POLYCHLORINATED BIPHENYLS (PCBs)

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October 18, 2005

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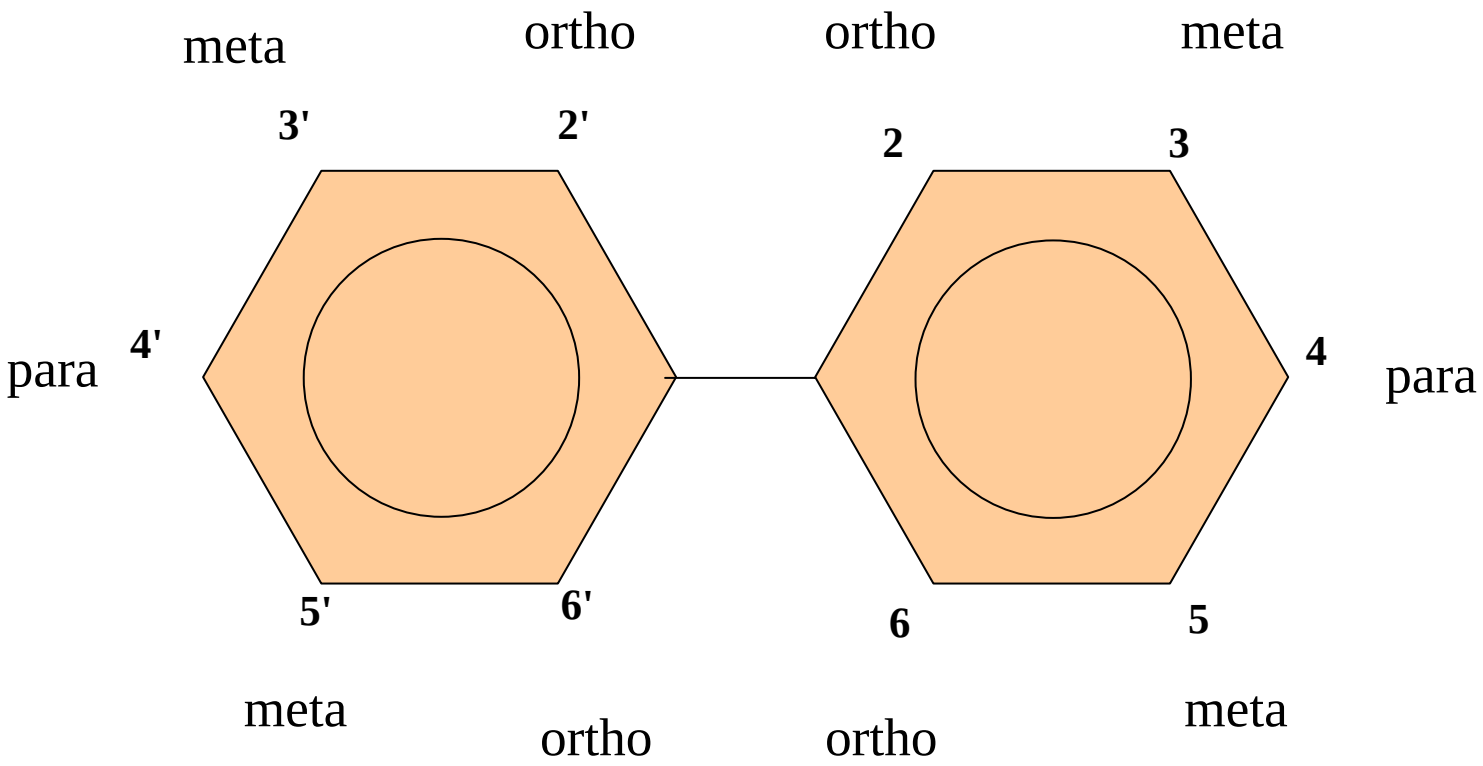
STRUCTURE OF POLYCHLORINATED BIPHENYL (PCB) MOLECULE

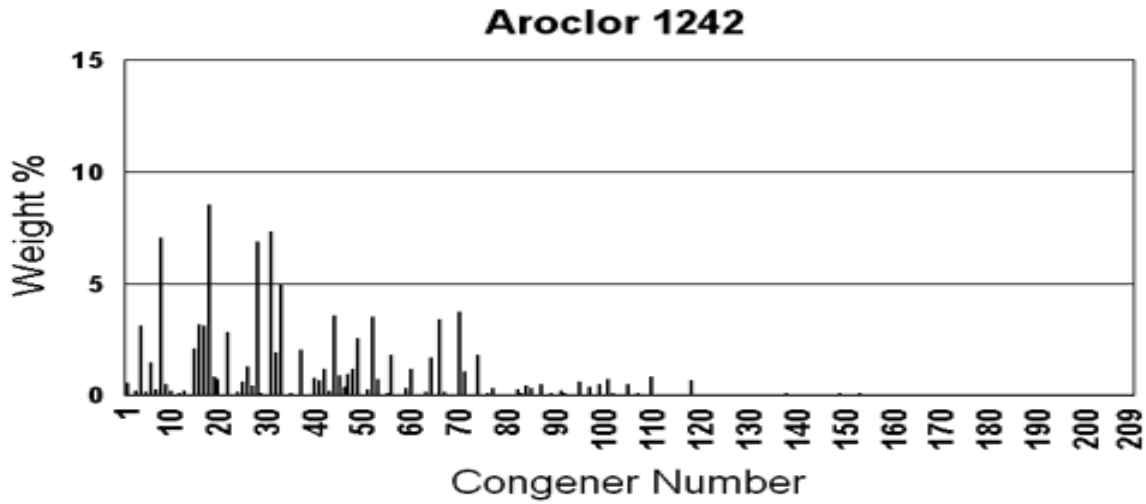


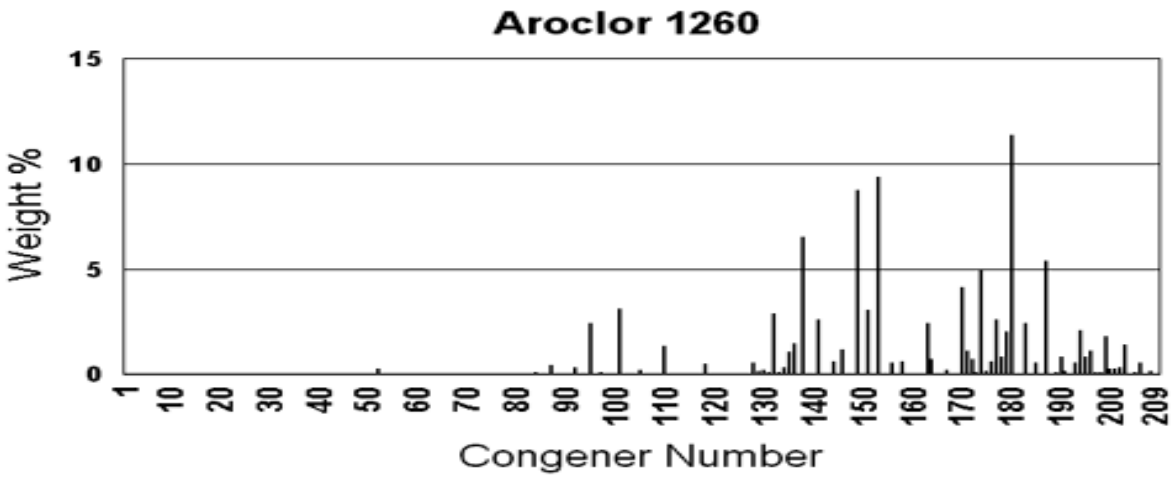
- Congener #1: 2 - Chlorobiphenyl
- Congener #209: Decachlorobiphenyl

HISTORY OF PCB MANUFACTURING

- Not known to naturally occur in the environment
- Manufactured primarily for use as an insulating fluid and coolant in electrical equipment and machinery
- Products containing PCBs are old fluorescent lighting fixtures, electrical appliances containing PCB capacitors, old microscope oil, and hydraulic fluids.
- Valued for chemical stability (does not dissolve in water) and fire-resistance
- Banned by EPA in 1979, and ultimately phased out of use in 1983
  - Sold as the “Aroclor" series
  - Five principal Aroclors: 1242, 1248, 1254, 1260, 1016

PCB (AROCLOR) COMPOSITION DATA





PCB IMPORTANCE

Health Effects:

- Studies in humans provide supportive evidence for potential carcinogenic and non-carcinogenic effects of PCBs.
- PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system and other health effects.

Persistence in the Environment:

- The total amount of PCBs produced annually has declined since the 1970's, but does not imply reduced toxicological threat posed by these compounds
- Low Degradability, high toxicity, and mutagenicity due to their ability to bioaccumulate (high lipophilicity)

Dioxin-Like Congeners:

- Of the 209 PCB congeners, a dozen are now considered by many toxicologists to be "dioxin-like" because of their toxicity and certain features of their structure which make them similar to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2378-TCDD).

PCB TRANSPORT – Oral, Dermal and Ground Water

Three Principal Pathways of Contamination:

- Oral: The consumption of food is believed to be the predominant route of exposure to PCBs for the general population. PCB contaminated fish, milk and dairy products, vegetables, meat and animal fat account for a large portion of this exposure.

- Dermal Contact/Ingestion: At sites where PCBs have been known to be present, there is risk of direct contact. For example, soil may adhere to the hands (and other exposed body parts) of children playing outdoors, and these children may ingest some of the soil from hand-to-mouth contact. Both residential and commercial scenarios may be of interest based on the site-specific analyses. (Example: site accumulation)

- Migration to Ground Water Pathway: Migration of PCBs from soil to ground water, which could lead to human exposure via contaminated water supplies. PCBs in general display low solubility in water, however, the potential for PCBs to migrate to ground water will be increased in the presence of non-aqueous phase liquids (NAPL), co-contaminants (e.g., chlorobenzenes or VOCs), and/or colloids (e.g., dissolved organic carbon, humic substances, and other macromolecules). Typically less-chlorinate

- Major issues: Time, identifying co-transporters

PCB TRANSPORT - Solid Surfaces (Cont'd)

- Contact from Solid Surfaces: When contaminated buildings, foundations, or other structures are to remain on a remediated site, it may be necessary to conduct an assessment of risks resulting from potential exposure to contamination that may remain on surfaces associated with these structures.

- New study, and current approach use the *World Trade Center Indoor Air Assessment Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks* ("WTC study") (U.S. EPA, 2003) as the benchmark.

- Major issues involved are : sampling, surface types, and dissipation

CASE STUDY: HUDSON RIVER FACILITY

- Major concern about the Hudson River's environmental health is related to the presence of (PCBs) in the Upper Hudson, especially in a stretch downriver from Hudson Falls to just north of Albany.

- From 1940-1977, the GE discharged as much as 1.3 million pounds of PCBs, which are used in the production of electric capacitors, into the Hudson from their two plants in those locations.

- EPA proposed removing the PCBs by dredging the sediment on the bottom of the river.

- Opponents to the proposal have argued that the consequences of dredging might create even greater dangers than any current risks, because buried PCBs might be disturbed during by the dredging.

PCB FATE

Overall:

- Vast quantities of PCB's have been dumped, spilled or have leaked into the environment. These toxins have accumulated in the air, water, and land, and pose health hazards to many animals, and perhaps some plants.

Atmospheric Deposition:

- One mechanism by which PCB's enter bodies of water is by atmospheric deposition. PCB's have a tendency not to stay dissolved in water and therefore volatize back into the atmosphere.

PCBs in Water:

- PCB's in water directly and indirectly is the main source of the toxic effects for animal life.

- Aquatic species are in turn eaten by birds; or mammals like humans or bears. In these animals again the PCB's accumulate in fatty tissues, and their concentration again becomes greater due to **biomagnification**.

PCB TOXICITY

Physical Properties:

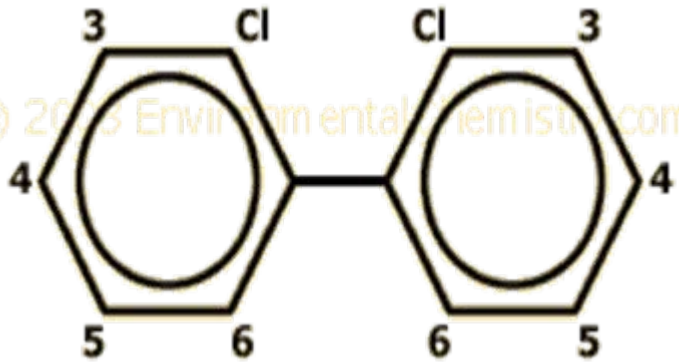
- PCB mixtures are usually light colored liquids that feel like thick, oily molasses
- Melting point and flammability limits are unknown
- Some PCB compounds form sticky, yellow liquids or a brittle gum ranging in color from amber to black
- PCBs are soluble in most organic solvents but are almost insoluble in water, so when added to it they sink to the bottom.

PCB TOXICITY (Cont'd)

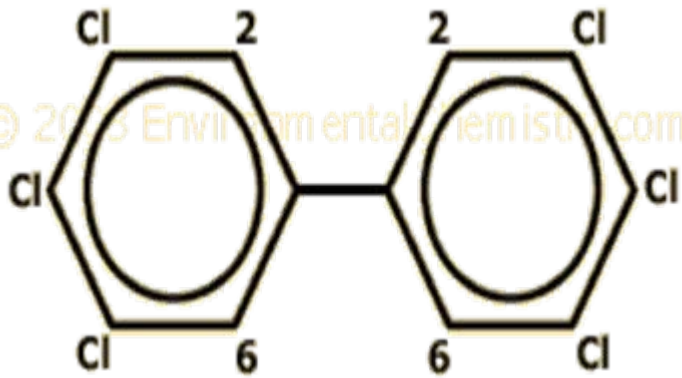
Chemical Properties:

- Toxicity of a PCB is dependent not only upon the number of chlorines present on the biphenyl structures, but the positions of the chlorines
- Chlorines in both para positions (4 and 4') and at least 2 chlorines at the meta positions (3, 5, 3', 5') are considered to be "dioxin like" and are particularly toxic.

LESS TOXIC PCB MOLECULE:



MORE TOXIC PCB MOLECULE:



PCB TOXICITY VALUES

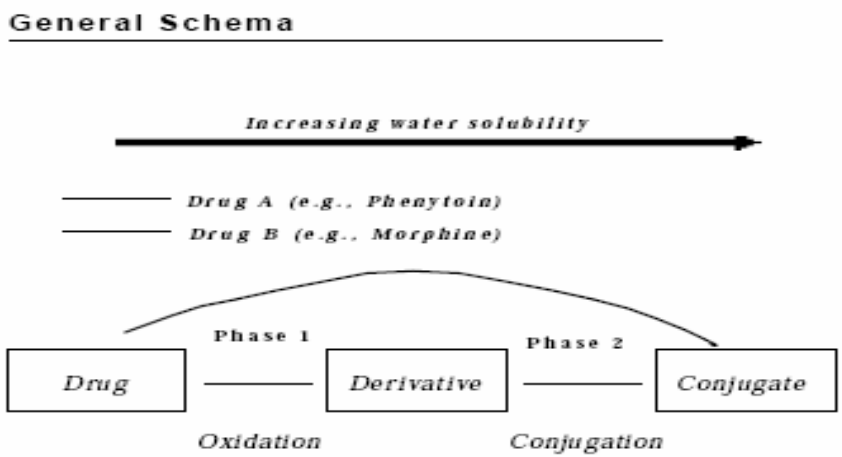
Risk Factor	Value	Units	Notes	Source
Cancer Slope Factor	2	$(mg/kg\text{-}d)^{-1}$	Used for high risk and persistence PCB mixtures.	U.S. EPA, 1996 IRIS, 2002
	0.4	$(mg/kg\text{-}d)^{-1}$	Used for low risk and persistence PCB mixtures.	U.S. EPA, 1996 IRIS, 2002
	0.07	$(mg/kg\text{-}d)^{-1}$	Used for lowest risk and persistence PCB mixtures.	U.S. EPA, 1996 IRIS, 2002
Reference Dose	$2x10^{-5}$	mg/kg-d	Reference dose for Aroclor 1254.	IRIS, 2002
	$7x10^{-5}$	mg/kg-d	Reference dose for Aroclor 1016.	IRIS, 2002

PCB BIOACCUMULATION/BIOMAGNIFICATION IN TISSUE

- PCBs are absorbed on a congener specific basis by passive diffusion
- Therefore, a large concentration gradient with high levels of PCBs in the gut and very low levels in serum lipids will yield nearly complete absorption.
- Once in the blood, PCBs are carried by lipoproteins and, due to the lipophilic nature of these congeners, they accumulate in lipid rich tissue with greater relative amounts usually found in the liver, adipose, skin, and breast milk.
- Potential for **biomagnification**, in which chemical levels in plants or animals increase from transfer through the food web (e.g., predators have greater concentrations of a particular chemical than their prey).

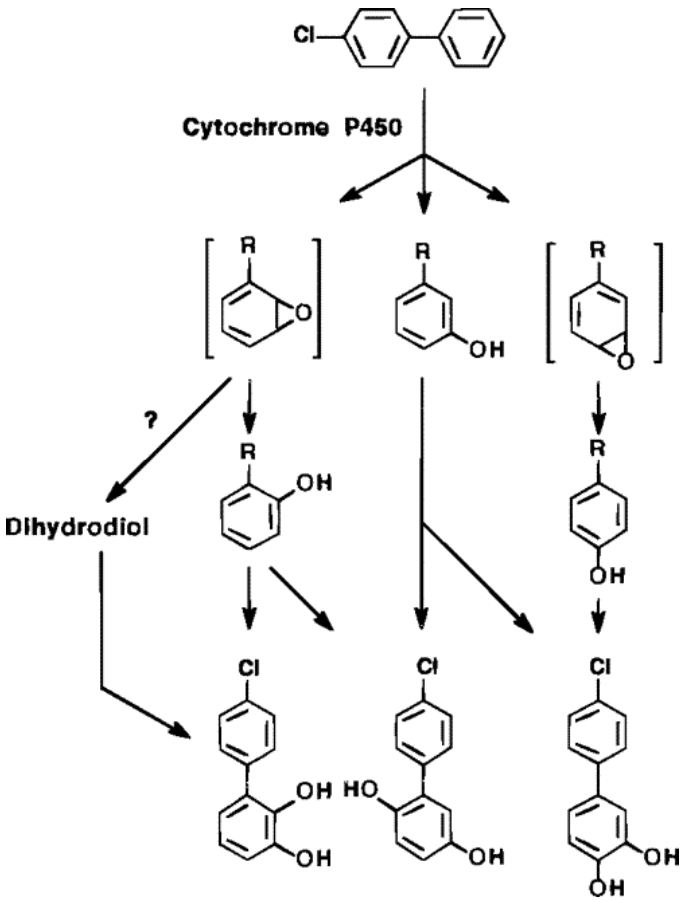
PCB METABOLISM

- The liver is the primary site of PCB metabolism
- Goal of metabolism is to transform the lipophilic PCB species into a more hydrophilic species (a metabolite) that can be easily excreted in urine or in bile.
- Two-step Process:
- **Phase 1**: Introduction or exposure to a functional group by oxidative or reductive processes or by hydrolysis (-OH, -NH2, -SH, -COOH, etc.) – make polar
- **Phase 2**: Reaction of a cofactor with an existing or created functional group (glucoronide conjugation) – increased polarity

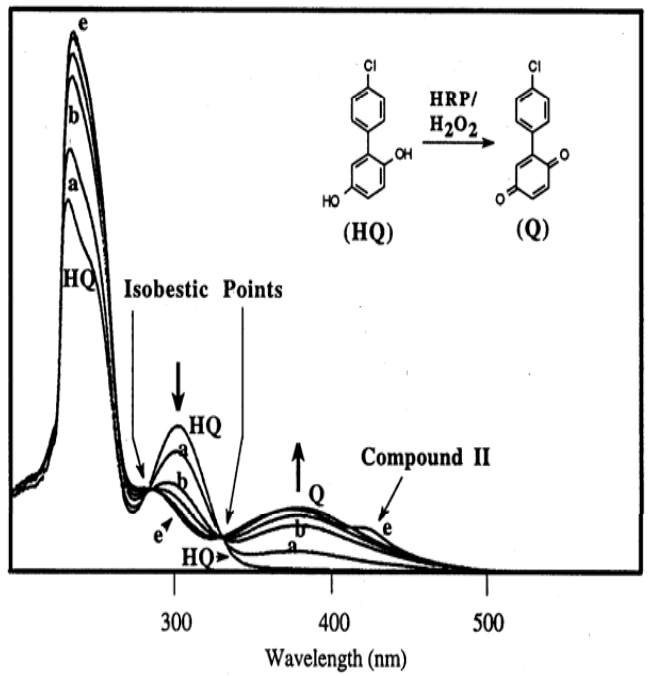


PCB METABOLISM (Cont'd)

Step 1



Step 2



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PCB PATHOLOGY

- Dermatologic Effects: Chloracne is the only overt effect of PCB exposure in humans. In a person with PCB-induced chloracne, the acne form lesions arise as a result of inflammatory responses to irritants in the sebaceous glands.

- Reproductive and Developmental Effects: Consumption of PCB-contaminated fish can

  cause disturbances in reproductive parameters and cause neurobehavioral and developmental effects in newborns and in children

- Endocrine Effects: PCBs can mimic or disrupt the action of the thyroid of naturally occurring hormones - Infants exposed to higher levels of PCBs also had lower plasma levels of free thyroxine and total thyroxine in the second week after birth (ATSDR and EPA 1998).

- Hepatic Effects: Although liver damage is common in PCB-exposed animals, overt hepatotoxicity is uncommon in humans.

- Carcinogenicity: On the basis of results from high-dose animal studies, PCBs are considered probable human carcinogens (Group 2A classification, International Agency for Research on Cancer).

PCB RISK ASSESSMENT - TARGET POPULATIONS

Residential Scenario :

- 30 years exposure (350 days per year), both as a child (up to six years) and an adult (24 years)
- Activities include both indoor and outdoor (e.g., sleeping, gardening, playing outdoors), with a higher soil ingestion rate during childhood years.

Commercial/Industrial Scenario:

- Outdoor worker and an indoor worker
- The outdoor worker spends most of the workday conducting outdoor activities, such as maintenance or gardening.
- The indoor worker spends the workday indoors

PCB RISK ASSESSMENT - HIGH-RISK POPULATIONS

Infants and Children:

- The offspring of low income subsistence fishers mothers who ate large amounts of contaminated fish or wild game while pregnant : Fetuses and neonates are potentially more sensitive to PCBs than are adults because the hepatic microsomal enzyme systems that facilitate the metabolism and excretion of PCBs are not fully functional.

Farmers:

- Farmers and their families who consume PCB-contaminated food via their own farm-raised beef and dairy cattle : Although most of these silos have been dismantled and removed, the remaining silos represent a potential source of exposure to PCBs

Hazardous Waste Workers:

- People living near incinerators, other PCB-disposal facilities, or NPL hazardous waste sites where PCBs have been detected.

Impaired Hepatic Function:

- Persons with impaired hepatic function might be at increased risk because of their diminished ability to detoxify and excrete these compounds.
- Persons with incompletely developed glucuronide conjugation mechanisms (such as those with Gilbert syndrome or Crigler-Najjar syndrome) fall into this category, as do those with chronic liver diseases such as cirrhosis or hepatitis B.

PCB ALTERNATIVES

Chemical Alternatives: Most frequently **mineral** and **silicone oils** are used as transformer fluids, but there are plenty of other alternatives.

Technical Alternative: Dry isolated transformers have been mentioned as an alternative to PCB-filled transformers. These alternatives avoid the problems of fire, but may be more problematic due to increased sensitivity to overload and voltage spikes

PCB DISPOSAL OPTIONS

- Creation of Chemical Landfill: This is one option to store contaminated soil. Storage requires the construction and maintenance of secure storage facilities. All storage sites today must meet stringent criteria for fire prevention, emergency situations, site access and design to ensure protection of the environment and human health. (Superfund program)

- Soil Excavation: Removes the contaminated soil, conducts confirmatory sampling and testing for PCB residues and restores the area to it's original state, including landscaping as required.

- Chemical treatment is used to treat low concentrations of PCBs in oils. This type of process uses chemical reactions to destroy PCBs. The treated oil from the process can generally be reused or recycled.

- Incineration can destroy liquid or solid PCB wastes. It is the most widely used technology for destroying highly concentrated PCBs. High temperature incineration is required to destroy PCBs at a destruction and removal efficiency of 99.9 percent

PCB REGULATIONS

- Clean Air Act. PCBs are considered Hazardous Air Pollutants (HAPs) under the Clean Air Act. EPA will be promulgating a new category of regulation, known as maximum achievable control technology (MACT standards) for "major source" facilities in any listed source category. Major sources are defined as those sources that release 10 tons per year of any HAP, or 25 tons per year in total HAP emissions.

- Clean Water Act: The ambient water quality criteria for PCBs in surface waters is 0.001 Fg/l. Section 129 of the Clean Water Act specifically bans the discharge of PCBs from PCB, electric transformer, and electric capacitor manufacturers.

- OSHA: The legal airborne permissible limit (PEL) for PCBs is 1 mg/m3 (42% chlorine) and .5 mg/m3 (54% chlorine) averaged over an 8-hour workshift.

- NIOSH: Airborne exposure limit of .001 mg/m3, averaged over a ten hour period. These exposure limits pertain to air levels only. They do not apply to skin contact.

- Department of Transportation: DOT currently requires specialized containers for packaging and transporting liquid and non-liquid PCBs

PCB REGULATIONS (Cont'd)

- Safe Drinking Water Act: Under the Safe Drinking Water Act, EPA established maximum contaminant levels for all public water systems in the United States. The MCL for PCBs is 0.0005 mg/l.

- CERCLA: Facilities must report disposal of PCBs in quantities greater than one pound to EPA for the purpose of tracking future liabilities.

- TSCA: TSCA relies on a theory of increasing regulatory burdens and maintaining management requirements with each higher level of PCB concentration

- Department of Agriculture Regulations: The United States Department of Agriculture (USDA) regulates PCB contamination of food products by placing restrictions on food packaging operations and by setting tolerance levels for PCBs in certain foods. New equipment or machinery for manufacturing food-packaging materials cannot contain or use PCBs. Equipment must be tested for PCBs and removed from use where they could contaminate food-packaging materials.

SUMMARY OF KEY ISSUES IN PCB RISK ASSESSMENT

Major Uncertainties:

- Do PCB's cause cancer?
- Methods of disposal
- Effects to early-life (0-2 years) is still unclear
- Potential for facilitated transport to water is not completely understood mechanistically.
- Understanding Aroclor weathering and potential biomagnification

PCBs in the future:

- Remains an environmental health risk although its creation has fallen
- PCBs are common contaminants at waste sites - they have been detected at 345 out of 1,244 sites on the Superfund National Priorities List (NPL)
- Cost-effective methods of removal and disposal will be debated

PCB REFERENCES

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