DYNAMAC
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Environmental Services

Final
Inorganic and Organic Mercury Contamination: Human Health Regulations and Guidelines Environmental Regulations and Guidelines

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What is Mercury?

Mercury is a naturally occurring element that exists in a variety of forms. It is found in soil, water, rocks, and living organisms, and it can exist as a gas, liquid, or solid. Mercury is found in three different forms in the environment: elemental or metallic mercury, inorganic mercury compounds, and organic mercury compounds. Depending on the concentration, all forms of mercury can be potentially toxic to humans and the environment, while some mercury compounds are more harmful then others.

Elemental mercury is not combined with any other element or compound; this is the type of mercury typically found in thermometers, batteries, and dental fillings. This form of mercury is not very abundant in the environment because most mercury is combined with other elements found in the soil and rock. Most of the elemental mercury in the environment is found as mercury vapor in the air. Elemental mercury has a very high evaporation rate at normal room temperatures.

Mercury is typically found in the environment combined with other minerals that form inorganic mercury compounds or "salts", such as mercury chloride. Mercury chloride and other inorganic mercury compounds can be more toxic to humans and the environment than elemental mercury.

The final form of mercury is organic mercury. Organic mercury compounds form as a result of mercury attaching to a carbon based compound. The most common organic form of mercury is methyl mercury. Methyl mercury is slowly produced by microorganisms present in the soil and water; it can also be formed by various chemical processes.

Mercury is widely distributed throughout nature as a result of both natural and man-made activities. Mercury is found naturally in cinnabar (mercury sulfide, HgS) and in fossil fuels, such as coal. Various forms of mercury have been used because of its diverse properties, which include the ability to conduct electricity, respond to temperature and pressure changes easily, and ability to form alloys with almost any other metal. The use of mercury to extract gold from mined ore is also a common use.

How can I be exposed to Mercury?

Mercury can enter the human body by breathing in vapors, ingesting contaminated water or foods, such as fish or plants, and by dermal (skin) absorption. Mercury vapors are present in the air near industrial areas and mining sites. Dental amalgams typically contain up to 50% mercury, therefore they can also give off low levels of mercury vapors. The ingestion of mercury is very common from contaminated water and food. Fish may have elevated methyl mercury levels as a result of biomagnification. Biomagnification of methyl mercury occurs as plankton and zooplankton begin to absorb small concentrations from the water and then are eaten by invertebrates or small fish. As smaller fish and other invertebrates are consumed by larger fish, the methyl mercury concentrations are cumulative and easily begin to reach very high levels.

These levels may be toxic to humans when large amounts of contaminated fish are consumed. The biomagnification process also occurs as plants take up mercury from contaminated soils. The plants are then consumed by animals, which may be consumed by humans.

The effects of mercury poisonings are dependant on the chemical form and concentration of mercury. Inorganic mercury is not as toxic as organic forms of mercury, with methyl mercury being one of the most toxic forms. Organic mercury is highly fat soluble and readily transferred across biological membranes (Hoffman, *et. al.*,1995). Organic forms of mercury are absorbed quicker in fat cells then in water cells. Therefore, the organic mercury is more likely to accumulate in fat tissues in the body.

What has been done to protect us from exposure to mercury?

State and federal agencies have established standards for the amount of mercury that can be harmful to human health and the environment. Regulatory or recommended action levels have been established by the Environmental Protection Agency (EPA) for human ingestion, inhalation and dermal exposure to mercury compounds. This includes EPA established drinking water standards for human consumption and ambient water quality standards to restrict the amount of mercury released into the environment by mining and smelting, the pulp and paper industry, chlor-alkali plants and other industries. The Food and Drug Administration (FDA) has set an action level for fish sold in the United States to protect consumers from methyl mercury poisonings. This level does not apply to substance, recreational and/or sport fishing. In these cases, people should be aware of local advisories issued by state government agencies that issue local advisories for waters that are known to have elevated mercury levels.

How do we know if mercury contamination is present?
Regulatory or Recommended Action Levels

Typically at sites where mercury contamination is suspected or known to exist, a preliminary assessment or site investigation will be conducted. These types of investigations are conducted to determine the nature and extent of contamination at the site. Analytical tests are typically conducted to determine the total amount of mercury in water, stream sediments, soil, and air samples at sites suspected or known to be contaminated with mercury. Tests have also been established to determine the concentrations in fish and plant matter. These tests determine the total amount of specific compounds of mercury in a sample in order to determine the total amount of mercury available to the environment. However, standards for specific compounds of mercury may not exist and many of the regulatory and recommended values are for organic or inorganic forms of mercury.

How does mercury affect us?

Inorganic Mercury

Elemental and inorganic mercury are known human toxicants, or poisons, that disrupt enzyme reactions and protein synthesis within the cells of the body, which in turn causes central nervous system damage. An acute exposure is defined as a sudden or short term exposure to a significantly high dose of a dangerous chemical. Short term exposures can range between hours to a couple days in duration. This type of high dose would not normally be found in the natural environmental. A typical camper, hiker, off road vehicle user, or outdoors enthusiast may not be at a contaminated site long enough to encounter this type of exposure level. An acute exposure of mercury vapor would likely be encountered by a worker at an industrial factory or at an ore smelting facility. Acute exposures to very high concentrations can cause hallucinations, delusions, excitement, blindness, deafness, and impaired levels of consciousness. It has been estimated that a continuous dose of 14 to 57 mg/kg of inorganic mercury for a 150 pound adult would be enough to cause death. This can be equated to approximately 0.0002 to 0.0083 ounces of mercury per pound of fish. Acute inhalation of mercury vapor can affect the gastrointestinal tract and respiratory system (U.S. EPA, May 26, 1998).

Chronic (long term) exposures to mercury affect the central nervous system by causing increased excitability, irritability, excessive shyness, and tremors. A person may receive this is the type of exposure if they are continuously subjected to contaminated drinking water or contaminated food over long periods of time.

The EPA has not listed elemental mercury as a carcinogen because no adequate human cancer data are available (U.S. EPA, May 26, 1998; ATSDR, April 1999).

What are the government established exposure levels?

Human Health and Exposure Levels

Drinking Water Standards

There is no listed drinking water standard for elemental mercury. The government health/environmental agencies have established Drinking Water Standards for inorganic mercury. This standard is set at 0.002 mg/l (0.002 ppm) in drinking water (U.S. EPA, February 1996; Title 18 Alaska Administrative Code 80.300).

The National Water Quality Criteria recommendations published by the EPA in the Federal Register on Tuesday November 9, 1999 (FR Vol. 64, No. 216) sets the human health criteria for the consumption of water and organisms contaminated with elemental mercury at 0.14 μg/l (0.00014 ppm). This is the recommended maximum level allowable in water and organisms to be consumed by humans. This is a very conservative number the EPA recommends to protect human health and the environment.

What if I breathe mercury vapor; how much do I have to breathe to cause harm?

Inhalation

The EPA has established recommended Reference Concentrations for chemicals to protect human health. These Reference Concentrations are based on the most conservative doses that will protect the most sensitive human population from adverse health effects. The EPA's recommended Reference Concentration for elemental mercury is 0.0003 mg/m^3. Inhalation of this concentration or less per day, over a lifetime, would not likely cause health effects in humans (U.S. EPA, May 26, 1998; IRIS, January, 2000). Typical concentrations of mercury vapor in the air is about 2.4 parts per trillion (ppt) (ATSDR, 1990).

The Occupational Safety and Health Administration's permissible exposure level for the short term exposure level, or ceiling is set at 0.1 mg/m^3 for inorganic mercury. This is the maximum (ceiling) allowable value of mercury in the air that a worker can be exposed to for fifteen minutes in a 8 hour work day (ACGIH, 1999). There are no values set for elemental mercury therefore the value for inorganic mercury is used.

How much soil would I have to ingest to cause harm?

Soil Screening Level

There are no final Federal Regulations on soil concentrations of elemental mercury. The EPA has an established guideline for mercuric chloride of 23 mg/kg or 0.000336 ounces per pound of soil ingested. The general soil concentration of mercury appears to be in the order of 0.05 $\mu g/g$ (micro gram per gram)of soil. In comparison cinnabar or meta-cinnabar ores may contain up to 1000 $\mu g/g$ of mercury (Hoffman, *et. al.*,1995).

Environmental Exposures

Ambient Water Quality Criteria

The EPA acute freshwater Federal Ambient Water Quality Criteria for elemental mercury is 2.1 $\mu g/l$ (0.0021 ppm). This is the highest level of elemental mercury to which aquatic life can be exposed for a one hour period without adverse health effects. The chronic freshwater Federal Ambient Water Quality Criteria is 0.012 $\mu g/l$ (0.000012 ppm). This is the highest concentration of total mercury to which aquatic life can be exposed for an extended period of time (four days typically) without adverse health effects. The marine acute (one hour) Federal criterion is 1.8 $\mu g/l$ (0.0018 ppm) and the chronic (four days) marine criterion is 0.025 $\mu g/l$ (0.000025 ppm) (Federal Register, November 1999). These levels are the highest concentrations of elemental mercury aquatic life can be exposed to without adverse health effects. Total mercury levels in freshwater typically range from 1 to 20 nano grams/liter (0.00001 ppm to 0.00002 ppm) (Hoffman, *et. al.*,1995).

Methyl Mercury

Methyl mercury affects the central nervous system in many of the same ways as elemental mercury. Chronic exposures to methyl mercury cause kidney damage, paresthesia (a pricking or tingling sensation of the skin), blurred vision, weakness or discomfort, speech difficulties, and constriction of the visual field. In addition methyl mercury exposure by ingestion has been linked to significant developmental effects in humans. A past epidemic in Iraq, the methyl mercury concentrations in people that became sick from ingesting contaminated grain were calculated to be in the range of 80 to 250 μg/kg/day or between 0.0000012 and 0.0000036 oz/lb/day (Klaassen, 1986). Women who ingested high levels of methyl mercury while pregnant gave birth to children with mental retardation, lack of coordination of the muscles, constriction of the visual field, blindness, and cerebral palsy (U.S. EPA, May 26, 1998; U.S. EPA, December 1997).

Methyl mercury has been classified as a possible human carcinogen by the EPA (IRIS, Methyl Mercury, January 2000).

Human Health and Exposure Levels

Oral Exposure

The recommended EPA oral Reference Dose for methyl mercury is set at 0.0001 mg/kg/day or 0.000000001 oz/lb/day. What this infers is that consumption of this daily dose or less, over a lifetime (a lifetime is considered to be 70 years), would not likely result in the occurrence of chronic non cancer effects. This Reference Dose is set conservative enough to also protect the developing nervous system of infant children (U.S. EPA, December 1997; EPA RBC, October 1999).

Inhalation Exposure

OSHA's limit for the average concentration of methyl mercury in the air for an 8 hour work day over a 40 hour work week, or time weighted average, is 0.01 mg/m^3. The short term exposure level, or ceiling is set at 0.04 mg/m^3. This is the maximum (ceiling) value of methyl mercury in the air that a worker can be exposed to for fifteen minutes in an 8 hour work day (ACGIH, 1999).

The recommended EPA risk-based concentration table sets an inhalation value at 0.37 μg/m^3 (EPA RBC, October 1999). This is the level at which a person could safely inhale methyl mercury and not expect to suffer any ill effects.

Drinking Water

The health based value for methyl mercury in drinking water is set at 3.7 μg/l (0.0037 ppm) (EPA RBC, October 1999). What this means, is that concentrations of methyl mercury in drinking water should not exceed 0.0037 ppm.

Industrial and Residential Soil Screening Values

The EPA established residential risk value is set at 7.8 mg/kg and the industrial risk value is set at 200 mg/kg (EPA RBC, October 1999). In general, this means that residential housing or industrial buildings can be built on sites where soil concentrations are below these levels.

Fish Consumption

The EPA human risk level for consumption of fish is set at 0.14 ppm in the risk based concentration tables (EPA RBC, October 1999). This is a very conservative health based number, which accounts for all sensitive human populations, such as young children. Below this level, methyl mercury in fish tissue is safe for consumption.

The Food and Drug Administration's (FDA) action level for retail/wholesale sale of fish containing methyl mercury is set at 1 ppm (U.S. FDA, May 1995). According to the EPA, the average concentration of mercury in fish in the United States is less than 0.2 ppm (U.S. EPA, December 1997). However, local advisories have been issued in areas where mercury contamination has impacted fish populations. Documentation of past epidemics have shown that fish contaminated with 10 to 30 ppm of methyl mercury cause serious health effects (U.S. EPA, December 1997). Fish may have high concentrations of methyl mercury due to bioaccumulation of the compound up the food chain. Methyl mercury binds to the proteins in fish tissues, therefore, no amount of cleaning or cooking will reduce the amount of methyl mercury in fish tissue. It is recommended that anglers keep smaller fish, because smaller fish contain less contamination then older, larger fish.

In general, anadromous fish contain lower concentrations of mercury then resident fish. This may be explained by the fact that anadromous fish live most of their lives in the open ocean where the mercury concentrations are lower then the fresh water areas near cinnabar deposits. Salmon do make up the majority of the fish harvested and consumed in this region of Alaska. Fish found in this stretch of the Kuskokwim River include: (anadromous) Chinook, Sockeye, Coho, and Chum salmon; (resident) Whitefish, Grayling, Sheefish, Dolly Varden, and Pike (Mike Coffing, Alaska Department of Fish and Game, 1999; Van Waggoner, Bruce Seppi, Jeff Denton, Bureau of Land Management, 1999).

Environmental Exposures

Aquatic Invertebrates

Freshwater invertebrates display a wide range of sensitivity to mercury. To establish these levels, laboratory tests are conducted: specifically, tests are run to determine the lethal concentration required to kill 50% of the population in laboratory experiments; this is called the LC_{50}. For example the lethal concentration to kill 50% of one type of waterflea is 2.2 μg/l (0.0022 ppm); mayfly 2.0 mg/l (2.0 ppm); and snail, 2100 μg/l (2.1 ppm) (Hoffman, *et. al.*,1995). These laboratory experiments have shown that these concentrations in water are toxic to some species. Typical concentrations of total mercury in aquatic invertebrates from uncontaminated areas are generally less than 0.1 μg/g wet weight (0.1 ppm)(Hoffman, *et. al.*,1995).

Terrestrial Invertebrates

The LC_{50} for mercury ranged from 2.39 mg/kg (2.39 ppm) at 10 days to 0.79 mg/kg (0.79 ppm) at 60 days for earthworms exposed to mercury chloride in contaminated soil. These results were observed in a laboratory toxicity test.

The regulations and guidelines mentioned above are current as of February 7, 2000. Regulations and health based guidelines are updated frequently by the EPA, therefore, one needs to be aware that these regulations and guidelines will change and may be updated by the EPA regularly in the future. It is prudent to always check the most recent federal and state regulations by contacting the appropriate agencies.

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