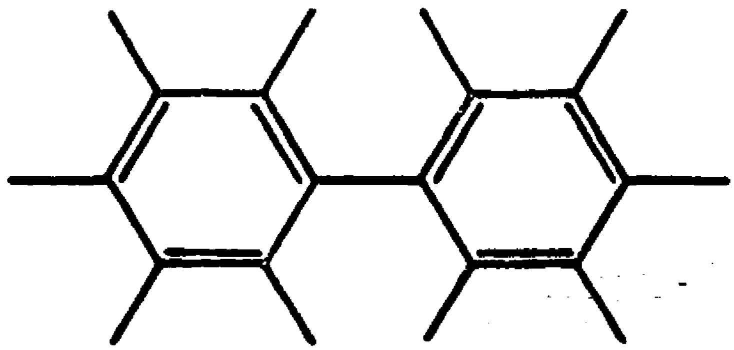

BY A. KARIM AHMED

The accumulation continues

POLYCHLORINATED BIPHENYLS (PCBs) were first introduced into commercial use more than 45 years ago, and for a long time the widely used industrial chemicals were considered to be relatively non-toxic. Their potential threat to the environment, however, was recognized in 1966, when the Swedish scientist, S. Jensen, observed the presence of the compounds in fish and wildlife samples while analyzing for chlorinated hydrocarbon pesticide residues.[1,2] Since that initial discovery, PCBs have been detected in numerous aquatic and animal species and have been found in high concentrations in industrial waste discharges, river-bottom sediments, food packaging materials, and in foods such as poultry, fish, and dairy products. Detectable levels of the chemical substance have been found in marine life ranging in size from small (plankton and zooplankton)[3,4,5] to large species (tuna).[6] High levels of PCBs have been found in fish-eating and predatory birds,[7,8,9,10] demonstrating the process of concentration of the substance along the food chain from lower to higher animals,[11] a process which unfortunately has become all too well known in the era of modern industrial and agricultural activity. Relatively large concentrations of PCBs also have been discovered in the eggs of wild birds.[6,9,12]

During the past ten years, PCB residues have been analyzed in wildlife and fish samples in Holland, Germany, and the Baltic Sea.[7,13] Off the coast of Scotland, PCB residues have been found in several marine species, the contamination presumably having arisen from sewage wastes dumped into the open sea.[14] Nevertheless, despite global incidence of the chemical in the environment, residues are generally found mostly in regions of the world where there is intense industrial and urban activity. In the U.S., PCBs in increasing amounts have been detected in the eastern and western coastal regions, in highly urbanized areas (for instance, in and around the Chesapeake Bay, San Francisco Bay, and Puget Sound), and in regions where industrial discharges are known to occur, such as Escambia Bay, Florida, and the Hudson River.[8,15,16,17]

The environmental accumulation of PCB residues continues despite attempts by both industry and the federal government to improve the situation. As will be explained, industry's countermeasures have been

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limited, and government action has been hesitant.

In the U.S., the impact of PCBs on the environment is best illustrated by ever increasing contamination of sport and commercial fisheries in the Great Lakes region and elsewhere. According to data from the Michigan Department of Natural Resources, levels of PCBs in lake trout and Coho salmon from Lake Michigan showed a sharply increasing trend since 1972. By 1974, the values ranged from more than 10 to nearly 25 parts per million (ppm), well above the present Food and Drug Administration's (FDA's) maximum allowable concentration of 5 ppm for fish and shellfish.[15] In sharp contrast, DDT levels in the same species of fish showed a declining trend since 1970, when DDT consumption in the U.S. was curtailed.[18] Not only are the ecological consequences of continued PCB contamination ominous, but the potential economic implications are serious, since the total annual value of sport fishing in Lake Michigan is as high as $46.5 million.[19] In addition, the commercial catch of fish is now worth about $2.5 million each year.[20]

The Michigan studies are supported by studies made by the Wisconsin Department of Natural Resources. Fish samples collected in 1974 showed extensive contamination.[21] Affected types included Chinook salmon, Coho salmon, brown trout, tiger trout, lake trout, whitefish, and carp. Generally, the residue levels ranged well above 5 ppm, with lake trout (up to 43.8 ppm) and carp (up to 51.6 ppm) showing the highest concentrations.

In the Upper Fox River, samples taken at one station by Wisconsin researchers in 1975 showed high concentrations of PCBs in white suckers (32.7 ppm), carp (average 35.9 ppm), and northern pike (average 15.4 ppm). Samples from several areas of the Mississippi River analyzed by the department in 1973 showed similar residues of PCBs in walleyed pike, largemouth bass, northern redhorse, and carp. An interagency task force on PCBs, formed of federal and several state agencies of Minnesota and Wisconsin, sampled fish in the Mississippi River during the early summer of 1975 and again found similar levels of PCBs in several fish species.[25]

Elsewhere, the Division of Fish and Game of the Commonwealth of Massachusetts has in the past detected high PCB levels in fish in several rivers and streams in the state.[23] From other data collected by the agency, it is clear that in 1972 there was extensive contamination of a large variety of fish species in nearly all the rivers which were sampled in the state, with mean PCB residue levels ranging between 1.11 and 197.0 ppm.

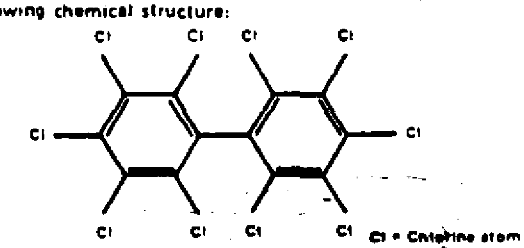
To date, however, the most contaminated fish in the U.S. have been found in the upper reaches of the Hudson River, near and below two General Electric plants in the Fort Edward-Hudson Falls area in the upper Hudson River more than 40 miles north of Albany. The two plants manufacture electrical capacitors in which PCBs are used as insulating fluids. In 1974, sampling by the U.S. Environmental Protection Agency (EPA) showed yellow perch and shiner minnows to contain average PCB residues of 17 and 78 ppm, respectively, with one rock bass sample containing 350 ppm.[24] It appeared that the two General Electric plants had been discharging approximately 30 pounds of PCBs into the river each day; in recent months, this amount seems to have declined to less than 10 pounds per day. Fish samples collected in 1975 by the New York State Department of Environmental Conservation confirm the earlier findings. The composite PCB averages in fish caught near one plant show typical values well above 20 ppm, with one American eel sample yielding residue values of 403.4 ppm (concentration measured as Aroclor 1016/1242).[25]

As large amounts of PCBs were being discovered in the upper Hudson River, New York State Department officials also were finding high residues of PCBs in fish species of recreational and commercial importance farther south in the Hudson River.[25] Striped bass caught near the Albany area showed total PCB residue values of between 11.08 and 89.76 ppm. Fish caught in the lower reaches of the river had a relatively higher concentration of an older PCB formulation (Aroclor 1254), indicating long-range transport of PCBs discharged by industrial activities in the past. Striped bass sampled near the West Point and Tappan Zee area of the Hudson River (50 miles north of New York City and several hundred miles south of the Fort Edward-Hudson Falls area where the General Electric plants are located) had total PCB residues of from 1.16 to 7.54 ppm. Similarly, a sample of American shad in the Poughkeepsie area showed PCB residue levels of 9.0 ppm.

Disruption of the striped bass commercial fishing industry on the Hudson

STRUCTURE OF PCBS

Polychlorinated biphenyls (PCBs) is a generic term used for a number of synthetic organic compounds that possess the following chemical structure:



PCBs are a mixture of different chlorinated biphenyl homologs (very closely related chemical substances). Thus, different PCB formulations or products may contain mixtures of biphenyls which have different percentages of the many possible chlorinated homologs, each containing a different number of chlorine atoms per biphenyl molecule. Monsanto Company, the sole U.S. producer of PCBs, sells its product under the trade name Aroclor. This product is sold under different formulations: Aroclor 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, 1016, and so on. The last two digits in this biphenyl series denote percentage of chlorine in the mixture. Aroclor 1016 is an exception to this nomenclature, since it contains 41 percent chlorine and is, in fact, very similar in composition to Aroclor 1242. Trade names used by foreign manufacturers include: Phenoclor and Pyralene (Prodelec, France), Kanechlor and Santotherm (Kanegafuchi Chemical Company and Mitsubushi-Monsanto, respectively, Japan), Clophen (I. G. Farben-Industrie A. G., Germany), Fenclor (Caffaro, Italy), and Sovol (U.S.S.R.).

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Environment — Robert C. Smith

High levels of PCBs have been detected in aquatic birds.

River would have serious economic consequences, since the value of the annual commercial catch appears to be about $1.2 million.[26,27,28] In addition, the annual take of striped bass by sportsmen exceeds the annual commercial catch.[28] Furthermore, the overall problem is serious in its relation to reproduction in striped bass. The striped bass is a migratory fish which has stock that intermingles in various locations such as the Chesapeake Bay, the Delaware River, and the Hudson River regions. As a result, PCB contamination may affect a large segment of the entire North Atlantic stock of striped bass.

Bottom Buildup

Of equal concern is the accumulation of PCBs in river-bottom sediments. PCBs, like most chlorinated hydrocarbons, are highly insoluble in water and tend to settle and then be adsorbed on silt and fine particles on the bottom.[15]

Data collected by the U.S. Geological Survey (USGS) on the Hudson River during the years 1973 and 1974 show the presence of PCBs in the water and in the bottom sediments of the river.[29] Values ranging between 0.3 and 3.0 parts per billion (ppb) PCBs have been reported in water samples collected at several stations on the Hudson River. The sampling sites include locations near Poughkeepsie, Waterford, Chelsea, and Rhinebeck.

In contrast to water samples, PCB concentrations analyzed from the river-bottom sediments showed considerably higher values characteristic of the insoluble nature of PCBs. The USGS data are summarized below:[29]

PCB Concentrations in Hudson River Sediments, USGS

Date	Station	PCB in Sediments (ppb)
7/74	Chelsea	3,200
7/74	Poughkeepsie	11,000
7/74	Waterford	13,000
7/74	Winebrook Hills	0.1
9/74	Chelsea	1,800
9/74	Poughkeepsie	3,600
9/74	Waterford	640
8/75	Roger's Island, south of Glenn Falls	18,000

More recently, the EPA conducted water and sediment analyses for PCBs in the vicinity of Ford Edward, New York, near one of the General Electric plants. Water samples collected directly south of the plant's waste-water discharge pipes had PCB values of 2.2 to 3.1 ppb. Nearby sediments, in contrast to the water, contained 540,000 to 2,980,000 ppb (540 to 2,980 ppm), with 6,600 ppb being detected several miles downstream of the discharge pipes.[24] These concentrations obviously are much larger than those at the more distant sites checked by USGS personnel, even though the latter concentrations are themselves excessive. One immediate practical problem is that the largest concentration of PCBs is likely to exist in the deep navigation channel of the Hudson, and dredging in this channel will further disperse the material.[15,30]

PCBs, like most chlorinated hydrocarbons, are highly insoluble in water and tend to settle and then be adsorbed on silt and fine particles on the bottom.

Toxic Effects of PCBs

Based on the high lethality of PCBs to marine and freshwater aquatic species, the National Academy of Sciences-National Academy of Engineering Committee made the following recommendation:[14]

"Aquatic life should be protected [that is, safe from toxic effects] where the maximum concentration of total PCB in unfiltered water does not exceed 0.002 microgram per liter [0.002 ppb] at any time or place and the residues in the general body tissues of any aquatic organism do not exceed 0.5 microgram per gram [0.5 ppm]."

These levels obviously are exceeded in areas of the Hudson River and elsewhere.

The danger to aquatic life is a warning of the danger to human life. In fact, the toxicity of PCBs to humans has been clearly and tragically demonstrated. In 1968, a severe form of skin disease was diagnosed in Japanese families who consumed rice oil contaminated with Kanechlor 400 (PCB with 48 percent chlorine content).[31,32] The disease, known as the "Yusho syndrome," is characterized by swelling of the upper eyelids, visual impairment, acne-like formations, and heightened pigmentation of the skin,[31] and a total of 1,057 poisoning cases have been recorded to date in Japan.[33] Patients with this disease also have exhibited neurological disorders and have shown signs of hearing loss. Babies born to several patients had many of the symptoms of the disease, indicating a placental transport of PCBs, most fetuses of the victims were smaller than the national average. Another disturbing feature of the disease was the observation that most patients recovered very slowly, which suggested that PCBs were retained in their bodies over a very long period.[43] PCBs have been detected in human adipose tissue (connective tissue in the body containing stored cellular fat) in such widespread occurrence that over 40 percent of the U.S. population contains one part per million or more.[34]

A number of studies have conclusively shown the effect of PCBs on the reproduction processes of some birds and animals, including monkeys.[31,35,36,37,38,39,40] It is important to note that PCBs with lower chlorine content may have a greater effect on reproduction than biphenyls with higher chlorine content, even though the former substances are now being suggested as substitutes for the latter. In a recent review article on the toxicology of PCBs, Renate Kimbrough of the Center for Disease Control in Atlanta, Georgia, stated:[41]

"The results obtained from the reproduction studies in birds particularly seem to indicate that the lower chlorinated biphenyls affect reproduction more than the higher chlorinated biphenyls, and it is very important to determine whether the lower chlorinated biphenyls that have been suggested as replacements for presently employed chlorinated biphenyls have an effect on reproduction."

The recent PCB toxicity tests in monkeys are particularly relevant to human health considerations. In an extensive series of tests carried out by James Allen and his colleagues at the University of Wisconsin School of Medicine, PCBs in the diet of rhesus monkeys caused significant effects that mimicked both the symptoms of known human toxicity and reproduction failures in experimental animals. When female rhesus monkeys were given 25 ppm of Aroclor 1248 for a period of two months, severe symptoms of facial swelling and skin eruptions were manifested.[38] At lower dietary levels (5.0 ppm and 2.5 ppm) of the same substance, similar clinical symptoms were observed after a few months; more significantly, these low levels of PCBs had a marked effect on reproduction. After three matings with male monkeys, only 12.5 percent of the 5 ppm PCB dietary group and 37.5 percent of the 2.5 ppm group were pregnant as compared to 90 percent pregnancies in a comparable control group.[39] At the same time, offspring were significantly smaller in size: their health was further threatened since they continued to ingest high PCB levels from the nursed milk of their mothers.[40] One notable consideration related to the experiments in monkeys is that the present FDA tolerance limit of 5 ppm[41] for PCB residue in fish and shellfish is based on the assumption that toxic effects occur at levels much higher than is actually the case. On this basis, then, the FDA tolerance limit is too high.

Also of serious concern is a recent study conducted by a group of research investigators at the Center for Disease Control in Atlanta, the EPA, the National Cancer Institute, and the Johns Hopkins University School of Medicine.[42] They observed that when experimental female rats were fed a diet containing 100 ppm of PCB (Aroclor 1260) for about 21 months, 26 of 184 of the experimental animals examined had malignant liver tumors (Hepatocellular carcinoma), whereas only 1 of 173 control animals had the disease. At the same time, 146 of the experimental and none of the control animals had tumorous lesions (neo-plastic nodules) in the liver.

Other effects of PCBs that have been reported in the scientific literature include: (1) increased production of certain enzymes in the livers of human beings and laboratory rats, (2) induction of liver porphyria in several animal species, (3) interference with the immune defense mechanisms in rabbits, (4) neurological disorders in rats, (5) increased PCB residue in fatty tissues, serum, and milk, and (6) toxic effects in chick embryos.[43,44]

There has been some concern that reported PCB effects may be attributed in part to the presence of chlorinated dibenzofurans as a contaminant in PCB mixtures.[31] Chlorinated dibenzofurans have been shown to be acutely embryotoxic and have been detected in several PCB preparations (Clophen A 60, Phenoclor DP-6, Aroclors 1248, 1254, 1260).[45] Recent reports by M. Kuratsune and his associates have indicated that the "Yusho" patients apparently had been exposed to PCBs in rice oil contaminated with chlorinated dibenzofurans and showed detectable levels of this compound in their body tissue.[46] However, it was not determined from this study whether the contamination occurred during manufacture of the PCBs or during the use of the PCB mixture as a heat exchange fluid in the rice oil plant, since high temperatures may have led to its formation through the hydroxylation and oxygen ring bridging of chlorinated biphenyl molecules. At present, the possible link of PCB toxicity to the presence of chlorinated dibenzofuran contaminants remains highly speculative, as there appears to be no direct experimental evidence that dibenzofuran derivatives have long-term chronic effects similar to those which have been amply demonstrated with PCBs.[31,46]

Control of PCBs

The attack on PCB contamination has taken two forms, one a voluntary response by manufacturers of the substance and the other a response by various government bodies. Both responses have been inadequate, as will be shown in what follows.

In 1971, over 106 million pounds of PCBs was produced in the industrial countries of the world, with a third of this, nearly 40 million pounds, being manufactured in the U.S.[47] During the late 1950s and into the 1960s, U.S. domestic sales of PCBs increased nearly threefold, reaching a peak of approximately 72 million pounds in 1970.[48] Prior to 1970, about 60 percent of PCB material sold domestically in the U.S. was used for closed electrical systems such as capacitors and transformers. Another 25 percent was used as plasticizers and in the production of carbonless duplicating paper.[48] In September 1970, Monsanto Company, the sole manufacturer of PCBs in the U.S., restricted its sale of PCBs because of environmental contamination by the chemicals. This restriction consisted of limiting sales to those materials earmarked for closed electrical systems. Thereafter, U.S. consumption was reduced considerably. It is important to note, however, that these reductions occurred mainly in the use of PCBs as plasticizers and as hydraulic and lubricating fluids, since the bulk of PCBs (60 percent), as mentioned above, had been used in electrical systems. This chemical substance is still being used almost exclusively as the insulating fluid for large, high-voltage capacitors (as well as for certain small ones) and for electrical transformers. In addition, the EPA estimates that approximately one-half million pounds of PCBs is being imported into this country each year[29] and presumably is being used in products other than electrical equipment.

As to government response to the PCB problem, a federal Interdepartmental Task Force was convened in 1972. The group concluded that because of the highly persistent nature of PCBs and their bioaccumulation in the food chain, these chemical compounds posed a serious threat to human health. The group recommended restriction of the use of PCBs to closed electrical systems such as electrical transformers and capacitors.[43] However, since Monsanto Company actually had already begun restricting domestic sales in this fashion, it is not clear whether the task force's recommendations, issued a year and a half after Monsanto's action, had any influence on the company's decision (although this has recently been suggested by a federal official).[50]

In July 1973, the FDA established PCB tolerance limitations in a variety of food products, as follows:[41]

FDA Tolerances for PCBs in Food and Food Packaging (ppm)

Milk*	2.5
Dairy products*	2.5
Poultry*	5.0
Fish and shellfish**	5.0
Eggs	0.5
Infant and junior food	0.2
Complete and finished animal feed	0.2
Animal feed components	2.0
Paper food-packaging material	10.0

*On fat basis
**Edible portion

Toxicity data obtained during the past year showing severe reproductive failure with low concentrations of PCBs in primates (5.0 and 2.5 ppm) and the recent demonstration of carcinogenicity with rats[40,42] indicate the need to substantially revise the present FDA tolerance limitations of PCBs in foods. Although the present tolerance standards are deficient, the FDA has in recent months taken seizure action based on these standards

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against several fish shipments earmarked for commercial markets in Lake Michigan, since PCB concentrations in the fish exceeded the present 5 ppm guideline.[51] Similarly, the FDA seized a shipment of carp this summer in Lake Pepin on the Mississippi River.[52] In view of a recent legal decision that apparently allows the FDA to define pesticide residues in foods as an indirect food additive, the FDA is expected to enforce its guidelines more forcefully in the future. FDA officials in the Great Lakes region have warned that shipment of chubs, Coho salmon, and lake trout may be disallowed in interstate commerce, since the fish continue to contain high residue levels of PCBs.[51] It is apparent that with a more thorough monitoring and surveillance program, many species of fish in the Great Lakes region and in several rivers in the East Coast area will be essentially unavailable for human consumption for many years.

One of the great ironies of the present situation is that *more than three years ago* the Federal Water Pollution Control Act (FWPCA) directed the federal government (specifically the EPA) to take swift action to reduce the discharge of PCBs and other toxic water pollutants to safe levels. The fact that today there is no meaningful national program to regulate PCB discharges is a result of the federal government's failure to carry out the act as written.

The congressional authors of the FWPCA believed that the "hazards posed by toxic substances" made their effective regulation "especially urgent."[53] Accordingly, they established in the act a "national policy that the discharge of toxic pollutants in toxic amounts be prohibited"[54] and added to the act a far-reaching special provision, Section 307(a), to ensure that this goal was fully implemented. If the section's mandatory deadlines had been met, toxic pollutant effluent standards covering PCBs and other toxic pollutants would have been promulgated by the EPA roughly two years ago and complied with by dischargers about one year ago. Yet, to date, the EPA has failed to promulgate a single standard under this provision.

Despite shortcomings in federal enforcement, several states have taken administrative and legislative initiatives to control the discharge of PCBs into lakes and rivers. Earlier this year, the Michigan Natural Resources Commission endorsed the recommendation of the Lake Michigan Toxic Substances Committee, calling for a ban on PCB imports and their use in the U.S. and for a rapid replacement of PCBs in electrical capacitors and transformers.[51] At the same time, a bill has been introduced in the state legislature to place strict control on the use and sale of PCBs in Michigan.[51]

In Wisconsin, the Division of Health of the State Department of Natural Resources has issued warnings on consumption of large lake trout and salmon from Lake Michigan and the upper Mississippi River. In August 1975, the department held a hearing with a view to developing a strategy to control the sale and distribution of PCBs within the state.[51] In Minnesota, an Interagency Task Force was established, principally to broaden the monitoring of PCBs in fish in several rivers and streams in the state.[52]

In terms of administrative remedies, the strongest action was taken this year in New York state, after it was discovered that the two General Electric plants on the Hudson River appeared to be the major dischargers of PCBs in upper regions of the river. On September 23, 1975, the New York State Department of Environmental Conservation issued an abatement order requiring the General Electric plants to achieve zero discharge of PCBs by September 30, 1976. Administrative hearings were begun on October 6, 1975.[55] At the same time, Ogden Reid, commissioner of the department, publicly warned consumers against eating striped bass from the Hudson River and salmon caught in Lake Ontario.[56]

On the international front, the Organization for Economic Cooperation and Development (OECD) a few years ago recommended that its member countries which are involved in PCB production (including the U.S., West Germany, France, the United Kingdom, Japan, Italy, and Spain) restrict the commercial use of PCBs to closed systems.[57] Only Japan has taken fur-

Large amounts of PCBs have been found in fish in the Hudson River, especially in those of recreational and commercial value.


Photo by Wesley Holmes

ther strict measures to completely eliminate the use of PCBs in all commercial applications, including capacitors and transformers. Japan also prohibits the import and export of the compound, and, since September 1972, there has been a virtual elimination of almost all applications of PCBs in that country.[50]

Most recently, following the National Conference of PCBs which was held in Chicago on November 19 to 21, 1975, the EPA on December 22, 1975, announced a far-reaching federal policy of "totally eliminating the use of polychlorinated biphenyls (PCBs) as rapidly as possible" in the U.S.[49,58] In a more specific action, the EPA has ordered the two General Electric plants on the Hudson River to achieve zero discharge by June 1977.[59] It is clear from these actions that the federal government has recognized the gravity of the PCB issue and at last has taken definitive steps to address the problem.

The title of this article as originally submitted was "A Review of Federal and State Government Roles in Controlling Impacts of PCBs on the Environment." The Publisher and Editors of Environment *are responsible for the published titles and subtitles, selection of photographs and lead-in excerpts, photo captions, and preparation of most graphs and illustrations which appear in* Environment *articles.*

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