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I. BACKGROUND

PCBs have been used in the United States since 1929. PCBs have been used in transformer cooling liquids, capacitor dielectric liquids, heat transfer and hydraulic liquids, and as a die carrier in carbonless copy paper, a plasticizer in paints, adhesives, and caulking compounds, and a filler in investment casting wax.

Monsanto was the major U.S. manufacturer of PCBs. Since 1972, Monsanto limited sales of PCBs to manufacturers of transformers and capacitors. Monsanto ceased manufacturing PCBs in mid-1977, and shipped the last remaining inventory by October 31, 1977.[1]

Small quantities of PCBs may also be produced as unintentional byproducts of other chemical processes. Similarly, chlorination of water which contains appreciable concentrations of biphenyl can result in the unintentional formation of PCBs. No natural sources of PCBs have been identified.[2] PCBs have also been imported for use in investment casting wax, for the maintenance of certain mining machinery, and as the coolant in electrical transformers.

Prior to the enactment of the Toxic Substances Control Act (TSCA), the authority of the EPA with respect to PCBs was limited to the regulation of contaminated water from point sources. EPA promulgated a rule under Section 307(a) of the Federal Water Pollution Control Act on February 2, 1977 (42 FR 6532-6556), which banned the discharge of PCBs into navigable waters by electrical transformer and capacitor manufacturers.

The enactment of TSCA in October 1976, placed additional restrictions on the use of PCBs and required that certain actions be taken by EPA. Section 6(e)(1) of the Act required that EPA promulgate a disposal and marking regulation for PCBs. This rule was promulgated by EPA on February 17, 1978 (43 FR 7150-7164).

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This rule requires that special warning labels be applied to large capacitors, transformers, and other PCB equipment, and regulates the disposal of PCBs. The regulation covers liquid PCBs and all other material and equipment components containing or having contained PCBs in concentrations of greater than 500 ppm (0.050 percent).

TSCA also establishes cutoff dates for certain PCB activities as follows:

January 1, 1978:	All manufacturing, processing, distribution in commerce, and use must be in a totally enclosed manner.
January 1, 1979:	No further manufacturing or importing of PCBs is allowed.
July 1, 1979:	No further processing or distribution in commerce of PCBs is allowed.

EPA is also authorized to grant authorizations and exemptions for continuation of specific activities beyond these dates in certain circumstances.

This Support Document/Voluntary Draft Environmental Impact Statement contains the same information as would be prepared to meet the requirements of Section 6(c)(1) of TSCA. While not legally required to prepare an environmental impact statement by Section 102(2)(c) of the National Environmental Policy Act (NEPA) of 1969, EPA has voluntarily prepared this Support Document/Voluntary Draft Environmental Impact Statement in conformance with the spirit of its 1974 statement on voluntary EIS's (39 FR 37419, October 21, 1974). The voluntary preparation of this document in no way legally subjects the Agency to NEPA requirements.

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II. ALTERNATIVES TO THIS RULE

In developing these proposed rules, EPA considered whether there were other regulatory or nonregulatory options available as alternative approaches to implementing the Section 6(e) prohibitions against PCB activities and otherwise satisfy the purposes of Section 6(e) of TSCA. The Agency has determined that there is no alternative to writing regulations under Section 6(e) to fulfill the requirements of the law.

Congress has explicitly mandated in the Act that the manufacturing, processing, distribution in commerce, and use of PCBs be prohibited according to a certain schedule. In taking any action relative to these prohibitions, EPA has the discretion under TSCA to establish and clarify certain definitions and to provide exceptions to the prohibitions. Such authority is not granted under any other statute. Therefore, EPA cannot use other laws or rely on nonregulatory mechanisms to make any exceptions to or otherwise alter in any way the impact of the prohibitions imposed by TSCA.

Section 6(e)(4) specifically exempts EPA from the requirements of Section 6(c)(1), including that of considering the use of other EPA-administered authorities as alternatives to rulemaking under Section 6 of TSCA. This indicates that Congress intended that EPA use TSCA to implement these prohibitions on PCBs. The use of other authorities to resolve the PCB problem addressed by Section 6(e)(2) and (3) would be impractical, complex, time consuming, and in some cases impossible. No other Federal statute grants the kind of authority necessary to directly control the range of PCB activities covered by Section 6(e). Sections of several statutes might have to be invoked in separate actions for each aspect of each PCB activity. A number of indirect controls would be necessary to effectively prohibit PCB activities as required by TSCA except in those cases where risks were found to be

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reasonable. The other relevant statutes, moreover, are often not designed to provide this comprehensive coverage, even when used in concert. For example, many sources of PCB air emissions are not included within the definition of sources regulatable under the Clean Air Act (CAA). The concepts of area-wide standards and controls in the Federal Water Pollution Control Act (FWPCA) and the CAA do not seem appropriate for implementing these prohibitions on PCBs and specific PCB articles or activities of concern. There are final regulations under Section 307(a) of FWPCA which set effluent standards prohibiting any discharge of PCBs, but only from PCB manufacturers, electrical capacitor manufacturers, and electrical transformer manufacturers. If the FWPCA, the Safe Drinking Water Act, or the Resource Conservation and Recovery Act were used, spills could be controlled, but other aspects of the PCB problem could not.

Some other Federal statutes not administered by EPA could also be ~~utilized~~ used to control some sources of PCBs. For example, the National Institute for Occupational Safety and Health has set a workplace exposure criterion of 5 ppm for employee exposure and recommended that the Occupational Safety and Health Administration prepare regulations accordingly. But again, this only addresses a part of the problem. A few States have regulations on PCBs, but they are not sufficient to cover all activities addressed by TSCA nor, obviously, do they provide control of PCBs on a national scale.

Existing rules were reviewed to identify any preemption problems, but no exhaustive analysis was done of all the health, environmental, and economic impacts of potential regulatory options other than action under Section 6(e). Implementing the Congressional mandate with respect to PCBs by using other statutes and regulations would be impractical. Not only would it be difficult to develop, understand, comply with, and enforce, but it could not be done within the timeframe established

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by TSCA. Even then it is doubtful that all aspects of the problem would be adequately handled as intended by Congress. Furthermore, there is a strong case that EPA is required by TSCA to use Section 6(c) of TSCA to implement, and grant exceptions to, the explicit prohibitions mandated by Section 6(e).

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III. SIGNIFICANCE OF THE RELEASE OF PCBs INTO THE ENVIRONMENT

Introduction

TSCA prohibits the manufacture, processing, distribution in commerce, or use of PCBs on or after January 1, 1978, in other than a totally enclosed manner [Section 6(e)(2)(A)]. "Totally enclosed manner" is defined by TSCA to mean a manner which will ensure no significant exposure of human beings or the environment to PCBs, as determined by EPA by rule [Section 6(e)(2)(C)]. The proposed regulations, in turn, provide that human or environmental exposure to any detectable quantities of PCBs shall be deemed significant. This provision is based on the finding that any release of PCBs into the environment will eventually result in widespread exposure of wildlife, including some of man's major food sources, and humans to these chemicals and that any such exposure may have adverse effects.

The following sections summarize the variety of adverse effects which PCBs have been found to induce in humans, laboratory animals, and other organisms, and the extent to which PCBs released into the environment become distributed throughout the biosphere. The adverse effects have been described in greater detail in various documents, including EPA Report No. 440/9-77-021, "Criteria Document for PCBs," July 1976; Criteria for a Recommended Standard: Occupational Exposure to Polychlorinated Biphenyls (PCBs), National Institute for Occupational Safety and Health, September 1977; and "Environmental Health Criteria: Polychlorinated Biphenyl: and Polychlorinated Terphenyls," World Health Organization, 1976. PCB-induced effects were also reviewed in detail in expert testimony at a public hearing before EPA and were acknowledged and described in a decision by the Administrator to promulgate toxic pollutant water effluent standards for PCBs (42 FR 6532-6556, February 2, 1977).

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Significance of Exposure to PCBs

A. Absorption and Storage

PCBs are absorbed through the lungs, the gastrointestinal tract, and the intact skin.[1] After absorption, PCBs are circulated throughout the body in the blood and are stored in adipose tissue and in a variety of organs and tissues, including the liver, kidney, lungs, adrenal glands, brain, heart, and skin.[2]

B. Specific Adverse Health Effects of PCBs as Observed in Toxicology Tests and Epidemiological Studies

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. The available toxicological and epidemiological data relating to the effects of PCBs are discussed below.

1. Oncogenicity

PCBs appear to have caused malignant and benign tumors in rats and mice in several experiments.[3] In one carefully conducted experiment, rats fed 10.0 ppm of Aroclor 1260 in the diet for 21 months developed a high incidence of carcinomas (26/184) and neoplastic nodules (144/184) in the liver. Only one of 173 control animals developed a carcinoma, and none developed neoplastic nodules. In another experiment, rats were fed Aroclors 1242, 1254, and 1260 for 24 months. Rats exposed to any of the three mixtures at 100 ppm in the diet developed malignant liver tumors (hepatomas and cholangiohepatomas), whereas none was observed in the

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controls (3/20 for Aroclor 1242, 6/27 for Aroclor 1254, 7/27 for Aroclor 1260, and 0/20 for the controls). A high frequency of nodular hyperplasia in the liver, considered by some authorities to be precancerous, was observed in the rats fed 100 ppm of the three mixtures. A significant increase in frequency in comparison to controls was observed down to the 10 ppm dosage level.[4]

The results of the epidemiological data, although somewhat ambiguous, provide additional evidence that PCBs pose a carcinogenic risk to man. In 1968, at least 1,291 persons were afflicted with a disease known as Yusho as a consequence of eating rice oil contaminated with PCBs and relatively smaller amounts of PCDFs. Although precise data are not yet available, a preliminary tabulation of the deaths among Yusho victims through 1975 showed an excess in the rate of cancer, particularly of the stomach and liver.[5] In another preliminary study, 92 workers considered likely to have been exposed to Aroclor 1254 at a New Jersey petrochemical facility between 1949 and 1957 indicated a significant excess of malignant melanoma and pancreatic cancer.[5a] In the third study, an examination of the death certificates of 50 employees formerly engaged in the manufacture of PCBs revealed seven cases of lung cancer, compared with an expected 2.5 cases. However, these results were not corrected for age or smoking habits and are only preliminary.[6]

2. Teratogenic, Fetotoxic, and Reproductive Effects

Beagle dogs fed Aroclor 1254 at the rate of 1.0 mg/kg/day had offspring with a significantly higher incidence of patent fontanelles than did controls but exhibited no decrease in the number of offspring. In the same experiment, dogs fed 5.0 mg/kg/day had a fetal resorption rate of 45.5 percent (a fourfold increase over controls). Patent fontanelles were present in 50 percent of the offspring.[7]

Sows fed Aroclor 1254 at a dose of 1.0 mg/kg/day for 21 days before breeding and throughout gestation experienced a statistically significant rate of fetal

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resorption. Higher dosages further reduced fertility and caused a variety of defects in the offspring, including cleft palate, syndactyly, and patent fontanelles.

Female rhesus monkeys fed PCBs at 5 ppm and 2.5 ppm in the diet for 6 months before mating with untreated males demonstrated severe reproductive dysfunctions. Only one of the eight animals fed the higher dose gave birth, with five animals experiencing abortions and two not conceiving at all. Of the eight monkeys fed the lower dosage, five gave birth to extremely small infants, and three aborted.[9]

In another experiment, three of six infant rhesus monkeys born to mothers fed 2.5 ppm of PCBs died within 6 months of birth. The surviving three infants exhibited behavioral and learning defects.[10]

Studies with mink have also demonstrated the adverse effects of PCBs on reproduction. Ranch mink fed coho salmon contaminated with 12-20 ppm of PCBs suffered from reproductive failure and kit mortality. Female mink fed dosages as low as 5 ppm of Aroclor 1254 and 2 ppm of Aroclor 1016 experienced substantial reductions in the number of live kits born.[11]

3. Enzyme Induction by PCBs

It has been demonstrated in several experiments that PCBs induce various microsomal enzymes of the liver, including mixed-function oxidases. Such induction has occurred after administration of Aroclors 1016, 1242, 1248, 1254, and 1260 to rats at dosages as low as 1 mg/kg/day for 21-28 days in the diet. Some of the enzymes induced by PCB mixtures and chlorobiphenyl isomers in rats and other animals are nitroreductases, dimethylases, deethylases, glucose-6-phosphatase, aryl hydrocarbon hydroxylases, cytochromes P-450 and P-448, NADPH cytochrome reductase, and delta-aminolevulinic acid synthetase.[12]

The consequences of this enzyme induction may be quite significant. Some of the enzymes induced by PCBs, such as cytochrome P-450 and cytochrome P-450 dependent

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N-demethylase, are involved in the metabolism of therapeutic drugs. Induction of these enzymes would therefore be expected to alter the function of such drugs and interfere with the treatment of diseases in humans. This possibility has been clearly demonstrated in one experiment in which workers occupationally exposed to Aroclor 1016 for the 2 years immediately before the experiment and to Aroclors 1242, 1254, and 1260 in earlier years were administered antipyrine, a prototype drug substrate. The half-life of the antipyrine in the plasma of the exposed workers was approximately two-thirds of that observed in control subjects.[13]

Another expected consequence of the induction of certain liver enzymes is an alteration of the incidence of human cancer. Although the mixed-function oxidases detoxify foreign chemicals in the body, they may also metabolize some of these substances into more toxic or carcinogenic forms.[14] However, it is difficult to predict whether induction of these enzymes would have a net effect of increasing or decreasing the incidence of cancer.

Induction of liver enzymes by PCBs could also result in alteration of the overall metabolism of the body by altering the metabolism of the steroid hormones.[15] In addition, stimulation of the production of the enzyme delta-aminolevulinic acid synthetase by PCBs has been demonstrated to cause porphyria and the accumulation of porphyrins in the liver in rats, mice, and rabbits.[16]

4. Effects on the Immunological System

Several experiments have demonstrated that PCB mixtures produce immunosuppressive effects in laboratory animals. In one study, guinea pigs were fed Aroclor 1260 at 10 ppm in the diet for 8 weeks and received injections of tetanus toxoid to stimulate antitoxin production by the lymphoid system. In comparison to controls, PCB-treated animals exhibited reduced numbers of gamma-globulin-containing cells in the lymph nodes as well as reduced serum gamma-globulin levels.[17] Infant rhesus monkeys dosed with 35 mg/kg of Aroclor 1248 for 4 weeks exhibited atrophy of the

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thymus. The same effect was observed in rhesus monkeys fed daily doses as low as 3 ppm of Aroclor 1242.[18] In addition, decreased weight and atrophy of the thymus and of the lymphoid system were observed in guinea pigs and rats administered oral doses of PCBs.[19]

5. Mutagenicity

Whydam and co-workers demonstrated that 4-chlorobiphenyl is a potent mutagen in the Ames test for bacterial mutagenesis.[20] These workers also found that the mutagenic activity of PCBs decreased with increasing chlorination and that the most highly chlorinated mixtures had almost no activity.

In several studies, various doses of Aroclor 1242 and Aroclor 1254 were administered to rats and the chromosomes of the bone marrow and testicular cells of these animals then examined for abnormalities. No significant increases in chromosomal aberrations were observed in comparison with controls. In another study, administration of these chemicals to rats did not appear to induce dominant lethal mutations.[21]

6. Effects on the Liver and the Stomach

The induction of hepatic microsomal enzymes and the causing of malignant tumors of the liver by PCBs have already been discussed. Other adverse effects on the liver have also been observed and are described here.

In one study, weaning rats fed Aroclor 1254 at 1 ppm in the diet exhibited significantly increased liver weights.[22] In another experiment, rats fed Aroclors 1248, 1254, and 1260 at 1000 ppm in the diet for 6 weeks were found to have hypertrophied livers weighing four times as much as those of controls. Abnormal ultrastructural changes within the liver cells of the PCB-treated animals included proliferation of smooth endoplasmic reticulum, development of large concentric arrays of membranes, atypical mitochondria, and increases in lipid droplets.[23]

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In guinea pigs, liver damage has been observed at dosages of Clophen A60 (a PCB mixture) as low as 250 ppm in the diet. Increased liver weight has been observed at doses down to 50 ppm.[24]

Low oral doses of PCBs have resulted in stomach lesions in several species. Dogs fed dietary levels of 1 ppm of Aroclors 1254 and 1260 and 10 ppm of Aroclor 1242 for 2 years suffered from stomach ulcers and nodules. Rhesus monkeys fed 2.5 ppm of Aroclor 1248 and 3 ppm of Aroclor 1242 in the diet developed stomach lesions which were severe in some cases. Sows also suffered from stomach lesions after being fed Aroclor 1242.[25]

7. Effects on Skin and Other Epidermal Tissues

Exposure to PCBs has resulted in various adverse effects on the skin and other epidermal tissues in humans. Chloracne, a specific type of acne caused by certain chlorinated hydrocarbon compounds, has developed among workers occupationally exposed to air containing PCBs at levels as low as 0.1 mg/cu m.[26] Skin lesions similar to chloracne have been one of the major clinical signs observed in victims of Yusho disease. In addition, Yusho victims have experienced eye discharges caused by hypersecretion of the meibomian glands, swelling of the upper eyelids, and hyperpigmentation of the skin, nails, and mucous membranes. It has been estimated that Yusho disease has resulted from ingestion of PCBs in contaminated rice oil at a rate as low as 67 µg of PCB/kg of body weight per day for 3 months.[27]

8. Other Effects

Workers exposed to PCBs have experienced numerous other symptoms and adverse effects, including digestive disturbances, jaundice, impotence, dry or sore throat, and headache.[28] In addition, Yusho victims have suffered from abdominal pain, menstrual irregularity, fatigue, cough, and disorders of the peripheral nervous system.[29]

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C. Effects on Wildlife

It is reasonable to expect that many of the adverse effects observed in laboratory animals could also occur in wild mammals exposed to PCBs. Since, as discussed below, PCBs have a tendency to collect in waterways and bioaccumulate in fish, fish-eating mammals such as otters, mink, and bears are particularly at risk. It has already been noted that mink fed PCB-contaminated fish suffered reproductive failure. Other adverse effects observed in exposed mink include increased mortality, enlargement of the liver, kidney, and heart, and reduced weight gain.[30]

Many wild birds are probably also highly susceptible to PCBs. Several fish-eating birds, including two bald eagles, have been found dead with lethal quantities of PCBs in the tissues.[31] Ring doves and American kistrels fed 10 ppm of PCBs suffered from severe reproductive failure. In addition, birds exposed to PCBs were also exhibited induction of hepatic microsomal enzymes, porphyria, changes in thyroid activity, abnormal behavior, and increased susceptibility to viral disease.[32]

The various PCB mixtures are highly toxic to several aquatic invertebrates and fish at extremely low concentrations. Aroclors 1248 and 1254 impair reproductivity of Daphnia magna at concentrations as low as 0.48-1.0 ppb. Aroclor 1254 is toxic to several types of shrimp at levels of approximately 1 ppb. Substantially increased mortality of the fry of sheepshead minnows resulted from exposure to water containing 0.16 ppb of Aroclor 1254. It is thought that PCB levels of only a few parts per trillion in Lake Michigan may be responsible for the reproductive failure of several species of fish in that body of water. There is also strong evidence that PCBs at concentrations below 1 ppb may adversely affect aquatic insects and crustaceans.[33]

Concentrations of Aroclors 1242, 1016, and 1254 as low as 0.1 ppb have been demonstrated to depress photosynthesis in phytoplankton and to reduce the rate of

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cell growth and division in these organisms. These effects are very significant since the productivity of the entire marine ecosystem may depend on the productivity of the phytoplankton within it.[34]

D. Toxicity of PCDFs

Polychlorinated dibenzofurans (PCDFs) are found in small but variable quantities as impurities in most PCB mixtures. In addition, PCDFs can be formed by photodegradation of PCBs in the environment. At present, it appears impossible to differentiate the toxic effects of PCBs from those of PCDFs. Consequently, it is necessary to regulate the commercial PCB mixtures with recognition that part of their toxicity may be attributable to unavoidable contaminants.[35]

E. Toxicity of PCB Metabolic Products

A number of studies have shown that PCBs are biodegraded into even more toxic metabolites. For example, it has been demonstrated that tetrachlorobiphenyl, which is a substantial component of several major commercial PCB mixtures, is transformed into toxic intermediate byproducts, including arene oxides and dihydrodiols. These substances have been found to cause cancer, mutations, and other toxic effects.[36]

F. Relative Toxicity of the PCB Mixtures

PCBs are usually sold commercially as mixtures of biphenyl molecules with varying degrees of chlorination. Aroclors 1016 and 1242 have relatively low chlorine content, whereas the chlorine content of Aroclor 1254 is relatively high. It has been argued that the less highly chlorinated mixtures and components may be less toxic and hazardous than the more highly chlorinated mixtures, and therefore the regulation of the former should be less stringent. This argument was considered in great detail at public hearings before EPA on Toxic Pollutant Effluent Standards for PCBs and was rejected by the Administrator.[37] There were several reasons for not establishing separate standards for the different PCB mixtures. It

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was determined that all PCB mixtures then in use, including the less chlorinated ones (e.g., Aroclor 1016), are capable of inducing severe toxic effects at low levels in mammals and aquatic organisms. In addition, the compositions of the different PCB mixtures change and may become more similar after release into the environment, so that it would make no sense to regulate the mixtures under different standards. Furthermore, important components of all the mixtures, including the less chlorinated ones, are highly persistent. Finally, while the less chlorinated components of the PCB mixtures are not stored in tissues as efficiently as the more highly chlorinated molecules, even the less chlorinated commercial mixtures have substantial amounts of components that are subject to significant uptake and storage.[38]

C. Inability to Establish a "Safe" Level of Exposure for PCBs

The available data indicate that PCBs may cause several adverse effects in humans, mammals, birds, and aquatic organisms at extremely low concentrations. Therefore, for all practical purposes, exposure of humans and other animals to any level of PCBs should be deemed significant. This is especially true in light of the demonstrated carcinogenicity of PCBs. EPA has adopted the view that "safe" or "threshold" levels for carcinogens cannot be established given the present state of scientific knowledge.[39] This policy has been upheld by the Federal courts in several decisions.[40]

Exposure of Organisms to PCBs

A. General

The purpose of this section is to discuss how PCBs released anywhere into the environment may eventually become widely distributed, with the result that many organisms, including man, may become exposed. This section also summarizes some of

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the data indicating that PCBs are already widely distributed throughout the physical environment and the biosphere and that this environmental burden is not likely to become reduced in the near future because of the persistence of these chemicals.

B. Overview of PCB Transport in the Environment

Before presenting a detailed analysis of the manner in which humans and the general biota might be exposed to "free" PCBs (i.e., PCBs which have been released into the environment), it is first necessary to determine the processes by which free PCBs are distributed throughout the three compartments of the environment--air, land, and water. A number of processes affect the nature of this distribution. Once a PCB substance has entered a physical compartment, it may be dispersed throughout that compartment. In addition, each compartment may have sinks wherein free PCBs may be rendered physically unavailable to the biota or may be degraded by chemical or metabolic processes. Finally, a more or less continuous interchange of PCBs between the three compartments might be expected. The general nature of these processes is illustrated schematically in Figure 1,[41] and a summary of the possible sources, sinks, and exchange processes is given in Table 1.

It should be pointed out that the processes described in Figure 1 and enumerated in Table 1 are theoretical possibilities that apply to any environmental pollutant. Which of these processes play an important role in the environmental transport of PCBs is determined by the specific chemical and physical properties of the PCBs as well as the characteristics of each of the compartments. In view of this, the physical and chemical properties of the PCBs are discussed next in order to lay the proper framework for a more detailed discussion of the transport of the PCBs.

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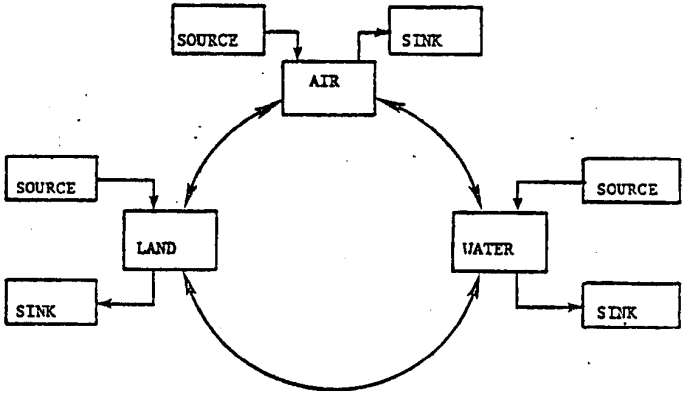


Figure 1

Schematic Representation of Transport Processes in the Environment

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Table 1.[42] Summary of Processes Involved in the Distribution of a Toxicant in the Environment

COMPARTMENT	SOURCES	EXCHANGE PROCESSES	SINKS
Atmosphere	Natural sources Gaseous residues from incineration of contaminated materials Evaporation during manufacturing processes Evaporation from consumer product uses Evaporation from accidental spills Degradation of other contaminants	Evaporation from terrestrial sources of free materials Coevaporation from contaminated water bodies	Photochemical reactions Oxidative reactions Reactions with other contaminants
Terrestrial	Degradation of discarded consumer products Industrial waste disposal by landfill Accidental spills Natural sources Degradation of other contaminants	Precipitation from contaminated air	Biodegradation - flora - fauna - microflora
Aqueous	Contaminated discharges Accidental spills Natural sources Degradation of other contaminants	Precipitation from contaminated air Runoff from contaminated soils Leachant processes from contaminated soils	Biodegradation - flora - fauna - microflora Chemical degradation - hydrolysis - photochemical - active chemical species reactions Sorption and entrapment onto fixed sediments

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C. Environmentally Relevant Properties of the PCBs

The PCBs are a group of compounds, some 209 in number, that are prepared by the partial chlorination of biphenyl to yield a complex mixture of the chlorobiphenyls in the form of high boiling point liquids of moderate viscosity. The environmentally significant physical properties of several of the commercial mixtures (Aroclors) are presented in Table 2. The properties of the PCBs that have made them so commercially attractive include low water solubility, low affinity for water (high lipid solubility), a high degree of chemical stability, and very low vapor pressure at ambient temperatures. A more detailed discussion of the relevance of these properties to the environmental hazard posed by the PCBs is presented in the following sections.

1. Chemistry of the Chlorobiphenyls

The chlorobiphenyls have been demonstrated to undergo a number of chemical reactions. Both oxidation and hydrolysis of these chemicals can be carried out, but only under conditions that are considerably more rigorous than would be found in an environmental situation.[43] Another class of reactions to which the PCBs are susceptible is that of cyclization. Of particular interest is the cyclization of 2,2'-dichlorobiphenyl, which yields the compound dichlorodibenzofuran.[44] The oral LD_{50} of the dibenzofuran for rats is approximately 250 mg/kg, whereas the LD_{50} for the chlorobiphenyl is in excess of 4000 mg/kg.[45]

As discussed below, it is thought that transport as a molecular species or as sorbed material on airborne particles is the major route of widespread transport of PCBs.[46] Since such processes would cause the PCBs to be exposed to ultraviolet radiation from the sun, considerable attention has been directed to the photochemical stability of the PCBs. A number of effects have been reported, including partial dechlorination and even, in some cases, the formation of very viscous

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Table 2.[47] Environmentally Relevant Properties of PCB Formulations

PARAMETER	AROCLOR 1242	AROCLOR 1248	AROCLOR 1254	AROCLOR 1260
Chlorine content (percent)	42	48	54	48
Water content, max. (ppm)	50	50	50	50
Distillation range (°C)	325-366	340-375	365-390	385-420
Evaporation loss (percent at 100°C, 6 hr)	3.0-3.6	3.0-4.0	1.1-1.3	0.5-0.8
Viscosity (sec at 37.8°C)	82-92	185-240	1800-2500	1200-4500 (54.5°C)
Water solubility (mg/l at 25°C)	0.24	5.4×10^{-2}	1.2×10^{-2}	2.7×10^{-3}
Vapor pressure (mm Hg at 25°C)	4.06×10^{-4}	4.94×10^{-4}	7.71×10^{-5}	4.05×10^{-5}
Volatilization half-life[47a] (from 1-m water column)	5.96 hr	58.3 min	1.2 min	28.8 min
Solubility in CH_3OH at 25°C	42.5 g/100 ml	--	15 g/100 ml	--
Octanol/water partition coefficient (est.)	3.5×10^3	6.4×10^3	1.18×10^4	2.2×10^4

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semisolids apparently arising from some complex polymerization processes.[48] The environmental significance of these observations is difficult to assess since the solvents usually used in these studies were hydrocarbons rather than water.

The hydroxylation of the PCB molecule is the first step by which organisms metabolize this chemical.[49] Once the target chlorobiphenyl has been hydroxylated, there appears to be a wide variety of species-specific addition processes that can make use of the hydroxylated molecule. In this context, the failure to detect chlorodibenzofurans suggests that metabolic processes are not available to cyclize the PCBs. The further observation that the residual body burden of PCBs usually consists of only the more highly chlorinated PCBs suggests that the higher the level of chlorination, the more resistant to metabolic processes.[50]

Several of the PCBs with relatively low chlorine content are readily metabolized by direct hydroxylation by both animals and microorganisms.[51] Consequently, di- and trichlorobiphenyls are not very persistent.[52] On the other hand, the highly chlorine-substituted PCB molecules are apparently not metabolized at all. In addition, these species of PCB are not easily excreted because of their very low aqueous solubility and high lipid solubility. As a result, these species tend to accumulate in exposed animals.[53]

2. Physical Properties of the PCBs

As indicated in Table 2, the PCBs and their technical mixtures are characterized by low water solubility, low vapor pressure at ambient temperatures, and very high octanol/water partition coefficients.[54] The significance of the combination of low water solubility and high octanol/water partition coefficient is that when organic matter is exposed to an aqueous solution of PCBs, there is a strong tendency for the latter to be preferentially taken up by the organic matter.[55] Consequently, when animals are exposed to aqueous solutions of PCBs, the

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lipids of these animals will preferentially take up and store the PCBs. Since there is usually little metabolic activity in lipid bodies, the stored PCBs are, in some measure, protected from metabolic degradation. Therefore, larger and larger body burdens may be built up after continued exposure. It is this mechanism that accounts for the very large bioaccumulation factors that have been reported.[56]

In general, the volatility of a solute from a solution is governed by the vapor pressure of the (pure) solute at the given temperature and the mole fraction of the solute in the solution.[57] However, in those cases where there is either a heat of mixing or a change in volume on mixing the solvent and the solute (nonideal solutions), the volatility of the solute is not simply proportional to the molar concentration of the solute in the solution.[58] In those cases, it turns out that the lower the ultimate solubility, the greater the effective molar concentration. Thus, the volatility of the solute is significantly higher than would be expected for the given vapor pressure and the actual molar concentration. This phenomenon, which is known as codistillation, is responsible for the very short volatilization half-life of PCBs in water as illustrated in Table 2.[59] Codistillation from water is thought to be a major route of entry of PCBs into the atmospheric reservoir[60] and is believed to be responsible for the worldwide distribution of these substances.

D. Transport of PCBs in the Environment

This section discusses the mechanisms by which PCBs are transported from each compartment of the environment to the others.

1. Atmospheric Compartment

A number of investigators have determined that PCBs are very widespread in the atmosphere[61] both as molecular species and as adsorbed species on particulates and aerosols.[62] The mean air concentration of PCBs at several locations in Sweden

was found to range from the detection limit of 0.8 to 3.9 ng/m^3. The highest detected level was 12.5 ng/m^3. In the United States, levels were found to range from 1 to 50 ng/m^3.[63] Over the Atlantic Ocean the airborne concentration was determined to range from 5 ng/m^3 near the northeast coast to 0.05 ng/m^3 at a distance of 2000 miles from the coast.[64] Numerous sources of airborne PCBs have been identified, including the incomplete incineration of PCB-containing materials (e.g., sewage sludge),[65] volatilization of PCBs from paints and plasticizers,[66] codistillation from surface waters that are PCB contaminated,[67] and direct volatilization from PCB end uses and spills.[68]

Various writers have pointed out that the atmospheric reservoir of PCBs is the principal route by which the worldwide distribution of PCBs has occurred.[69] Thus the principal effect of the atmospheric reservoir is to serve as a mechanism for the dissemination of PCBs to the other compartments of the environment.

2. Terrestrial Compartment

The most significant sources of free PCBs in the terrestrial compartment of the environment include discarded consumer end use products that contain PCBs,[70] atmospheric fallout,[71] and spills associated with the use of or the transport of PCBs.[72]

For that portion of the free PCBs that is confined to terrestrial sites, the primary mechanisms for dispersal are volatilization and solubilization by ground or surface waters. Since the vapor pressures of the typical PCB preparations (Aroclors) lie in the range of 10^{-2} to 10^{-4} mm Hg[73] at ambient temperatures, the loss rate by direct volatilization should be very small even in the absence of significant soil binding. It is possible, however, that under certain conditions the heat produced by oxidation of organic materials in a landfill could raise temperatures significantly and thereby substantially increase the volatization of PCBs located in the fill.

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PCBs are soluble in water so that direct solubilization by percolating waters is a possible mechanism for the admission of these substances into the ground waters. As an example, the limiting solubility of Aroclor 1254 in water is about 54 ppb[74], and the average rainfall on the continental United States is about 34.5 in. per year.[75] It therefore follows that, with the normal long percolation time, the losses into the local ground waters could be as high as 0.04 g/m^2/year in a region where PCBs have been landfilled.

In addition to solubilization, PCBs may be removed from land and enter the aquatic compartment by surface water runoff. This latter effect is of great concern in areas where contaminated oils have been used on highways or where land spills of PCBs are possible. There is no direct evidence that PCBs are degraded by soil microflora.[76]

3. Aquatic Compartment

Figure 2 illustrates the nature of the processes that are involved in the transport of PCBs to and from a body of water. It illustrates that the principal PCB inputs to a body of water are contaminated inflowing streams and the PCBs that precipitate from the atmospheric reservoir. An example of the significance of the inflowing streams is given in a recent report[77] which indicates that detectable PCB levels were found in some 40 percent of a total of 900 industrial effluent streams that were tested in Michigan. An earlier estimate[78] indicated that as much as 1 ton of PCBs was entering the Clyde River in Scotland per year as a component of crude sewage sludge from the Glasgow district. In addition, as noted above, PCBs on land may enter the aquatic reservoir as a result of solubilization and surface water runoff.

It has been demonstrated that the PCBs have a high affinity for soils in soil-water systems[79] but that these same hydrosoils may serve as a reservoir for resolution when the PCB concentration in the sediments becomes sufficiently high.[80]

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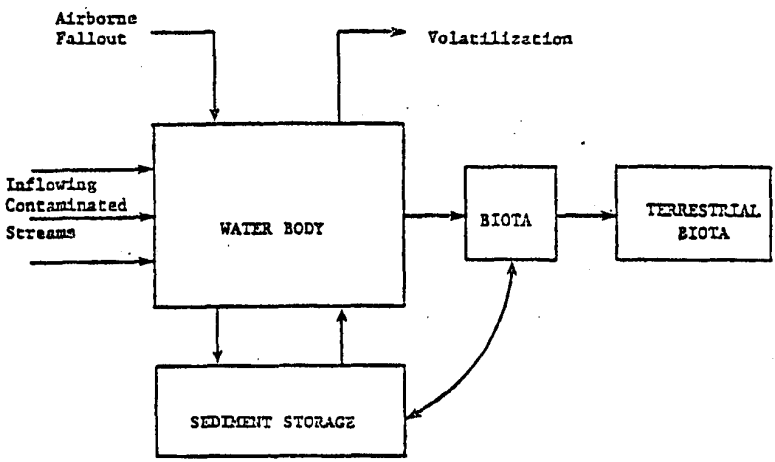


Figure 2

Model of Sources and Sinks for a Body of Water

In addition, when contaminated sediments are disturbed (as, for example, in river scour), some of the PCBs may be resuspended either in actual solution or as sorbed material on resuspended solids. The processes associated with desorption from a sorbent may also tend to fractionate the components of the commercial PCB mixtures in favor of the more soluble components. In general, it is believed that the material that is sorbed onto the sediments is eventually removed by migration to the deep ocean depths. Thus, the sediments constitute a sink and, most probably, the principal sink for the removal of PCBs from the environment.

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Measurements of the PCB concentrations in the sediments in the Hudson River above the General Electric outfall indicated levels ranging from 0.0 to 16.9 ppm.[81] At Thomson Island, about 1 mile downstream, typical sediment levels ranged up to 3700 ppm,[82] with the PCB levels in the overwaters ranging from 0.06 to 3.0 ppm. Fish collected within 1 mile of the General Electric outfall indicated PCB levels ranging from 78 ppm in minnows to 350 ppm in rock bass.[83] Striped bass sampled near West Point (well over 100 miles downstream of the GE outfall) had PCB residuals of between 1.16 and 7.54 ppm.[84]

The magnitude of the PCB losses through the process of volatilization (co-distillation) is not fully established, but there is general agreement, as noted above, that this process is of significance in the detailed mass balance for an aqueous system and that volatilization from the air/water interface is a principal source of the atmospheric reservoir of PCBs.[85]

E. Exposure to PCBs

1. Current Environmental Load of PCBs

It has been estimated that between 300 and 400 million pounds of PCBs entered the general environment up to and including 1975. Of this total, it is estimated that some 25 to 30 percent is free material and thus constitutes the reservoir from which exposure of the biota might occur.[86] The remainder of the environmental load, mostly in the form of industrial waste and discarded end use products, is believed to be in landfill sites and thus constitutes a potential source of new free PCBs. It is further estimated that, at any given time, approximately one-third of the nonterrestrial free PCBs are in the atmospheric reservoir, while the remaining two-thirds are in the aquatic reservoir.[87]

2. Exposure of Organisms to the Terrestrial Reservoir of PCBs

As pointed out above, the largest portion of the terrestrial reservoir of PCBs remains in the discarded PCB-containing products that are contained in landfills.[88]

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The average soil concentration of PCBs taken in nonlandfill areas has been found to be below detection level.[89] A recent report[90] indicates that only 0.1 percent of the soil samples analyzed showed detectable PCB levels. Sixty-three percent of the contaminated samples were from urban areas.[91] It is not clear whether any substantial exposure of the biota to the terrestrial reservoir of PCBs occurs.

3. Exposure of Organisms to the Atmospheric Reservoir of PCBs

Inhalation and dermal contact by humans and other animals are two possible modes of exposure to the atmospheric reservoir of PCBs. Although measurements taken at widely separated points have shown that there is a detectable level of PCBs in most air samples, the observed levels are mostly close to the limits of detection except in the vicinity of PCB sources.[92] If the estimated atmospheric load noted above were uniformly distributed throughout the atmosphere, the concentration of PCBs in the air would be approximately 5 ng/m^3.

4. Exposure of Organisms to the Aquatic Reservoir of PCBs

The rather complex relationship between the aqueous phase, the biota, and the sediments is illustrated in Figure 2 by the interconnecting lines in the figure. The biota incorporate PCBs either by direct sorption from the contaminated waters or through the food chain relationship between the benthic organisms living within the contaminated sediments and the free-swimming organisms. There can be little doubt that the direct pickup of PCBs from the surrounding waters is a major route by which these compounds enter the biota. A large number of marine and freshwater species have been demonstrated to take up PCBs selectively from surrounding water and concentrate these compounds at levels many times higher than those in the water. The phenomenon is known as bioconcentration. A typical example[93] is the reported bioconcentration of PCBs by the fathead minnow by a factor of 230,000.

At the present, there is considerable disagreement as to the role played by the process of bioaccumulation (the selective retention of PCBs entering the organism via contaminated foods) in the contamination of aquatic organisms.

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However, this process is apparently the major source of PCB contamination of terrestrial animals that feed upon aquatic organisms. This relationship is illustrated by the right-hand side of Figure 2. It should be noted that terrestrial animals may have significantly higher concentrations of PCBs in their tissues than the aquatic forms they feed on. For example, while cod and pike have been found with PCB levels on the order of 10 mg/kg of extractable fat, fish-eating birds such as herring gulls and cormorants have been found with levels of 600-700 and 400 mg/kg of extractable fat, respectively.

It appears that biocentration of PCBs by aquatic organisms is the principal route by which these compounds enter the biota. However, as just noted, the impact of this route of exposure is not limited to aquatic species. Man as well as fish-eating terrestrial animals and birds also may be adversely affected. Fish constitutes a substantial part of man's diet. Therefore, the concentration of PCBs in fish gives man the choice of either giving up an important food source or subjecting himself to the adverse effects of PCBs. In addition, man may be exposed to lower levels of PCBs by drinking contaminated water.

F. Present Distribution of PCBs in the Environment

This document has shown that the additional release of PCBs into any of the environmental compartments may be expected to result in widespread distribution into all three compartments and in the eventual exposure of large populations of wildlife and man. This conclusion is further supported by the fact that PCBs are already widespread in the physical environment and in the biosphere.

Since the earliest identification of PCBs in fish samples,[94] literally thousands of environmental and ecological samples from all over the world have been analyzed and reported. For example, PCBs have been identified in Antarctic ice samples from depths as great as 5.5-6 meters.[95] Sea and air samples taken in the Sargasso Sea showed PCB levels on the order of 1 ng/m^3 in the air samples and up to

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10 ng/l in the sea samples.[96] Approximately 75% of human adipose tissue samples, taken from 31 persons in the United States in 1973, showed PCB levels ranging from 1 to greater than 3 ppm.[97] Polar bears, sampled as indicators of the top tropic level in the arctic and sub-arctic food chains, have been shown to have PCB levels of up to 8 ppm (wet weight in fat).[98] Seals taken from a variety of Canadian waters show levels of from a few ppm to a high of 52 ppm.[99] In addition, PCBs have been detected, frequently at high levels, in a large number of fish and bird species inhabiting widely separated geographic areas.[100] These samples, which are by no means all-inclusive, indicate that PCBs are a global problem.

G. Conclusions

PCBs have been demonstrated to cause a number of severe adverse effects on many living organisms at very low concentrations. As a practical matter, it is not possible to determine a "safe" level of exposure to these chemicals. Because PCBs are already widely distributed throughout the biosphere, they presently pose a significant risk to the health of man as well as that of numerous other living things. As a consequence, any further increase in levels of PCBs in the biosphere is deemed unacceptable by EPA. It has also been demonstrated that PCBs released anywhere into the environment will eventually enter the biosphere. Therefore, as a corollary, EPA has determined that any such release of PCBs must be considered "significant."

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IV. DEFINITION OF PCB MIXTURE

This proposed rule for the implementation of the TSCA bans on the manufacture, processing, distribution in commerce, and use of PCBs covers all mixtures containing 50 ppm or greater of PCB chemical substance. The rule also proposes to revise the definition of PCB mixture in the PCB Disposal and Marking Rule, which was promulgated on February 17, 1978 (43 FR 7150). That rule defines a PCB mixture to be any mixture which contains 500 ppm or greater of PCB chemical substance. However, for the reasons discussed below, that level was subsequently determined to be too high to adequately control PCBs under Section 6(e) of TSCA.

The definition of PCB mixture was formulated to include within the scope of the rule commercial products which intentionally contain PCBs and wastes contaminated with PCBs. Products intentionally containing PCB chemical substances include the PCB cooling liquids in transformers, PCB dielectric fluids in capacitors, PCB hydraulic and heat transfer liquids; the transformers, capacitors, and other systems which use and contain these fluids; paints, adhesives, caulking compounds, rubber and synthetic resins which contain PCBs as a plasticizer; inks, lubricants, cutting oils, investment casting waxes; and any other products in which PCBs are used. These materials may release PCBs during their manufacture, processing, or use and can also expose the environment to PCBs upon their disposal.

Another category of materials which is intended to be within the definition of PCB mixture includes items which do not intentionally contain PCBs but which are contaminated as a direct result of the use or disposal of PCBs. These are items such as soil, rags, other debris contaminated by a PCB spill; sludges from systems into which PCBs have been dumped; oils to which waste PCB fluids or PCB-contaminated fluids have been added; and equipment refilled with new fluid which has been contaminated by residual PCBs in the equipment or in the system used for the refilling

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operation. Also included are other organic compounds which contain substantial amounts of PCBs as a result of an inadequately controlled manufacturing process.

The definition of PCB mixture has been modified so that commercial products, byproducts, waste materials, and environmental media containing PCBs at levels well above those due to general environmental levels but below the 500 ppm concentration promulgated in the Disposal and Marking Rule would be subject to regulation. In prescribing a concentration at which regulation becomes operable, EPA has had to consider the feasibility of controlling the introduction of PCBs into the environment. EPA has determined that the 50 ppm PCB concentration is a reasonable level at which the Agency can feasibly begin to control PCBs entering the environment as a direct result of the manufacture and/or use of PCBs or PCB-contaminated material.

Concentrations of PCBs below 50 ppm which enter the environment as a consequence of background, or ambient, concentrations have been deemed not reasonable or feasible to control. The definition of PCB mixture has been modified to exclude low levels of contamination by PCBs which occurs merely as a consequence of exposure to background levels in the environment. Due to the widespread use and the persistence and ubiquitousness of PCBs, the chemical is present in detectable amounts throughout the world.[1] However, to control all PCBs in this regulation would be impractical and unreasonable. Examples of such contamination are sludges which do not have an identifiable source of PCBs but which contain low PCB concentrations.[2] Moreover, EPA has the authority to regulate these low PCB concentrations under other statutes. This proposed regulation would not preempt those statutes.

The proposed definition of PCB mixture would also exclude certain organic compounds (e.g., chlorinated organic compounds) which may contain trace amounts of PCBs despite the use of carefully controlled manufacturing processes. A facility might emit exhaust gases which have a measurable concentration of PCBs, or the PCB

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concentration may be attributable to the PCB concentration in the ambient air which is taken into the facility for use in the plant's process.

If the rule were carried to the extreme and anything containing a detectable amount of PCBs were included within the definition of PCB mixture, practically every object, material, waterway, and organism would be subject to the processing, use, distribution in commerce, and disposal and marking regulations.

To prescribe a PCB concentration below which the rule will not apply is not inconsistent with the Administrator's determination that any exposure to PCBs is "significant." EPA recognizes that it would be unreasonable to regulate background concentrations of PCBs. The rule is intended to control those PCB activities which are primarily responsible for contaminating other materials and for creating background PCB levels. It is only these PCB activites which the rule can or should address.

Obviously, a wide range of PCB concentrations occurs in various types of mixtures. PCB products and those materials to which PCBs are intentionally added will have very high concentrations of PCBs and are within the scope of the rule. For example, the fluids in electrical transformers may be 60 to 70 percent PCBs. Those materials directly contaminated as a result of the use or disposal of PCBs will generally exhibit high PCB concentrations, but low PCB concentrations are not uncommon. Refilled hydraulic systems which formerly contained PCBs have been measured with between 6,000 ppm of PCBs to concentrations below the level of detection.[3] Food packaging made with PCBs contaminated by recycled paper has been found to contain from trace levels (<0.02 ppm) to 53.9 ppm of PCBs.[4] Soil samples taken near a PCB-manufacturing facility and a facility using PCBs decreased from over 20 ppm to 0.001 ppm as distance from that facility increased from less than

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1/4 mile to over 1 mile.[5] It appears that the lower end of the range of direct contamination overlaps the higher end of the range of background contamination. However, contamination caused by background concentrations would be very unlikely to reach the high levels of PCBs that directly contaminated mixtures do. Background levels of PCBs in municipal sewage treatment sludge have been found to range from an average of 15.6 ppm of PCBs[6] in some areas to approximately 1 ppm in others. Ocean water in the North Atlantic averaged 35 ppt of PCBs,[7] and uncontaminated freshwater levels of PCBs are found to be in the 0.5-ppt range.[8] PCB levels in the Hudson River, measured at points above any industrial discharge, range between 0.0 and 1.0 ppb, while immediately below a PCB-using industrial facility, PCB levels of 6.6 to 6,700 ppm were measured.[9] However, these background-level exposures are not realistically controllable and are intended to be excluded from the rule.

The 50 ppm PCB concentration has been chosen to represent the level at which EPA can regulate PCBs. EPA believes that it would be technically impossible and administratively unreasonable to establish a separate level to define each type of PCB mixture or PCB exposure.

During the development of the rule for the disposal and marking of PCBs, it seemed that a reasonable level for regulation was 500 ppm of PCB. However, in view of information outlined below, which was acquired after the proposal of that rule, it appears that the 500-ppm level is too high by a factor of 10. There is not an extensive amount of data on PCB levels in municipal sewage sludge. However, studies which have been done indicate that concentrations of PCBs are normally less than 500 ppm. Surveys of persistent organic chemicals in municipal sludges of 10 U.S. cities have shown that PCB concentrations normally range between 10 and 30 ppm.[10] A study at Cornell University analyzed municipal sewage sludges of 16 American cities for 68 elements, dieldrin and PCBs. Levels of PCB ranged from less than

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0.01 ppm to 23.10 ppm.[11] In 1976, EPA's Office of Solid Waste (OSW) in Region I conducted an analysis of samples of sewage treatment sludge for three types of PCB in five cities. The nine samples taken exhibited levels of PCB ranging from "not detected" (normally less than 1 ppb) to 74 ppm--the one sample which contained more than 50 ppm PCB.[12] Another study undertaken by OSW measured PCB levels in sewage sludges applied to agricultural lands around nine cities. In the 38 samples taken, PCB levels ranged from less than 0.01 ppb to 5872 ppb (5.9 ppm).[13] A 1976 survey by EPA of 10 cities in the Northeast found levels of PCB in sewage sludge ranging from less than 0.001 ppm to 1.18 ppm.[14] EPA's Regional Office in Kansas City sampled the municipal sludges of 36 cities in that region for pesticides and PCBs. Only five cities had PCBs above the level of detection and levels ranged from 2.3 ppm to 99.1 ppm, although the latter was the only one to exceed 37.9 ppm.[15] It is assumed from the studies cited that the PCB levels found to be above 50 ppm are associated with the known PCB-using activities in the area, and that the numerous other samples which have PCB concentrations well below 50 ppm represent the results of background levels. It was learned in testimony from the industry that similar levels (a maximum of approximately 25 ppm of PCBs) are present in chlorinated organic compounds.[16] The ambient level of PCBs appears to be much lower than had been believed. Similarly, it was found that exposures to PCB concentrations below 500 ppm do occur as a result of direct action. Many such sources are controllable and should be within the scope of this rule. For example, hydraulic systems that once contained PCB hydraulic fluids may be drained and refilled with non-PCB fluid. The new, non-PCB fluid may become contaminated from residual PCBs[17] and, even though the PCB concentration in this fluid does not reach 500 ppm, this fluid would represent a potential problem if it were spilled or otherwise improperly used or disposed of.

It appears from the information summarized above that a more appropriate concentration for regulation is 50 ppm of PCBs. Since the rule for the disposal

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and marking of PCBs has been promulgated with a definition of PCB mixture at 500 ppm, there would be an inconsistency if this rule contained a different definition. The result would be restrictions on uses of certain materials, but no control whatsoever with respect to their disposal. To correct this inconsistency, a new definition of PCB mixture, at 50 ppm of PCB, is proposed for this rule and for the disposal and marking rule. The result will be that all appropriate provisions of both rules will apply to all mixtures with PCB concentrations of 50 ppm or more.

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V. PCB SUBSTITUTES*

The following is a discussion of substitutes available or in the process of development for PCB dielectric fluid used in capacitors and transformers. This discussion of substitutes is intended as a brief summary. Inclusion or omission of any substance in this discussion should not be construed as an indication of EPA approval or disapproval of its use.

A. Capacitors

1. Phthalate Esters[1]

Dioctyl Phthalate (DOP) has been used in capacitors manufactured in Japan since 1974. It is presently being used in most of the capacitors manufactured in the United States.

Advantages of DOP are: (1) the cost is approximately one-half that of PCB; (2) DOP is now available as a substitute since it is currently used as a plasticizer for polyvinyl chloride; and (3) its dielectric constant is 5.3, similar to that of PCB.

Disadvantages of DOP are: (1) the maximum service temperature of capacitors containing DOP is 85°C, as opposed to 95°C for PCB; (2) the corona inception voltage is lower than that of PCB but can be raised by the addition of trichlorobenzyne to the mixture.

Diisononyl phthalate is a potential substitute for PCB. It is manufactured by Exxon under the tradename Enjoy 2065 and is not available in large quantities. Diisononyl phthalate is similar to DOP, although it is more stable chemically.

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*The information on substitutes for PCB capacitors and transformers was primarily based on data contained in the Versar study, PCBs in the United States: Industrial Use and Environmental Distribution. Some of the facts in that study have been updated based on a review by Versar of this discussion of substitutes. Information on Uniroyal PAO-20E was provided by the Uniroyal Chemical Company.

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The flash points for DOP and diisononyl phthalate are relatively high (220° for DOP), yet both of these phthalate esters are more flammable than PCBs. It should be noted that a particular class of phthalate esters, the alkyl phthalates, were recommended for testing by the TSCA Interagency Testing Committee.[2]

2. Alkylated Chlorodiphenyl Oxide[3]

Butylated monochlorodiphenyl oxide is marketed by Dow Chemical Company under the tradename XFS-4169L. Based on four years of testing, McGraw-Edison, a capacitor manufacturer, has found this material (which they tradenamed EDISOL) to be a "viable substitute" for PCBs in high voltage power capacitors. Although the dielectric constant of EDISOL is somewhat lower than that of PCB (4.5 versus 5.85), the size of EDISOL capacitors marketed by McGraw-Edison is the same as PCB capacitors at equal KVAR ratings.

Advantages of butylated monochlorodiphenyl oxides are: (1) a lower loss-tangent; (2) a higher corona inception voltage than PCB by 20 to 30 percent; (3) a higher flash point (174°C). Advantages of this substitute vis-a-vis toxicity are that it (1) is more biodegradable than trichlorobiphenyl; (2) has been shown to be non-mutagenic in an Ames test; (3) has a lower bioconcentration factor than PCB; (4) has a lower adipose concentration than PCB; and (5) does not show chloracnegencity.

Disadvantages of butylated monochlorodiphenyl oxide are: (1) the higher material costs, and (2) a lower fire point (199°C) than that of PCB.

B. Transformers

1. Fluorocarbons[4]

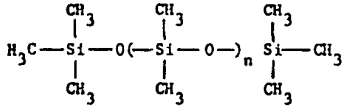
Certain fluorocarbon compounds have properties similar to PCBs. Fluorocarbons are highly volatile in comparison to PCB, and they are about six times as expensive.

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Perfluoroethane is extensively used as a dielectric gas in totally enclosed gas filled transformers, which can be used to replace PCB transformers in certain hazardous locations.

2. Silicones[5]

Low viscosity silicone fluids, on the order of 50 centistokes, are possible substitutes for PCBs in transformers. They are produced by General Electric, Dow Corning, Union Carbide, and SWS Silicones. Polydimethyl siloxane, a potential substitute, has the molecular structure:



Silicone fluids have the special advantage of a relatively temperature-independent viscosity. The silicone fluids have somewhat poorer heat transfer characteristics than askarel but can be substituted directly for askarel in existing transformers, resulting in only a small decrease in the transformer rating.

Electrical Properties:

Dielectric Constant	2.72
Dielectric Strength	200 volt/mil
Resistivity	7.1×10^{14} ohm-cm
Dissipation Factor	1.8×10^{-5} at 100 Hz, 23°C

Polydimethyl siloxane has a higher flash point than conventional, non-PCB transformer coolants: 280°C for mineral oil (PCBs have no true flash point). The heat of combustion of 50-centistoke polydimethyl siloxane is lower than that of mineral oil--7.67 kcal/gm versus 11.0 kcal/gm--and since the silicones burn more slowly, they are considered poor fuel.

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On the Underwriters Laboratories' fire-hazard classification (in which water is rated as 0 and ether as 100) polydimethyl siloxane is classified as 4 to 5, which is slightly higher than the 2 to 3 rating given to PCBs, but is considerably less than the mineral oil rating of 10 to 20.

These compounds do not biodegrade, as measured by sewage sludge breakdown to CO_2. However, there is evidence that they partly depolymerize to low molecular weight compounds upon contact with soil and water. Since ultraviolet light decomposes methyl silicones, sunlight exposure may be the mechanism for environmental degradation.

No tendency for bioaccumulation or bioconcentration has occurred in experiments. In mammals the compound is not absorbed through the gastrointestinal tract or the skin.

The PCB substitute developed by Dow Corning for transformers is called DC561. This is a mixture of polydimethyl siloxanes of various chain lengths which have a viscosity of 50CS. The literature on environmental and health characteristics of silicones refers to at least six fluids, most of which are probably similar to the DC561, but some of which could be other mixtures with certain additives. By necessity, the usefulness of published toxicological data depends on the validity of the assumption that all of these compounds have identical persistence, bioaccumulation, and toxicity properties.

A review of toxicological studies of silicones reported the following results:

Dietary Toxicity:

LD_{50} (rats) >28 gm/kg

Extended Feeding Tests:

Guinea pigs--47 gm/kg/day for extended period--no toxic effect.

Mallard ducklings and bobwhite quail--5000 ppm for 5 days--no effect.

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Rats--20 gm/kg/day for 28 days—no effect.

Rats--190 mg/kg/day for 90 days--no effect level.

Beagle dogs--300 mg/kg/day for 120 days--no effect.

Mice--3 percent in diet for 80 weeks—no effect.

Man--FDA allows silicones as food additives at up to 10 ppm.

The major deficiency in knowledge of the silicones appears to be in their fate in the environment and the toxicity of their breakdown products.

The silicone transformer fluids currently cost up to twice as much as PCBs on a volume basis.

Dow Corning has completed evaluation of polydimethyl siloxane as a high voltage insulating fluid. They report, though, that a near term 100 percent replacement of PCBs in transformers by this fluid is not possible. If a transformer market were to develop for polydimethyl siloxane, the present domestic capacity could be adequate to supply new transformers. The time lage for a 100 percent replacement of PCBs in transformers by polydimethyl siloxane would be on the order of 5 to 10 years.

3. Mineral Oils[6]

Mineral oils are widely used in transformers. The flash point of mineral oils is a function of its molecular weight. Since crude petroleum can be refined to have any required molecular weight over a wide range, it is possible to specify any particular flash point that is desired for the minimal oil transformer liquid. This approach has been taken by RTE Corporation in the development of their proprietary transformer liquid, which has the tradename RTEmp.

RTEmp is a highly refined paraffinic mineral oil that has a flash point of 285°C, approximately the same as the 50CS silicone liquid proposed by Dow Corning as a PCB substitute. To achieve this higher flash point, the oil is refined to have a

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higher molecular weight and consequently a higher viscosity, which reduces its effectiveness in convective cooling.

The major current advantage of the high flash point mineral oils is their low price relative to silicone and askarel and their inherent biodegradability and low toxicity.

4. Synthetic Hydrocarbons[7]

Certain mixtures of synthetic hydrocarbons may result in a liquid having the high flash point characteristics of RTEmp or silicone combined with a relatively low viscosity and satisfactory heat transfer characteristics. Examples of synthetic hydrocarbons being tested as PCB substitutes include FR Dielectric Fluid manufactured by Gulf Oil Chemical Company and PAO-20E.

PAO-20E[8] produced by Uniroyal Chemical was designed for use in transformers. Its dielectric strength (KV/0.25 cm) is 50, and its dielectric constant is 2.15, as compared with 40 and 4.3, respectively, for PCB. It has a flash point of 276°C and a fire point of 307°C. Its acute oral LD_{50} (rats) is over 40 mg/kg.

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VI. REASONABLE USE DETERMINATIONS

The intent of Section 6(e) of the Toxic Substances Control Act (TSCA) is to ban activities using PCBs in a nontotally enclosed manner. However, the Administrator may authorize the manufacture, processing, distribution in commerce, and use of PCBs in a nontotally enclosed manner. For such an authorization to be granted, the Administrator must make a finding that each activity authorized will not present an unreasonable risk of injury to health or the environment [TSCA, Section 6(e)(2)(B)]. Since the intent of the law is for PCB activities and their uses to be banned, it must clearly be evident that an activity is not unreasonable. In the absence of such clear evidence, an activity is banned.

Section 6(c)(1) of TSCA contains the factors which EPA considered in determining whether a PCB activity conducted in a nontotally enclosed manner is reasonable or unreasonable. In addition to the effect of PCBs on human health and the environment, the other factors that were considered are summarized below:

1. The likelihood, magnitude, and nature of exposure of human beings or the environment.
2. The availability and characteristics of substitutes for the particular PCB activity.
3. The economic significance of the activity, including its importance to the national economy, small business, technological innovation, the environment, and public health.

Only if a ban on a nontotally enclosed use activity would cause major and extensive economic disruptions would EPA consider granting a limited authorization for that activity.

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A. Transformers

1. Manufacture of PCB Transformers

As of June 1977, only one transformer manufacturer produced transformers filled with PCB fluid. That firm stopped producing these transformers in late 1977.[1] No other transformer manufacturer has any PCB fluid in inventory. Transformers without PCBs presently account for about 98 percent of those in use.[2] Since no one is either manufacturing or planning to manufacture PCB transformers, the absence of an authorization for that activity will have no economic impact.

2. Transformer Servicing

Servicing of PCB transformers falls into two general categories: 1) routine servicing of functioning transformers, and 2) rebuilding failed transformers. Routine servicing can be performed by either the owner of the transformer or a contractor. There are two distinct types of owners of PCB transformers: public utilities and all others. Utilities are more likely to consistently perform routine maintenance than the other users, who almost exclusively own small transformers.

PCB transformers rarely fail. If nothing warrants a more frequent inspection, utilities will generally check a PCB transformer once every 3 to 5 years.[3] Routine maintenance includes taking a sample of the internal fluid to determine its moisture content as well as other physical properties. The fluid may be filtered through Fuller's earth to cleanse it of impurities and then returned to the transformer. Filtering increases the expected life of the transformer and also provides an indication to the owner of the condition of the transformer, particularly with respect to failure.

Inspection of the exterior of the transformer takes place at more frequent intervals. External servicing is performed when gaskets leak. If a gasket below the

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internal liquid level leaks, the internal liquid must be drained below the level of the gasket so that it can be repaired. When this operation is performed, the PCB fluid is pumped out of the transformer into a closed container and returned after the repair is completed.

The average failure rate for large utility transformers is approximately 0.2 percent per year[4]; however, smaller transformers fail more frequently because of poor servicing procedures. Rarely will a transformer fail such that PCB liquid is spilled from the transformer. When transformers fail, they are removed and sometimes rebuilt. The rebuilding process includes draining the internal liquid, removing the coils, rewinding the coils, and refilling the transformer. Since owners and contractors prefer not to handle PCB fluid or PCB articles, rebuilding is less frequently performed. Rebuilding is universally regarded as a messy operation and one which results in great exposure of both humans and the environment to PCBs. Most failed transformers are now taken to a disposal site. In fact, many working PCB transformers are now being removed from service because owners do not want to incur the liability of servicing them.

During routine servicing, exposure occurs when the liquid is removed or filtered. Exposure could be either direct through contact with spilled liquid or through handling of contaminated equipment. Air emissions occur when the liquid sample is taken unless a closed system is used. If the fluid is filtered, the filter media must be disposed of. During disposal, exposure to both humans and the environment can result. In addition, solid waste is created in the form of rags and other materials used to clean PCBs from different surfaces. Should additional liquid be required to replace that lost due to spillage, sampling, or filtration, humans and the environment may be further exposed to PCBs.

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Exposure during rebuilding is much greater because of the nature of the operation involved. Liquid must be drained from the transformer. The coils, which are saturated with PCB fluid, are removed, cleaned, and reworked, and the transformer is then refilled. The original fluid must be disposed of properly, and some disposal method must be found for the old coils. There is no enclosed method of performing these operations, and the result is exposure of humans and the environment to large quantities of PCBs. It appears that PCBs end up as air emissions, water discharges, and solid waste from this process. The actual extent of this exposure is not known; however, the amount of liquid involved in a large transformer is considerable. In addition, the coils are disposed of separately instead of remaining in the casing, as would be the case if the transformer were simply drained and disposed of. Disposal of the coils would probably result in greater environmental exposure since the coils are saturated with PCBs and would be directly exposed to the environment.

There are three generally available substitutes for PCB transformer fluid: mineral oil, siloxanes, and RTEmp fluid. Mineral oil has been in use for many years and is generally accepted by transformer users. Mineral oil is usually required in larger quantities than are PCBs; however, the mineral oil is substantially cheaper than PCB fluids. The service life of mineral oil is shorter than for PCB fluids, and it cannot be used in circumstances where there is a danger of fire.

Siloxanes are a more recent substitute for PCBs. They appear to be between mineral oil and PCBs in their physical properties. The most recent substitute for PCBs is RTEmp. Its manufacturer claims properties superior to both mineral oil and siloxanes, at a cheaper cost than either. All of these substitutes are commonly available, and the only impediment to their use is the standard delivery time for new transformers, 18 months.[5] Mineral oil transformers have been found to require more

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servicing than PCB transformers, but the service life of siloxanes and RTEmp has not yet been determined. No evidence has yet developed of any health or environmental risks associated with the use of these substitutes.

Option 1

The prohibition of routine servicing of transformers and the rebuilding of transformers.

Discussion

This option provides for minimum exposure, since routine servicing would not be permitted. Any exposure resulting from the handling of liquid or rags of filter media or sampling would be eliminated. Transformers would be contained in a closed system from the time they left the factory until eventual failure and disposal. However, there are high costs associated with this option.

If it is not possible to routinely check transformers, there is a good possibility that the rate of catastrophic failure could increase and that as a result, both humans and the environment could be exposed to a large quantity of PCBs (an average transformer contains about 2150 pounds of PCB mixture).[6] At present, it is exceedingly rare for a PCB transformer to fail in a manner such that the PCB liquid inside is spilled outside the container. This is partially because of the nature of the PCBs and partially because the routine servicing permits the owner to assess the condition of the transformer and remove it from service whenever there is any possibility of failure.

Furthermore, owners of transformers would experience additional problems due to an increased failure rate of the transformers. Because routine preventive servicing would not be permitted, transformers would fail with greater frequency. It is expected that without routine maintenance, the failure rate of PCB transformers would increase from 0.2 percent per year to 2-4 percent per year.[7] This tenfold increase

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would increase the capital outlay required for replacing transformers by about the same amount. This means that about $15 million would be spent each year to replace transformers that otherwise would not have failed. In addition, there will be increased costs associated with the expected increase in failures that result in liquid losses. These costs would include cleanup labor costs, paperwork costs, and legal costs, as well as the cost of replacing the failed transformer.

Option 2

Permit the routine servicing of transformers but prohibit the rebuilding of transformers.

Discussion

Rebuilding transformers would be banned because of the extensive exposure resulting from this activity. However, failure to perform routine servicing on transformers may lead to catastrophic failures and therefore extensive and hazardous exposure to PCBs. The risks associated with catastrophic transformer failure far outweigh the relatively small risks associated with servicing transformers.

The major economic impact of this option would be the closing of the PCB transformer rebuilding industry, which represents a very small percent of all transformer rebuilding. The replacement of failed transformers with new transformers instead of rebuilt transformers would impose an additional cost on the transformer owner. This additional cost should not be burdensome. In addition, it appears that many owners are replacing PCB transformers with new transformers instead of rebuilding them. This trend would further reduce the economic impact of this option.

Option 3

Permit the continued routine servicing and rebuilding of transformers.

Discussion

This option would cause no adverse economic impact for either the transformer owners or the transformer rebuilding industry. However, this option would permit

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the continuation of practices which result in large exposures of humans and the environment to PCBs.

Decision

Option 2 was chosen since exposure risks will be greatly reduced without creating a severe adverse economic impact. EPA believes that although there is some exposure to PCBs during routine servicing, this exposure is very small and does not pose an unreasonable risk, particularly in light of the extensive and hazardous exposure that will occur when a transformer fails because it has not been serviced. Allowing existing transformers to remain in use and permitting routine servicing would prevent a substantial economic loss to transformer owners. Rebuilding of transformers whose fluid contains 500 ppm or greater will not be authorized. EPA has found that the extensive exposure associated with the rebuilding activity poses an unreasonable risk. Moreover, EPA believes that no undue economic burden will be placed on transformer owners by not authorizing rebuilding.

B. Railroad Transformers and Self-Propelled Cars

Background

There are 1009 transformers containing PCB fluid which are utilized in railroad locomotives and self-propelled cars.[8] The equipment is used exclusively in the Northeast by AMTRAK, Conrail, and five intracity transit authorities.[9]

Transformers in these applications are known to be a servicing problem because of the design limitations imposed by space requirements, in addition to the shock, vibration, and mechanical impacts encountered in service. Thus, leakage of PCBs resulting from punctures or overheating of the transformer while in use is not an unusual occurrence.

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The leaked PCBs are frequently discharged into well-drained roadbeds, causing serious exposure of the environment to PCBs. Clearly, the use of railroad transformers presents a substantially higher risk than use of their stationary counterparts.

There are several alternatives with respect to controlling the risk associated with use of railroad transformers:

1. Replacement of PCB transformers with non-PCB units. This would be extremely expensive ($50,000-$185,000 per transformer),[10] and considerable lead time would be necessary.

2. Draining, flushing, and refilling PCB transformers with a substitute dielectric fluid. This option is much less expensive ($5,000-$15,000 per transformer),[11] but there are questions with respect to the technological feasibility of this process.

The Federal Railroad Administration has sponsored research by Westinghouse and General Electric (GE) to determine the feasibility of refilling existing PCB railroad transformers with silicone.[12] The performance characterization of a 418 KVA transit car transformer which contained 168 gallons of askarel was compared with that of a transformer filled with silicone after it had been drained, flushed, and refilled.

The results obtained by GE indicated that hot draining of the transformer removed 85 percent of the askarel, and that circulating hot silicone through the transformer for 288 hours reduced the residual askarel to 107 pounds. The rate of residual askarel leaching into the silicone was found to be diffusion limited. The operating temperature of these transformers was 9.7°C hotter with silicone than with askarel. No conclusions were drawn as to whether the silicone-filled transformer would have satisfactory long-term performance.

A similar procedure was performed by Westinghouse on a different transformer of the same age and model. The transformer was initially flushed with mineral spirits,

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followed by circulation with silicone. The report concluded that there was no reduction in operating performance when using silicone.

Westinghouse has succeeded in reducing the PCB concentration below detectable levels at least temporarily. Dow Corning's results, reportedly using Westinghouse's approach, have been very promising but seem to reach a lower concentration limit even with multiple filtration using fresh filters. Nor is there any evidence yet that the lower levels achieved by filtration can be maintained in operations without periodic refiltration.

Dow Corning has a joint development project with Transformer Consultants of Akron, Ohio, and DC Filter & Chemical Inc. of Sandusky, Ohio, assisted by the Westvaco Chemical Division of Covington, Virginia.[13] The third phase of the project, using a full-size transformer (a GE 1967 building substation unit) began in November 1976 and shows very promising results:

	Date	Percent PCB
After refill*	11-05-76	0.7
2 months	01-05-77	2.22
6 months	05-06-77	2.33
9 months	08-17-77	2.53
After filter cleanup (8 hr)**	09-16-77	0.43
Resampled	10-25-77	0.615
After 5 hr on 6 filters	11-10-77	0.0677
After 1 additional hr on 3 replacement filters	11-10-77	0.0472

*With Dow Corning® 561 Silicone Transformer Liquid (180 gallons).

**Six Brute filters (120 #WV-G Carbon).

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Option 1

No authorization for use or servicing of the equipment.

Discussion

It would be impossible to immediately replace all railroad transformers. A ban against the use of PCB railroad transformers would cause massive economic and social disruption in the Northeast United States with an adverse impact on the nation's economy.

Option 2

Phase out PCB railroad transformers by requiring refilling to lower the PCB level to 5 percent PCB over a 5-year period and replacement of the transformers over a 10-year period.

Economic Impact

Annual costs to the railroads will be:[14]

1978-1981	1982-1987
$6.5 million	$5.2 million

Thus, the total cost by the end of 1987 would be $57.2 million. These costs are based on the assumption that replacement transformers will be available as needed and that the total cost of replacement is due to the regulation.

Replacement transformers are available with a 21- to 30-month lead time. Therefore, it is necessary that flexibility be built into the replacement schedule. By requiring that 30 percent be replaced by the end of 1980 and 10 percent per year each year thereafter, the necessary lead time for orders is available under this option.

There do not appear to be any employment costs to railroads, although there could be some additional employment requirements in railroad service shops. Record-keeping and monitoring the concentration of PCBs will require additional expenses, but these will be minor compared with costs of replacing transformers.

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Option 3

Phase out the use of PCBs in railroad transformers by authorizing the use of PCBs in the following concentrations:

1. 40,000 ppm of PCBs starting 15 months after the effective date of the rule.
2. 1000 ppm of PCBs starting 36 months after the effective date of the rule.

This would offer the railroad transformer owners a choice--to replace the PCB transformers with a non-PCB unit, or to refill existing transformers with either non-PCB fluid or fluid which has been filtered through carbon.

Assuming the railroads will choose the latter (less costly) option, the total annual cost to railroads would be:[15]

	Amount	Timing
Cost of retrofill program	$7,043,000	1979
Cost of processing program	5,200,000	1980-1982
Final analysis for PCBs	100,000	1983
Reporting	5,000	1979
Spill prevention plans	20,000	1979
Total	$12,368,000	

Decision

Option 1 was rejected because of the massive adverse economic impact that would result. Option 2 was rejected because, although environmentally effective, it would require the replacement of transformers before the end of their normal lifetime of over 30 years. Option 3 was chosen since it would allow the continued use of equipment while substantially reducing the PCB levels in that equipment. Option 3, while not requiring the equipment's replacement, would achieve a significant reduction in possible environmental exposure and allow for the eventual removal of virtually all PCB contamination from the transformers through refilling and filtration.

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C. Mining Machinery

Background

There are two types of mining machinery containing PCB fluids—loaders and continuous miners. In both types the fluid functions as a nonflammable coolant which also lubricates bearings for large alternating current electric motors. The moving parts of the motors are totally immersed in the fluid, which by convection and conduction carries heat from the electrical windings to the external surfaces of the motor casing.

There are approximately 533 loaders and some 652 PCB cooled loader motors which are currently operable.[16] For continuous miners there are 18 machines and 46 motors currently operable.[17] Each loader uses two motors, and each continuous miner uses three motors.

One firm, Joy Manufacturing Company, has been the sole manufacturer of mining machinery which utilizes PCB-filled motors as part of its equipment. Joy discontinued production of loaders using PCB-filled motors in early 1973; continuous miners have not been produced with PCB-filled motors since 1970. Production of these units was discontinued because of the PCB environmental issue.

Although mining equipment using PCBs is no longer manufactured, Joy does provide service and repair for equipment. The steps undertaken in servicing a failed motor are:

1. Opening
2. Draining of PCB fluid
3. Degreasing of internal parts
4. Cooking of case
5. Burning out of insulation
6. Rewinding, reassembling, and filling

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All of these operations are carried out in an open area, with the fumes vented to the atmosphere through the roof by exhaust fans. It is estimated that from 1 to 5 percent of the total PCB volume in each motor could be lost during this maintenance.

The motors in the loaders require rebuilding every 18 to 24 months. Motors in the continuous miners are operated under heavier loads and require rebuilding every 12 weeks. Rebuilding, from the time the motor is removed from service until the time the machine is put back into service, usually requires 1 to 2 weeks.[18]

Normal operation of mining machinery causes losses of PCB fluids by overflow as a result of overfilling and subsequent leaking and expansion of the fluids. The PCB fluid lost in the operation of the equipment in the mines is replaced by operators in the field.

Quantities of PCB used in this machinery vary, depending on the type of motor. Loaders have two motors, each using 4 gallons of PCB fluid. Continuous miners have three motors, holding either 4 or 5 gallons of PCB fluid.

New motors using non-PCB liquid coolant could be installed in all the machinery. However, no non-PCB motors are currently available. The PCB motors on the loaders can be replaced with air-cooled motors. The present motors can also be rebuilt to be air-cooled. This cannot be done with the continuous miners because of space limitations. The cutting head on most of the miners can be replaced with one which does not use PCB-cooled motors. The only other alternative is to cease using the machinery and replace it with new pieces of equipment.

A procedure for refilling the continuous miner motors has been developed; however, it is understood that the PCB content of the fluid in the motors is in the range of 100 to 500 ppm.[19] Also, there is a controversy as to possible fire hazards associated with operating continuous miners that have been refilled with a non-PCB fluid.

Equipment not using PCB fluid accounts for around 99 percent of the miners and 85 percent of the loaders currently in use. All currently produced mining machinery contains air-cooled motors.

Option 1

No authorization for use or maintenance of PCB mining equipment.

Discussion

There are many costs associated with replacing the 652 PCB-cooled motors on the loaders. It costs $6,258 to replace each motor.[20] The total cost for the motor replacement would thus be $4.1 million. If it is assumed that new motors could be supplied at the same rate as are conversion kits (30 per month after 6 to 8 weeks), it would take 24 months to supply enough motors to complete all the conversions. Delivery of the first motors could not take place for 6 to 8 months after an order is received.[21] The loaders would be out of commission for an average of 12 months, resulting in lost coal production. In addition, 3,700 jobs would be affected initially, with the number declining as the loaders were converted.

Joy has been converting motors in the loaders to air-cooled motors. There are currently approximately 320 conversion kits, each valued at approximately $3100, which would have to be scrapped. There are also higher maintenance costs associated with using air-cooled motors. In addition to the overall costs listed above, some of the individual mines dependent upon the loaders would be severely affected.

Replacing the cutting heads on the 18 "9 CM" continuous miners in use would cost approximately $80,000 to $100,000 per machine.[22] It is doubtful whether this would be an economically viable alternative for an older machine which cost $120,000 when it was new.

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The only other alternative for the continuous miners is scrapping the old machines and buying new ones. New miners roughly comparable to those scrapped would cost approximately $250,000 to $300,000.[23] Replacing the 18 continuous miners currently in use would cost $4.5 million.

The loss of 290 loaders and 18 continuous miners would cause a curtailment in coal production of around 150,000 tons per day assuming a production of 250 tons per shift, 2 shifts per day. If this production rate is assumed to occur 5 days per week, 50 weeks per year, this would be equivalent to 38 million tons per year, or in the range of 5 to 10 percent of the nation's annual coal production. The value of the lost production, at $20 per ton, would be around $3 million per day. In addition to lost revenues and reduced coal production, the jobs of the miners who work on the involved sections would be affected.

Option 2

Authorize servicing and use of the equipment in a nontotally enclosed manner until December 31, 1981, with certain conditions: the motors in the loaders will be converted to dry operation as they are serviced, and the continuous miners will be converted to non-PCB operation as they need rebuilding beginning 12 months after the effective date of the rule.

Discussion

It costs $3,100 excluding labor[24] to convert each motor in a loader to dry operation, for a total cost of $2 million. Since the economic life of the loader equipment will continue for many years, the cost of eliminating PCBs from the equipment must be incurred before the equipment is at the end of its lifespan. Conversion at normal maintenance intervals will enable a smooth transition from PCB motors without disrupting coal production, as would probably occur with a conversion period of less than 3 years.

Replacing the cutting heads on the continuous miners would cost approximately $80,000 to $100,000. Since these machines cost $120,000 each when new, it is doubtful that this would be an economically viable alternative for a machine owner.[25] Thus, the machines would be replaced in lieu of PCB motor replacement only. New continuous miners cost approximately $250,000 to $300,000. Because continuous miners with PCB motors are very near or at the end of their economic lifetime, their value is relatively small. The order time for a continuous miner is currently as long as 6 months, and it is estimated that a large number of orders made at once in response to this rule would only marginally affect delivery lead times. Therefore, beginning the phase-out of this equipment twelve months after the effective date of the rule would allow for a smooth transition if new equipment must be ordered and would not cause an interruption of coal production.

Decision

Option 2 was chosen. Option 1 would cause severe economic disruption, while Option 2 allows for conversion as quickly as possible without causing equipment to be idle for long periods. Therefore, this option balances the environmental effects with economic impact and eliminates this use of PCBs as soon as possible without causing economic disruption on a large scale.

D. Hydraulic Die Casting Systems

PCB fluids are contained in a large number of hydraulic systems used in die casting. PCB fluid is used in such systems because of high-temperature stability and fire resistance. In 1972, when PCB hydraulic fluids were no longer available, the users had to switch to substitute fluids. Since the substitutes were compatible with the PCB fluids, the machines were not drained and flushed but were simply topped-off as required with the new fluid. Topping-off generally requires adding new fluid at the rate of 2-10 times the system capacity per year.[26]

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When hydraulic system owners were made aware of the environmental hazards associated with PCBs, many of these owners drained and flushed their machines and refilled them with non-PCB hydraulic fluid. The success of refilling varied considerably as shown in the following table.

PCB Levels in Drained & Flushed Hydraulic Systems[27]

Company	PCB level (ppm)
Cast Forge Co.	80
Caterpillar Tractor	Below detection limit (systems are drained twice a year)
General Motors	100-500
Outboard Marine	90-6000 (currently average 500)

There are several sources of PCB contamination at these facilities. The high operating temperatures cause vaporization of the hydraulic fluid during use, and as a result, PCBs are emitted to the ambient air around the plant. The inherent leaking of these systems, characterized by the large amount of topping-off required, results in water effluent and solid waste (e.g., rags and cleaning agents). Because of the contribution to ambient levels of PCBs, several studies have been conducted of these facilities by regional offices of EPA.

Option 1

Require the disposal of all die casting machines that have used PCB hydraulic fluid.

Discussion

This option would remove PCB-contaminated equipment from use and would thereby drastically reduce the environmental contamination resulting from the continued use

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of these machines. These machines, however, represent a very large capital investment by their owners. The removal of these machines would create problems for their owners not only because of the amount of capital lost, but because of the loss of production during replacement and the length of time required to replace each machine. It is presumed that from time of order to time of replacement would be at least 6 months.

Option 2

Hydraulic fluid in die casting machines with a PCB concentration greater than 50 ppm would be replaced with fluid with no more than 50 ppm within 1 year of the effective date of the rule. The fluid would be checked every 6 months to test the PCB concentration; fluid with a 50-ppm or greater PCB concentration would have to be filtered or replaced.

Discussion

This option would significantly reduce the environmental contamination from the use of these machines and would eventually reduce the concentration of PCBs in the hydraulic fluid to very low levels. It has been suggested that such a procedure will not be able to reduce the hydraulic fluid to a low-level PCB concentration. However, the experience of Caterpillar Tractor shown in the table above would seem to provide ample evidence that such a goal is well within reach of the other companies owning systems. General Motors has stated that the cost of this operation would be about $9.40 per gallon of hydraulic fluid. This is broken down as follows:

Item	Cost per gallon of fluid replaced ($)[28]
Solvent	2.26
New hydraulic fluid	7.57
Disposal	0.57
Total	9.40

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Option 3

This option would place no requirement on the owners of these machines based on the presumption that the high flushing rate that already exists as a result of the high leakage will eventually reduce the PCB concentrations to acceptable levels.

Discussion

This option would impose no additional cost on the companies that use hydraulic die-casting systems. As described above, the refilling rate on these machines is approximately two to ten times their capacity every year. The results show that there has been some reduction of PCB concentrations, and it can be expected that these levels will continue to drop. However, some systems have not achieved the same levels as others, and this might be explained by possible reuse of the leaked hydraulic fluid. For those systems with existing high levels, it could be quite some time before they achieved a PCB concentration of 50 ppm or less.

Decision

Option 2 has been chosen because it does not require that companies with these systems suffer large capital losses. PCB concentrations in the hydraulic fluids will be reduced. This will result in a reduction in PCB emissions to the environment. The Caterpillar Tractor experience in reducing PCB concentrations in the hydraulic fluid is evidence that substantial reductions in PCB contamination levels can be achieved. Costs will be imposed on companies operating these systems, but they will not be continuing costs since the PCB concentration should drop below 50 ppm in less than 5 years.

E. Carbonless Copy Paper

Prior to 1971, carbonless copy paper distributed by NCR Corporation was made with ink containing PCBs. There does not appear to be a way of distinguishing PCB

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carbonless copy paper from non-PCB carbonless copy paper, with the possible exception of dates or other indications in unused inventories. A large portion of the PCB carbonless copy paper that has not been destroyed is probably in files. The proposed rule authorizes the use of PCB carbonless copy paper for the following reasons: (1) the inability to readily distinguish between PCB and non-PCB carbonless copy paper; (2) the enormous undertaking that would be required of both business and government to purge files of PCB carbonless copy paper, even if a way to distinguish it from non-PCB carbonless paper were devised; and (3) the small amount of PCB on each piece of carbonless copy paper. In addition, paper recyclers have for some time been careful not to accept any carbonless copy paper for recycling.

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VII. WASTE OIL

Sealants, coatings, and dust control agents made from waste oil are often contaminated with PCBs, and because of their particular uses, these PCBs are quickly introduced directly into the environment. For example, waste oil is frequently used as a coating for roads, which have well-drained surfaces and whose run-off frequently goes to municipal treatment plants or rivers and streams. In addition, although the PCB concentration is low, the large volume of oil that is used results in a large quality of PCB entering the environment. Because the PCBs in waste oil can so easily find their way into the environment through these uses, the EPA is proposing that waste oil containing any amount of PCB contamination shall not be used as a sealant, coating, or dust control agent. Waste oil containing less than 50 ppm may still be used as a fuel, as a feedstock for rerefining, or any other use except as a sealant, coating, or dust control agent.

Approximately 1.3 billion gallons per year of used oil is collected for use as road oil, fuel oil, rerefined hydraulic oil, and rerefined lubricating oil.[1] Much of the waste oil previously used in applications other than automotive lubrication has been contaminated with low levels of PCBs. Dissipative uses of this contaminated oil can introduce PCBs directly into the environment. These include the use of contaminated waste oil as a dust control agent, sealant, or coating. The PCB contamination of the waste oil could originate from contaminated industrial hydraulic oil or transformer oil or from PCB additives used in lubricating oils prior to 1973.

Unless there has been an unusual incident of contamination, normally the level of PCB in waste oil should be well below 50 ppm.[2] Examples of such incidents include mixing oil with PCB dielectric fluids or with large amounts of PCB hydraulic fluid.

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The use of waste oil contaminated with any level of PCB as a dust control agent, coating, or sealant is prohibited by this proposed rule. However, waste oil contaminated at levels below 50 ppm may still be used for such things as boiler fuel or feedstock for rerefining.

If, as expected, virtually all use of waste oil to control dust on roads is ended, 319 million gallons of waste will be diverted to fuel usage.[3] Past users will be forced to forego road oiling or use a substitute. The cost to users has been estimated to be approximately $100 million annually if a synthetic substitute is used. However, it is possible that the substitute may require application less often.[4]

Because of contamination above 50 ppm of PCBs, transformer oil will not be available to collectors, initially reducing the total supply.[5] However, transportation of the contaminated oil to chemical waste incinerators will be required and could offer new market opportunities to the collectors.

Rerefiners should be operated at capacity and thus be more profitable as a result of this proposed rule. Increased interest in the use of recycled oils and rising oil prices should increase the market for all uses of waste oil.

Those industries whose waste oil contains more than 50 ppm of PCBs will incur disposal costs of $0.0832 per pound. Waste oil containing less than 50 ppm of PCBs can be mixed with virgin oil for use in industrial boilers.

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VIII. FOOTNOTES

I. BACKGROUND

1. Microeconomic Impacts of the Proposed PCB Ban Regulations, Versar, Inc., Chap. 1.

2. Microeconomic Impacts, Chap. 1.

III. SIGNIFICANCE OF THE RELEASE OF PCBs INTO THE ENVIRONMENT

1. World Health Organization; "Environmental Health Criteria 2: Polychlorinated Biphenyls and Polychlorinated Terphenyls"; pp. 43-44.

2. World Health Organization; "Environmental Health Criteria 2: Polychlorinated Biphenyls and Polychlorinated Terphenyls"; pp. 44-45.

3. EPA; Toxic Pollutant Effluent Standards - Standards for Polychlorinated Biphenyls (PCBs), Final Decision; (Hereinafter referred to as EPA Final Decision); 42 Fed. Reg. 6537-8.

4. EPA Final Decision; 42 Fed. Reg. 6538.

5. EPA Final Decision; 42 Fed. Reg. 6537.

5a. Bahn, Anita K., "Report on Paulsboro, N.J., Mobil Oil Plant Study" (unpublished, University of Pennsylvania School of Medicine, April 27, 1976).

6. NIOSH; Criteria for a Recommended Standard: Occupational Exposure to Polychlorinated Biphenyls (PCBs); (Hereinafter referred to as NIOSH Criteria); 65.

7. NIOSH Criteria; p. 98.

8. NIOSH Criteria; pp. 98-99.

9. EPA Final Decision; 42 Fed. Reg. 6535.

10. EPA Final Decision; 42 Fed. Reg. 6535.

11. EPA Final Decision; 42 Reg. 6535-36.

12. EPA Final Decision; 42 Fed. Reg. 6536.

13. Alvares, Alvito P. et al.; "Alteration in Drug Metabolism in Workers Exposed to Polychlorinated Biphenyls"; Clinical Pharmacology and Therapeutics; 22:140-145 (1977).

14. EPA Final Decision; 42 Fed. Reg. 6536.

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15. EPA Final Decision; 42 Fed. Reg. 6536.

16. EPA Final Decision; 42 Fed. Reg. 6536.

17. NIOSH Criteria; pp. 73-74.

18. EPA Final Decision; 42 Fed. Reg. 6535.

19. NIOSH Criteria; pp. 74-75, 87.

20. Research Communication in Chemical Pathology and Pharmacology, 15:563-570 (1976).

21. NIOSH Criteria; p. 119.

22. EPA Final Decision; 42 Fed. Reg. 6537.

23. NIOSH Criteria; pp. 78, 81-82.

24. NIOSH Criteria; pp. 74-75.

25. EPA Final Decision; 42 Fed. Reg. 6537.

26. NIOSH Criteria; p. 54.

27. NIOSH Criteria; pp. 41-42.

28. NIOSH Criteria; pp. 49-53.

29. NIOSH Criteria; pp. 47-48; EPA Final Decision, 42 Fed. Reg. 6537.

30. EPA Final Decision; 42 Fed. Reg. 6535.

31. EPA Final Decision; 42 Fed. Reg. 6534.

32. EPA Final Decision, 42 Fed. Reg. 6534.

33. EPA Final Decision; 42 Fed. Reg. 6534.

34. EPA Final Decision; 42 Fed. Reg. 6534.

35. EPA Final Decision; 42 Fed. Reg. 6543.

36. EPA Final Decision; 42 Fed. Reg. 6542, 6533.

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