

ABCs of PCBs

The University of Wisconsin Sea Grant College Program has been studying the PCB problem, as it relates to the Great Lakes, since 1970. During that time, Sea Grant scientists have looked at: the occurrence and concentration of PCBs in the sediments and waters of Lake Michigan; the accumulation and transport of these compounds through the food chain; the route of uptake and accumulation of these chemicals in Great Lakes fish; the means by which PCBs degrade in the environment; and, via studies on monkeys, the probable effects of PCBs on man.

Over the past six years, the PCB problem on the Great Lakes has, if anything, become more acute. For this reason, the Sea Grant Program has produced this pamphlet which answers some of the most prevalent questions about PCBs.

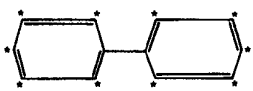
WHAT ARE PCBs?

PCBs, or polychlorinated biphenyls, are chemical compounds similar to DDT and dieldrin.

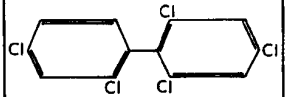
They are generally colorless, odorless liquids with a thick molasses-like consistency. They are fire resistant, having high boiling points. PCBs do not dissolve easily in water, do not readily conduct electricity and are poor conductors of heat.

These chemicals are chlorinated hydrocarbons in which chlorine replaces hydrogen in the molecular structure. There are over 100 varieties of PCBs, each containing a slightly different number or arrangement of chlorine atoms. Chlorine content in PCB compounds commercially available in the U.S. ranges up to 68 percent—the higher the percentage the higher the compound's boiling point. Recent evidence also suggests that the higher the chlorine content, the more toxic the PCB compound is.

THE PCB MOLECULE



• — points where chlorine can be substituted for hydrogen atoms in the biphenyl structure.



example: pentachlorobiphenyl

WHAT ARE THEY USED FOR?

Because of their chemical stability and their low conductivity of heat and electricity, PCBs are very useful as industrial chemicals. The primary uses of PCBs at present are in the coolant insulation fluids in electrical transformers and capacitors. Presently, about 70 percent of the PCBs produced in the U.S. are used in capacitors; the other 30 percent, in transformers.

Prior to 1971, PCBs saw a much greater variety of uses. They were added to adhesives, plastics, paints, varnishes, sealants and other surface coatings, and they were widespread as a component of carbonless carbon papers.

WHO MAKES PCBs, WHERE DO THEY COME FROM?

PCBs were discovered in 1881, but it wasn't until 1929 that industrial uses were found for these compounds and they began to be manufactured commercially.

The Monsanto Industrial Chemicals Company is the sole manufacturer of PCBs in the United States. They market their product under the trade name, Aroclor. In 1971 when PCBs began to be recognized as a problem, Monsanto voluntarily restricted the sale of the compound to only those uses in closed electrical systems in which they could not easily escape into the environment. Since then, annual U.S. sales of PCBs have been cut in half. Monsanto Company is now producing 35-40 million pounds of PCBs per year.

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In addition to Monsanto, there are several foreign companies producing PCBs without restrictions on their use. Recent estimates from the Environmental Protection Agency indicate that the U.S. is importing 500,000 pounds of these chemicals per year, and an unknown amount in PCB-containing products.

According to the EPA, about 1.4 billion pounds of PCBs have been produced in the United States over the past 45 years. Of that amount, over half has already entered the environment through discharges to the air, water and land.

WHY ARE PCBs A PROBLEM?

Studies have shown that PCBs are highly toxic to animals and man.

They were first recognized as a problem by scientists in Sweden in 1966. But they came to world-wide attention in 1968 when five people died and 1,000 others were stricken in Japan after eating cooking oil contaminated by PCBs. Since that time, Japan has banned all import and production of these compounds.

PCBs came back into the news recently in this country when it was discovered that high, possibly dangerous levels of these compounds were being found in some freshwater fish, particularly in the Great Lakes. Although severe injury from short-term exposure to PCBs is unlikely, scientists are concerned about the effects caused by long-term, low level exposure to the compounds.

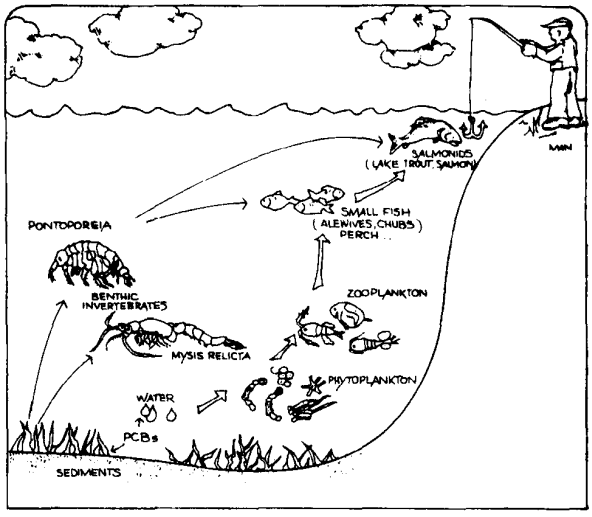
The fact that PCBs seem to persist in the environment for long periods of time and are hard to eliminate makes them more of a threat. Today these compounds are found all over the globe —in Arctic polar bears, New York chickens, England's rainfall, human blood plasma, the world's oceans and mother's milk.

HOW DO PCBs GET INTO THE ENVIRONMENT?

Through the soil:

Almost three-fourths of the amount of discarded PCBs have ended up in our nation's dumping grounds—in junked plastics, paints and, primarily, in abandoned capacitors and transformers. In junk yards PCBs can slowly leak out and can be washed by rain and melted snow into nearby waterways.

HOW PCBs ARE PASSED THROUGH THE LAKE MICHIGAN FOOD CHAIN



Through the water:

The world's rivers, lakes and oceans have been the traditional sewers and sinks for its wastes. Until recent years, these waters seemed a suitable place for disposing of PCBs and many other questionable compounds.

But fish can take up PCBs through their gills, fins and skin. PCBs also adhere to small particles in the water and thus are taken in by lower forms of aquatic life and passed up through the food chain to the top predators, fish and fish-eating birds and mammals. Scientists have found that some fish contain concentrations of PCBs that are 100,000 to a million times greater than the concentrations in surrounding waters.

Through the air:

Although PCBs are transported globally through the air, most PCB fallout in an area comes from local sources. Across the United States an estimated 1,000 tons of PCBs come down in precipitation and dry particulates each year. Much of this aerial contamination may come from the vaporization of heated casting waxes and from the incineration of PCB-impregnated materials such as paints, plastics or copy paper.

PCB levels found in Wisconsin's snow suggest that airborne sources may be the principal means by which PCBs enter the state's waterways. This may be especially true in Lake Superior, which has few industrial tributaries.

DO PCBs AFFECT HUMANS?

Yes! Some symptoms of PCB poisoning are acne-like eruptions of the skin, nausea and vomiting, abdominal pain, swelling, jaundice and fatigue. Long-term exposure to small amounts of PCBs may weaken the body's ability to recover from other illnesses, and may affect our ability to reproduce. PCBs can also harm unborn children—babies born to Japanese mothers who had eaten PCB-contaminated rice oil had greyish-brown discolored skin, suffered discharge from the eyes, and were of below average weight. PCB poisoning has also been seen in factory workers in the U.S. and Japan who are exposed to PCBs.

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WHAT LEVELS OF PCBS ARE CONSIDERED SAFE FOR MAN?

The Food and Drug Administration's tolerance levels for PCBs in food were set in 1973 before much was known about the potential effects of PCBs on health. Current levels are set at five parts of PCBs per million parts of fish, shellfish and poultry; 2.5 parts per million (ppm) for milk and dairy products; and 10 ppm for food packaging materials and ten ppm for food packaging materials. Experiments done at the University of Wisconsin-Madison with rhesus monkeys indicate that even these levels may be too high (see box) and, as a consequence, the Food and Drug Administration may soon lower these tolerance levels.

HOW HIGH ARE PCB LEVELS IN HUMAN TISSUE NOW?

The Environmental Protection Agency estimates that half of the U.S. population contains 1-3 ppm of PCBs in their adipose (fat) tissues. Surveys done in Canada show PCB levels in humans to be 1-2 ppm. Levels in the fat of Japanese suffering PCB poisoning were as high as 75 ppm. PCBs concentrate mainly in fat, although they have also been found in the kidney, liver, brain, muscle and blood. Humans may ingest as much as nine micrograms of PCBs per day, according to one estimate. Since human milk has a high percent of fat, it contains relatively high levels of PCBs. This means that breast fed infants receive more than 50 times the concentration of PCBs that is in the food eaten by their mothers.

HOW ARE PCBs GETTING INTO OUR BODIES?

PCBs can enter the body from the air or through food. Scientists disagree over which pathway is most significant, but evidence is mounting which points to airborne pathways as a major source. The thin cell layer separating the air spaces from the blood in the lungs allows easy passage of residues and chemicals into the bloodstream. According to the EPA (August 1975), PCB levels in most foods are now declining. Foods most likely to contain high levels of PCBs include milk, eggs, chicken, turkey, beef and especially fish.

SHOULD I STOP EATING FISH?

No. Most fish contain safe levels of PCBs. In the Midwest the large carp of Lake Pepin and the Mississippi River, carp, lake trout and salmon on Lake Michigan and some other Great Lakes are the only fish that pose a real problem.

Some PCBs can be eliminated in the cleaning of contaminated fish. PCBs are stored in the fat—in fact, fat tissue has about ten times the PCBs found in lean tissue—so *all* fat should be removed in cleaning. Be sure to remove the fatty belly flap. Then remove the fat along the lateral line as well as the fatty portions along the dorsal line and around the fish's belly.

In cooking the fish, again get rid of the fat. Broil, barbecue or bake it. Avoid cooking the fish in its own juices and if you must fry it, be sure and get rid of the drippings.

WHAT DO PCBs MEAN FOR THE SPORTS AND COMMERCIAL FISHERMEN?

The U.S. Seafood Industry recently called for a ban on PCBs. Although the PCB problem is not acute on a widespread basis, it is acute in certain regions of the U.S.—namely, the Hudson and Mississippi Rivers and the Great Lakes. In these areas, fish have been found to have more than the allowable levels of PCBs for human consumption set by the U.S. Food and Drug Administration. Some commercial fishing in these areas has been halted.

Most affected in Wisconsin has been the carp fishery in Lake Pepin and in Lake Michigan's lower Green Bay. Last year, Wisconsin commercial fishermen harvested 500 million pounds of carp, much of it used for gefilte fish. Today some of these fishermen are out of the carp business because of high PCB levels.

Aside from carp, the fish most affected by PCBs in Lake Michigan are the large lake trout and salmon. PCBs in Lake Michigan coho salmon have not decreased over the past three years and lake trout levels may have increased. So far, there has been no action taken to curtail sports fishing for these species but the Wiscon-

Under Sea Grant sponsorship, James Allen, a pathologist with the UW-Madison Medical School and the Regional Primate Research Center, has been feeding PCBs to monkeys and monitoring their effects. The results of his experiments hold some clear implications for humans since humans have metabolic pathways similar to those of the monkey.

Allen fed monkeys, in a steady diet, concentrations as low as five and 2.5 ppm PCBs. The monkeys suffered severe health problems—loss of hair and acne lesions—within one or two months. These monkeys also showed reduced rates of conception. The young that were born to mothers on PCB diets were small and had PCB levels in their own fat tissues which were close to the levels found in their mothers. Allen also found that detectable levels of PCBs persisted in infants and adults for more than a year and a half following exposure.

According to Allen, PCBs are toxic to primates over a wide dose range. Although the possibility of man consuming a steady diet containing these concentrations of PCBs is remote, Allen feels these data do point out that only small amounts of PCBs are required to produce toxicity and that a safe level of consumption has not yet been established for these compounds.



Monkeys fed steady diets containing 2.5 ppm PCBs (left) and 5 ppm (right) both show toxic effects.

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sin Department of Health and Social Services has advised consumers not to eat more than one meal a week from these fish. The State Department of Natural Resources has prohibited commercial fishermen from selling trout, caught incidentally in their nets, that are longer than 24 inches.

As far as the fisheries goes, things could get worse before they get better. Canada recently lowered permissible PCB levels in fish from 5 to 2 ppm and U.S. fishermen are worried that the FDA may soon do the same.

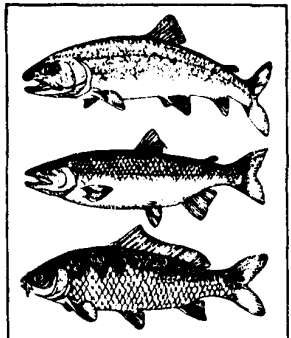
HOW DO PCBs AFFECT FISH AND WILDLIFE?

According to the Environmental Protection Agency, PCB levels in wildlife are rising. PCBs were first noticed in 1966 in birds thought to be dying of DDT poisoning. Since then, PCBs have been found in all organisms examined in the North and South Atlantic, and have probably been contaminating wildlife since the 1940s.

The effects of PCBs are more severe in birds and higher mammals than they are in lower vertebrates and invertebrates. The most serious consequence in birds is reproductive failure, although other symptoms such as kidney, heart and liver damage can also occur. Fish take in PCBs both through the food chain and directly from the surrounding water through gills and skin. Fish can contain very high concentrations of PCBs without being severely effected although it may affect their reproduction. Shellfish, oysters and shrimp, on the other hand, are highly sensitive to PCBs—only very small concentrations in the water can kill them.

ARE PCBs REDUCING BIRD AND MAMMAL POPULATIONS?

Scientists are not yet sure whether PCBs are significantly reducing wildlife populations, but there are indications that they may be. As is the case with DDT, birds and mammals high on the food chain, especially those consuming fish, are hard-hit. High PCB concentrations have been found in herons and scaups in New York, petrels and peregrine falcons in California, eagles in Sweden and the U.S., terns in Florida and gulls on the Great Lakes, to mention a few. Like DDT, PCBs degrade Vitamin D and estrogen in birds, resulting in eggshell-thinning and reproductive failure.



Most affected by PCBs are lake trout, coho salmon, and carp.

WHERE IS PCB POLLUTION THE GREATEST?

Geographically, it is greatest in industrial countries. In the United States, the highest concentrations of PCBs are in the *sediments* of the St. Lawrence-North Atlantic drainage basin and in the *water* of the southeastern coastal states.

However, all large water systems are transporting PCB molecules—including the Mississippi, Columbia, Sacramento, Colorado, Rio Grande and Savannah rivers. PCBs accumulate in harbors and estuaries, *wherever the current slackens.* Sampling of sediments have shown that the Milwaukee River has 3.5 ppm and Superior harbor, 9 ppm. As might be expected from these measurements, the Great Lakes themselves contain significant amounts of PCBs although at far lesser concentrations.

Biologically, this accumulation of PCBs is a continuing process as the smallest aquatic organisms are eaten by successively larger predator fish which are, in turn, consumed by fish-eating birds and mammals. The larger, fatter and older the fish, the greater chance of PCBs having collected in its organs, skin and fatty tissue.

HOW LONG WILL PCBs REMAIN A PROBLEM?

For at least two or three decades, PCBs will remain a significant contaminant in the environment. In many places it may get worse before it gets better. Here's why:

1) PCB molecules do not readily break down into other molecules.
2) PCBs do not dissolve readily in water, so they are not quickly absorbed and washed out to sea.
3) PCBs are heat resistant and so are not destroyed by usual fire temperatures.
4) Because they seek out fatty tissue, PCBs accumulate in fish and animals.
5) Scientists have shown that fish, while quick to pick up PCBs, are very slow in eliminating them, making recovery from PCB contamination a lengthy process.
6) Being prevalent in so many industrial products with service lives of ten to 20 years or more, PCBs will continue to be released to the environment as these materials are gradually discarded and decompose.

WHAT HAS INDUSTRY DONE TO SOLVE THE PCB PROBLEM?

On August 30, 1971, the Monsanto Industrial Chemicals Company voluntarily began to curtail its sale of PCBs. The only U.S. company producing PCBs, they continue to sell these chemicals to industries using them in capacitors and transformers. These include primarily electric utilities and railroad companies. About 35-40 million pounds of PCBs are manufactured annually, and the EPA has so far identified some 120 users of PCBs in this country. Monsanto plans to abandon PCB production as soon as substitute(s) can be found.

Still PCB input into the environment remains a problem. The EPA reports 10 million pounds a year are lost into the environment. To dispose of PCBs properly they must be burned in a specially designed industrial incinerator at 2,400 degrees F. The Monsanto Company has installed such a device and will destroy waste PCBs as a service to its customers.

CAN OTHER COMPOUNDS BE SUBSTITUTED FOR PCBs?

Yes. In recent years, chemical companies have been looking for fire-resistant compounds that could be used instead of PCBs in electronic and hydraulic closed systems. Exxon, Dow Chemical, Dow Corning and, most recently, General Electric have offered substitute compounds. Many of these are being tried on a limited basis, although they will have to meet industry insurance standards before they can be licensed for general use. The Japanese are now using a Dow Corning silicone product for their transformers.

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WHAT IS BEING DONE ABOUT THE PCB PROBLEM?

—IN WISCONSIN

On September 23, 1971, Governor William Milliken of Michigan banned the commercial sale of Lake Michigan coho salmon because of high levels of PCBs. Wisconsin Governor Patrick Lucey followed suit on October 1, 1971 by restricting the sale of fish, primarily coho and chinook salmon and lake trout, from Lake Michigan and the Upper Mississippi River.

At that time, Monsanto Chemical Company restricted their sales of PCBs and the states assumed the problem would be solved. But PCBs have proven more persistent than was thought and in 1975, they emerged as a problem once again.

In December 1975, the Wisconsin Natural Resources Board adopted strict PCB discharge standards which must be reviewed by the Natural Resources Committee of the Wisconsin legislature before becoming effective.

The proposed standards, to become effective January 1, 1977, would limit industrial and municipal sewage PCB discharges to less than .01 milligrams per liter (roughly equivalent to .01 ppm) more than PCB amounts in discharge receiving waters, monitored over a 24-hour period. By February 3, 1979, this standard would be cut in half. To remove PCBs from industrial effluents requires the removal of suspended solids from waste water since PCBs are adsorbed in these solids.

Some Wisconsin paper companies are concerned about those effluent standards because they will create a problem for recycled paper operations. PCBs are found in the ink and carbonless copy paper among the waste papers collected for recycling by Wisconsin paper mills. Papers containing PCBs are impossible to separate out and in the recycling process, some PCBs inevitably escape to the environment. But DNR scientists believe that as paper companies reduce their discharges of suspended solids, these discharges of PCBs will diminish.

To combat other PCB inputs into the environment, State Representative Mary Lou Munts (Madison) and eight other legislators introduced a bill into the Wisconsin Assembly on January 29, 1976. In March 1976, an amended version of that bill was passed overwhelmingly by the House and the Senate. If signed into law by the Governor, it would give the Department of Natural Resources the authority to control the sale and disposal of PCBs in the state of Wisconsin, effective July 1, 1977.

—IN THE REGION

In Wisconsin's neighboring state of Michigan, there has also been alarm over high levels of PCBs in the Detroit River and Lake Michigan. The Michigan legislature has recently passed a bill to ban sales of PCBs for nonessential uses. Minnesota has requested a similar ban. Beyond the states, the list of public and private organizations, industrial groups and state and federal agencies advocating some PCB controls continues to grow.

—IN THE U.S.

The Environmental Protection Agency has been under intensive criticism for "dragging its feet" on the PCB problem. In May of 1972, an Interdepartmental Task Force concluded that PCBs were highly persistent and could have adverse effects on human health. But because of Monsanto's limited sales and more restrictive FDA food standards, the EPA thought the problem would clear up, and until 1975 took no action on PCBs.

Then, on December 22, 1975, EPA Administrator Russell Train announced plans to control PCBs. The EPA intends to regulate PCBs using the 1971 Federal Water Pollution Control Act. Industries requiring permits under section 402 of the Act would be required to meet a zero discharge standard for PCBs.

Other federal actions to control and/or ban PCB uses include the Toxic Substances Act (S. 776), a bill introduced by California Senator John Tunney. The bill is now in committee in both houses of Congress and action is expected this year.

This Act would give the EPA authorization to regulate the manufacture, importation and selling of industrial chemicals such as PCBs. It also would require pre-market screening for safety of all new chemicals and existing chemicals with significant uses. The bill does not regulate pesticides, food, drugs or tobacco.

In addition, on September 10, 1975 Congressman Les Aspin of Wisconsin introduced a bill (H.R. 9525) to prohibit the introduction of PCBs into commerce. It is now being considered by the House Commerce Subcommittee on Consumer Protection and Finance. No action is expected on the bill for several months.

Wisconsin Senator Gaylord Nelson, on December 9, 1975, initiated legislation that would severely limit and ultimately ban the use of PCBs. This legislation is in the form of an amendment to the Toxic Substances Act (Amendment 1324 to S. 776), which is now pending before the Senate Commerce Committee. If it is not acted on in committee, Senator Nelson will reintroduce the amendment on the Senate floor. His office will continue to press the PCB issue until they are satisfied that something is being done to solve the problem.

—AROUND THE WORLD

In February 1973, the Organization for Economic Cooperation and Development recommended to member countries that PCB use be prohibited except in certain closed systems. This marked the first international agreement aimed at limiting the production and use of chemicals. Shortly thereafter, Sweden established a permit system for PCB use and Japan instituted a ban on all production, import and sales of PCBs. Most recently, America's closest neighbor, Canada, took action on PCBs, lowering the allowable levels of PCBs in fish from 5 to 2 ppm.

The ABCs of PCBs

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PCB 746

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