery.

Supporting data, rationale for the selection of above recommended treatment technologies and associated costs are contained in this report.

C-10

DEVELOPMENT OF A STUDY PLAN FOR DEFINITION  
OF PCBs USAGE, WASTE, AND POTENTIAL SUBSTITUTION  
IN THE INVESTMENT CASTING INDUSTRY

FINAL REPORT, TASK III

JANUARY, 1976

EPA 560/6-76-007

NTIS PB 251-842

This report summarizes the use of decachlorobiphenyl (deka) and polychlorinated terphenyls (PCTs) as wax fillers in the investment casting industry and develops a detailed study plan of the industry. Significant information gathering efforts would be required to establish a complete picture of the practices, processes, and products of this industry, which in this instance, is taken to include casting wax manufacture as well as wax usage in foundries. Definition of the waste streams and emissions from the processes used will require sampling and analysis and gathering available process data from the industry.

An approach to determining the most suitable alternatives to decachlorobiphenyl and PCTs is presented. Filler substitutes and the use of unfilled waxes are the two general alternatives to be studied. At present there appear to be no technical barriers to discontinuation of deka and PCTs as fillers, although use of alternatives may increase product cost on the order of 10 percent. In determining the most promising alternatives, product and process oriented technical factors must be evaluated, but potential environmental and human health effects may prove to be the most important factors in selection. An approach to comparison of alternatives based on technical factors and toxicology data is presented. However, it is anticipated that toxicological data on most alternatives, and also on the currently used materials, will be sparse.

The success of information gathering and in-plant sampling efforts is expected to depend heavily on use of Section 308 (FWPCA) authority. Air emission sampling would be very important to the establishment of an overall process material balance and definition of process losses to the environment.

PCBS INVOLVEMENT IN THE PULP AND PAPER INDUSTRY  
FINAL REPORT, TASK IV February 25, 1977 EPA 560/6-77-005  
NTIS PB-271 017/GWP

This paper discusses in detail the sources, distribution, and losses of PCBs in the U. S. pulp and paper industry. The major use of PCBs in the industry was as an ink solvent in carbonless copy paper that was manufactured by various paper mills for NCR from 1957 to 1971. Since 1977, PCB levels in recycled paper have diminished rapidly but PCBs are still present in the effluent water from companies that recycle waste paper.

Aroclor 1242, a PCB mixture containing 42% chlorine, was used as a solvent for color reactants which were then microencapsulated and applied to one side of the carbonless copy paper. The microspheres ruptured and released the dye under high pressure, such as would be applied by a pen or pencil. 44,162,000 pounds of Aroclor 1242 were used for this purpose during the period 1957-1971. The average content of PCBs in the paper was 3.4%. A minor use of PCBs in the paper industry, was in inks, which consumed approximately 50,000 pounds of PCBs from 1968 to 1971.

Recycling of wastepaper is a large part of the paper industry. Wastepaper is the third most important source of pulp behind pulpwood and forest product wastes. 19% of the annual output of finished paper is recycled each year. There are 230 paper mills that produce pulp completely derived from wastepaper and 550 other facilities that use 10-15% secondary fiber in their pulp production.

PCB concentrations in paper products, paper mill effluents, and sludges have declined sharply since the use of PCBs in carbonless copy paper was terminated in 1971. Concentrations in paper products are now in the 0-1 ppm range. Sludges have been in the < 1 to 24 ppm range which is common for municipal sewage treatment plants. The major reasons behind this sharp reduction in PCB concentrations are the elimination of PCB use and the disposal each year of 81% of the annual, paper production via incineration or landfilling; together these removed approximately 80% of the PCBs from the paper cycle each year. A small amount of PCBs is added to paper products each year because of the

presence of PCBs in plant influent water, but this contribution does not appear to be significant at present.

Prediction of PCBs in paper mill effluent and products by using a mathematical model of the industry indicates that PCB concentration reached its peak during 1970-71 and is declining to pre-1957 levels because amounts of PCBs in the recycled wastepaper stream are also declining.

On-site measurements and laboratory experiments have shown that PCBs are attracted to the fibers rather than to the water in which they are carried. Discharge of PCBs from a paper mill appears to be by way of suspended solids and removal of these suspended solids should substantially reduce PCB effluents.

The paper industry as a whole is continuing to develop and install water recycling technology in order to minimize waste treatment costs and recover chemicals, heat, and raw materials. New treatment systems also offer the promise of reduced PCB discharges. Some data indicate that PCBs are being removed from influent streams and are becoming fixed in the paper products, thereby producing a net reduction in PCBs which are free in the environment. However, these PCBs could be re-released when the paper products are disposed of.

It is believed that essentially all of the PCBs used in the production of carbonless copy paper have been released to the environment. Half are believed to reside in landfills and the remainder have been dissipated.

A FIRST ORDER MASS BALANCE MODEL FOR SOURCES,  
DISTRIBUTION, AND FATE OF PCBs IN THE ENVIRONMENT

FINAL REPORT, TASK V

JULY, 1977

EPA 560/6-77-006

NTIS PB 270-220

The work presented here, an extension of that reported in the Task I report, is an attempt to answer the question, "How did it come about that a compound, such as the PCBs, is so widespread an environmental contaminant?" The work involves the construction of several descriptive mathematical models made necessary by the lack of historical data and the absence of a large base of reliable contemporary measurements. The work is necessary since the measurements that do exist strongly suggest that the PCBs are a persistent menace to the biosphere and hence that actions to control them cannot be delayed while a truly adequate data base is obtained.

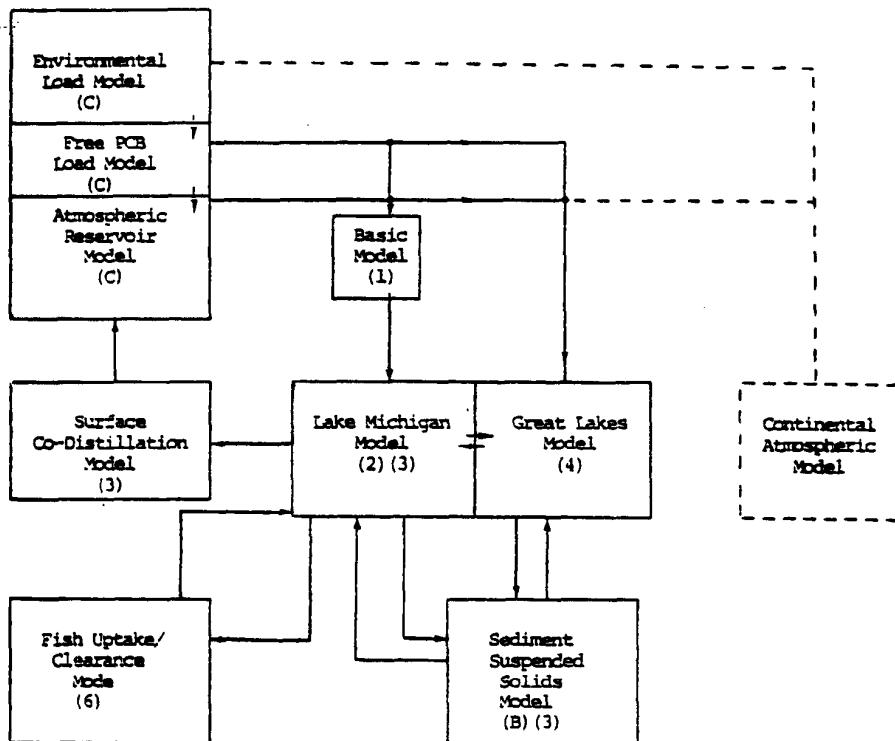
The basic model is constructed on a mass balance principle; that is, all the PCB input to a restricted region of the lithosphere may be accounted for by solution, by uptake on suspended solids, and by uptake within the biota, with the remainder of the input PCBs being carried off by the "loss" processes consisting of surface co-distillation, carryoff by outflowing streams, and entrapment within the sediments.

The model is somewhat complicated by the necessity of an analytic expression for the PCB input rate as a function of time; i.e., the driving function. In the absence of a sufficient amount of data, a model has been constructed to account for the losses to the environment, for the free or "wild" PCB load, and for the atmospheric reservoir of PCBs. The actual relationship of the various parts of the model are shown in Figure I.

Environmental Load Model

Appendix C and Appendix D attempt to determine the magnitude of the total environmental load, the free environmental load, and the atmospheric reservoir of PCBs, all as functions of time.

Figure I  
Schematic Showing Relationship of the Various Sections of Report\*



\*The number or letter associated with each block refers to section dealing directly with the subject matter.

The results of this analysis are:

- a. In 1975, the total environmental PCB load is estimated to be  $3.76 \times 10^8$  lbs. within the continental United States.
- b. In 1975, the total free or mobile PCB load in the continental United States is estimated to be  $8.31 \times 10^7$  lbs. The remainder of the total environmental load is thought to be encapsulated in one form or another (in landfills, for example).
- c. As of 1970, the cumulative atmospheric reservoir contained some  $6 \times 10^7$  lbs. of PCB indicating a rather rapid exchange between the total mobile PCBs and the atmospheric reservoir.
- d. As of 1975, the PCB concentration in the air near Lake Michigan was of the order of  $10 \mu\text{g}/\text{m}^3$ .
- e. The estimated half life for fallout from the atmospheric reservoir is 0.9 years.
- f. The average chlorine number for environmental PCBs is of the order of 4.32.

Results of Mass Balance Model Applied to Lake Michigan

The results of this analysis are:

- a. A plausible scenario indicates a present-day PCB concentration (water plus suspended solids) of the order of 7-10 ppt.
- b. Atmospheric fallout constitutes the major input of PCBs to Lake Michigan.
- c. Surface evaporation or co-distillation (the exact nomenclature is not known because the process is incompletely understood) constitutes a significant PCB loss mechanism.
- d. The presence of suspended solids within the water column can be expected to have a dominant effect on the actual (filtered) aqueous concentration.

- e. The sediments should act as a significant sink for the removal of PCBs from the water column.
- f. Even though there is considerable uncertainty as to the proper value for some of the important parameters, the sheer bulk of the water mass makes the aqueous concentration essentially independent of these parameters over wide ranges.
- g. 70 years would be required to reduce the present PCB concentration by one-half in the absence of all external sources.

#### Results of Mass Balance Model Applied to the Entire Great Lakes System

- a. A plausible scenario leads to an estimate of aqueous PCB concentrations within the range of measured values, i.e., less than 40 ppt.
- b. The estimated average PCB concentration in the sediments of Lake Erie and Lake Ontario fall within an order of magnitude of other estimates.
- c. The estimated fallouts in 1974 onto Lake Erie and Lake Ontario both fall within a few percent of other estimates.
- d. Point source inputs, when introduced into Lake Erie and Lake Ontario, led to PCB concentrations in the aqueous phase as well as within the sediments which are within a factor of 2 or 3 of direct observation.
- e. The lifetime of the present PCB loads in the absence of all sources can be estimated.

#### Other Results

Other results obtained somewhat incidentally to the main effort include:

- a. An estimate of the bioconcentration rates of PCBs for a trout (about  $4 \times 10^6$ ).
- b. An estimate that, for the trout, the uptake of PCBs from contaminated food is 50 times greater than from respiration.

- c. The MacKay and Wolkoff model for co-distillation is apparently not applicable in the situation where infalling PCB complicates the situation.
- d. The significant difference in activity of PCBs in bulk solution compared to that in the surface layer is probably the driving force for the creation of a surface concentration gradient.
- e. A formulation is developed that suggests the possibility of an analysis of the continental PCB atmospheric reservoir.

ASSESSMENT OF THE ENVIRONMENTAL AND ECONOMIC  
IMPACTS OF THE BAN ON IMPORTS OF PCBs

FINAL REPORT, TASK VI

JULY 1977

EPA 560/6-77-007

NTIS PB 270-225

This report summarizes an investigation into the uses of imported PCBs in the United States and a determination of the economic impacts which may occur as a result of the impending ban on importing PCBs. Imported PCBs are currently used only for the maintenance of two types of mining machinery produced in the past by Joy Manufacturing Co. PCBs may also be a significant contaminant in polychlorinated terphenyls (PCTs) which wax manufacturers import for use in tooling compounds and investment casting waxes. However, the sole U.S. distributor of PCTs is currently guaranteeing that such contamination is less than 0.05%.

PCB fluids were used as coolants in mining machinery because of their low combustability, low electrical conductivity, and inertness which minimizes system corrosion even at continuous high operating temperatures. The two types of mining machinery manufactured by Joy which use PCBs are loaders, of which there are approximately 350 and which were last produced in 1973, and continuous miners, of which there are approximately 50 and which were last produced in 1970. Converting the motors in the loaders to air cooling would cost about \$6,200 per loader. Converting the continuous miners would require replacement of the cutting heads and would cost about \$65,000 per miner. As a result of the Toxic Substances Control Act, owners of the machinery which use PCB fluids have three options:

- 1) Petition for an exemption to the Act.
- 2) Bear the cost of converting the machinery motors to air-cooling.
- 3) Scrap the machinery.

PCTs are used in wax formulations known as tooling compounds, which are used to provide support to thin walled objects so that they may be

machined without being damaged. After machining, the tooling compound is removed either by melting or by using an aqueous acid solution. The sole producer of tooling compounds which contain PCTs is M. Argueso & Co. of Mamaroneck, N.Y.

Investment casting is a method of producing metal castings which may have complex shapes and which have a surface finish and dimensional tolerance which cannot be matched by other casting processes. It involves first making a pattern out of wax; the pattern is then covered, or "invested," with a refractory coating which hardens at room temperature. The wax is then melted and/or burned out of the mold. The metal is then poured in and allowed to harden. Investment casting is best suited to the production of a large volume of small, intricate parts made of metals which are difficult or impossible to machine.

PCTs are used in investment casting waxes for several reasons. They make the wax harder at all temperatures below the melting point; they cause the wax to harden faster by improving thermal conductivity; and they reduce the coefficient of thermal expansion of the wax, resulting in improved dimensional accuracy in the finished casting. Detailed data on PCT loss to the environment is not available, but possible sources of loss include mold production, mold dewaxing, mold firing and preheating, and wax reclamation. There are eleven manufacturers of investment casting waxes in the United States; three currently use PCTs in their formulations, and three others did in the past but no longer do so. All three current users of PCBs receive them from the same distributor.

The following points with respect to PCT use in tooling compounds and investment casting waxes are noted:

- 1) PCT containing casting waxes cost 15¢ to 25¢ per pound more than non-PCT containing waxes and comprise less than half of the total sales of manufacturers who sell them.
- 2) Of the three manufacturers of PCT containing waxes who ceased using PCTs in their waxes within the past decade, none seems to have been placed in an unfavorable competitive position.

- 3) One investment casting foundry, General Electric, has ceased using PCT waxes. They have apparently found adequate substitutes for use in casting turbine blades, an application which is critically dependent upon high dimensional accuracy and extremely fine surface finish.
- 4) From 2 and 3 above, it appears that acceptable substitutes for PCT-containing waxes are available.
- 5) If imported PCTs are found to contain PCBs in excess of 0.05%, the EPA can take action to ensure adequate quality control.
- 6) If PCTs are found to "present an unreasonable risk of injury to health or the environment," they may be banned.

ASSESSMENT OF THE USE OF SELECTED REPLACEMENT FLUIDS FOR  
PCBS IN ELECTRICAL EQUIPMENT

Final Report, Task VII, April 1979

EPA 560/6-77-008

NTIS No. Forthcoming.

This report discusses the use of PCBs as dielectric liquids in transformers, motors, electromagnets, and capacitors. The performance criteria for replacement liquids are summarized and alternative technologies are reviewed.

The major alternatives to the use of PCBs in transformers are:

- Dry type transformers, including gas-filled and cast coil construction
- Oil-filled transformers located in safe locations or installed in a vault
- High fire point liquid dielectric-filled transformers, including silicone, paraffinic hydrocarbon, and synthetic hydrocarbon liquids
- Non-PCB askarel liquids based on chlorinated benzenes

PCB filled electromagnets may be replaced with available oil-filled, high-fire point liquid-filled, or dry type units. Dry air-cooled motors are also available for most of the previous applications using PCB-filled electric motors.

Alternative capacitor liquids are:

Phthalate esters  
Alkylated monochlorodiphenyl oxide  
Isopropyl biphenyl

Other possible capacitor dielectric liquids are also discussed, and the status of dry film capacitors is reviewed.

PCBs WATER ELIMINATION/REDUCTION TECHNOLOGY AND ASSOCIATED COSTS,  
MANUFACTURERS OF ELECTRICAL CAPACITORS AND TRANSFORMERS

ADDENDUM TO FINAL REPORT, TASK II

JULY 2, 1976

EPA 440/9-76-020

The general potential for reduction of water use in the electrical equipment manufacturing industry is favorable, since water has to be carefully excluded from the internals of both transformers and capacitors for the units to meet product and performance specifications. Newer plants in these categories, particularly those of smaller size, use much less water per unit of PCB use than the older plants. However, the existing plants would require a combination of process and plant modifications and wastewater treatment and recycle to achieve a goal of no discharge of PCB-contaminated waters. This addendum to the Task II report summarizes the quantities and sources of the wastewaters; describes the available alternative technologies for reducing or eliminating the discharges on a source-by-source basis; and tabulates the estimated costs for achieving such reduction or elimination.

Section 2.0 of this report addresses the point sources from the capacitor and transformer manufacturing industry with the absolute goal (with a single exception from one plant) of no point-source discharges of any waters. Extensive applications of process changes (from wet to dry unit processes or unit operations), of water segregation practices, of water treatment and recycle practices, and of water-quantity reduction practices were investigated. The residual contaminated wastewaters not eliminated by these practices were then hypothesized to be "incinerated," e.g., heated to a sufficiently high temperature for a sufficiently long time to ensure destruction of PCB contaminants.

Section 3.0 presents the technologies and costs for eliminating PCB contamination of rainwater runoff from manufacturing plants in this industry.

Section 4.0 presents the technical basis and estimated costs for three

alternative approaches to PCBs reduction in the direct discharges from this industry to waterways. The technology and costs presented are based on those of Reference 1 and Sections 2.0 and 3.0 of this Addendum. The approaches were selected to offer a range of PCBs control at various levels of costs.

The estimated costs are as accurate as was possible within the scope of work. Based on previous experience in this area, we feel that the least reliable costs tabulated are those for waste stream segregation. Costs for segregation are highly variable from plant to plant, and accurate estimation is only possible as a result of detailed study of plant layout, piping, etc., which was beyond the scope of this study.

ECONOMIC ANALYSIS OF PROPOSED TOXIC POLLUTANT EFFLUENT  
STANDARDS FOR POLYCHLORINATED BIPHENYLS;  
TRANSFORMER, CAPACITOR, AND PCB MANUFACTURERS

October 1976

EPA 230/1-76-068

(Prepared by Jack Faucett Associates Under Subcontract from Versar)

This report presents an assessment of economic impacts from PCB effluent controls. Because of the cost of required effluent controls, it is estimated that a minimum of nine and maximum of all eleven direct discharging plants will stop using PCBs depending on the particular regulation issued. According to industry opinion, the estimated minimum is very unlikely because additional PCB controls would encourage stopping use of PCBs. Decisions against investment in control equipment does not mean, however, that the impacts of these regulations are zero. Company decisions to cease PCB use will have impacts, particularly with regards to the timing of the decision to stop using PCBs. The earlier the switch to substitutes the more likely that product prices and performance will change in the transition.

There is evidence that some industries will cease PCB use prior to implementation of Section 307(a) controls. That evidence is based on investment analysis of probable effects on company profits, announced decisions such as those by General Electric and Monsanto, and capacitor/transformer users' preparations for PCB substitutes. These decisions are significant in light of the range of government alternatives that were considered. A major force in government controls affecting PCB use is the Toxic Substances Control Act, which will prohibit the use of PCBs in capacitors and transformers by 1980. The EPA proposed toxic pollutant effluent standards for PCBs in July 1976, and EPA is scheduled to promulgate regulations in January 1977. Depending on the final standard, the affected plants which continue PCB use are likely to install one of the treatment technologies presented below. Circumstances at

each plant could cause deviations in technology costs from the following summaries:

| <u>Government<br/>Regulatory<br/>Options</u> | <u>Potential Technology</u>       | <u>Average Investment<br/>Cost/Plant</u> |
|----------------------------------------------|-----------------------------------|------------------------------------------|
| A                                            | Process Change & Carbon Treatment | \$ 527,000                               |
| B                                            | Maximum Carbon Treatment          | \$1,207,000                              |
| C                                            | Minimum Carbon Treatment          | \$ 392,000                               |
| Zero<br>Discharge                            | Process Change and Recycle        | \$ 555,000                               |

The cost of each of the technologies varies considerably among plants, but the above costs are an average of investment costs for model plants that were considered.

Since few if any plants will actually install effluent control equipment in response to Section 307 (a) directly, economic impacts can be viewed as emanating from timing of decisions. Monsanto's voluntary ban on PCB production and the new Toxic Substances Control Act will effectively terminate PCB use by 1980 independent of Section 307 (a) provisions.

Total investment costs and total annual costs for each of the four treatment technologies are given in the table below. Our analysis focuses on the 11 direct discharging plants of the 37 plants that manufacture PCB transformers and capacitors.

The following summaries are based on analysis of investment, i.e., investment to meet only federal effluent controls under Section 307 (a), for model plants. Conclusions on whether companies with plants similar to each model would actually install the specified treatment are based on a comparison of present costs of the equipment.

INVESTMENT AND ANNUAL COSTS FOR DIRECT DISCHARGING TRANSFORMER  
AND CAPACITOR PLANTS

(Millions of Dollars)

|                                | <u>Required Treatment</u> |          |          | <u>Zero Discharge</u> |
|--------------------------------|---------------------------|----------|----------|-----------------------|
|                                | <u>A</u>                  | <u>B</u> | <u>C</u> |                       |
| Number of Plants that would    |                           |          |          |                       |
| Install Treatment:             |                           |          |          |                       |
| Transformer                    | 0                         | 0        | 0        | 0                     |
| Capacitor                      | 1                         | 0        | 2        | 1                     |
| Total Investment: <sup>a</sup> |                           |          |          |                       |
| Transformer                    | 0.0                       | 0.0      | 0.0      | 0.0                   |
| Capacitor                      | .26                       | 0.0      | .23      | .31                   |
| Total Annual Cost:             |                           |          |          |                       |
| Transformer                    | 0.0                       | 0.0      | 0.0      | 0.0                   |
| Capacitor                      | .14                       | 0.0      | .10      | .19                   |

a) Investment analysis indicates an acceptable return on investment.

#### Alternative A Treatment Costs

EPA standards which would lead firms to invest in Alternative A would cause 5 direct discharge capacitor plants and all 5 direct discharge transformer plants to stop using PCBs in January 1978 rather than by 1980 as would otherwise occur. The one remaining direct discharging capacitor manufacturer could comply with the regulation by installing the necessary treatment equipment. These early curtailments in production would reduce industry-wide production capacity of PCB capacitors by about 35 percent and of PCB transformers by about 50 percent. Industry-wide investment for control equipment would be \$ .26 million with annual costs of \$ .14 million.

#### Alternative B Treatment Costs

EPA standards which would lead firms to invest in Alternative B would cause all capacitor and transformer plants among the direct discharges to stop using PCBs in January 1978 rather than by 1980 as would otherwise occur. These early curtailments in production would reduce industry-wide production capacity of PCB capacitors by about 45 percent and of PCB transformers by about 50 percent.

#### Alternative C Treatment Costs

EPA standards which would lead firms to invest in Alternative C would cause 4 direct discharge capacitor plants and all 5 direct discharge transformer plants to stop using PCBs in January 1978 rather than by 1980 as would otherwise occur. The two remaining direct discharging capacitor manufacturers could comply with the regulation by installing the necessary treatment equipment. These early curtailments in production would reduce industry-wide production capacity of PCB capacitors by about 30 percent and of PCB transformers by about 50 percent. Industry-wide investment for control equipment would be \$ .23 million with annual costs of \$ .10 million.

### Zero Discharge Treatment Costs

EPA standards which would lead firms to invest in zero discharge would cause all but 1 direct discharge capacitor plant and all 5 direct discharge transformer plants to stop using PCBs in January 1978 rather than by 1980 as would otherwise occur. The one remaining direct discharging capacitor manufacturer could comply with the regulation by installing the necessary treatment equipment. These early curtailments in production would reduce industry-wide production capacity of PCB capacitors by about 35 percent and of PCB transformers by about 50 percent. Industry-wide investment for control equipment would be \$ .31 million with an annual cost of \$ .19 million.

The following economic impacts for the eleven direct discharge plants are based on industry trends as well as data collected from transformer and capacitor users and producers directly.

Average transformer price increases due solely to PCB effluent controls will be minimal because (1) PCBs used by direct discharge plants represent less than 10 and possibly only 5 percent of total transformers and (2) other expected controls and voluntary bans will already have caused a further shift to non-PCB units. The price adjustment for the less effective non-PCB transformers could be significant, but little of this increase can objectively be attributed to Section 307 (a) controls.

The dollar value of all transformer sales is likely to increase more because of higher costs with PCB substitutes than they decrease because of demand response to higher prices. However, recent data indicate that an increase in imports could easily offset any increase from higher prices, leaving domestic producers with slightly lower dollar sales.

Industry-wide capacitor price increases due solely to changes resulting from PCB effluent controls are likely to be less than 5 percent in 1977 and to decrease to less than 2 percent as PCB substitute technology improves by 1980. All environmental controls combined can generate up to a 20 percent increase in average capacitor prices. However, only part of that increase

can be attributed to Section 307 (a) effluent controls which will affect only six specific plants in the entire 19 plant capacitor industry. The remaining plants will be covered by a future regulation, however.

There are no significant effects on energy consumption, balance of payments, or employment. The announced and apparent shifts to non-PCB units and the expected demand for capacitors and transformers are likely to increase rather than decrease sales and industry-wide employment. However, to prevent losses to foreign competition, domestic producers might have to absorb some cost increases in lower profits. Since all of the affected plants are either part of a much larger company or have a reasonably good PCB alternative, reduced profits will not necessarily lead to significant reductions in employment. There will be no reductions if sales in fact do increase and if similar numbers of people are needed to manufacture non-PCB units.

## COSTS FOR UV - OZONATION PROCESS

Addendum to Final Report, Task II

September 27, 1976

The costs presented in the Task II Final Report were reevaluated based on new tests that determined that complete removal of the organic content in wastewaters is not required prior to removal of the PCBs.

Comparison of the terminal treatment capital costs of UV-ozonation systems with carbon adsorption systems for reducing the concentration of PCBs in effluent waters to below 1 ppb indicated a greater than 50% higher cost for ozone system over the carbon system. However, combining the pre-treatment costs with the terminal treatment costs results in UV-ozonation system costs about 5 to 10 percent higher than the carbon system costs.

MONS 010506

DETAILED COST ESTIMATES FOR ALTERNATIVE PCBs  
TREATMENT TECHNOLOGIES APPLIED TO HYPOTHETICAL LARGE AND MEDIUM SIZED PCB  
CAPACITOR AND TRANSFORMER MANUFACTURING PLANTS

Addendum to Final Report, Task II

October 15, 1976

The three treatment alternatives for which costs were estimated are:

- A) Process and plant modifications and pretreatment of process water.
- B) Maximum use of carbon adsorption.
- C) Minimum treatment.

The estimates for these three alternatives are:

|               |                    | <u>Large Plant</u><br><u>2,500,000 lbs. PCB</u><br><u>use/yr.</u> | <u>Medium Plant</u><br><u>500,000 lbs. PCB</u><br><u>use/yr.</u> |
|---------------|--------------------|-------------------------------------------------------------------|------------------------------------------------------------------|
| Alternative A | Capital Investment | \$1,997,900                                                       | \$647,000                                                        |
|               | Annual Cost        | 528,900                                                           | 164,700                                                          |
| Alternative B | Capital Investment | 3,811,400                                                         | 935,500                                                          |
|               | Annual Cost        | 922,900                                                           | 222,300                                                          |
| Alternative C | Capital Investment | 1,588,400                                                         | 575,500                                                          |
|               | Annual Cost        | 374,000                                                           | 138,200                                                          |

## COST FOR EQUALIZATION BASIN BASED ON BENTONITE CLAY LINER

Special Report

October 1976

The capital cost for the equalization basin with a bentonite clay lining is shown below. This cost was estimated based on a basin volume of three times the design flow, 24 hour residence time, and \$5.00 per cubic yard of excavation cost consistent with the Task II report basis for the reinforced concrete equalization basin. The report also summarizes total installed costs, maintenance costs, and operating costs, and compares these costs to those estimated for concrete storage basins described in the Task II Final Report.

- Bases:
1. 24 hour retention
  2. 3 times normal flow
  3. Bentonite lining at 80 tons/acre and lining cover @  $\$0.3/\text{yd}^2$
  4. 12 ft depth
  5. 10 ft water depth
  6. L/W - 2.0

|                                  |      |      |      |      |      |       |       |
|----------------------------------|------|------|------|------|------|-------|-------|
| Flow (gpm)                       | 20   | 40   | 80   | 160  | 320  | 640   | 1700  |
| Liquid Vol. (1000 gal)           | 86   | 176  | 345  | 690  | 1380 | 2760  | 7340  |
| Width (ft)                       | 24   | 34   | 48   | 68   | 96   | 136   | 222   |
| Length (ft)                      | 48   | 68   | 96   | 136  | 192  | 272   | 444   |
| Excavation Cost (\$1000)         | 2.6  | 5.1  | 10.2 | 20.5 | 41   | 82    | 218   |
| Lining & Cover Cost (\$1000)     | 0.5  | 0.7  | 1.3  | 2.3  | 4.1  | 7.6   | 18.4  |
| Total Basin Cost (\$1000)        | 3.1  | 5.8  | 11.5 | 22.8 | 45.1 | 89.6  | 236.4 |
| Pumps & Sump (\$1000)            | 20   | 20   | 21   | 22   | 27   | 32    | 42    |
| Total Basin & Pump Cost (\$1000) | 23.1 | 25.8 | 32.5 | 44.8 | 72.1 | 121.6 | 278.4 |

IMPACTS OF SUBSTITUTES FOR PCBs ON FIRE HAZARDS IN COMMERCIAL  
AND RESIDENTIAL BUILDINGS

(Draft) Special Report      October, 1976

This report reviews the technologies that were being developed for the replacement of PCBs as dielectric liquids in transformers and capacitors. All of the potential substitute liquids are more flammable than PCBs, and this flammability presents a potential fire hazard. The report reviews the changes in design and the effects of changing fire codes and insurance underwriter's requirements on limiting the potential hazard resulting from the use of substitutes for PCBs in electrical equipment.

The report concludes that there is no basis to assume that properly engineered and tested equipment would result in an increase in risk. Any safety problems that occur may be the result of inadequate testing and evaluation prior to commercial introduction of the electrical transformers and capacitors that use the substitute materials.

RECENT ADVANCES IN PCBs DETOXIFICATION IN WASTEWATER  
Supplement to Final Report, Task II

January 8, 1977

This report summarizes a brief study made to update information on methods (other than adsorption) for removing or detoxifying PCBs present in industrial wastewater. Information was obtained from Westgate Research and Houston Research on UV-catalyzed ozonation, from Envirogenics Systems Company on catalyzed reduction, and from Environment Canada and others on biodegradation.

In the area of UV-ozonation, both Westgate Research and Houston Research have run tests in which the level of PCBs has been reduced almost to the detection limit of 0.1 ppb. Both companies have stated that they can provide an operational operating costs for a 640 gpm system at \$1,750,000 and \$120,800/yr., respectively. The decomposition products of UV-ozonation of PCBs are not known at this time. The catalyzed reductive dechlorination process being developed by Envirogenics has been tested on PCBs. A 75 ppb concentration of the PCB isomer 4,4'-dichlorobiphenyl was reduced to about 1.0 ppb. The Envirogenics process is currently being used at the Velsicol Chemical Corporation plant in Memphis where it was put into service in mid-May. It is expected that a contamination level of 1000-15000 ppm of heptachlor and 500-700 ppm of endrin will be reduced to less than 1 ppb of total contaminants. Envirogenics is expecting a grant to set up a plant-scale system to handle PCBs at one of the GE plants. Decomposition products of this process are being investigated.

The work being conducted on biodegradation by Environment Canada has produced a bacterial strain which subsists solely on PCBs. However, this process is not yet ready for commercial scale demonstration because the lowest PCB concentration reached (as of August, 1976) is 19 ppb.

PCB LEVELS IN NON-CONTACT COOLING  
WATERS AND OTHER EFFLUENTS FROM CAPACITOR  
AND TRANSFORMER PRODUCTION FACILITIES

Supplement to Final Report, Task II  
January 19, 1977

This work provides a tabulation and analysis of the current status of non-contact cooling water waste streams from the capacitor and transformer production facilities which use PCBs.

Data on PCB levels in 1974-75 and 1976 samples from cooling water effluents from PCB capacitor and transformer manufacturers were obtained for ten streams at six different facilities. All but one of the 1976 levels were below 10 ppb total PCBs, and five were at 2 ppb or lower. These levels are compared to combined plant effluents and rainfall runoff samples at four plants. The highest and most variable PCB levels occurred in runoff samples, and the lowest and least variable occurred in the cooling water effluents. In general, one to two ppb appears to be a typical PCBs level for non-contact cooling water in this industry for plants which practice good plant housekeeping and segregate their cooling water.

REFINEMENT OF ALTERNATIVE TECHNOLOGIES AND ESTIMATED  
COSTS FOR REDUCTION OF PCBs IN INDUSTRIAL  
WASTEWATER FROM THE CAPACITOR AND TRANSFORMER  
MANUFACTURING CATEGORIES

Supplement to Final Report, Task II  
December 16, 1976

This report augments and refines the available information on technology and estimated costs for abatement of PCB discharges from the capacitor and transformer manufacturers who use PCBs in their products. It includes:

- 1) A description of modifications being performed at two GE plants to reduce PCB effluents;
- 2) An updated cost estimate for UV-ozoneation;
- 3) A cost estimate for the use of bentonite-lined equalization basins;
- 4) A general review of the current industry trends towards abatement of PCB discharges.

As of September, 1976, GE had reduced PCB discharges from 8 to 9 pounds per day to one pound per day at their Fort Edward and Hudson Falls manufacturing plants. This was accomplished by:

- 1) Segregating wastewater;
- 2) Preventing spills and leaks from contaminating clean water;
- 3) Decreasing wastewater volume;
- 4) Eliminating batch dumping;
- 5) Treating sanitary wastewater at Fort Edward.

Additional projects intended to reduce PCB discharge to less than 1 gram per day were underway and were scheduled for implementation by April or May, 1977.

These include:

- 1) Recirculating non-contact cooling water;
- 2) Consolidating discharges and impoundment basins;
- 3) Treating impounded water at Fort Edward.

The cost of constructing and operating an equalization basin based on the use of a bentonite clay lining was calculated and compared with figures which had been previously derived for a concrete lined basin. It was determined that the annual operating cost for a bentonite lined basin was approximately half that for a concrete basin the same size. In actual practice, however, the bentonite lined pond would be much larger than a concrete lined basin in order to reduce the frequency of pond dredging and cleaning. Thus, the costs for the two alternatives will be more nearly equal.

Westgate Research Corporation's continuing UV-ozonation development program has produced some system simplifications which made it necessary to re-estimate the cost of removing PCBs in a UV-ozonation treatment plant. The new treatment costs ranged from \$16.00/1000 gal. for a 20 gpm plant to \$1.50/1000 gal. for a 1,700 gpm plant. Typical costs for PCB removal using activated carbon range from \$4.47/1000 gal. for 20 gpm capacity to \$1.18/1000 gal. for 1,700 gpm.

An examination of current industry trends towards abatement and disposal of PCBs revealed several things. Calgon is furnishing GE with carbon adsorption technology and generally agreed with the technical conclusions and cost estimates determined by Versar. There are at least three PCB users which have no discharge of process water or non-contact cooling water to waterways or POTWs. Segregation of cooling water streams appears to be well in hand or underway in five plants. Three potential suppliers of incinerators for waste PCB-containing liquids indicated that they could supply incinerators within 6 to 18 months of receiving an order.

COSTS ASSOCIATED WITH INSTALLING PRODUCTION  
EQUIPMENT FOR USE OF NON-PCB DIELECTRIC  
FLUIDS IN TRANSFORMER AND CAPACITOR MANUFACTURE

Supplement to Final Report, Task II

January 19, 1977

This report summarizes the costs associated with the expected changeover from polychlorinated biphenyls (PCBs) and PCB-containing askarels to substitute (non-PCB) dielectric fluids in the manufacture of transformers and capacitors.

The approach taken was to contact industry representatives at the various meetings of industry committees dealing with disposal of obsolete PCB-contaminated equipment and waste oils. In addition, discussions were held with other industry personnel from whom information on similar matters had been obtained in the past.

The results indicated that no significant process changes would be required of any producer to convert to a PCB substitute. However, minor to extensive retooling will be required for most capacitor producers that produce their own containers and/or utilize their product capacitors in assemblies (ballast assemblies, for example). Design, testing, and other activities required by the product changes will also result in costs associated with the changeover but not with process changes. In addition, clean-up and disposal costs will be borne by all firms.

MONS 010514

MICROECONOMIC IMPACTS OF THE PROPOSED MARKING AND  
DISPOSAL REGULATIONS FOR PCBs

FINAL TASK REPORT

April 1977

EPA 560/6-77-013

NIIS PB 267-833/3WP

This study evaluates the economic impact of the draft regulations for the marking and disposal of PCBs. The report includes estimates of the quantities of PCBs and equipment containing PCBs that will be affected, present and future required availability of PCBs, PCB disposal facilities, secondary costs (including storage), recordkeeping, transportation, and the cost of the actual marking. The economic analysis includes estimates of additional costs by year and economic sector, effects on price, investment requirements, and employment. Finally, the effects of compliance on energy requirements and on the availability of strategic materials are estimated.

The basic disposal requirement for all PCBs is controlled use and storage followed by high temperature incineration. The proposed regulations are very specific on what is to be done and how it is to be done. Consideration of the present lack of incineration facilities and the high costs which would be incurred by requiring removal and special handling of fluorescent light ballasts and small capacitors have resulted in the following exemptions from the basic requirements of incineration:

- 1) Until July 1, 1979, non-liquid PCB mixtures, PCB capacitors, and PCB fluorescent light ballasts may be disposed of in chemical waste landfills.
- 2) PCB containers may be decontaminated by triple rinsing.
- 3) PCB transformer may be rinsed and disposed of in chemical waste landfills.
- 4) Small PCB capacitors in electrical equipment do not have to be removed before disposal of the equipment.
- 5) Small capacitors and fluorescent light ballasts used in private homes may be disposed of as municipal solid waste.
- 6) Material or equipment containing less than 500 ppm of PCBs will not require special handling or disposal.

MOHS 010515

Most storage areas required by the regulations will be established by office and commercial buildings, electrical repair shops, and small industrial buildings for the storage of small capacitors and fluorescent light ballasts removed during normal maintenance. Cost of establishing a small storage area is estimated at \$145 with an annual operating cost of \$95/year. It is suggested that these costs may be reduced by using unused space and establishing the area during a time of slack labor demand. A larger area, such as required by utilities and transformer repair shops is estimated to cost \$1,000-\$5,000 to establish and \$2,125 to operate annually.

The draft regulations require that chemical waste landfills used for the disposal of PCBs be approved by the EPA Administrator for that purpose. At present there are sixteen chemical waste landfills in the U.S., but none have been approved for PCB disposal. Average cost for disposing of materials in these landfills, including freight and state fees, is estimated at \$3.00 per cubic foot of material.

There are currently nine commercial incinerators with the capacity to destroy liquid PCB waste. In addition, three of these facilities have the capacity to destroy PCBs contained in solid wastes. Charges at these facilities are 7-14¢/lb. for liquid waste and \$40/drum for solid waste. Estimated operating cost of a unit capable of shredding and disposing of capacitors is 52¢/lb. It may also be possible to dispose of PCB liquids in cement kilns and power boilers. Shipping charges for liquid PCB wastes in 55 gallon drums range from \$1.14 to \$6.24 per hundred pounds depending upon the number of drums and the shipping distance. In addition, there may be a charge of \$2.85 per platform handling for each drum. There will also be additional recordkeeping charges of \$2 to \$5 per item.

For estimating the total cost to industry which will be incurred in complying with the draft disposal regulations, three options were identified. Option 1 assumes that all PCB capacitors are removed from equipment before it is scrapped. Option 2 assumes that 2/3 of all small appliance capacitors, HID capacitors, and fluorescent light ballast capacitors are not removed from the

equipment but are disposed of as municipal solid waste while the remaining 1/3 are incinerated. Option 3 allows the disposal of fluorescent light ballasts in chemical waste landfills.

Associated with each of these regulatory options are aggregate, industry-wide costs for decontamination, storage, landfill and incineration costs, transportation costs, and recordkeeping costs. The maximum expected cost for decontamination of askarel filled transformers is \$365,000 per year. The cost for storing PCBs prior to disposal is estimated to be \$8.2 million the first year (including cost for setting up storage areas) and \$4.2 million per year in subsequent years. The maximum expected cost for disposal in chemical landfills is expected to be \$5.5 million. The estimated incineration costs range from \$134 million per year for Option 1 to \$39 million per year for Option 3. Estimated transportation costs for incinerating PCBs vary from \$7.4 million to \$13.2 million per year, depending on how many incinerators are assumed with the various disposal options. Recordkeeping costs are estimated to be \$8 million initially plus \$4.0 million per year thereafter.

In addition to the economic impacts which will result from the disposal regulations, there will also be substantial costs incurred due to the marking regulations. Manufacturers will be faced with major retooling costs, on the order of \$25,000 each, in order to comply with the proposed regulations. The majority of the marking cost, however, will be borne by the present users of PCB electrical equipment who need to mark existing equipment. The total cost is estimated to be \$33.2 million.

The aggregate effects which the proposed marking and disposal regulations will have on the electrical pricing, energy consumption, and strategic materials are slight. The price of electricity will increase by an average of 0.06%. The upper bound estimate for increased energy consumption is 17,700 Bbl/day. Reclamation of copper windings from transformers may be inhibited but the total amount affected would be less than 1% of the total copper reclaimed every year in the U.S. and is an insignificant portion of the copper consumed each year.

POTENTIAL IMPACTS OF THE BANS ON PCB MANUFACTURING, PROCESSING, AND USE  
Special Report, PCB Activity Analysis Papers

July 11, 1977

This report describes the current uses of PCBs in the United States and draws particular attention to those uses which present environmental hazards or problems of a regulatory or economic nature.

At the present time the only uses of PCBs in the United States are in capacitors, transformers, and the maintenance of a number of mining machines formerly manufactured by Joy Manufacturing, Inc. Capacitor and transformer manufacturers and transformer maintenance shops currently receive their PCBs from Monsanto, the sole U.S. producer of PCBs. Monsanto intends to stop manufacturing PCBs by August 1977, and will cease shipment from inventory as of October 1977, even though the Toxic Substances Control Act permits the manufacture of PCBs for use in a totally enclosed manner through January 1979. Small custom chemical companies may be attracted to this market, requiring definition of allowable manufacturing processes and/or air and water emission regulations. Another possible source of PCB "manufacture" which may arise is the reclamation of used askarels from transformers. This may create some regulatory difficulties.

It appears that either presently or in the near future, GE and Westinghouse will be the only companies who will service PCB transformers. With the sole domestic producer of PCBs about to cease production, GE and Westinghouse will be forced to decide whether to import PCBs before January 1, 1977, in order to meet an anticipated upward trend in PCB use by the transformer service industry. GE has indicated that in no event will they stockpile more than a 1 or 2 year supply.

In any event, the transformer repair industry will remain a potential source of PCB emissions for the immediate future. PCB air emissions from the repair shops may need to be monitored and regulated. The majority of documented PCB releases attributable to the transformer repair industry have occurred

while transporting filled transformers by truck. Draining of transformers before they are shipped would alleviate this problem.

Retrofilling of all PCB transformers with silicone based oil is possible but is not justified on either economic or environmental grounds. The cost would be \$45,000-\$50,000 each for the largest units, and the increased risk of spills makes this environmentally unattractive. Generally, when a transformer is retrofilled, some of the PCBs remain trapped in the windings. However, it may be possible to remove nearly all the remaining PCBs by periodically filtering the new transformer fluid through activated carbon until the PCBs are reduced to an acceptable level.

The users of PCB equipment may be categorized as utility, commercial-industrial, and residential. It appears unlikely that PCBs used in residences (low voltage capacitors) present any great danger because only small amounts of PCBs are present in any residence and there is little chance that one of these capacitors will rupture upon failure. There is a much greater danger from utilities and commercial-industrial users. Spills or losses are known to occur from damaged equipment and through improper handling of PCB liquids. It is estimated that 78,295 pounds of PCBs will be released into the environment each year from utility transformers and capacitors.

It may be possible for PCBs to enter the environment as a contaminant in another chemical or as a by-product of some chemical process. PCB has been reported as a low-level contaminant in some cases where water containing biphenyl is chlorinated. PCBs already free in the environment may become more of a hazard if contaminated sewage sludge is used as a soil conditioner.

Unless carefully worded, regulations to enforce the ban on "distribution in commerce" could have adverse effects on inventories, equipment resale, and maintenance. Strict enforcement could result in the scrapping of large inventories of capacitors without any decrease in the potential for environmental damage. Another question to be considered is that raised by the disposal of PCB wastes in a landfill. That is, when the title to the material passes from the original owner to the landfill operator, does this constitute "distribution in commerce"?

## MICROECONOMIC IMPACTS OF THE DRAFT "PCB BAN REGULATIONS"

(Draft Report) March 8, 1978

This report analyzed the economic impacts of an early draft of the proposed PCB ban regulations. The draft report was used by EPA in preparing the final proposed regulations. The material in this report was superseded by the report of the same title published in May, 1978, except that this draft report included two appendices that did not appear in the published version.

Appendix C of the draft report, "Characterization of U.S. Waste Oil Industry," described in detail the uses of waste oil and characterized the structure of the waste oil collecting and re-refining industry.

Appendix D of the draft report, "Supply and Demand Effects of PCB Ban," presented a formal microeconomic analysis of the supply, demand, and price effects of the increased demand expected for substitutes for PCBs. The purpose of this exposition was to correct an error in a similar analysis previously published by Ashford and Murry of MIT<sup>(1)</sup>.

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- (1) Ashford, Nicholas A., Murry, Albert E. (1976) The Impact of Governmental Restrictions on the Production and Use of Chemicals: A Case Study on Polychlorinated Biphenyls (Report No. CPA-76-3/b). Cambridge, MA: Center for Policy Alternatives, Massachusetts Institute of Technology, April 30, 1976.

"MICROECONOMIC IMPACTS OF THE PROPOSED "PCB BAN REGULATIONS"

MAY 1978

EPA 560/6-77-035

NTIS PB 281 881/3WP

The purpose of this study was to evaluate the economic impacts of the proposed "PCB Ban Regulations." These regulations were prepared by the Office of Toxic Substances of the U.S. Environmental Protection Agency with the technical support of the Interagency PCB Work Group. These regulations implement the bans on various PCB activities which were established by Congress in Section 6(e) of the Toxic Substances Control Act - Public Law 94-469.

The economic costs reported are those directly and indirectly attributable to those changes in future PCB activities which would be caused by implementation of the proposed regulations. From the wording of Section 6(e), it is clear that the intent of Congress was to ban the manufacture of PCBs after December 31, 1978, and to ban the distribution of polychlorinated biphenyls (PCBs) after June 30, 1979. Therefore, the long-term costs of using substitutes for PCBs will be a consequence of this legislated ban on the manufacture of PCBs and not a consequence of discretionary regulatory actions taken by the Environmental Protection Agency.

This analysis of the proposed regulations considered both the direct costs of complying with the requirements and the indirect effects of these requirements on price levels, capital needs, employment, energy consumption, and the availability of strategic materials. The calculated economic impacts were the incremental impacts of the proposed regulations on a base of 1976 practices as modified by the previously promulgated PCB effluent standards and the marking and disposal regulations. The costs of these other PCB regulations were considered during their development and are not considered to be a result of these proposed ban regulations.

The expected transitional and long term costs resulting from the proposed regulations are summarized in the following tables. The report also estimated employment effects and other economic consequences.

Table 1  
Transitional Cost Impacts of Proposed PCB Ban Regulation

|                                     | \$ Million Per Year       |                                   |                                   | Estimated                           |
|-------------------------------------|---------------------------|-----------------------------------|-----------------------------------|-------------------------------------|
| <u>Item (Number)</u>                | <u>1979</u>               | <u>Successing</u><br><u>Years</u> | <u>\$ Million</u><br><u>Total</u> | <u>Liability</u><br><u>of Total</u> |
| <b>ICB Transformers:</b>            |                           |                                   |                                   |                                     |
| Manufacturer clean up costs (16)    | \$ .1                     | 0                                 | \$ .1                             | -50% 1500%                          |
| Run on Building (4)                 |                           |                                   |                                   |                                     |
| Program Savings                     | 14.3                      | 1.4% less<br>per year             | 420                               | 150%                                |
| Lost Service Time                   | 2.4                       | 1.4% less<br>per year             | 75                                | 150%                                |
| <b>Transformer Service (5)</b>      |                           |                                   |                                   |                                     |
| Lost Wages                          | 1                         | 0                                 | 1                                 | 1100%                               |
| Spill Prevention Plan               | 1                         | 0                                 | 1                                 | 1100%                               |
| <b>Incremental Transformers (6)</b> |                           |                                   |                                   |                                     |
| Retrosill Program                   | 7                         | 0                                 | 7                                 | 120%                                |
| Processing Program                  | 0                         | 2.7 (2 years)                     | 5.4                               | 120%                                |
| Final Analysis for ICBs             | 0                         | .1 (1983)                         | .1                                | 120%                                |
| Reporting                           | .005                      | 0                                 | .005                              | 1100%                               |
| Spill Prevention Plan               | .02                       | 0                                 | .02                               | 150%                                |
| <b>ICB Capacitors</b>               |                           |                                   |                                   |                                     |
| Equipment Analysis (15)             | •                         |                                   |                                   |                                     |
| Inventory Classification (3)        | 1                         | 0                                 | 1                                 | 1100%                               |
| <b>Oil Filled Transformers (7)</b>  |                           |                                   |                                   |                                     |
| ICB Analysis and Disposal           | 24                        | 1.4% less<br>per year             | 700                               | 130%                                |
| <b>Mining Machines (8)</b>          |                           |                                   |                                   |                                     |
| Rebuild Machine                     | Complete by Dec. 31, 1981 |                                   | 2                                 | 120%                                |
| Scrap Classification Minus          | Complete by Dec. 31, 1981 |                                   | .6                                | 150%                                |
| Reporting Costs                     | .02                       | 0                                 | .02                               | 1100%                               |
| Spill Prevention Plans              | .04                       | 0                                 | .04                               | 150%                                |

\*Data not available to suggest estimates; probably small cost impact.

Table 1  
Transitional Cost Impacts of Proposed PCB Ban Regulation (Continued)

|                                               | \$ Million Per Year |                         |                  | Estimated Reliability of Total |
|-----------------------------------------------|---------------------|-------------------------|------------------|--------------------------------|
| Item (Category)                               | 1979                | Successing Years        | \$ Million Total |                                |
| Electrodeposits (9)                           |                     |                         |                  |                                |
| Replacement Cost                              | \$ 3.5              | 0                       | \$ 3.5           | 120%                           |
| Increased Labor Costs                         | .5                  | 0                       | .5               | -100% (1900)                   |
| Hydraulic Systems (10)                        |                     |                         |                  |                                |
| Die Casting Machines                          |                     |                         |                  |                                |
| Analysis and Sampling                         | .8                  | 0                       | .8               | 150%                           |
| Recoating                                     | .2                  | 0                       | .2               | 150%                           |
| Spill Prevention Plans                        | .5                  | 0                       | .5               | 140%                           |
| Decontamination                               | 7.3                 | 7.3 (1980)              | 14.6             | -30% (200%)                    |
| Other Hydraulic Systems                       |                     |                         |                  |                                |
| Decontamination                               | 3.6                 | 0                       | 3.6              | -10% (100%)                    |
| Production Interruptions                      | **                  | 0                       | **               | **                             |
| Heat Transfer Systems (11)                    | **                  | 0                       | **               | **                             |
| Compressors (12)                              | .2                  | 0                       | .2               | -50% (100%)                    |
| Reclaimed Oil (13)                            |                     |                         |                  |                                |
| Increased Cost of Synthetic Heat Oil Material | 100                 | 100 (years 2-5)**** 500 |                  | -80% (10%)                     |
| Increased Cost of Heat Oil                    |                     | 6.4 (years 6-15)        | 64***            | -80% (200%)                    |
| Lost Production of Reclaimed Hydraulic Fluid  | .4                  | .4 (1980)               | .8               | 120%                           |
| Polychlorobiphenyls (14)                      |                     |                         |                  |                                |
| Process Changes                               | .5                  | 0                       | .5               | -50% (200%)                    |
|                                               | \$168.3 million     |                         | \$1,002 million  | -60% (40%)                     |

\*\*Data not available to support estimate, potentially large cost impact.

\*\*\*Costs to continue indefinitely until waste industrial oil no longer contains measurable amounts of PCBs.

\*\*\*\*Higher level estimate. Increased demand may result in significantly reduced impacts.

Table 2

Long Term Cost Impacts of Proposed PCB Ban Regulations

## Transformers: (Chapter 16)

|                                        |                        |
|----------------------------------------|------------------------|
| Increased cost of non-PCB transformers | \$0 to 10 million/year |
| Increased fire losses                  | Data not available     |

## Capacitors: (Chapter 15):

|                                                   |                                       |
|---------------------------------------------------|---------------------------------------|
| Increased cost of non-PCB power factor capacitors | \$5.5 to 10.9 million/year            |
| Increased cost of non-PCB capacitors              | \$7.8 to 10.3 million/year<br>(+ 50%) |
| Increased fire losses                             | Data not available                    |
| Decreased service life                            | Data not available                    |

## Dairylide Yellow Pigment (Chapter 14)

|                                       |                                |
|---------------------------------------|--------------------------------|
| Increased cost of substitute pigments | <u>\$10 to 25 million/year</u> |
|---------------------------------------|--------------------------------|

|       |                         |
|-------|-------------------------|
| TOTAL | \$23 to 56 million/year |
|-------|-------------------------|

Present value of long term cost impacts assuming 10%  
discount rate = \$230 to 560 million

PCB MANUFACTURING, PROCESSING, DISTRIBUTION IN COMMERCE, AND  
USE BAN REGULATION: ECONOMIC IMPACT ANALYSIS

FINAL REPORT

MARCH 1979

EPA 230-03/79-001

NTIS No. forthcoming

This report is a revision of the report "Microeconomic Impacts of the proposed PCB Ban Regulations." The report summarizes the economic impacts of the promulgated ban regulations and incorporates the information made available during the rulemaking hearings on the proposed regulation. The total economic costs and estimated pounds of PCBs diverted from the environment by the regulation are summarized the following Table.

MONS 010525

# Economic Costs of the PCB Ban Regulation

| Chapter Number | Item                                               | Total Cost<br>\$ Million                                                                                                  | Pounds PCBs Diverted<br>from the Environment | Cost per Pound<br>of PCBs |
|----------------|----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|---------------------------|
| 3              | Scrap Spare PCB Capacitors                         | 1                                                                                                                         | 500                                          | \$ 2,000                  |
| 3              | Remove PCB Capacitors from Equipment in Inventory  | 1,000                                                                                                                     | 5,360                                        | \$187,000                 |
|                |                                                    | These costs will be significantly reduced or eliminated if EPA grants exemptions from the "distribution in commerce" ban. |                                              |                           |
| 4              | Ban Rebuilding Askarel Transformers                | 397 to 771 (30 yrs)                                                                                                       | 47,000 to 925,000                            | \$429 to \$16,400         |
| 5              | Retrofill Railroad Transformers to 6%              | 6.7                                                                                                                       | ** (3.76 million lb) total                   | ** (>\$1.75)              |
| 5              | Retrofill Railroad Transformers from 6% to .1%     | 5.15                                                                                                                      | ** (80,240 lb. total)                        | ** (>\$68)                |
| 6              | Require Incineration of Transformer Oil            | 96 to 510 (30 yrs)                                                                                                        | 200,000                                      | \$480 to \$2,550          |
| 7              | Special Storage Areas at Transformer Service Stops | *                                                                                                                         | *                                            | *                         |
| 8              | Retrofill/Ban PCB Miner Motors                     | 2.6 to 4.3                                                                                                                | ? (27,500 lb total)                          | ? (>\$94 to \$155)        |
| 9              | Ban Rebuilding Electro-magnets                     | .96                                                                                                                       | 200 to 2,000                                 | \$480 to \$4,800          |

\*Information not available in record to make estimate.

\*\*Figure represents total amount of PCBs in this use. Information not available in record to make an estimate of amount diverted from the environment.

ECONOMIC COSTS OF THE PCB BAN REGULATION (Continued)

| <u>Chapter<br/>Number</u> | <u>Item</u>                                                | <u>Total Cost<br/>\$ Million</u> | <u>Pounds PCBs Diverted<br/>from the Environment</u> | <u>Cost per Pound<br/>of PCBs</u> |
|---------------------------|------------------------------------------------------------|----------------------------------|------------------------------------------------------|-----------------------------------|
| 10                        | Decontaminate Hydraulic Systems                            | 21.4 to 25                       | 470 to 2,390                                         | \$6,000 to \$53,000               |
| 11                        | Decontaminate Heat Transfer Systems                        | 12.8 to 17.2                     | 1,872 to 2,496                                       | \$6,870                           |
| 12                        | Decontaminate Compressors                                  | .2                               | *                                                    | *                                 |
| 13                        | Ban Use of Waste Oil on Roads                              | 0 to 31.7/year                   | 8,073/year                                           | \$0 to \$3,925                    |
| 14                        | Phthalocyanine Blue Pigments                               | .425/year                        | 544/year                                             | \$781                             |
| 14                        | Diarylide Yellow Pigments                                  | .478/year                        | 441/year                                             | \$1,084                           |
| 15                        | Spill Materials (50-500ppm)-<br>to Chemical Waste Landfill | *                                | *                                                    | \$182                             |
| 16                        | Ban New Large PCB Capacitors                               | 5.5 to 11/year                   | 14,200                                               | \$387 to \$775                    |
| 16                        | Ban New Small PCB Capacitors                               | 6.6 to 18.9/year                 | 6,930/year                                           | \$950 to \$2,730                  |
| 17                        | Ban New PCB Transformers                                   | 0 to 10/year                     | 12,000/year                                          | \$0 to \$833                      |

\*Information not available in the record to make estimate.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                   |                                                     |                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----------------------------------------------------|----------------------------|
| BIBLIOGRAPHIC DATA SHEET                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1. Report No.<br>EPA 560/6-79-004 | 2.                                                  | 3. Report Project File No. |
| 4. Title and Subtitle<br>Polychlorinated Biphenyls 1929-1979: Final Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                   | 5. Report Date<br>May 16, 1979                      |                            |
| 7. Author(s)<br>Robert A. Westin                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                   | 8. Performing Organization Rep No. 474.5F           |                            |
| 9. Performing Organization Name and Address<br>VERSAR, Inc.<br>6621 Electronic Drive<br>Springfield, Virginia 22151                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                   | 10. Project Task Force Unit No.                     |                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                   | 11. Contract/Grant No.<br>68-01-3259                |                            |
| 12. Sponsoring Organization Name and Address<br>Office of Toxic Substances<br>U. S. Environmental Protection Agency<br>Washington, D. C. 20460                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                   | 13. Type of Report & Period Covered<br>Final Report |                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                   | 14.                                                 |                            |
| 15. Supplementary Notes<br>EPA Program Manager: Mr. Thomas E. Kopp                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                   |                                                     |                            |
| 16. Abstracts<br>The primary emphasis of this report is a summary of the work that Versar performed in support of the EPA's regulatory activities involving polychlorinated biphenyls over the past four years. The report includes summaries of 24 reports on PCBs that Versar submitted to EPA during this period. Also included are a summary of the uses of PCBs from 1929 through 1979, a review of much of the early literature on the uses and toxicity of PCBs, and a discussion of the various regulatory activities that limited human exposure to PCBs and eventually banned their manufacture, processing, and use. |                                   |                                                     |                            |
| 17. Key Words and Document Analysis. 17a. Descriptors<br>Polychlorinated biphenyls<br>PCBs<br>Regulations<br>Water Pollution Abatement<br>Economic Analysis<br>Toxic Substances Control Act<br>Toxicity<br>Environmental Transport<br>Effluents                                                                                                                                                                                                                                                                                                                                                                                 |                                   |                                                     |                            |
| 17b. Identifiers/Open-Ended Terms                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                   |                                                     |                            |
| MONS 010528                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                   |                                                     |                            |
| 17c. COSATI Field Group                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                   |                                                     |                            |
| 18. Availability Statement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                   | 19. Security Class: This Report<br>UNCLASSIFIED     | 21. No. of Pages<br>90     |
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MONS 010529

CLINICAL AND METABOLIC ABNORMALITIES IN OCCUPATIONAL EXPOSURE TO  
POLYCHLORINATED BIPHENYLS (PCBs)

Kenneth H. Chase, M.D.<sup>1</sup>, Otto Wong, Sc.D.<sup>2</sup>, David Thomas, D.Stat.<sup>2</sup>

Bertram W. Berney, M.H.S.<sup>1</sup> and Robert K. Simon, Ph.D.<sup>3</sup>

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Presented at the American Occupational Health Conference, Atlanta,  
Georgia -- May 1, 1981

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## ABSTRACT

A cross-sectional study of 120 male workers was conducted to determine the prevalence of increased PCB absorption as well as the presence of potentially related clinical and metabolic abnormalities. Three exposure categories ("exposed", "nominally exposed", "non-exposed") were defined. Complete work histories, clinical histories, physical exams and lab tests were obtained including PCB plasma level determinations. In addition, PCB fat levels were determined in a portion of each exposed group.

Findings of dermatotoxicity were observed and elevated PCB levels more frequently noted in the exposed group ( $p < 0.0001$ ) correlating well with age and duration of employment. These correlations were stronger for fat ( $p < 0.001$ ) than for plasma ( $p < 0.01$ ) PCB levels. In the exposed group, a significant correlation was found between PCB plasma and serum triglyceride ( $p < 0.0001$ ) and SGOT levels ( $p < 0.01$ ). These correlations remained significant after controlling for either age or length of employment. No significant correlations were found between PCB levels and cholesterol, HDL cholesterol or liver function tests other than SGOT.

Further analyses relating frequency of reported direct contact with PCB levels suggested a dermal route of exposure. An analysis by union affiliation demonstrated that crafts with greater direct exposure had correspondingly higher elevations of PCB levels.

## BACKGROUND

Polychlorinated biphenyls (PCBs) comprise a group of synthetic chlorinated hydrocarbon compounds with considerable industrial utility based on their resistance to oxidation and dielectric properties. They have been used world-wide in capacitors and transformers and many other applications described elsewhere (1). The contamination of the general environment as well as the workplace by PCBs was appreciated only recently leading to the ban of their continued manufacture under the Toxic Substances Control Act of 1976 (2). This action was prompted by greater awareness of animal toxicity studies (3), the stability and persistence of PCBs in the environment, the tendency of PCBs to accumulate in human tissues (4,5) and the documented chronic toxicity of PCBs in humans following accidental oral ingestion in the "Yusho" incident (6).

In spite of legislative and regulatory actions to phase out the use of PCBs, solutions to problems of effective disposal have not been forthcoming. In 1977 Hecht (7) estimated that of the 1.25 billion pounds produced in this country since the 1930s, 750 million pounds were still in use and 450 million pounds had found their way into the general environment. A review (8) by the National Institute for Occupational Safety and Health (NIOSH) of clinical and metabolic abnormalities in both environmentally and occupationally exposed groups revealed inconsistent relationships between tissue PCB levels and abnormal findings. A more

recent publication (9) suggests alterations of lipid metabolism at PCB levels less than those usually reported in association with findings of clinical toxicity.

An opportunity to re-examine these relationships was recently provided in a railroad passenger car and locomotive maintenance facility at which some employees have been exposed to PCB-containing transformer fluids (Pyranol, Inerteen, Askarel) for nearly 40 years. Inasmuch as the potential health hazards of PCBs were not apparent until the past few years, the handling of transformer fluids at this facility was on a casual basis with few or no special handling procedures in effect for the greater part of this exposure period. A change in management followed by the documentation of elevated PCB levels in the work environment in early 1979 provided the impetus for developing more conservative handling procedures as well as a medical monitoring program which included the design and execution of an epidemiologic study herein described. It was the purpose of this study to determine the prevalence of increased PCB absorption among exposed workers as well as the prevalence of findings compatible with PCB toxicity. In addition two control groups were defined with either nominal or non-exposure against which comparisons could be made. Lastly, through detailed work histories, an attempt was made to determine those factors most predictive of elevated PCB levels as well as to shed light on the most probable route of exposure.

## MATERIALS AND METHODS

One hundred and twenty male employees participated in the study according to the following exposure groups:

Group I -- Exposed (86 subjects)

Group II -- Nominally Exposed (15 subjects)

Group III -- Non-Exposed (19 subjects)

Subjects within each of these three groups were randomly selected by a computer program from the corresponding underlying populations. Group I subjects were defined as "exposed" on the basis of their frequent opportunity for direct contact with PCB-containing transformer fluids in their assigned shop areas. Group II subjects were defined as "nominally exposed" on the basis of their employment at the same facility but without the opportunity (work assignment) characterizing Group I subjects. Group III subjects were defined as "non-exposed" on the basis of the absence of PCB-containing fluids in their work environment and were employed elsewhere. All three groups reside in the same geographic region.

All participants completed a detailed work history questionnaire in which tasks entailing potential exposure to PCB-containing fluids were characterized and quantified. Information related to potential exposure to other toxic substances was also obtained. Complete medical histories and physical examinations were performed on all participants. A comprehensive battery of clinical laboratory tests were performed in the fasting state (12 hours)

as outlined in Table 1. Plasma PCB levels were determined on all subjects. In addition, 50 randomly selected subjects (36 in Group I, 5 in Group II and 9 in Group III) underwent subcutaneous fat biopsies upon which fat PCB levels were determined. Analytical determinations for PCBs in heparinized human plasma and fat specimens were performed as specified by EPA methods (10). In brief, hexane extraction was followed by specified silica gel and/or florisil cleanup to remove pesticides. The isolated PCB fraction was assayed by electron capture gas chromatography according to Webb/McCall (11). All of the laboratory testing was performed by Professional Clinical Laboratories, Inc. in Wilmington, Delaware. This laboratory participated in the Center for Disease Control (CDC) trial PCB testing program conducted during the course of this study.

Student's t-tests were used to compare average values of selected variables among the three groups. Correlation between selected variables in Group I was assessed using Pearson's simple correlation coefficients, and partial correlation coefficients to adjust for confounding variables. The chi-square procedure was used to test for association in the contingency tables.

## RESULTS

Table 2 shows the age distribution of the three groups. The two exposed groups are older than the non-exposed group. The average age for the exposed group was 41.4 years; the nominally exposed group 37.2; and the non-exposed group 30.7. The difference in average age between the exposed group and the non-exposed group is statistically significant ( $p < 0.05$ ). This age difference should be taken into consideration when comparisons between the groups are made, since many of the parameters vary with age.

Table 3 presents the distribution of length of employment by exposure category. The average lengths of employment were 17 years, 3 years and 9 months, and 4 years and 3 months for the exposed, nominally exposed, and non-exposed groups, respectively. The difference between the exposed group and the nominally exposed group or the non-exposed group is highly significant ( $p < 0.0001$ ). This was not surprising in view of the traditionally stable crafts represented by the exposed group.

Review of medical histories and physical findings failed to reveal findings of organ toxicity in the exposed group although several cases of chloracne were encountered in this group with none being found in the other groups. Other dermatological findings were more prevalent in the exposed group as well, but no significant association between these and PCB levels could be demonstrated within the group. Historically,

there was a common reporting in Group I of transient skin and eye irritation attributed to accidental spills in which there was direct contact with PCB-containing fluids.

The averages of some selected biochemical parameters by exposure category are shown in Table 4. There is no statistically significant difference among the groups in triglycerides, cholesterol, HDL, SGOT, SGPT. For  $\gamma$ -glutamyl transpeptidase ( $\gamma$ GTP), the highest value, 37.1 IU/l, was reported among the exposed employees, the intermediate value, 34.1, among the nominally exposed, and the lowest value, 29.8, among the non-exposed; an indication of a trend by exposed category. However, because of the considerable variabilities in the measurement and the relatively small sample sizes of both the nominally exposed and the non-exposed groups, these differences are not statistically significant.

For PCB levels, the exposed group showed a clear elevation when compared to either the nominally exposed or the non-exposed groups (Table 5). The average plasma PCB level (33.4 ppb) of the exposed group was more than twice that of either the nominally exposed group (14.2 ppb) or the non-exposed group (12.0 ppb). The differences in plasma PCB level between the exposed group and the other two groups are highly significant ( $p < 0.0001$ ), but the difference between the nominally exposed and the non-exposed group is not statistically significant. The discrepancy in fat PCB level for the exposed group was 5.6 ppm, more than three

times that of either the nominally exposed (1.4 ppm) or the non-exposed group (1.3 ppm). Again the difference between Group I (exposed) and either Group II (nominally exposed) or Group III (non-exposed) is highly significant ( $p < 0.0001$ ), but that between Group II and Group III is not significant.

In an attempt to determine any association or correlation between PCB exposure and other variables in Group I, Pearson's correlation coefficients were calculated. Similar analyses were not performed for Groups II or III as the PCB levels were well within the normal range (12,13) and the sample sizes for these groups were relatively small. Table 6 shows the correlation coefficients and the corresponding p values for selected biochemical parameters, length of employment and age for the exposed group. Apart from the obvious expected association between length of employment and age, significant correlations were found between length of employment and plasma PCB level, as well as between length of employment and fat PCB level. However, the correlation between length of employment and fat PCB level ( $r = 0.54$ ,  $p < 0.001$ ) was stronger than that between length of employment and plasma PCB level ( $r = 0.27$ ,  $p < 0.01$ ). Similar significant correlations were observed between age and plasma PCB as well as fat PCB levels. A discussion on the possible confounding effect between age and length of employment is given below.

Also in Group I, statistically significant correlation was demonstrated between plasma PCB levels and triglycerides ( $r = 0.56$ ,  $p < 0.0001$ ) but not between fat PCB levels and triglycerides. Plasma PCB levels were also significantly correlated with SGOT ( $r = 0.28$ ,  $p < 0.01$ ) but not with SGPT or  $\gamma$ GTP. Fat PCB levels were not significantly correlated with SGOT, SGPT, or  $\gamma$ GTP.

Since many of the variables examined in Table 6 are inter-related, partial correlation coefficients, which take into account confounding factors, were calculated and are presented in Table 7. The correlation between plasma PCB levels and triglycerides remained highly significant even after adjusting for either age or length of employment ( $r = 0.54$  and  $0.55$  respectively,  $p < 0.001$ ). On the other hand, there was no significant correlation between fat PCB levels and triglycerides, adjusting for age or length of employment. Among the liver function parameters, SGOT was found to remain significantly correlated with plasma PCB levels even after adjusting for age ( $r = 0.26$ ,  $p < 0.05$ ).

To determine the possible relationship between the frequency of direct contact with PCB-containing fluids and PCB levels, all 120 subjects in the study were asked whether or not they ever had direct contact with such fluids and, if so, to report the frequency with which this had occurred. Table 3 shows the

crosstabulation of plasma PCB levels and reported frequency of direct contact. The figures clearly demonstrate a direct relationship between the two parameters. Among those who reported no direct contact with PCB-containing fluids, 41% had PCB plasma levels less than or equal to 10 ppb, whereas only 4% of those with frequent contacts had plasma PCB levels in this range. On the other hand, only 3% of those who reported no direct contact had plasma PCB levels greater than 30 ppb, compared to 44% among those with frequent such contacts. This association is highly significant (chi-square = 28.83,  $p < 0.005$ ). Table 9 demonstrates a similar relationship between fat PCB levels and reported frequency of direct contact.

As it was evident from the work histories that certain crafts inherently provided greater opportunity than others for direct contact with PCB-containing fluids, an attempt was made to correlate plasma PCB levels with union affiliation for those subjects employed at the maintenance facility (Groups I and II). The result was highly significant (chi-square = 42.89,  $p < 0.001$ ) and is presented in Table 10. Similar calculations were not performed for fat PCB levels as the number of subjects with recorded levels was too small to permit same.

## DISCUSSION

In this study Groups I (exposed) and II (nominally exposed) consisted of male subjects employed at a railroad passenger car and locomotive maintenance facility, whereas Group III (non-exposed) subjects were employed elsewhere. All subjects were of the same sex, shared the same employer, and lived in the same geographic area. The greater length of employment noted in Group I subjects was attributed to the traditional stability in the crafts represented by that group. These employees have remained at the same facility for a mean duration of 17 years with a range of a few months to 40 years.

Comparable occupational PCB exposure studies have variously shown findings of dermatotoxicity, hyperpigmentation and liver function abnormalities but without consistent relationships to PCB levels when measured (8). The transient symptoms of skin and eye irritation associated with acute exposures, as well as the occasional finding of chloracne reported in this study, are in keeping with these other studies. A recent comprehensive study of capacitor manufacturing workers by Fischbein et al. (14) was similarly notable for its relative absence of physical findings outside of a high prevalence of dermatologic abnormalities in spite of a mean plasma PCB level of 172 ppb (n=289). Even more recently Baker et al. (9) reported no symptoms or physical findings of organ toxicity in a different group of PCB exposed capacitor workers whose mean plasma PCB level was 75.1 ppb (n=18).

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(18) with structural similarities to PCBs. There have been less than a handful of reports outside the Yusho incident describing lipid abnormalities in human exposures to PCBs but these have supported the finding of elevated serum triglycerides (9). The additional finding of lowered HDL lipoprotein levels in this latter study was not confirmed by the current investigation.

Although no evidence of overt hepatotoxicity was evident in the exposed group, the association between plasma PCB levels and SGOT was statistically significant, a finding which has been recently reported by others (14). It is tempting to incriminate the liver as a target organ for PCB exposure responsible for both the triglyceride and SGOT abnormalities as has been suggested in animal studies (16), but this requires further testing of alternative hypotheses.

The demonstrated relationship between PCB levels and reported frequency of direct contact with PCB-containing fluids suggests a dermal route of exposure. As PCBs generally exhibit low vapor pressures (19), an airborne route of exposure is not likely unless the PCB-containing fluids are heated to a significant degree. There is thus theoretical support for the use of suits impervious to PCBs in protecting the worker from further exposure to PCBs and the potential, yet still unknown, risks for same.

Those crafts with known direct exposure to PCBs are at greater risks for PCB absorption as has been shown earlier (Table 10). The predominant crafts in this study are represented by the following

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unions:

BMWE -- Brotherhood of Maintenance of Way Employees

BRAC -- Brotherhood of Railway and Airline Clubs

JCC -- Joint Council of Carmen

IAM -- International Association of Machinists

SMWIA - Sheet Metal Workers International Association

IBEW -- International Brotherhood of Electrical Workers

Analyses of this type provide a rational basis for the assignment of protective equipment and the development of appropriate handling procedures for PCB-containing fluids.

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Table 1. - Laboratory Tests Determined in Study Subjects

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|                      |                                   |
|----------------------|-----------------------------------|
| Complete Blood Count | A/G Ratio                         |
| Urinalysis           | Total Bilirubin                   |
| Glucose              | SGPT                              |
| BUN                  | SGOT                              |
| Uric Acid            | LDH                               |
| Creatinine           | $\gamma$ -Glutamyl Transpeptidase |
| Calcium              | Triglycerides                     |
| Phosphorous          | Cholesterol                       |
| Alkaline Phosphatase | HDL Cholesterol                   |
| Total Protein        | LDL Cholesterol                   |
| Albumin              | VLDL Cholesterol                  |
| Globulin             | Phenotype                         |

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Table 2. - Age Distribution of 120 Workers by PCB Exposure Category

| Age<br>(years) | Exposed |      | Nominally Exposed |      | Non-exposed |      |
|----------------|---------|------|-------------------|------|-------------|------|
|                | No.     | %    | No.               | %    | No.         | %    |
| 15-19          | 1       | 1.2  | 0                 | 0    | 2           | 10.5 |
| 20-24          | 14      | 16.3 | 1                 | 6.7  | 3           | 15.8 |
| 25-29          | 17      | 19.8 | 2                 | 13.3 | 6           | 31.6 |
| 30-34          | 5       | 5.8  | 6                 | 40.0 | 4           | 21.1 |
| 35-39          | 7       | 8.1  | 1                 | 6.7  | 2           | 10.5 |
| 40-44          | 6       | 7.0  | 2                 | 13.3 | 0           | 0    |
| 45-49          | 2       | 2.3  | 1                 | 6.7  | 1           | 5.3  |
| 50-54          | 11      | 12.8 | 1                 | 6.7  | 0           | 0    |
| 55-59          | 17      | 19.8 | 1                 | 6.7  | 1           | 5.3  |
| 60+            | 6       | 7.0  | 0                 | 0    | 0           | 0    |
| Total (N)      | 86      | 71.7 | 15                | 12.5 | 19          | 15.8 |
| Average        | 41.4    |      | 37.2              |      | 30.7        |      |

Table 3. - Distribution of Length of Employment of 120 Workers by PCB Exposure Category.

| <u>Length of Employment</u><br>(years) | <u>Exposed</u> |      | <u>Nominally Exposed</u> |      | <u>Non-Exposed</u> |      |
|----------------------------------------|----------------|------|--------------------------|------|--------------------|------|
|                                        | No.            | %    | No.                      | %    | No.                | %    |
| <5                                     | 30             | 34.9 | 13                       | 86.7 | 17                 | 89.5 |
| 5- 9                                   | 20             | 23.3 | 1                        | 6.7  | 1                  | 5.3  |
| 10-14                                  | 4              | 4.7  | 0                        | 0    | 0                  | 0    |
| 15-19                                  | 0              | 0    | 1                        | 6.7  | 0                  | 0    |
| 20-24                                  | 0              | 0    | 0                        | 0    | 0                  | 0    |
| 25-29                                  | 3              | 3.5  | 0                        | 0    | 0                  | 0    |
| 30-34                                  | 3              | 3.5  | 0                        | 0    | 0                  | 0    |
| 35-39                                  | 19             | 22.1 | 0                        | 0    | 1                  | 5.3  |
| 40-44                                  | 6              | 7.0  | 0                        | 0    | 0                  | 0    |
| 45+                                    | 1              | 1.2  | 0                        | 0    | 0                  | 0    |
| Total (N)                              | 86             | 71.7 | 15                       | 12.5 | 19                 | 15.8 |
| Average                                | 17.0           |      | 3.8                      |      | 4.3                |      |

Table 4. - Averages of Selected Biochemical Parameters in 120 Workers by PCB Exposure Category

| <u>Parameter</u>      | <u>Exposed</u> | <u>Nominally Exposed</u> | <u>Non-Exposed</u> |
|-----------------------|----------------|--------------------------|--------------------|
| Triglycerides (mg%)   | 135.8          | 128.7                    | 145.5              |
| Cholesterol (mg%)     | 231.7          | 238.3                    | 238.2              |
| HDL Cholesterol (mg%) | 58.8           | 57.2                     | 61.7               |
| SGOT (IU/l)           | 19.6           | 19.1                     | 19.4               |
| SGPT (IU/l)           | 21.7           | 21.6                     | 21.3               |
| γGTP (IU/l)           | 37.1           | 34.1                     | 29.8               |

Table 5. - Averages and Ranges of Plasma and Fat PCB Levels in  
120 Workers by PCB Exposure Category.

|                                 | <u>Exposed</u> | <u>Nominally Exposed</u> | <u>Non-Exposed</u> |
|---------------------------------|----------------|--------------------------|--------------------|
| <u>Plasma PCB Levels (ppb*)</u> |                |                          |                    |
| Average                         | 33.4           | 14.2                     | 12.0               |
| Range                           | 10-312         | 10-30                    | 10-27              |
| <u>Fat PCB Levels (ppm**)</u>   |                |                          |                    |
| Average                         | 5.6            | 1.4                      | 1.3                |
| Range                           | 1.0-21.6       | 1.0-1.8                  | 1.0-2.0            |

\* parts per billion

\*\* parts per million

Table 5. - Averages and Ranges of Plasma and Fat PCB Levels in  
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|                                 | <u>Exposed</u> | <u>Nominally Exposed</u> | <u>Non-Exposed</u> |
|---------------------------------|----------------|--------------------------|--------------------|
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| Average                         | 33.4           | 14.2                     | 12.0               |
| Range                           | 10-312         | 10-30                    | 10-27              |
| <u>Fat PCB Levels (ppm**)</u>   |                |                          |                    |
| Average                         | 5.6            | 1.4                      | 1.3                |
| Range                           | 1.0-21.6       | 1.0-1.8                  | 1.0-2.0            |

\* parts per billion

\*\* parts per million

Table 7. - Selected Partial Correlation Coefficients and Probabilities  
for Selected Variables in 86 Workers Exposed to PCBs.

| <u>Variables</u>                                                         | <u>Coefficient</u> | <u>Probability</u> |
|--------------------------------------------------------------------------|--------------------|--------------------|
| Plasma PCB level and triglycerides<br>adjusting for age                  | .54                | <.001              |
| Plasma PCB level and triglycerides<br>adjusting for length of employment | .55                | <.001              |
| Fat PCB level and triglycerides<br>adjusting for age                     | .20                | ns*                |
| Fat PCB level and triglycerides<br>adjusting for length of employment    | .23                | ns                 |
| Plasma PCB level and SGOT<br>adjusting for age                           | .26                | <.05               |

\*ns = not significant

Table 8. - Relationship Between Plasma PCB Levels and Frequency of Reported Direct Contact with PCB-Containing Fluids

|                                                         |              | <u>Plasma PCB Levels (ppb)</u> |              |              |               |            |
|---------------------------------------------------------|--------------|--------------------------------|--------------|--------------|---------------|------------|
|                                                         |              | <u>≤10</u>                     | <u>11-20</u> | <u>21-30</u> | <u>&gt;31</u> |            |
| <u>Frequency of<br/>Reported<br/>Direct<br/>Contact</u> | Never        | 16<br>(41%)*                   | 17<br>(44%)  | 5<br>(13%)   | 1<br>(3%)     | 39<br>100% |
|                                                         | Rarely       | 7<br>(30%)                     | 7<br>(30%)   | 6<br>(26%)   | 3<br>(13%)    | 23<br>100% |
|                                                         | Occasionally | 5<br>(15%)                     | 9<br>(27%)   | 9<br>(27%)   | 10<br>(30%)   | 33<br>100% |
|                                                         | Frequently   | 1<br>(4%)                      | 8<br>(32%)   | 5<br>(20%)   | 11<br>(44%)   | 25<br>100% |
|                                                         |              | 29                             | 41           | 25           | 25            | 120        |

chi-square = 28.83, p < .005

\*The figures in parentheses are row percentages.

Table 9. - Relationship Between Fat PCB Levels and Frequency of Reported Direct Contact with PCB-Containing Fluids

|                                                         |              | <u>Fat PCB Levels (ppm)</u> |                  |                 |            |
|---------------------------------------------------------|--------------|-----------------------------|------------------|-----------------|------------|
|                                                         |              | <u>&lt;1.5</u>              | <u>1.51-2.25</u> | <u>&gt;2.26</u> |            |
| <u>Frequency of<br/>Reported<br/>Direct<br/>Contact</u> | Never        | 8<br>(73%)*                 | 2<br>(18%)       | 1<br>(9%)       | 11<br>100% |
|                                                         | Rarely       | 5<br>(42%)                  | 1<br>(8%)        | 6<br>(50%)      | 12<br>100% |
|                                                         | Occasionally | 5<br>(31%)                  | 1<br>(6%)        | 10<br>(63%)     | 16<br>100% |
|                                                         | Frequently   | 2<br>(18%)                  | 0<br>(0%)        | 9<br>(82%)      | 11<br>100% |
|                                                         |              | 20                          | 4                | 26              |            |

chi-square = 13.06, p < .05

\*The figures in parentheses are row percentages.

Table 10. - Relationship Between Plasma PCB Levels and Union Affiliation of Workers at Maintenance Facility

|                         |       | Plasma PCB Levels (ppb) |             |            |             |            |
|-------------------------|-------|-------------------------|-------------|------------|-------------|------------|
|                         |       | ≤10                     | 11-20       | 21-30      | ≥31         |            |
| Union<br>Affiliation ** | BMWE  | 5<br>(56%)*             | 2<br>(22%)  | 2<br>(22%) | 0<br>(0%)   | 9<br>100%  |
|                         | BRAC  | 2<br>(50%)              | 1<br>(25%)  | 1<br>(25%) | 0<br>(0%)   | 4<br>100%  |
|                         | MISC  | 4<br>(57%)              | 2<br>(29%)  | 0<br>(0%)  | 1<br>(14%)  | 7<br>100%  |
|                         | JCC   | 1<br>(7%)               | 4<br>(27%)  | 8<br>(53%) | 2<br>(13%)  | 15<br>100% |
|                         | IAM   | 4<br>(12%)              | 15<br>(45%) | 7<br>(21%) | 7<br>(21%)  | 33<br>100% |
|                         | SWMIA | 0<br>(0%)               | 2<br>(29%)  | 2<br>(29%) | 3<br>(43%)  | 7<br>100%  |
|                         | IBEW  | 1<br>(4%)               | 9<br>(35%)  | 4<br>(15%) | 12<br>(46%) | 26<br>100% |
|                         |       | 17                      | 35          | 24         | 25          | 101        |

chi-square = 42.89, p<.001

\* The figures in parentheses are row percentages.

\*\* See text.