Identification, Management, and Proper Disposal of PCB-Containing Electrical Equipment used in Mines

ABSTRACT

This paper is written for a domestic and international audience and describes environmental hazards, how to identify PCBs, hidden sources to look for, potential liabilities, and what to do if you find PCBs. All references to regulations in this paper are to the United States PCB regulations at 40 CFR Part 761 which should be consulted for more complete information. PCB-containing electrical equipment in surface and underground mines has been documented during U.S. Environmental Protection Agency (EPA) Region 8, mine inspections. PCB-containing electrical equipment is likely to be in mines worldwide because electrical systems in mines follow the same general patterns as any other industry. This equipment has been often abandoned underground because it was not cost effective to remove it. PCBs are highly stable toxic organic compounds that persist in the environment and can remain a threat for decades. This can contribute to local and worldwide PCB contamination of the ocean, which is considered to be the final sink for PCBs[1], through ground water circulation and result in problems for which there may be no reasonable solution. PCBs are among the twelve chemicals designated as persistent organic pollutants (POPs) that are targeted by the UN Stockholm Convention with152 signatories, including the United States of America, to eliminate production, use, and/or release. They are one of several truly global environmental pollutants that bioconcentrate in phytoplankton which is the basis of the ocean food chain and produce about 50% of the atmospheric oxygen.

PCB PROPERTIES

There is no longer any doubt that PCBs present threats to human health and the environment. PCBs are one of the 12 chemicals targeted by the global Stockholm Convention on Persistent Organic Pollutants (POPs). "POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms, and are toxic to humans and wildlife. POPs circulate globally and can cause damage wherever they travel.[2]" In implementing the Convention, governments are taking measures to eliminate or reduce the release of POPs into the environment. There are 152 signatories to the convention, including the United States.

The physical and chemical properties that make PCBs valuable commercially also make them environmentally detrimental. PCBs are very stable and resist breakdown from high temperature and aging. "Once in the environment…PCBs can easily cycle between air, water, and soil."[3] PCBs are soluble in fats and can enter the food chain. "The major dietary sources of PCBs are fish (especially sportfish that are caught in contaminated lakes or rivers), meat, and dairy products."[4]

The release of PCBs from mines can have important large-scale negative social and ecological impacts. The mining industry can play a significant role in preventing further increases of PCB contamination in the ocean by eliminating or controlling PCBs. PCBs in the ocean can cause a number of potentially serious problems. For example: PCBs and other POPs will bioconcentrate[*] in "phytoplankton--unicellular algae in the surface layers of fresh water

---

[*]Bioconcentration is defined as uptake of a chemical from water alone, and bioaccumulation is the result of combined uptake via food, sediment, and water.

lakes, rivers and the ocean…[that] play a key role in regulating atmospheric carbon dioxide concentrations."[5] "Phytoplankton is the primary food source, directly or indirectly, of all sea organisms. Data shows that PCBs affect the productivity of phytoplankton and the composition of phytoplankton communities."[6,7] Not only do phytoplankton play a key role in regulating atmospheric carbon dioxide concentrations, but about 50% of the world's oxygen is produced by phytoplankton in the oceans.[8]

The "Median BCFs [bioconcentration factors] for accumulation [of PCBs] from water by phytoplankton range from $1x10^4$ to $1x10^6$…"[9] Given that PCB concentrations range from 0.24 to $5.7x10^{-12}$ g/L in the North and South Atlantic oceans,[10] PCBs can bioconcentrate in phytoplankton and then bioaccumulate in the food chain through phytoplankton being eaten by zooplankton which are in turn are eaten by small fish and then larger fish that enter the human food chain. The Federal Food and Drug Adminstration (FDA) has been compelled to issue the temporary PCB tolerance of 2 ppm for human consumption of the edible portion of fish.[11]

Polychlorinated Biphenyls were first commercially manufactured in the United States in 1929 and rapidly found numerous industrial uses. PCBs have been used as dielectrics in electrical equipment and as coolants in motors in continuous miners and loaders in the mining industry. A common misperception is that because the regulations banned the manufacture of PCBs in 1979, PCB-containing electrical equipment is no longer in use. The regulations, however, authorize the use of intact and non-leaking PCB-containing dielectrics in transformers, capacitors, and fluorescent light ballasts for the useful life of the equipment. Today, the mining industry still uses PCB-containing electrical equipment, some of which continues to be abandoned underground. The abandonment of PCBs is not only a hazard to human health and the environment it also presents potential pollution-related liabilities to the mining industry. PCBs abandonment underground can cause long-term water pollution for which there may be no solution.

PCBs IN THE UNITED STATES

PCBs were manufactured in the US under the trade name Aroclor before manufacture was prohibited by the regulations in 1979. Aroclors, which are waxes or oils, were liquefied using technical grade tri and tetrachlorobenzenes, which give high-concentration PCB dielectrics their characteristic odor. Aroclors are odorless; different aroclors have different percent chlorine weight fractions of PCBs that result in different properties. A typical aroclor is designated 1254. Twelve denotes the number of carbons in the PCB molecule and 54 denotes the percent chlorine weight fraction. Aroclor 1016, commonly used in capacitors, is an exception to this nomenclature. Mixtures of PCBs and solvents were sold under the trade names that appear on the manufacturer nameplates of PCB electrical equipment and are referred to in this paper as PCB trade name dielectrics. Some of the more common PCB dielectric trade names are: Pyranol, Interteen, Elemex, and Chlorextol. There are many others. They contain, on average, about 60% PCBs. The generic name for these fluids is Askarel.

PCBs are not the only chemicals used in mines. Underground repair facilities have used chlorinated solvents such as trichloroethane, tetrachloroethene, and methylene chloride for cleaning and degreasing equipment. The release of these solvents, in addition to constituting their own threats of ground water contamination, can mobilize PCBs, facilitating transport into ground and surface waters. Some mines maintain their own landfills which contain improperly disposed PCBs and solvents.

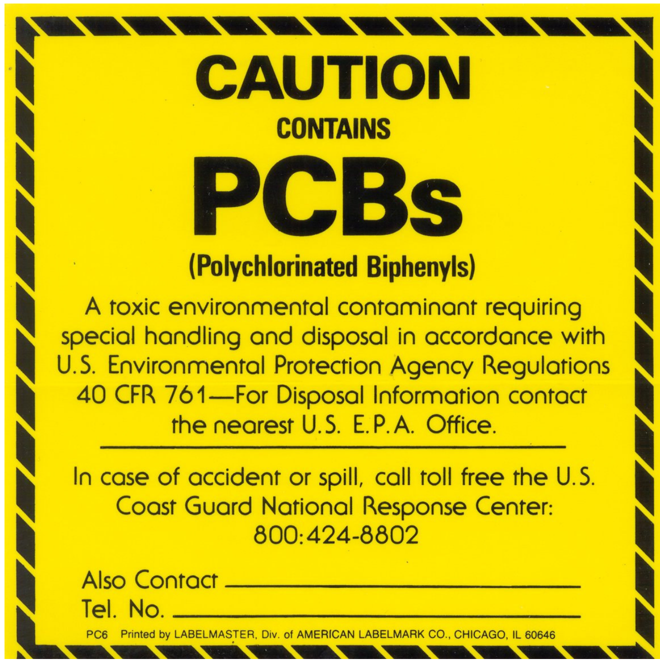

Fig. 1
PCB Marks may also have a white background.

IDENTIFYING PCB-CONTAINING ELECTRICAL EQUIPMENT

The regulations require transformers and capacitors containing three pounds or more of dielectric be identified by PCB Marks (Fig.1), placed on the equipment by the owner or user if they contain ≥500 ppm (0.05%) PCBs. They are designated PCB transformers or PCB capacitors. Mineral oil transformers containing ≥ 50 ppm (0.005%) PCBs are designated PCB contaminated transformers. All of the above are regulated for use and disposal. This does not necessarily mean that PCBs of lower concentrations or PCBs in small capacitors are not hazardous to human health and the environment. For purposes of this paper “PCB-containing” means dielectrics containing any detectable quantity of PCBs.

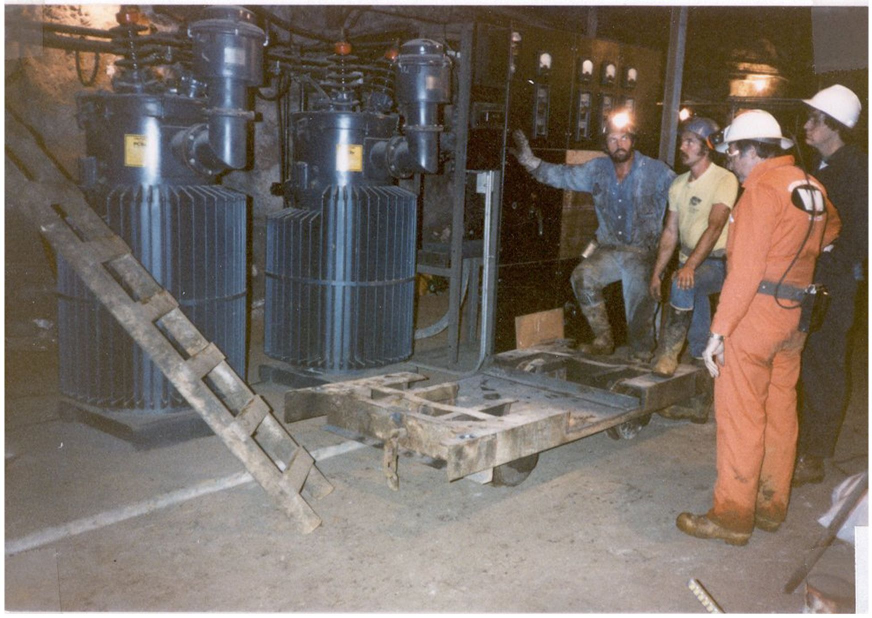

Fig. 2
76-gallon PCB (Pyranol) transformers in the Eagle Mine at Gilman, Colorado

PCB transformers

PCB transformers (Fig. 2) may carry a PCB trade name on the manufacturer nameplate. The regulations require the assumption "…that a transformer manufactured prior to July 2, 1979, that contains….fluid other than mineral oil and whose concentration is not established, is a PCB Transformer…" and contains ≥ 500 ppm PCBs. If the date of manufacture or the type of dielectric fluid is unknown, the transformer must be assumed to be a PCB transformer. PCB concentrations must be established by chemical analysis or testing using SW 846-Method 8082 and other methods[12], (see ASTM D-4059), to document compliance with the regulations. Rebuilt transformers may carry replacement nameplates that do not correctly identify the dielectrics.

Mineral oil transformers and voltage regulators

Transformers with "oil" or "mineral oil"on the manufacturer nameplate originally contained only mineral oil dielectrics but may have been contaminated with PCBs. Sometimes there is no dielectric listed. This is common when a transformer has been rebuilt. Testing is the only way to determine whether or not a mineral oil transformer has been contaminated

Dielectrics of mineral oil transformers and PCB transformers were often mixed during servicing resulting in transformers with mineral oil on the nameplates that may contain PCBs as a contaminant. In writing the regulations, EPA concluded the hazards of PCBs warranted regulation in transformers at ≥50 and ≥500 ppm PCB. This is why mineral oil transformers contaminated with ≥500 ppm PCBs are regulated as if they are trade name PCB transformers that typically contain about 600,000 ppm (60%) PCBs. Voltage regulators and substation transformers can become regulated PCB articles if internal small PCB starting capacitors leak (see **Be aware of hidden sources of PCBs** below).

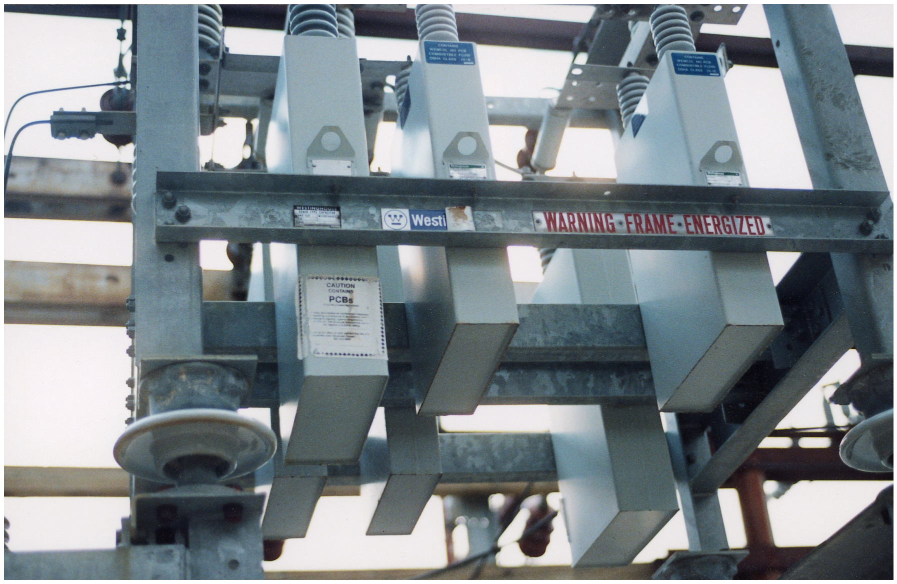

Fig. 3
PCB marked capacitor on the left

PCB capacitors

By 1976, 95 % of the capacitors produced in the United States were filled with PCBs[13] (Fig.3). PCB capacitors contain the pure aroclors, 1242 or 1016. Manufacture before July 2, 1979, or a PCB trade name on the nameplate is a good indicator of high concentration PCBs. The regulations require the assumption “that a capacitor manufactured prior to July 2, 1979, and whose PCB concentration is not established, contains ≥ 500 ppm PCBs” and is a PCB capacitor. If the date of manufacture is unknown the capacitor must be assumed to be a PCB capacitor and assumed to contain ≥ 500 ppm PCBs. Because most capacitors are sealed units, that testing will require penetration of the casing that may destroy their usefulness and result in leaks which must be eliminated or contained. A helpful aid in identifying capacitors that do not contain PCBs is that the regulations require capacitors manufactured between1978 and 1998 be marked “No PCBs” by the manufacturer.

Fig. 4
Fluorescent light ballast

Fluorescent light ballasts

Typical fluorescent light ballasts (Fig. 4) manufactured before May 31, 1979 contain a small capacitor buried in the tar or asphalt potting material filling the ballast that functions as an insulator. These capacitors hold about an ounce of aroclor. Asphalt material in fluorescent light ballasts manufactured before 1978 has been found to have a better than 50% chance of containing regulated levels of PCBs[14]. As with capacitors, a means of identifying fluorescent light ballasts that do not contain PCBs is a manufacturer emplaced "No PCBs" mark required between 1978 and 1998.

Fig. 5
Lead jacket electrical cable

Electrical cable

Electrical cable (Fig. 5) can contain PCBs. In some cases, the cable is enclosed in a lead jacket which makes it difficult to handle. If electrical cable contains liquids or damp insulation, PCBs should be suspected.

PCB REPLACEMENT

Replacement of PCB dielectrics can be a good investment considering the potential costs of cleanup from PCB spills or fires. In the United States, PCB contamination can result in liabilities under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) at any concentration. Fires and explosions involving PCB-containing capacitors, transformers or any other PCB-containing electrical equipment, including transformers with contaminated mineral oil dielectrics, can create polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans some of which may be more toxic than PCBs and not be easily cleaned up and can permanently shut down facilities.

Mines and related facilities need not face these risks today because there are good alternatives to PCBs on the market. Transformers, capacitors, fluorescent light ballasts, and cable manufactured in the United States after July 2, 1979 should not contain PCBs. Mineral oil dielectric fluids in transformers are common but can present fire and explosion hazards as can vegetable oil dielectrics when subject to high temperature faults within the transformer. A number of major United States power distribution companies have programs to eliminate PCBs and are adopting biodegradable vegetable oil dielectrics. Company representatives report biodegradability is an important consideration. Many coal and hardrock mining companies have adopted dry-type transformers for underground use. Dry-type transformers are transformers in which the core and coils are in gaseous (usually air) or dry compound insulating mediums. In explosive atmospheres dry-type transformers must be in properly ventilated non-combustible containers. Associated switch gear, or spark producing items, such as fuses, circuit breakers, and relays must be in explosion proof enclosures.[15]

There are a number of PCB-free capacitor dielectrics on the market. Some of these dielectrics can present their own hazards to human health and the environment and constitute financial risks if released into the environment.

MINES AND PCBs

Underground and surface mines and the attendant crushing, milling, and smelting facilities may use PCB-containing electrical equipment. PCBs are most likely to be in transformers, capacitors, fluorescent light ballasts, cable, and drums of unidentified oils. Underground inspections have revealed transformers grouped in permanent substations, located singly, or mounted on mine cars that can be transported throughout the mine. Capacitors are found in locations similar to those of transformers. PCB capacitors have been found in electric locomotives. In coal mines, PCB capacitors have been found in wheel or skid-mounted power centers (Fig. 6).

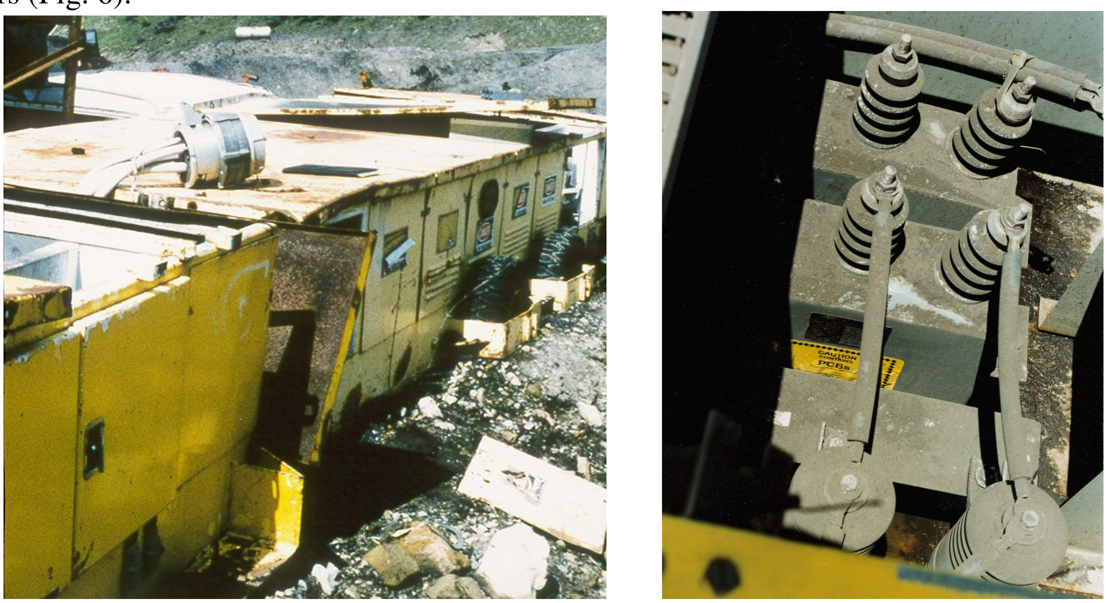

Fig. 6
Coal mine power center containing PCB capacitors

Inspections have revealed PCB electrical equipment in just about every major electrically powered activity: in draglines in open-pit coal mines, power shovels in open-pit metal mines, and in discarded equipment. PCBs have been found in underground substations, pump stations, mine power centers, and electric locomotives. PCBs have also been found in surface facilities including hoist facilities, mills, smelters, metal refineries, breaker houses, and transfer facilities. Experts in the mining industry believe that substantial quantities of electrical equipment with PCB-containing dielectrics had been abandoned underground before the advent of the PCB regulations.[16] Even after promulgation of the PCB regulations, PCBs have been abandoned underground, especially in situations where it was not cost effective to remove them.

PCB MANAGEMENT AND DISPOSAL

The following is a summary of ways to manage PCBs. This information should be supplemented by consulting the PCB regulations.

Identify and inventory PCB-containing electrical equipment. Equipment should be marked so it is easily recognizable and not disposed inadvertently. Written records identifying PCB equipment and their locations are essential. Records should include a serial number from the manufacturer nameplate or a company assigned number that has been placed on the equipment, dielectric identification from the nameplate, dielectric quantity, and PCB concentrations from lab analyses.

Examine the equipment for leaks and clean up any leaks or spills potentially containing PCBs. A common concept of a leak is a drip, sometimes referred to as a weep or seep. However, a leak is defined in the regulations as any instance in which a PCB article (including a transformer, voltage regulator, capacitor, lead cable, or fluorescent light ballast) or container "…has any PCBs on any portion of its external surface." This means a leak can be an oily film or oily dirt near any port or opening in the equipment. Leaks should be cleaned up and the equipment repaired or the leaking equipment containerized, moved to safe storage, and replaced. PCBs that have run off the equipment onto the concrete or soil below should be cleaned up and stored pending disposal. Personal protective equipment and cleanup materials may be contaminated with PCBs and require proper disposal.

It is a good idea to replace and properly dispose of PCB-containing equipment that is no longer needed, keeping in mind this can be a good long-term investment to avoid liability.

Storage should be in a building with an adequate roof and walls that is in a location selected to protect the PCBs from the possibility of release. Storage facilities should not be in a flood plain. Leaking equipment should be stored in metal drums with lids. Containment should prevent escape of PCBs into the environment through volatilization and containers should carry PCB marks. PCBs will penetrate most plastics.

Be aware of hidden sources of PCBs. The largest single hidden PCB source resulting in improper disposal is transformer bushings. The dielectrics in bushings have no fluid connections with the dielectrics in the transformers to which they are attached so analysis of the transformer dielectric will not reveal anything about PCBs in the bushing. Bushings can contain anything from mineral oil to pure aroclor to tar-like compounds containing very high concentrations of PCBs. "Pot heads,"cable termination apparatus that connect transformers to incoming power sources, can be filled with a tar-like material that can contain very high concentration PCBs. Any tar-like or asphalt-like material used as an insulator or dielectric should be suspected of containing PCBs. Small motors often require starting capacitors that can contain PCBs. Voltage regulators and substation transformers can contain load tap changers operated by small motors that contain PCB starting capacitors. Small motor capacitors can leak contaminating the dielectric fluid. Asphalt material in fluorescent light ballasts, along with lubricants and caulks are other potential sources. Air compressors have been serviced with PCB containing lubricants. Oil-filled switches, circuit breakers, and enclosures should also be suspect.

It is of utmost importance to keep in mind the dangers and persistence of PCBs in the environment when deciding on storage locations and disposal. PCB-containing dielectrics require specialized disposal techniques that destroy the PCB molecule. Incineration of PCB-containing dielectrics is the preferred destruction method. However, the PCB regulations require 99.9999% destruction of the PCBs[17] and incinerators can burn PCBs only if they obtain an EPA PCB disposal approval which includes successful completion of a trial burn to demonstrate this level of destruction. Inefficient incinerators or open burning can vaporize and disperse PCBs and convert them to even more hazardous dioxins. Disposal of PCB-containing dielectrics in landfills is not permitted because of the potential for ground water contamination. If there are no adequate disposal facilities long-term storage will be your only option.

The extent and complexity of underground mines present opportunities for abandonment or illegal disposal of hazardous wastes. The presence of hazardous wastes may not be evident until they are found in the local ground water. PCBs released underground from abandoned electrical equipment can cause water pollution in mining districts which will eventually introduce PCBs into the environment leading to contamination of the ocean and the human food chain regardless of the location of their release.

Abandoned underground electrical equipment may remain intact and not release PCBs for a very long time. Testing waters issuing from abandoned mines may not indicate whether or not PCBs are present in intact electrical equipment.

SUMMARY

PCBs are hazardous not only to human health and the environment but also to the mining industry because of potential worker exposure and improper disposal liabilities. Risk management should be an important part of PCB management planning. PCB managers should take into account not only the regulatory requirements for use and disposal, but also financial risks that can result if PCBs are inadvertently released into the environment. Compliance with the regulations will not protect against liabilities under other federal laws while minimal compliance can result in unanticipated risks. For example, the regulations permit the disposal of fluorescent light ballasts containing small capacitors with about an ounce of pure aroclor as municipal solid waste. Nevertheless, the preamble to the regulations states: “However, disposers of fluorescent light ballasts that contain a small PCB capacitor should be aware that they could be subject to CERCLA liability if the municipal solid waste landfill becomes a Superfund site.”[18] This small thimble sized capacitor contains enough aroclor to contaminate 166 gallons of mineral oil at 50 ppm.

In the United States, PCB contamination can result in liabilities under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) at any concentration if there is an actual or threatened release of PCBs to the environment which presents an “imminent and substantial” endangerment to public health or the environment. Because PCBs are considered hazardous substances under CERCLA, EPA can also act whenever there is an actual or threatened release even in cases where there is no imminent and substantial endangerment.[19]

Replacement and proper disposal of PCB-containing dielectrics can protect you from future liabilities.

Dan Bench, a mining engineer, is the U.S. Environmental Protection Agency Region 8 PCB Coordinator (E-mail: bench.dan@epa.gov or 303-312-7090, the Mining Hotline). For the regulations and more information on PCBs, check www.epa.gov/pcb.

REFERENCES

1. Celine Goddard *et al*., Preliminary Report on the Sperm Whale Data Collected During the *Voyage of the Odyssey*, Ocean Alliance, Lincoln, MA, USA and Woods Hole Oceanographic Institution, Woods Hole, MA, USA*, 2003.*
2. Stockholm Convention on Persistent Organic Chemicals (POPs) homepage, retrieved from the internet July 7, 2008.
3. Toxicological Profile for Polychlorinated Biphenyls (update),*US Department of Health*

and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, November 2000, p. 2.
4. *Ibid*. p. 4.
5. Victor Smetacek and James E. Cloern, On Phytoplankton Trends*, Science*, March 7, 2008, vol. 319, pp. 1346-1348.
6. Management of Polychlorinated Biphenyls in the United States, *Health and Environmental Effects of PCBs, U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics*, January 30, 1997, Sec 1.4.
7. Ronald Eisler, Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review, Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service Laurel, MD 20708, Biological Report 85(1.7) April 1986, pp.7 and 14.
8. Nine Years of Ocean Chlorophyll*, NASA News, Earth Observatory News, New Images,* http://earthobservatory.nasa/gov/Newsroom/NewImages/images.php3?img_id=17405 retrieved from the internet May 5, 2008.
9. *Op. cit*. Toxicological Profile for Polychlorinated Biphenyls, p. 493.
10. Gioia, Risalinda, *et. al.*, Polychlorinated biphenyls (PCBs) In Air and Seawater of the Atlantic Ocean: Sources, Trends and Process*, Environmental Science & Technology*, vol. 42, no.5, 2008, pp. 1416-1422.
11. 21 CFR Part 109.30 Tolerances for Polychlorinated Biphenyls (PCBs).
12. 40 CFR Part 761.60 T*esting procedures* (g)(1)(iii).
13. *Op. cit*. Toxicological Profile for Polychlorinated Biphenyls, p. 469.
14. 63 FR 35384, 35403 (June 29, 1998).
15. 30 CFR Secs. 75.2 and 75.340.
16. Personal communications from company officials during inspections, 1978-1994.
17. 40 CFR Part 761.70(b)(1).
18. *Op. cit*. 63 FR 35384, 35404
19. CERCLA section 104(a), 42 U.S.C. § 9604(a).