PCBs, Mining, and Water Pollution

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The presence of PCB-containing electrical equipment in underground mines has been documented during U.S. Environmental Protection Agency (EPA) mine inspections conducted over the last 20 yr. PCB-containing electrical equipment may be found in mines throughout the world because both electrical systems and mining methods follow the same general patterns. The abandonment of this equipment in underground mines is likely to present worldwide ground water contamination in mining districts.

Before the mid-1960s, when analytical techniques were insufficiently refined to detect PCBs, it was not recognized that large amounts of these chemicals were escaping into the environment. Unlike DDT, a ubiquitous environmental contaminant that had been introduced into the environment on a large scale for insect control, PCBs had been confined to limited industrial uses. PCBs were beginning to show up all over the world. They were found in the fat of Antarctic penguins and Arctic polar bears, in the Sargasso Sea, in fish in the Great Lakes, and as a fat and blood serum contaminant of human populations worldwide. These findings were a major factor in the passage of the 1976 Toxic Substances Control Act (TSCA), which regulates industrial chemicals in use; PCBs are mentioned specifically in the Act.

The major use of PCBs today is in electrical equipment servicing industries with large electrical power consumption, which include smelting and mining. PCBs pose potential threats to the environment in the event of releases. This is particularly important in the mining industry because mines generally penetrate the water table. When PCBs are spilled or PCB equipment is abandoned underground, the PCBs can be expected to eventually be released into the ground water with no possibility of source retrieval. This can result in water pollution problems for which there may be no solutions.

Health and Environmental Effects

PCBs are among the 16 chemicals designated as persistent organic pollutants (POPs). They are the subject of negotiations on a global agreement for their control that began in late 1998. POPs are highly stable organic compounds that persist in the environment, accumulate in the fatty tissues of most living organisms, and are toxic to humans and wildlife. The protocols under negotiation will ban the production and limit the uses of PCBs.

There is no longer any doubt that PCBs present a threat to human health and the environment. PCBs are hazardous to health at extremely low levels. PCBs can enter the body through the lungs, the gastrointestinal tract, and the skin. Once ingested, inhaled, or absorbed into the body, PCBs are circulated throughout the body in the blood and are stored in fatty tissue and several organs, including the liver, kidneys, lungs, adrenal glands, brain, heart, and skin. Once in the body, PCBs can wreak havoc. Among the most stable organic chemicals known, they have found their way into air, water, soils, and animals worldwide. PCBs have become so widely distributed that the Food and Drug Administration issued tolerances for PCBs in cardboard, food packaging, soap, fish, meat, milk, and eggs, and it has been difficult to find populations of humans who do not have measurable concentrations in their body fat.

PCBs are highly concentrated in fatty tissue of animals even when exposure levels are very low. Stream invertebrates have been shown to concentrate PCBs by a factor of up to 100K, with fish consuming these invertebrates showing concentration factors as high as 274K

This process of bioaccumulation has resulted in the closure of fisheries in the Great Lakes and the issuance of PCB sport fisheries advisories regarding fish consumption in the Great Lakes and the lakes of northeastern Canada. Fish, birds, amphibians, and even polar bears have been shown to have birth defects and declines in fertility linked to PCB exposure. The ocean is the final and largest sink of PCBs, the consequences of which remain unknown. It has been demonstrated that phytoplankton communities are affected by PCBs, but it is seldom noted that these communities are the basis of the ocean food chain and are a major source of atmospheric oxygen.

In addition to being classified by the EPA as probable human carcinogens, PCBs have been demonstrated to be responsible for liver disorders, chloracne, and reproductive problems in humans. PCBs are among a number of chemicals considered environmental endocrine disruptors, suspected to be the cause of decreases in human sperm counts, increases in birth defects in reproductive organs, as well as increased incidence in breast, prostate, and testicular cancers.

PCB Properties and Uses

PCBs are a group of man-made structurally related chemicals. The basic structure consists of two rings of six carbon atoms, which are joined, and to which up to 10 chlorine atoms can attach. There are approximately 200 different PCBs, because about 200 different chlorination patterns are possible on the basic PCB structure.

PCBs were manufactured in the United States under the trade name Aroclor until manufacture was prohibited by the PCB regulations in 1978. Aroclors are essentially different chlorine concentration fractions of PCBs that have different properties. Two of the most common are Aroclor 1254 and Aroclor 1260. These Aroclors were mixed with solvents, for example, trichlorobenzene, and sold under the trade names that appear on the manufacturer nameplates of PCB-containing electrical equipment. Some of the more common PCB dielectric trade names are Pyranol, Inerteen, Elemex, and Chlorextol. There are many others.

PCBs have properties that have made them useful in a wide variety of applications. PCBs in the dielectrics of transformers, voltage regulators (variable voltage transformers), and capacitors are the major regulated industrial uses today.

The physical and chemical properties that make PCBs valuable commercially also make them environmentally detrimental.

- PCBs are very stable compounds that resist breakdown from high temperatures and aging;
- PCBs are not biodegradable and are persistent in the environment;

- The vapor pressure is very low and PCBs are not considered volatile at ambient temperatures.

PCBs and Mines

The latest PCB regulations were issued in 1998. The regulations dictate strict requirements to prohibit all but authorized uses, to mark, inspect, and track the disposal of PCBs. The use of PCBs at concentrations at or above 2 ppm is prohibited without an exemption or use authorization. PCBs at any detectible concentration may not be used for dust control. Certain uses have been authorized, including use as a dielectric fluid in transformers and capacitors. The regulations allow PCB-containing transformers and capacitors to be introduced into commerce for the useful life of the equipment. This means, that even after more than 20 yr of regulation, PCB-containing transformers and capacitors remain in use and can be bought and sold.

Depending on the cost effectiveness of removal and salvage, mines may be abandoned without removing any of the underground mining, haulage, hoisting, or electrical equipment.

It is believed that substantial quantities of PCB-containing electrical equipment were abandoned underground before the advent of the PCB regulations in 1978.

In the following discussion, underground mines are emphasized because abandoned PCB-containing equipment is likely to cause water pollution for which there may be no solutions. PCBs are most likely to be in transformers as shown in Fig. 1., drums of used transformer oils, and capacitors as shown in Fig. 2. The regulations require these items to be identified by PCB marks if they contain 500 ppm or more PCBs. Transformer oils have been used for lubrication, dust suppression, or as fuels. Capacitors occur in similar locations to transformers; in addition, PCB-containing capacitors have been found in electric locomotives. In coal mines, capacitors are often in wheel- or skid-mounted power centers, as shown in Fig. 3.

ulates the generation, handling, and disposal of hazardous wastes, but not PCBs. The release of these solvents can pose their own threats of ground water contamination. In addition, released solvents such as trichloroethane can mobilize PCBs, making transport into the water easier. Some mines maintain their own landfills and scrap yards that have been shown to be repositories of improperly disposed PCBs and RCRA solvents.

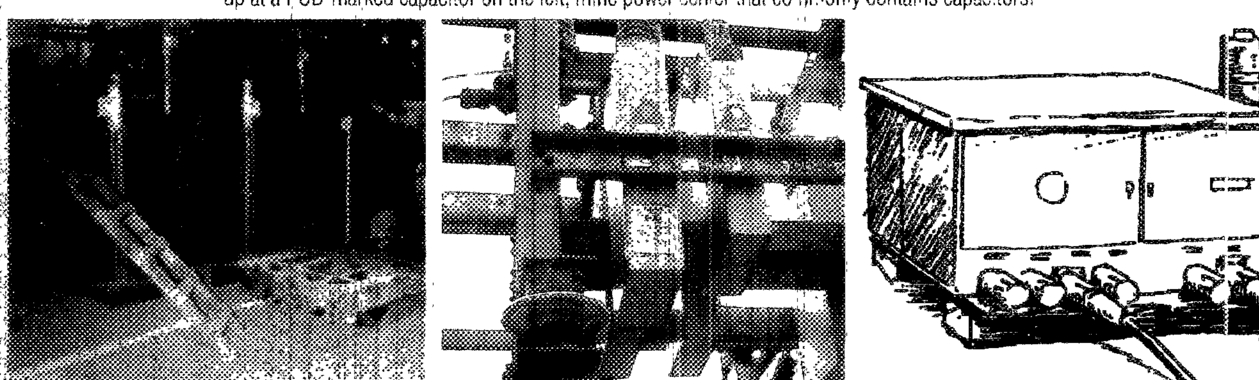
It is understandable that management and inspectors unfamiliar with underground mines may feel at a loss when faced with conducting PCB compliance inspections. Concerns have been expressed for the safety of inspectors in underground mines. This issue will be further discussed below in the section on EPA Region 8 experiences with underground mine inspections.

PCB trade name dielectrics are heavier than water and will sink, while mineral oil dielectrics containing PCBs will float to the water surface. In either case, surface waters will eventually be contaminated. Driving shafts, mining operations, and intentional caving in both coal and hardrock mines typically result in extensive areas of highly fractured rock. Fracture produces additional avenues through which ground waters from disrupted water tables can be expected to percolate throughout rock within and surrounding the entire mining area.

Some argue that even if the liquid did escape, the dilution ratio would be so great there would be basically no impact

Hydrologists cannot predict ground water flow patterns or PCB dilution rates because of the fracture caused by mining operations and the unknown groundwater pathways. PCB water solubilities are in the ppb range. A bioaccumulation factor of 274K in fish tissues, as mentioned above, demonstrates that minute quantities of PCBs dissolved in water can get into the food chain in significant concentrations. Even at the surface water standard of 14 ppt under the Clean Water Act, this bioaccumulation factor can result in contamination of fish at 3.8 ppm PCB, which exceeds FDA tolerances for human consumpt on. Consumption of contaminated fish is one of the major routes of human exposure.

From left to right: 76-gal transformers (cylindrical objects with cooling fins) with PCB marks; looking up at a PCB-marked capacitor on the left; mine power center that commonly contains capacitors.



It is important to keep in mind that PCBs are not the only regulated man-made chemicals used underground. There are other chemicals, the releases of which may pose environmental threats. Underground repair facilities, like any other repair facilities, may use solvents for cleaning and degreasing equipment. Two examples are trichloroethane and methylene chloride. The disposal of these solvents is regulated under the Resource Conservation and Recovery Act (RCRA), which reg-

EPA Region 8 Experience

Region 8 encompasses six states: Colorado, Montana, North and South Dakota, Utah, and Wyoming. This area contains a substantial portion of the underground hardrock and coal mines in the country. Region 8 experiences should serve as an indicator for other agencies and other countries with a mining industry. An underground mine inspection program was begun with the promulgation of the PCB regulations in 1978. About 75 mines have been inspected during the last 20 yr and 33 government-issued administrative complaints resulting in penalties for violations of the PCB regulations have been issued. This means that 44% of the mines inspected were in violation of the PCB regulations.

"Inspections revealed PCB-containing electrical equipment in just about every conceivable activity."

Inspections were concentrated in underground mines as a first priority because of the potential for abandonment of PCB-containing electrical equipment and ground water contamination, so the majority of the inspections and administrative complaints involved underground mines. Underground coal and hardrock mines were the major targets. However, surface mines should not be overlooked; EPA issued an administrative complaint proposing a penalty of more than $1M for violations of the PCB regulations to an open pit mine in 1994.

Whenever inspectors entered a district without a previous EPA enforcement presence they found a lack of awareness of PCBs and the PCB regulations. They also found a similar lack of awareness in other government agencies that had authority over PCBs.

Inspections revealed PCB-containing electrical equipment in just about every conceivable activity: in drag lines servicing open-pit coal mines, power shovels servicing open-pit metal mines, and "bone yards" where transformers and capacitors were commonly destined for disposal. They were found in underground substations, pump stations, mine power centers, and electric locomotives. PCB-containing electrical equipment was found in surface facilities, including mills, smelters, metal refineries, breaker houses, and transfer facilities.

The majority of inspectors are not willing to do underground mine inspections due to perceived hazard. Inspectors only need minimal training because they are accompanied at all times by mine personnel. The training may be obtained from the U.S. Mine Safety and Health Administration (MSHA), which has jurisdiction over mine safety, and inspectors may be accompanied by an MSHA inspector if necessary. MSHA conducts annual safety inspections of all working mines in the country. Region 8 is confident that if MSHA deems mines safe enough for miners, then inspected mines are certainly safe enough for EPA inspectors to enter. Inspections historically have included only working mines and mines on standby status to ensure safe entry. These inspections have been conducted with the intention of maintaining an enforcement presence and to help prevent abandonment of PCB equipment underground by persons unacquainted with the regulations.

Abandoned mines have not been part of the inspection program because of inaccessibility, flooding, cave-ins, and very real hazards that will not be dealt with in this article. However, it appears the major water contamination problems involving PCBs and mines in the future will come from PCB equipment abandoned underground. An inspection program could help to prevent future abandonment.

Some examples. EPA has reason to believe that PCB-containing transformers were disposed of under waste rock in an underground coal mine directly above a burning coal seam. Because of "bad air" in this location and hazardous conditions preventing the use of heavy equipment to remove the waste rock, the investigation was discontinued.

An inspection in a previously uninspected mining district followed by an administrative complaint resulted in the burial of transformers by a different party at a nearby mine site. Upon exhumation by EPA, the transformers were found to contain no PCBs. The mine management, fearing an inspection, had tested the dielectrics for PCBs, but had been unable to understand the field test results and buried unregulated transformers.

In 1984, Region 8 conducted an Immediate Removal Action under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), in which the author participated, in the Eagle Mine at the town of Gilman, a few miles from Vail, Colo. The mine consisted of a 400-ft vertical shaft from the surface to the main haulage level. From the haulage there are two inclines both servicing the 20 level. Below the 20 level, the mine was flooded to the bottom at the 28 level. The mine consisted of about 100 mi of drifts, most of which were inaccessible due to flooding, bad ventilation, and an active fire encompassing one of the inclines. The entire mill, with PCB-containing electrical equipment was underground. The owner had been advised by EPA to remove the PCB-containing electrical equipment from areas of the mine in danger of flooding before insufficient funds were available to maintain the pump station at the 20 level. No action had been taken when the electrical service was discontinued. EPA assumed the electrical bills and removed three 76-gal Pyranol (PCB) transformers and 27 large Pyranol capacitors during a 3-d operation. Three previously drained, 76-gal Pyranol transformers remained underground because of the hazards and cost of removal from an active fire area. Whether or not PCB-containing electrical equipment remains in the accessible portions of the mine and below the 20 level is unknown. This lack of information is typical of abandoned or flooded portions of mines. Although this operation may appear hazardous, the risks were known and controlled, and MSHA inspectors were present throughout the entire removal. If there had not been a mine inspection program, this PCB-containing electrical equipment would have been undetected, and today, would be under more than 700 ft of water that drains into the Colorado River.

Conclusion

It is apparent from the extent of large mines that there are opportunities for disposal of hazardous wastes in mines that are so vast that it is unlikely the wastes could ever be located. Many mines, regardless of size, present these opportunities. These possibilities should be guarded against.

The release of PCBs into the environment from end-use products, uncontrolled disposal, landfills, and underground mines where they were disposed of prior to the PCB regulations can be expected to add to the PCB environmental burden with unforeseeable consequences for the future. The abandonment of PCB-containing electrical equipment underground is a preventable increase to this burden. Released PCBs underground from abandoned electrical equipment may cause water contamination problems in mining districts throughout the world, which can introduce PCBs into the human food chain. Routine underground mine inspections by a government authority having jurisdiction over PCBs would help to prevent this. There is no legitimate safety concern that should prevent such inspections. Both education and enforcement would have their places here. Whenever cleanups and environmental restoration take place, the potential presence of PCBs should be considered. ■