Mercury Compounds

Hazard Summary

Mercury exists in three forms: elemental mercury (Hg, oxidation state 0); inorganic mercury compounds (oxidation state +1, univalent; or +2, divalent); and organic mercury compounds. Elemental mercury can exist as a shiny silver liquid, but readily vaporizes into air. All forms of mercury are toxic, and each form exhibits different health effects.

Elemental Mercury: Acute (short-term) exposure to high levels of elemental mercury vapors results in central nervous system (CNS) effects such as tremors, mood changes, and slowed sensory and motor nerve function. Ingestion and inhalation of elemental mercury can cause adverse effects quickly. Chronic (long-term) exposure to elemental mercury in humans also affects the CNS, with effects such as erethism (increased excitability), irritability, excessive shyness, and tremors.

Inorganic Mercury Compounds: Acute exposure to divalent mercury by the oral route is corrosive and may result in nausea, vomiting, severe abdominal pain, and ulceration of mucous membranes. The major effect from chronic ingestion or inhalation of low levels of divalent mercury is kidney damage. Animal studies have reported effects such as alterations in testicular tissue, increased fetal resorption rates, and developmental abnormalities. Chronic exposure of experimental animals to divalent mercuric chloride has resulted in forestomach, thyroid, and renal tumors.

Organic Mercury Compounds: Methylmercury (CH₃Hg⁺) is the most common organic mercury compound in the environment. Acute exposure of humans to very high levels of methyl mercury results in profound CNS effects such as blindness and spastic quadriparesis. Chronic exposure to methyl mercury, most commonly by consumption of fish from mercury contaminated waters, also affects the CNS with symptoms such as paresthesia (a sensation of pricking on the skin), blurred vision, malaise, speech difficulties, and constriction of the visual field. Ingestion of methyl mercury can lead to significant developmental effects. Infants born to women who ingested high levels of methyl mercury exhibited mental retardation, ataxia, constriction of the visual field, blindness, and cerebral palsy.

Please Note:

• The main sources of information for this fact sheet are EPA's Integrated Risk Information System (IRIS), which contains information on inhalation chronic toxicity and the RfC for elemental mercury (4) and oral chronic toxicity and the RfD for inorganic and methyl mercury (5,6), and the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Mercury. (1,2)

Uses

• Elemental mercury is used in thermometers, barometers, and pressure-sensing devices. It also is used in batteries, lamps, industrial processes, refining, lubrication oils, and dental amalgams. (1)

- Inorganic mercury was used in the past in laxatives, pharmaceuticals, skin-lightening creams and soaps, agricultural products, and in latex paint (e.g., to prevent bacterial and fungal growth). These historic uses have since been banned. (1)
- Methyl mercury has no industrial uses; it is formed in the environment from the methylation of inorganic mercury ions. (1)

Sources and Potential Exposure

- Mercury is a naturally occurring element in rocks, soil, and volcanic dust and gases and found throughout the environment. (1)
- Human activities such as mining, smelting, burning of waste, and fossil fuel burning can contribute to mercury release. Both its uses by humans and its occurrence in ore and fossil fuels contribute to potential human exposures. (1)
- Mercury occurs in the environment predominantly in one of three different states: elemental, divalent, and methyl mercury. (1)
- In air, elemental mercury can be transformed to another state and further transported via soil, rain, or snow. In water or soil, inorganic mercury can be transformed to methyl mercury by microorganisms. This organic form of mercury has the potential to bioaccumulate in fish up the food chain. (1)
- Humans may be exposed to mercury via inhalation of air, ingestion of food or water, or dermal contact with products or soil that contain mercury. (1)

Elemental Mercury

- A major source of exposure to elemental mercury is through inhalation in occupational settings. (1)
- Another source of exposure to low levels of elemental mercury in the general population is elemental mercury released in the mouth from dental amalgam fillings. (1)
- Although use in household products has been phased out, another potential source of exposure to elemental mercury is breakage or improper disposal of a variety of household products, including thermostats, fluorescent light bulbs, barometers, glass thermometers, and some blood pressure machines that contain elemental mercury. (1)

Inorganic Mercury

- Most mercury found in the environment is in the form of metallic mercury and inorganic mercury compounds and exposure to inorganic mercury can occur via inhalation or ingestion of contaminated media. (1)
- Exposure to inorganic mercury compounds may occur in workplaces where inorganic mercury compounds are used or produced. (1)
- Individuals who live near abandoned mines, hazardous waste sites, agricultural fields treated with mercury fungicides, or industrial facilities that emit inorganic compounds may have increased exposure. (1)

Methyl Mercury

• The most important organic mercury compound, in terms of human exposure, is methyl mercury. Methyl mercury exposure occurs primarily through the diet, with fish and fish products as the predominant source. Studies have shown mercury levels in tuna sold in the United States ranging from 0.063 to 0.639 ppm. (1,2)

Assessing Personal Exposure

• Laboratory tests can detect mercury in blood, urine, and hair samples. (1)

Health Hazard Information

Acute Effects:

- Elemental Mercury
 - The major systems impacted by human inhalation of elemental mercury vapors are the kidneys and central nervous system (CNS). (1,4)
 - Acute inhalation exposure of humans to high levels of elemental mercury results in CNS effects, such as tremors, irritability, memory loss, neuromuscular changes, headaches, increased salivation, metallic taste, slowed sensory and motor nerve function, and reduction in cognitive function. (1,4)
 - Acute exposure to lower levels of elemental mercury can result in nonspecific symptoms, such as shyness, insomnia, anxiety, and loss of appetite. (1,10)
 - Acute inhalation exposure of humans to high concentrations has resulted in kidney effects ranging from mild transient proteinuria to acute kidney failure. (1)
 - Gastrointestinal effects, such as inflammation of the mouth lining, nausea, and vomiting, and respiratory effects, such as chest pains, difficulty breathing, cough, impaired lung function, and interstitial pneumonitis, have been noted from human inhalation exposure to elemental mercury. (1)
 - \circ Dermal exposure to mercury may cause skin irritation. (10)
 - $_{\odot}$ $\,$ Lethal blood levels of mercury have been reported to range from 0.4 to 22 mg/mL. (10)
- Inorganic Mercury
 - Inorganic divalent mercury compounds are corrosive to eyes, skin, the respiratory tract, and the digestive tract. (10)
 - Symptoms noted in humans after acute oral exposure to divalent mercury compounds include caustic gastrointestinal effects (nausea, vomiting, bloody diarrhea, ulceration of mucous membranes, and abdominal pain) and acute renal failure (reduced or no urinary output). (1,10)
 - Symptoms noted after dermal exposure to divalent mercury salts include dermatitis and burns. (10)
 - Although difficult to estimate, a lethal dose of mercuric chloride was estimated to be 5-50 mg/kg, or between seven drops and one teaspoon for a 150-pound person. (1,10)
- Methyl Mercury
 - Acute inhalation exposure to high levels of methyl mercury is unlikely in humans, although acute high-level inhalation exposure to an unspecified alkyl mercury compound has been reported to cause profound neurological symptoms followed by death. (1)
 - Acute, high-level oral exposure to methyl mercury is rare, but accidental poisonings have resulted in severe neurological impairment and kidney and liver damage. (1,3)
 - Acute dermal exposure may cause sensitization and, if contact is maintained, second-degree burns.
 (10)

Chronic Effects (Noncancer):

- Elemental Mercury
 - The CNS is the major target for elemental mercury toxicity in humans. Effects noted include erethism (increased excitability), irritability, excessive shyness, insomnia, increased salivation, tremors, headache, impaired memory, possible permanent brain damage, and impaired muscle control. (1,10)

- Chronic exposure to elemental mercury also affects the kidney in humans, including changes in urine and the development of proteinuria. (1,10)
- Chronic exposure to elemental mercury may cause liver damage. (10)
- Possible dermal effects of long-term elemental mercury exposure include skin allergy, raised red areas, and blistering (10).
- Chronic elemental mercury exposure can have other effects including loosening of teeth, irritation of the gums, loss of appetite, clouding of the eyes, and gray skin color (10).
- Acrodynia is a rare syndrome found in children exposed to elemental mercury compounds. It is characterized by severe leg cramps, irritability, paresthesia (a sensation of prickling on the skin), and painful pink fingers and peeling hands, feet, and nose. (1)
- EPA has not established a Reference Dose (RfD) for elemental mercury. (4)
- The Reference Concentration (RfC) for elemental mercury in air is 0.0003 milligrams per cubic meter (mg/m³) based on CNS effects in humans. The RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime. It is not a direct estimator of risk, but rather a reference point to gauge potential effects. At exposures increasingly greater than the RfC, the potential for adverse health effects increases. Lifetime exposure above the RfC does not imply that an adverse health effect would necessarily occur. (4)
- EPA has medium confidence in the RfC due to medium confidence in the studies on which the RfC was based: although the studies used sufficient numbers of human subjects and appropriate control groups, exposure levels in several studies had to be extrapolated from blood mercury levels. EPA also has medium confidence in the database overall due to a lack of human or multispecies reproductive/developmental studies. (4)
- Inorganic Mercury
 - The primary effect in humans from chronic exposure to inorganic mercury is kidney damage, primarily due to mercury-induced autoimmune glomerulonephritis (induction of an immune response to the body's kidney tissue). (1)
 - Chronic dermal exposure to mercuric chloride may cause dermatitis. (10)
 - Repeated or prolonged exposure may lead to death by nephrotic syndrome or kidney failure. (10)
 - Acrodynia also may occur from exposure to inorganic mercury compounds. (1)
 - The RfD for inorganic mercury (mercuric chloride) is 0.0003 milligrams per kilogram body weight per day (mg/kg/day) based on autoimmune effects in rats. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancer effects during a lifetime. It is not a direct estimator of risk, but rather a reference point to gauge the potential for effects. At exposures increasingly greater than the RfD, the potential for adverse health effects increases. Lifetime exposure above the RfD does not imply that an adverse health effect would necessarily occur. (5)
 - EPA has high confidence in the RfD based on the weight of evidence from the studies using Brown Norway rats and the entirety of the mercuric chloride database. (5)
 - EPA has not established an RfC for inorganic mercury, which has limited volatility. (5)
- Methyl Mercury
 - The primary effect from chronic exposure to methyl mercury in humans is damage to the CNS. The earliest effects are symptoms such as paresthesia, blurred vision, and malaise. Effects at higher doses include deafness, speech difficulties, and constriction of the visual field. Over time, tremors may

become coarse and convulsive, speech may become slurred, and difficulty in pronunciation may occur. (1,2,10)

- Chronic exposure to methyl mercury also may cause death by nephrotic syndrome or kidney failure.
 (10)
- Chronic dermal exposure to methyl mercury may cause dermatitis. (10)
- The RfD for methyl mercury is 0.0001 mg/kg/day based on developmental neuropsychological impairment in children exposed to methyl mercury in utero. The RfD is based on a benchmark dose lower limit (BMDL) range of mercury in maternal blood that was estimated to correspond to maternal daily intakes ranging from 0.857 to 1.472 µg/kg/day. (6)
- EPA has high confidence in the RfD because it is based on analysis of three high quality epidemiological studies. EPA's benchmark dose analysis of the endpoints from these studies converge on the RfD value, as did the integrative analysis combining all three studies. (6)
- \circ EPA has not established an RfC for methyl mercury. (6)

Reproductive/Developmental Effects:

- Elemental Mercury
 - Studies on the reproductive and developmental effects of elemental mercury in humans have shown mixed results. One study did not see an association between mercury exposure and miscarriages, while another revealed an increased rate. Another study showed a higher than expected frequency of birth defects, which was not confirmed in a fourth study. (1)
- Inorganic Mercury
 - No information is available on the reproductive or developmental effects of inorganic mercury compounds in humans. Animal studies have reported effects including alterations in testicular tissue, increased resorption rates, and developmental abnormalities. (1)
- Methyl Mercury
 - A large number of human studies on the systemic effects of methyl mercury ingestion have been carried out. These included analysis of two large-scale poisoning incidents in Japan and Iraq and several epidemiological studies investigating populations that consume large quantities of fish. In the Iraqi population, only a small number of women were pregnant, so reproductive effects were not studied. Developmental neurotoxic effects in the children, however, were observed. (1,2,6)
 - Oral exposure to methyl mercury has been observed to produce significant developmental effects in humans. Infants born to women who ingested high concentrations of methyl mercury exhibited CNS effects, such as mental retardation, inability to move, incoordination, deafness, constriction of the visual field, blindness, and cerebral palsy. (1,2)
 - At lower methyl mercury concentrations, developmental delays and abnormal reflexes have been noted. (1,2)
 - Studies of human populations in the Seychelles and Faroe Islands have reported neurobehavioral effects, including motor and language delay and IQ score deficits in infants and children exposed preand postnatally to methyl mercury. (2)
 - Animal studies have reported impaired learning and motor function in animals exposed to methyl mercury in utero or through lactation. (2)
 - The critical effect for EPA's methylmercury RfD (see above) is developmental and neuropsychological impairment (e.g., a child's ability to learn and process information). (6)

Cancer Risk:

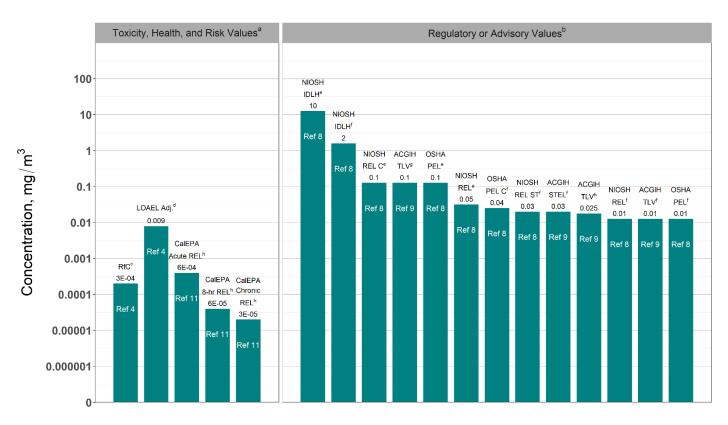
- Elemental Mercury
 - Several studies have been carried out regarding elemental mercury and cancer in humans. These studies are inconclusive due to lack of valid exposure data and confounding factors. (1)
 - EPA has concluded elemental mercury is not classifiable as to human carcinogenicity, based on inadequate human and animal data. (4)
- Inorganic Mercury
 - No studies were located on the carcinogenic effects of divalent inorganic mercury in humans.
 - A National Toxicology Program (NTP) study on the oral carcinogenicity of mercuric chloride in rats and mice reported an increased incidence of forestomach and thyroid tumors in male rats and an increased incidence of renal tumors in male mice. (7)
 - EPA has concluded that mercuric chloride is possibly carcinogenic to humans based on the absence of data in humans and limited evidence of carcinogenicity in rats and mice. (5)
- Methyl Mercury
 - There is inadequate evidence to determine if methyl mercury has carcinogenic effects in humans; one animal study reported renal tumors in mice. (1)
 - EPA has concluded that methyl mercury is possibly carcinogenic to humans based on inadequate data in humans and limited evidence of carcinogenicity in animals. (6)

Physical Properties

- Elemental mercury is a silver-white metal with an atomic weight of 200.59 g/mol. (1)
- Mercury is a liquid at room temperature and has a vapor pressure of 0.002 mm Hg at 25 °C. (1)
- Mercury can exist in three oxidation states—elemental (Hg), mercurous (Hg⁺), and mercuric (Hg⁺⁺)—and it can be part of both inorganic and organic compounds. (1)
- Inorganic mercury compounds include mercuric chloride, mercuric sulfide, and mercurous chloride. Organic mercury compounds include methyl mercury, mercuric acetate, methylmercuric chloride, dimethyl mercury, and phenylmercuric acetate. (1)

Conversion Factors:

To convert concentrations in air (25°C) from ppm to mg/m³: mg/m³ = (ppm) × (molecular weight of the compound)/(24.45). For elemental mercury: 1 ppm = 8.2 mg/m³. For mercuric chloride: 1 ppm = 11.1 mg/m³. For methylmercuric chloride: 1 ppm = 10.3 mg/m³.



Health Data from Inhalation Exposure to Various Forms of Mercury

ACGIH TLV — American Conference of Governmental and Industrial Hygienists' threshold limit value; ACGIH-recommended time-weighted average concentration to which most workers can be exposed over a lifetime without adverse effects. The **ACGIH STEL** (short-term exposure limit) is the legal maximum average exposure for a 15-minute period.

CalEPA REL — California Environmental Protection Agency Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Level (REL) is the airborne concentration of a chemical that is not anticipated to result in adverse noncancer health effects for specified exposure durations in the general population, including sensitive subpopulations. Exposure averaging time for the **Acute REL** is 1 hour. For the **8-hour REL**, the exposure averaging time is 8 hours, which may be repeated. The **Chronic REL** is designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure.

LOAEL — Lowest observed adverse effect level is the lowest dose or concentration at which there was an observed toxic or adverse effect of a target organism distinguished from a normal or untreated organism of the same species.

NIOSH IDLH — National Institute of Occupational Safety and Health's immediately dangerous to life or health concentration; NIOSH-recommended exposure limit to ensure that a worker can escape from an exposure condition that is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from the environment.

NIOSH REL — National Institute of Occupational Safety and Health's recommended exposure limit; NIOSH-recommended time-weighted average exposure concentration for up to a 10-hour workday during a 40-hour workweek that should not be exceeded. The short-term exposure limit **(ST)** is a 15minute TWA exposure that should not be exceeded at any time during a workday. The ceiling limit **(C)** should not be exceeded at any time.

OSHA PEL — Occupational Safety and Health Administration's permissible exposure limit; timeweighted average concentration that must not be exceeded during any 8-hour work shift of a 40-hour workweek. The ceiling value **(C)** is the exposure level that shall at no time be exceeded.

RfC (Reference Concentration) — Estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

^aToxicity, Health, and Risk Values are toxicological values from animal testing or risk assessment values developed by EPA or other agencies.

^bRegulatory values are exposure levels that have been incorporated in Government regulations, while advisory values are nonregulatory exposure levels provided by Government agencies or other groups as advice. OSHA values are regulatory, whereas NIOSH and ACGIH values are advisory. ^cElemental mercury.

^dThe LOAEL (and subsequently the adjusted LOAEL) are from the critical study used as the basis for the EPA RfC for elemental mercury.

eAll mercury compounds except (organo)alkyls.

fAlkyl compounds.

gAryl compounds.

^hElemental and inorganic forms.

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