The ABCs of PCBs

Polychlorinated biphenyls, or PCBs, are a group of oily liquid and solid compounds that do not burn easily and thus make good insulators. Since the 1930s, PCBs were widely used in the manufacture of electrical transformers, household appliances, TVs, and fluorescent lamps. In the early days of such industries when manufacturing plants were located on rivers, runoff from these industrial sites often contained PCBs. The compounds have no odor or taste and are often colorless—but they are toxic. In humans, PCBs act as carcinogens and cause skin irritation, liver and kidney damage as well as thyroid gland injuries.

Although the manufacture and importation of PCBs were banned in the United States in the late 1970s, large quantities of PCBs are still in storage or in use. During the many years that PCBs were used unchecked, the compounds accumulated in the sediments of New York's lakes and rivers. These compounds do not readily break down and become persistent environmental toxins that bioaccumulate in organisms. By way of example, concentrations in top-of-the-food-chain fish can reach levels hundreds of thousands of times higher than in the water in which the fish live. Human consumption of PCB contaminated food is considered the major source of PCB accumulation in humans. PCBs also get into the air and eventually return to the land and water via snow, rain or in runoff.

Removing PCBs from soil, water, or underwater sediments is a daunting challenge. Activities in busy waterways often disturb the sediment and dredging is a necessary action taken to keep shipping lanes, ports, or docks open for commerce. But what happens to the PCBs that are pulled up with dredged sediments?

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Birds on the winter ice in Oswego Harbor in Lake Ontario, the site of NYSG-funded PCB research.
Photo by Barbara A. Branca

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PCBs in the Air

One line of research has been to better understand how PCBs degrade under sunlight in the environment. It is known that semiconductors, such as titanium, zinc or iron oxide when suspended in water can effectively degrade PCBs when irradiated with ultraviolet or solar radiation. A team of SUNY Oswego researchers funded by NYSG investigated this method of chemical decomposition of PCBs by way of sunlight radiation, or photolysis. The team, led by **Dr. Ronald Scrudato**, used natural particulates in sediments to assess the rate and extent to which PCBs would be degraded by sunlight.

In a series of experiments run by **Dr. Gideon Oenga** (then a Sea Grant Scholar), sediment containing the contaminant was dredged from Oswego Harbor. After three weeks of irradiating the sediment, the team found no change in the concentration or distribution of PCBs. These results suggested to the investigators that photolysis does little to destroy or alter PCBs in aqueous environments during short time periods.

However, during experiments on the exposed sediment as it was drying, **Dr. Gail Arnold**, then an undergraduate fellow, discovered that PCBs are far more volatile than previously recognized. Significant amounts of PCBs were rapidly lost to the air during the drying of contaminated sediments. This finding has direct implications for ports or marinas undergoing dredge operations. In the process of dredging and taking away dredge materials, many operations set up "dewatering sites" where the material is left to dry before being taken away. With this finding, now precautions are being taken at such sites to prevent the PCBs from contaminating the air.

The lower Hudson River. Dredging to remove PCBs in sediments in the upper Hudson will soon begin. A new guide for Hudson marina owners describes dredged sediment contaminants. See page 15 to learn more or to order PCB research articles.
Photo courtesy of Nordica Holochuck

Says investigator Scrudato, "There is also the possibility of using the volatilization of PCBs as a remedial process. Once the dredged PCB-contaminated sediments are removed from the impacted waterway, by continuing to wet the dredged material to stimulate volatilization, it may be possible to capture the volatized compounds and use either trapping systems such as granulated active carbon or even destroying the compounds with ultraviolet or photocatalytic processes."

The discovery of the volatilization of PCBs also led to further studies of PCBs in the soil and sediment downwind of Lake Ontario as well as the PCBs in the air near the lake and over the water.

The volatile losses of PCBs may pose a more significant source of PCB exposure and have more serious health implications than previously thought. After the completion of Scrudato's project in the late 1990s, another team member, **Dr. Jeffrey Chiarenzelli**, reports that the data sets were used for an unexpected purpose. **Drs. Glenn Johnson** (University of Utah) and **Anthony DeCaprio** (University at Albany) have compared PCB blood data to Chiarenzelli's air data. Comparisons show that some Mohawks who live on the Akwesasne Reserve have blood serum PCB patterns similar to the volatile fraction of PCBs at a nearby Superfund site along the St. Lawrence River in Massena, NY—the site of an old aluminum plant. This implies that in contrast to conventional wisdom, ingestion of PCBs may not be the only significant route of human exposure for all individuals.

The study above is an example of an environmental forensics investigation, which involves taking multiple lines of scientific evidence into account in order to piece together a story of contaminant sources, fate, transport and exposure. It involves analysis of large volumes of chemical data from a site, and comparison of that data to industrial production histories, known and suspected source patterns, as well as environmental weathering patterns. Johnson and his associates have taken an environmental forensics approach in their research and also in assigning responsibility for contamination in several lawsuits. His group is currently working on a chapter in an environmental forensics textbook which summarizes (among other things) the discoveries at Akwesasne as related to volatilization of PCBs and human exposure.

PCBs Resuspended in the Water Column

Most busy industrial ports have another added factor when considering remediation of contaminated sediments that contain PCBs. The turbulence caused by storms, currents and ship traffic churns up the sediment and clouds the water column with resuspended contaminants. PCBs show a great affinity for staying attached to particles of sediments—the finer the particle, the greater the attachment. Thus resuspension poses a serious risk to water quality in many areas, particularly around the ports in Lake Erie, Lake Ontario and the Hudson River. Scientists use various models to calculate how long it takes for these contaminanted particles to settle back into the sediment—sometimes on the order of weeks to months. In another NYSG-funded project, the research team of **Joe Atkinson** and **Joe DePinto** from SUNY Buffalo studied the interaction between turbulence and sediment particle size and aggregation that led them to develop a model used to simulate how and when the contaminanted particles would drop back down into the sediment.

To simulate what happens in ports, the researchers created their own unique reactor made entirely from fused glass to minimize chemical reactions with the sides of the reactor. Within the reactor they could control the amount of mixing from slight to turbulent and measure effects on particle concentration and size distributions.

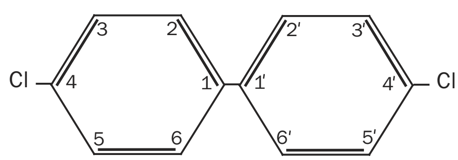
The Buffalo team's observations were aided by cameras and strobe lights that provided high resolution images of the particles. In general, their model predicts a quicker removal of contaminants because the resuspended particles settle back to the bottom before they reach an equilibrium state with the water concentration. These results provide a tool that can be used to assess the general health of a particular waterway by giving a means of estimating transport of a contaminant out of the system (as during a storm event) or by materials disturbed during dredging. This information can also aid the development of predictive chemical transport models and allow regulators to better manage contaminants that remain in place.

Through the cooperative efforts of state and federal regulators as well as industry, dredging operations will soon begin to remove PCBs from the sediment in the upper Hudson River. At some sites, environmental engineering techniques such as hydraulic dredges will likely be used to suction up the contaminated sediments. A surrounding "silt curtain" may be used in some sites to prevent contaminant resuspension, leakage or disturbance of the surrounding river water. Coverings at the dredge sites will trap volatile PCBs. As PCB remediation proceeds, **Larry Gumaer** of the NYS DEC will lead the damage assessment on the Hudson River resources. Characteristics of PCBs such as the rates of volatilization and resuspension characteristic of PCBs will have to be factored for the safe operation of each dredge site. The foundation of knowledge gained about PCBs from these two NYSG-funded projects will continue to have impacts as future PCB remediation is planned.

— Patrick Dooley and Barbara A. Branca

PCB Basics

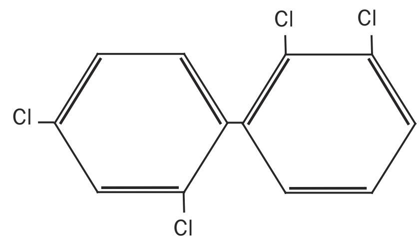
dichlorobiphenyl



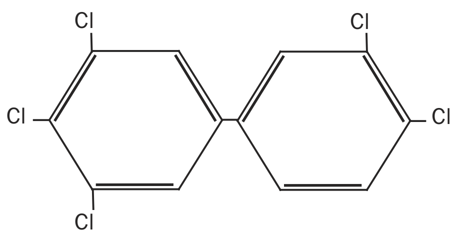
Polychlorinated biphenyls are made of biphenyl molecules (two carbon-hydrogen rings bonded together) with additional chlorine molecules attached at specific positions on each ring.

Each PCB is named according to the bonding position.

tetrachlorobiphenyl



pentachlorobiphenyl



For example, the molecule with five chlorines is named 3, 3', 4, 4', 5-pentachlorobiphenyl.

In general, the more chlorinated molecules are less soluble in water and thus accumulate in sediments. These same PCBs can be released into the air when dredged sediment is drying.