MERCURY - TOXGUIDE™

CHEMICAL AND PHYSICAL INFORMATION

Mercury (Hg) a naturally occurring element. Elemental Hg exists as a gas, liquid, or solid. All mercury compounds are solid at room temperature except mercuric oxide, which is a gas. Mercury and mercury compounds are odorless.

Mercury compounds are classified into three general categories:

- **Elemental mercury**
- **Inorganic mercury compounds (e.g., mercuric chloride; HgCl)**
- **Organic mercury compounds (e.g., methylmercury; MeHg)**

Mercury is primarily used in the manufacture of electronics, fluorescent-lighting, and the production of chlorine-caustic soda; it is also used in dental products (fillings), although use in dentistry is being phased out. Other historical uses of elemental mercury (alkaline batteries, electronic switches, and lighting applications, fungicides and pesticides, paints and pigments, and thermometers and other scientific and medical devices) have been eliminated or drastically reduced.

ENVIRONMENTAL FATE AND DETECTED LEVELS

Air: Mean mercury levels in U.S. ambient air were 1.11 2.22 ng/m^3 in 2019.

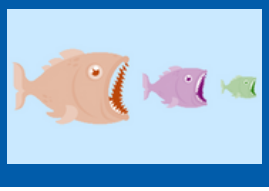
Mercury may enter the air from natural processes via volatilization. Industries may release mercury to air; however, releases to air have been steadily decreasing over the past few decades. Atmospheric mercury is primarily in the form of gaseous elemental mercury, which is subject to long range transport. Therefore, mercury can be found in locations far removed from its release site.

Water: There are no recent monitoring data for water levels of mercury in groundwater or surface water. U.S. drinking water generally contains <0.025 µg Hg/L.

Mercury may enter water through natural processes, industrial waste discharge, or leaching from landfills.

Sediment and Soil: There are no recent monitoring data for sediment and soil levels of mercury. Hg naturally occurs at a concentration of 80 µg Hg/kg soil.

Atmospheric deposition of mercury from both natural and anthropogenic sources has been identified as an indirect source of mercury to soil and sediments. Mercury may also be released to soil via disposal of industrial and domestic solid waste products to landfills (e.g., thermometers, electrical switches, and batteries).



Bioconcentration: Mercury in water can be methylated by anaerobic bacteria, producing a highly bioaccumulative form of organic mercury (MeHg) that biomagnifies in the aquatic food chain. For this reason, mercury can often be detected at high levels in fish and other aquatic organisms, rice, and other vegetation.

GENERAL POPULATION EXPOSURE

Most likely exposure route: Oral

- Primary source: Contaminated food (MeHg); fish and seafood are the primary sources of dietary intake; rice may also be a significant contribution
- Minor sources: Contaminated water; elemental mercury released from mercury amalgam dental restorations

Potential exposure route: Inhalation

- Minor sources: Contaminated ambient air, elemental mercury released from mercury amalgam dental restorations or from breakage, and/or spills of older items containing liquid mercury (e.g., thermometers)

Potential exposure route: Dermal

- Minor source: Use of consumer products containing mercury (e.g., skin lightening creams)

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POPULATIONS WITH POTENTIALLY HIGH EXPOSURE

Workers employed in industries that used mercury (e.g., electronic manufacturing), mercury recycling and reprocessing facilities, or dental offices where elemental mercury is used in dental amalgams may be exposed via

- Inhalation of contaminated workplace air
- Direct skin contact with mercury (or mercury compounds) or mercury vapor

Compared to the general population, the following groups may also have increased risk of exposure:

- Populations that live in proximity to former mercury mining or production sites, secondary production (recycling) facilities, municipal or medical incinerators, or coal-fired power plants (via ambient air and/or groundwater contamination)
- Communities with high dietary consumption of fish or marine mammals (oral exposure)
- Individuals with mercury amalgam dental restorations (oral and/or inhalation exposure)
- Individuals who regularly use consumer products containing mercury such as traditional or herbal remedies, or cosmetics, including skin lightening creams (inhalation, oral, and/or dermal exposure)
- Individuals who use mercury as part of spiritual practices (inhalation, oral, and/or dermal exposure)

BIOMARKERS

Mercury levels can be measured in blood, urine, hair, or toenails.

Organic mercury:
Biomarkers more strongly correlated to MeHg exposure include MeHg in whole blood or total mercury in red blood cells or hair.

Elemental mercury:
Biomarkers more strongly correlated to exposure to elemental mercury and inorganic mercury include mercury in blood (or plasma) and mercury or total mercury in urine.

BIOMONITORING LEVELS

Measured levels in humans in the United States (NHANES 2015 2016):

Geometric mean blood levels:
Total Hg: 0.810 µg/L
MeHg: 0.518 µg/L

Median total urinary mercury level:
0.140 µg/L

TOXICOKINETICS

Absorption

- **Elemental Mercury:** Well absorbed via the inhalation route, with small amounts absorbed through the skin and gastrointestinal tract.
- **Inorganic Mercury:** Absorbed to some extent via all routes. Mercuric (Hg^{2+}) compounds are absorbed more readily than mercurous (Hg^{+}) compounds.
- **Organic Mercury:** Absorption of MeHg through the gastrointestinal tract is nearly 100%. It is also absorbed through the skin.

Distribution: For all species, absorbed mercury is distributed throughout the body, with the highest concentrations in the kidney. All forms of mercury are distributed to the brain. Mercury is found in human cord blood, placenta, and breast milk and is transferred to the fetus.

Metabolism

- **Elemental Mercury:** Rapidly oxidized by catalase in blood and tissues to mercuric mercury (Hg^{2+}) in tissues.
- **Inorganic Mercury:** The low pH and high chloride concentration of the gastric environment results in oxidation of ingested Hg^{+} to Hg^{2+}.
- **Organic Mercury**: Some MeHg is demethylated to form Hg^{2+}.

Excretion: The major routes of excretion for mercury are through exhaled air (elemental mercury), urine and feces (Hg^{2+}), and hair (MeHg).

HEALTH EFFECTS

Neurological effects (tremor, sensory and motor impairments, cognitive deficits, altered mood) have been seen in humans after inhalation exposure to elemental mercury or oral exposure to MeHg. Similar effects were observed in animals exposed to elemental, inorganic, or organic mercury.

Health effects are determined by the dose (how much), the duration (how long), the mercury compound, and the route of exposure.

Cognitive, neuromotor, and neurosensory effects have been seen in humans with prenatal exposure to MeHg. Neurodevelopmental effects were also seen in animals orally exposed to inorganic or organic mercury compounds. Birth defects have also been seen in humans with high dietary levels of MeHg.

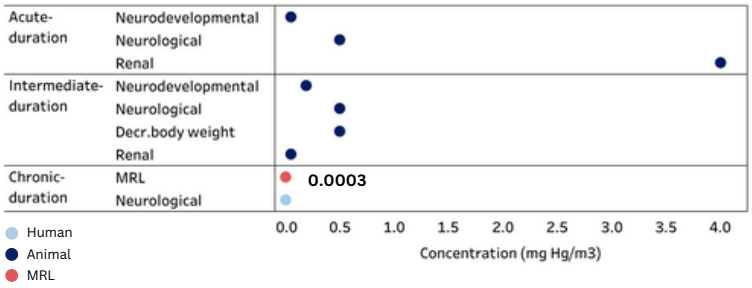
Renal effects (impaired function, tubular injury) have been observed in workers exposed to elemental mercury. Renal damage has consistently been observed in animals exposed to elemental mercury via inhalation and inorganic and organic mercury compounds via oral exposure.

Impaired fertility has been observed in animals following oral exposure to inorganic or organic mercury compounds.

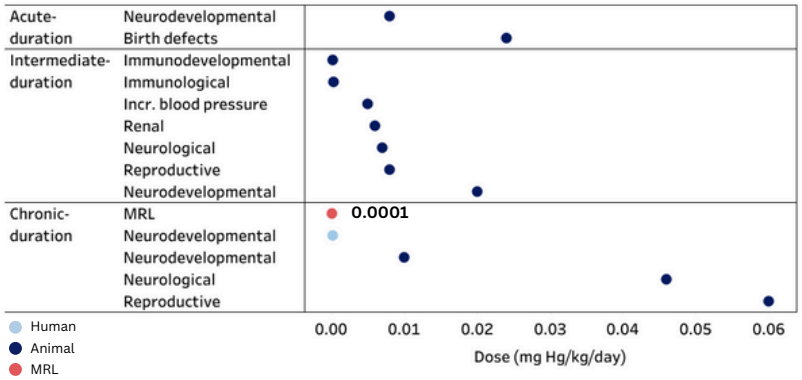
High blood pressure has been observed in humans and animals following oral exposure to inorganic or organic mercury.

Alterations in immune system function and/ or cells have been observed in humans and animals following oral exposure to inorganic or organic mercury.

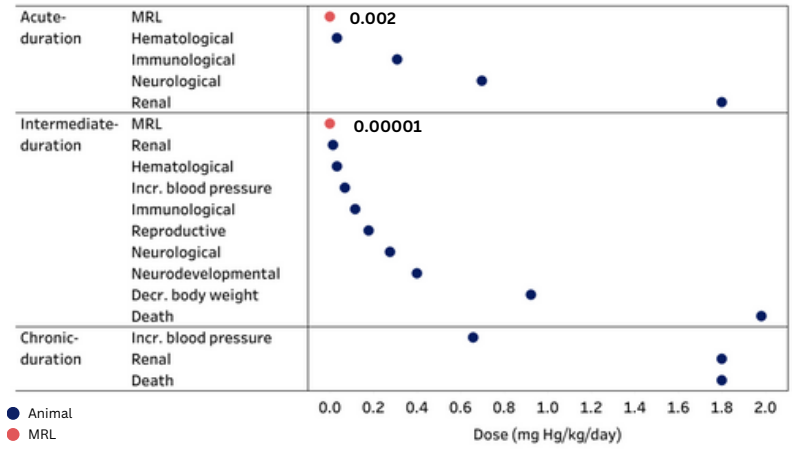
Sensitive Effects of Inhalation Exposure to Elemental Mercury



Sensitive Effects of Oral Exposure to Organic Mercury



Sensitive Effects of Oral Exposure to Inorganic Mercury



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POPULATIONS WITH INCREASED SUSCEPTIBILITY TO HEALTH EFFECTS

Children

- Mercury that crosses the placenta is distributed to the fetus, and nursing neonates may be exposed to mercury in breast milk.
- Evidence from human and animal studies indicates associations between mercury exposure during development and adverse health outcomes during childhood, most notably neurodevelopment.
- Differences in elimination kinetics may also contribute to differences in susceptibility of children and adults.

Older adults (≥65 years of age) and pre-existing conditions

- Populations with age-related compromises in physiological function (e.g., renal, neurological) would be anticipated to be more susceptible to mercury than younger adult populations.
- Populations with pre-existing conditions or diseases that compromise physiological function of key targets of mercury toxicity (e.g., kidney, nervous system) may increase susceptibility to mercury toxicity.

Nutritional status

- Differences in selenium, copper, and zinc nutritional status may infer differential susceptibility to mercury toxicity.

Genetic polymorphisms

- Genetic polymorphisms in glutathione-associate genes and genes associated with mercury transport and elimination are associated with altered susceptibility to mercury through altered toxicokinetics.

MINIMAL RISK LEVELS (MRLs)

Acute: ≤14 days; Intermediate: 15 364 days; Chronic: ≥365 days

Inhalation:

- **Acute:** Not derived for elemental, inorganic, or organic mercury.
- **Intermediate:** Not derived for elemental, inorganic, or organic mercury.
- **Chronic:** A chronic duration inhalation MRL of 0.3 µg Hg/m^3 was derived for elemental mercury based on neurological effects in humans. Chronic duration inhalation MRLs were not derived for inorganic or organic mercury.

Oral:

- **Acute:** An acute duration oral MRL of 2 µg Hg/kg/day was derived for inorganic mercury based on kidney effects in rats. Acute duration oral MRLs were not derived for elemental or organic mercury.
- **Intermediate:** An intermediate duration oral MRL of 0.01 µg Hg/kg/day was derived for inorganic mercury based on kidney effects in rats. Intermediate duration oral MRLs were not derived for elemental or organic mercury.
- **Chronic:** A chronic duration oral MRL of 0.1 µg Hg/kg/day was derived for organic mercury based on neurodevelopmental effects in humans. Chronic duration oral MRLs were not derived for elemental or inorganic mercury.

CANCER

The U.S. Department of Health and Human Services has not evaluated the potential carcinogenicity of mercury or mercury compounds. Mercuric chloride and MeHg have been classified by the U.S. Environmental Protection Agency as possible human carcinogens; the carcinogenic potential of elemental mercury was not classified. MeHg has been classified by the International Agency for Research on Cancer as possibly carcinogenic to humans; the carcinogenic potential of elemental mercury or inorganic mercury was not classified.

REFERENCE

Agency for Toxic Substances and Disease Registry (ATSDR). 2024. Toxicological profile for mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Services. https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=115&tid=24.