PCBs In Perspective

by Harry A. Oriahi
and W. Corey Trench

Once again PCBs have surfaced to become a major topic for discussion. For that reason it seems worthwhile to develop a brief history of the life of this group of organic chemicals that has drawn such extensive attention from scientists, mass media and the general public. This article endeavors to bring PCBs into perspective and to express a reasonable hope for a sound solution to the PCB problem in the long range interest of the nation.

PCBs are Polychlorinated Biphenyls—a broad range of organic chemicals also commonly known as chlorinated hydrocarbons. PCBs are a complex mixture of compounds. Theoretically, some 209 different molecule structures may be formed. In general though, a much smaller number arise in the manufacturing process or occur

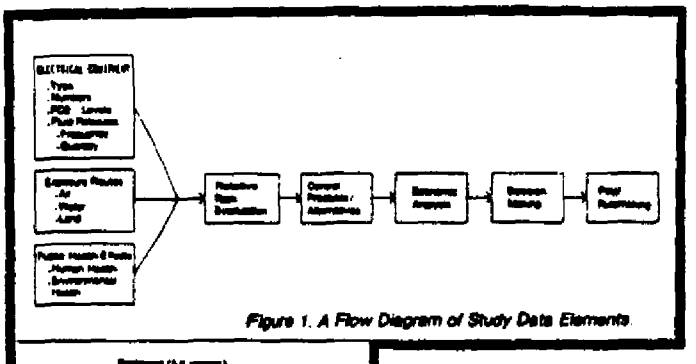


Figure 1. A Flow Diagram of Study Data Elements

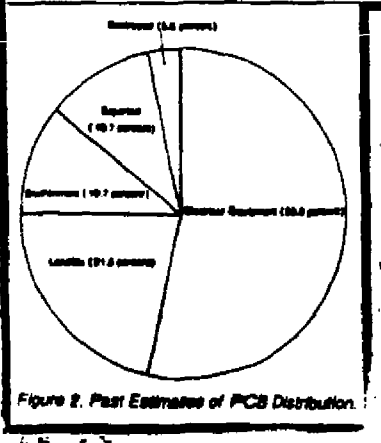


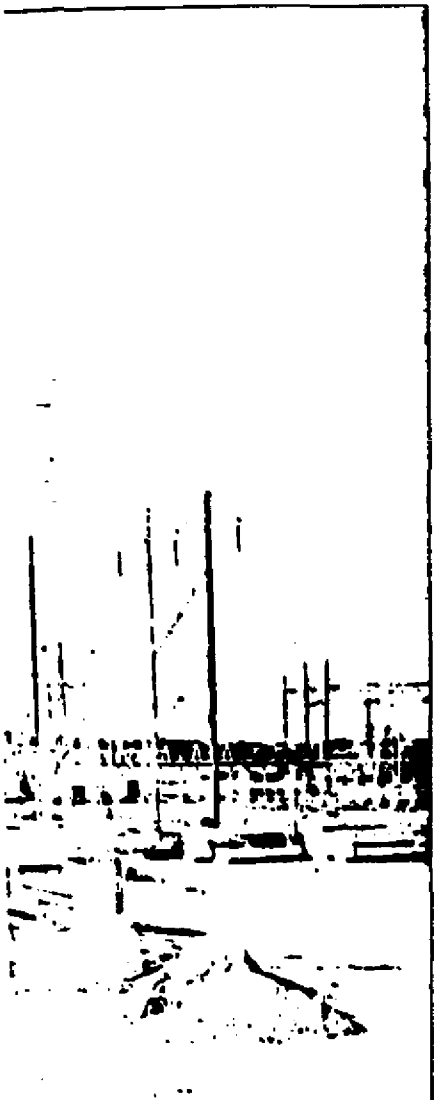
Figure 2. Past Estimates of PCB Distribution.

MONS 216414

in the environment.

PCBs are very stable, possess excellent dielectric and cooling properties and are fire resistant. Initially, these properties made PCBs a superb fluid for use in transformers and capacitors to prevent or reduce fire risk in cases where the location of equipment was of particular importance. Later, PCB uses expanded to include: hydraulic lubricants, paints, varnishes, sealants, plasticizers, carbonless paper and other coatings.

The generic name for the fire resistant dielectric fluids is Askarel. Transformers that employ PCB fluids are commonly referred to as Askarel transformers. Companies manufacturing electrical transformers and capacitors with PCB may use a different trade name: Prydaual, Pyranol, Inerteen, SAF-T-Kuhl exemplify just a few. Askarel fluids consist of a mixture of PCB and solvents, generally chlorinated benzenes.



Typical transformer use in a low-pressure substation.

Monsanto Company was the principal manufacturer of PCBs, trademarked Aroclor, in the United States. The company entered the business in 1935 upon the acquisition of Swann Chemical Company. From 1935 through the early 1970s, production steadily increased to meet the demand. In the early '70s, however, Monsanto voluntarily restricted the sale of chlorinated biphenyls. Production of open-ended uses—hydraulic fluids, lubricants and the like—was curbed owing to a greater potential of PCB dispersal into the environment. Enclosed electrical systems uses of PCBs continued until 1977. By 1977, all manufacture of PCBs ceased, nearly two years in advance of a ban on their manufacture imposed by the Toxic Substance Control Act.

In 1976, Versar Inc., under contract to EPA, assembled an inventory of PCB sources. The quantities could only be estimated yet they represent an attempt to account for the mass balance of PCBs in use and in the environment. Commercial manufacture of PCBs is probably not the entire source of the compounds. Other industrial and municipal processes have the potential for producing different PCBs in varying quantities. Nature's processes have never been identified as PCB contributors, but the mechanisms have not been proven implausible. Of the documented estimates, an approximate 1.4 billion lb of PCB was produced in the United States. Fifty million lb have been destroyed, 300 million lb reside in landfills, 150 million lb occur in the environment, 150 million lb were exported and 750 million lb exist in use. Seven hundred and fifty million lb represent about 53.6 percent of the total PCB production and the bulk of these PCBs occur in enclosed electric equipment systems. The remaining material is used in "open-ended" applications such as the hydraulic fluids, lubrication fluids, etc. (Fig. 2).

For electrical systems, an estimated 300 million lb occur in transformers, 270 million lb in large capacitors and 180 million lb are in small capacitors and other devices (Table 1).

Environmental and Health Significance

PCBs became the center of national and international concern in the late 1960s. Two events are credited with the evolution of concern: The discovery and identification of PCBs in environmental samples by Soresen Jensen, and the Yusho incident in Japan.

In the course of environmental studies to detect chlorinated hydrocarbons and DDT in a variety of samples, Jensen discovered PCBs. Their presence, though an unexpected find, distinguished PCBs as an environmental contaminant. Subsequent studies detected PCBs in remote as well as industrial environments and established the widespread distribution phenonmenon of PCBs. Also, some of the desirable aspects of PCBs were singled out as undesirable from an environmental perspective, such as the chemical's stability and non-biodegradability. PCBs were found in varying concentrations in ecological food chains.

Meanwhile, an incident occurred in Yusho, Japan that involved the contamination of rice oil by heat exchange fluids and ingestion of the oil by an isolated human population. An outbreak of adverse human health effects was related back to the contamination. The fluid was tested and found to contain concentrations of PCBs, polychlorinated dibenzofurans (PCDFs) and polychlorinated quaterphenyls. The latter two compounds were impurites of the PCB fluid. The PCBs and the impurities were linked to the registered health effects. In retrospect, it seems more likely that PCDFs or other impurities may have played the more significant role in the outbreak as opposed to PCBs. PCDFs are known to be more toxic than PCBs on several orders of scale.

Nevertheless, the results of Yusho began the establishment of PCB as toxic to man.

Actions Taken to Control PCBs

Following the Yusho event, Japan prohibited the use of PCBs in new replacement and replaced PCB equipment in high exposure areas such as electric trains. However, existing PCB-filled transformers and capacitors were to remain in use until termination of the service lives of the equipment. Other European countries have also prohibited further use of PCBs; however, some countries have not believing PCBs can be controlled by proper handling and disposal practices. As a matter of interest, PCBs are still manufactured in Germany, France, Spain, Italy and certain Eastern European countries. They continue to be used throughout the world.

As for practices in the United States, the Toxic Substances Control Act (TSCA) was passed in 1976 authorizing the U.S. Environmental Protection Agency (EPA) to promulgate PCB regulations. Initial regulations were issued in Februnry, 1978 setting forth requirements for marking, recordkeeping, storage for disposal and

MONS 216415

regulations banned the manufacture, processing, distribution in commerce and use of PCBs, except in totally enclosed systems such as transformers and capacitors or other uses specifically authorized by the Administrator of EPA.

Regulations were developed to control PCBs from all sources. The extent of these regulations has been primarily applied to the utility industry and owners/operators of electrical equipment. The voluntary termination of production of PCBs relieved a major source of potential environmental contamination. Regulations have also effected some chemical manufacturers incidently producing low level PCBs in certain chemical processes.

The full brunt of regulations has been borne by those with PCBs in closed systems, i.e., electrical transformers and capacitors. Utilities have significant numbers of PCB (Askarel) transformers and power capacitors on their systems. In addition, utilities possess transformers and other electrical devices that may contain incidental concentrations of PCBs in the oils of these pieces of equipment. The May 31, 1979 federal regulations define PCBs as any mixture containing 50 ppm (parts per million) or greater. The definition covers mineral oil-filled transformers which may be contaminated by previous manufacturing practices or in the servicing of transformers. Virtually all transformers on utility systems are classified as PCB contaminated under the current regulations and special care must be taken on ultimate disposal of these oils.

Actions Taken by Utilities

The government control of PCBs from the Congressional ban to regulation by state and federal agencies has been extensive. Utilities and enterprises have, in many cases, gone well beyond regulatory requirements. A summary of these activities includes

- Rapid response/comprehensive spill prevention and cleanup protocol.
- Use of sensor and relay devices to detect incipient equipment failure.
- Phase-out of PCB-filled equipment on accelerated bases or use of retrofilling options.

One should keep in mind that for self-imposed control activities, the possibilities may be limited. Limiting variables abound in:

- Excessive capital and operating costs balanced against limited benefits.
- Unavailability of replacement equipment or fluids.
- Pending tests of new technologies, and resulting unresolved problems or economic infeasibility.
- Unavailability of adequate or realizable disposal capacity.

EDF vs. EDA: Starting over Again

In late 1979, the Environmental Defense Fund (EDF), a Washington, D.C based environmental group, challenged certain provisions of the EPA regulations. The results of the case temporarily stunned the regulated community and resulted in further government actions. Challenged issues included: The distinction between a non-PCB item and a PCB-item by a 50 ppm cut-off; classification of transformers, capacitors, and electromagnets as totally enclosed systems; and authorized use of 11 activities, including the servicing and maintenance of transformers.

The U.S. Court of Appeals rendered a decision on October 30, 1981, the Court ruled in favor of EDF on the first two issues and in favor of EPA on the use authorizations. On the former issues, the Court found the rulemaking record deficient in information justifying EPA's selection of a 50 ppm cut-off level and classification of electrical equipment as totally enclosed systems. The deficiency in recorded information precipitated the Court's decision, not the inappropriateness of EPA's intent. The Court remanded the two issues back to EPA and ordered the Agency to initiate a new rulemaking in a timely fashion, replete with the appropriate support information.

The consequences of the decision were potentially significant. No cut-off would exist and formerly totally enclosed systems could be construed to be open uses. The possibly far-reaching effects led representatives of industry, Edison Electric Institute (EEI) and the Utility Solid Wastes Activities Group (USWAG) among other parties to achieve a negotiated agreement with EPA and EDF and avert the disruption of electrical service. A joint petition was filed on January 21, 1981. Shortly thereafter, on February 12, 1981, the Court acted to stay its mandate for 18 months granting time for EPA to promulgate new regulations. As conditions of the stay, the electric utilities agreed to carry out a temporary, Interim Measures Program and to initiate an information gathering study to assist the Agency in the new rulemaking.

The Interim Measures Program requires the inspection and maintenance, if necessary, of certain transformers. Instituted May 11, 1981, the program monitors the possibility of exposure to fluids that may contain PCBs. Specifically, *all* transformers at federally inspected meat, poultry products and egg product establishments as well as other establishments engaged in the manufacture, processing, packaging or holding of human food or animal feed for wholesale purposes—exclusive of retail locations such as grocery stores, restaurants, bakeries, etc., that pose a risk of potential contamination—must be inspected on a weekly basis. In addition, *all* other PCB (Askarel) transformers must be inspected on a quarterly basis. The Interim Measures Program aims to further reduce a minimal risk of widespread PCB contamination

Table 1
Quantities of PCBs in Use

Use	Pounds Used	Pounds Regulated	Pounds Prohibited
PCB Transformers	286,000,000	286,000,000	0
PCB Contaminated Transformers	400,000	400,000	0
Railroad Transformers	6,000,000	6,000,000	6,000,000
Mining Motors	34,000	34,000	34,000
Hydraulic Systems	780,360	780,360	780,360
Carbonless Copy Paper	?	?	?
Pigments	6,700 /yr.	6,700 /yr.	6,700 /yr
Electromagnets	20,000 -30,000	20,000 -30,000	0
Compressors	Small	All	All
Small quantity R&D	Very Small	All	Authorized Use
PCB Capacitors/PCB Equipment	450,000,000	285,500,000	Authorized Use
Process Contamination	100,000 -500,000/yr.	100,000 -600,000/yr.	100,000
Dust Control, Sealants, Coatings from Waste Oil	32,000 /yr.	32,000 /yr.	32,000
	750,850,000	583,300,000	843,000

Reference: Federal Register/Volume 44, No. 108, Thursday, May 13, 1979, Rules and Regulations, P. 31615

MONS 216416

during the 18 month period of new rulemaking.

Above and beyond the inspection program, the utility industry will furnish EPA with data on utilities to add to new rulemaking. EEI/USWAG is undertaking the wide scale study. Data under study cover:

- Numbers and types of equipment that may contain PCBs.
- Typical distribution of PCB levels in that equipment.
- Frequency of fluids releases from equipment.
- Volumes of material lost.
- Feasibility of various mitigative programs: inspection/maintenance, secondary containment, and equipment phase-out.
- Health effects of PCBs vs. replacement fluid.
- Analysis of environmental pathways taken by PCBs from equipment.

Analysis of the Problem

In the next year, EEI/USWAG will be preparing a data base of information and analysis of PCB uses, practices, and economics, forming the bases for new regulations. The study will be performed over 9-12 months. The data requirements are extensive and the electrical utility industry sizable. Yet, the design of the study must be comprehensive enough to yield reasonable data for the benefit of the decision-makers.

In the conceptualization of a study, definition of the problem is a first step. One must comprehend and combine the source, forms and distribution of PCBs, the release mechanisms, exposure routes, health effects from PCB exposure, then evaluate the magnitude and significance of this compilation as the best summary that can reasonably be expected. More specific knowledge must be developed on the quantites of PCBs occurring where they reside, and the harm they present—short- or long-term. This information along with other considerations should form the building blocks for strategies and types of control to maintain a certain warranted level of protection.

Upon reaching a definition we must proceed to design an approach to solving the problem. Data requirements have previously been identified. They fit together in a flow of (Fig. 1) data inputs leading to interpretation and decisions.

On physical effects, a wealth of information, both published and unpublished, exists on human and environmental health, and environmental chemistry of PCBs. In general, it appears that PCBs, though linked to certain health effects in animals, wildlife and man, are only slightly toxic in the acutely toxic sense. PCBs persist in the environment and have a tendency to bioconcentrate in fatty tissues, but the chronic, long term significance of these facts appear uncertain.

If one examines the more recent literature on the trends of PCB levels in the environment, with the past control of bulk manufacture and open uses, a gradual, but marked decline has been observed. Studies performed on the Great Lakes and in other major surface waters, employing concentrations in fish as an indicator of PCB, document the decline. One must examine the period of PCB existence since 1929 and its consequences to begin to develop an understanding of its significance. Extensive studies of workers involved in equipment manufacturing have shown no adverse health effects. The exposure to levels experienced by these workers has far exceeded that of the general public.

Another emphasis of the health affects effort is to provide a common base from which to compare substitute fluids with PCBs and their respective and acceptable applications.

Limited information is available on substitutes for PCBs. Since PCBs were employed in equipment primarily to provide fire protection, few, if any, substitutes have been marketed that offer the same characteristics. If they do exist, certain environmental and health criteria must be met.

On PCB sources and distribution, the study plan includes refining and upgrading information on typical quantities of PCBs in present electrical equipment as summarized earlier. This effort will supply a more accurate insight into electrical equipment, making use of PCBs compared to that equipment which contains a fluid with low to non-detectable PCB levels.

The frequency and likelihood of the escape of fluid from electrical equipment will tend to identify the exposure of the environment to PCBs. Data on the types, frequency, corrective/preventative action and environmental setting of releases will be collected.

Later, release data will be evaluated opposite the health evidence and PCB distribution to help determine the magnitude and significance of episodic releases of fluids containing PCBs. Interest in this part of the study lies with the sources and concentration of material, pathways of PCB movement, the ultimate receptors of PCB exposure and the likely consequences.

Availability of approved PCB disposal equipment exerts a major effect on the ability to remove or retire electric equipment before its usefulness ends. In the case of disposal, the utility industry is deeply concerned about their ability to handle capacitor disposal. Only one incinerator is available to dispose of the nation's capacitors. Two incinerators, including the one already mentioned have been approved to handle PCB liquids. The options appear severely limited. Logistically, the transportation of PCBs seems the less desirable approach. Available technologies, new processes, possible mobile equipment and expanded use of high efficiency boilers on site will be evaluated in the interest of attempting to be helpful in speeding up the disposal. Similarly, the ability of manufacturers to supply new and replacement equipment and/or fluids will be addressed.

Various control strategies are under consideration. They have been limited to: (1) inspection, maintenance and secondary containment, and (2) phase-out or accelerated removal options. An effort has been made to outline, in general, the type of report which will be prepared for the EPA. Following an analysis of the data, EPA will initiate a rulemaking proceeding that will culminate in final regulations.

Final Observations

PCBs are one of many organic and inorganic chemicals to which man may be exposed. Each is essential or unwanted depending on the specific circumstances of its use and residency. Though specifically cited in TSCA for a ban, PCBs occur in the environment, limiting the provision of a PCB-free society. Similarly, there are limits to providing a risk-free way of life. Therefore, society must evaluate the devotion of resources to deal with an accumulative exposure to situations or materials based on: Can the effort necessary be justified and can the nation afford the required costs?

PCBs are *not* "acutely toxic," "deadly poison," "lethal" or a proven "cancer-causer." Evidence clearly demonstrates this case and accordingly the preservation of a right to question and seek improvement in regulations that may lead to the betterment of all.

Careful evaluation of the current protection under TSCA and existing regulations, review of the trends in PCB levels in the general environment must precede the setting of a future course for regulatory control. Finally, in a responsible way, assurance that workers and the general public are given all the necessary and current facts to see PCBs in a proper perspective is essential. ■

About the Authors

Mr. Onishi is Transportation Engineering Mgr. with the Environmental Department of Commonwealth Edison Company. Mr. Trench is associate environmental scientist with Edison Electric Institute.

MONS 216417