



Human Health Effects of Heavy Metals

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Introduction

Heavy metals are individual metals and metal compounds that can impact human health. Eight common heavy metals are discussed in this brief: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. These are all naturally occurring substances which are often present in the environment at low levels. In larger amounts, they can be dangerous.

Generally, humans are exposed to these metals by ingestion (drinking or eating) or inhalation (breathing). Working in or living near an industrial site which utilizes these metals and their compounds increases ones risk of exposure, as does living near a site where these metals have been improperly disposed. Subsistence lifestyles can also impose higher risks of exposure and health impacts because of hunting and gathering activities.

Arsenic

Aside from occurring naturally in the environment, arsenic can be released in larger quantities through volcanic activity, erosion of rocks, forest fires, and human activity. The wood preserving industry uses about 90% of the industrial arsenic in the U.S. Arsenic is also found in paints, dyes, metals, drugs, soaps and semi-conductors. Animal feeding operations and certain fertilizers and pesticides can release high amounts of arsenic to the environment as can industry practices such as copper or lead smelting, mining, and coal burning.

Health effects

Arsenic is odorless and tasteless. Inorganic arsenic is a known carcinogen and can cause cancer of the skin, lungs, liver and bladder.

- Lower level exposure can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of “pins and needles” in hands and feet.

- Ingestion of very high levels can possibly result in death.
- Long-term low level exposure can cause a darkening of the skin and the appearance of small “corns” or “warts” on the palms, soles, and torso.

Regulatory limits

- Environmental Protection Agency (EPA) - 0.01 parts per million (ppm) in drinking water.
- Occupational Safety and Health Administration (OSHA) - 10 micrograms per cubic meter of workplace air ($10 \mu\text{g}/\text{m}^3$) for 8 hour shifts and 40 hour work weeks.

Barium

Barium is a very abundant, naturally occurring metal and is used for a variety of industrial purposes. Barium compounds, such as barium-nickel alloys are used for spark-plug electrodes and in vacuum tubes as a drying and oxygen-removing agent; barium sulfide is used in fluorescent lamps; barium sulfate is used in diagnostic medicine; barium nitrate and chlorate give fireworks a green color. Barium compounds are also used in drilling muds, paint, bricks, ceramics, glass, and rubber.

Health effects

Barium is not known to cause cancer.

- Short term exposure can cause vomiting, abdominal cramps, diarrhea, difficulties in breathing, increased or decreased blood pressure, numbness around the face, and muscle weakness.
- Large amounts of barium intake can cause, high blood pressure, changes in heart rhythm or paralysis and possibly death.

Regulatory limits

- EPA - 2.0 parts per million (ppm) in drinking water.
- OSHA - 0.5 milligrams of soluble barium compounds per cubic meter of workplace air for 8 hour shifts and 40 hour work week.

Cadmium

Cadmium is a very toxic metal. All soils and rocks, including coal and mineral fertilizers, contain some cadmium. Cadmium has many uses, including batteries, pigments, metal coatings, and plastics. It is used extensively in electroplating.

Health effects

Cadmium and cadmium compounds are known human carcinogens. Smokers get exposed to significantly higher cadmium levels than non-smokers. Severe damage to the lungs may occur through breathing high levels of cadmium.

- Ingesting very high levels severely irritates the stomach, leading to vomiting and diarrhea.
- Long-term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage, and fragile bones.

Regulatory limits

- EPA – 5 parts per billion (ppb) or 0.005 parts per million (ppm) of cadmium in drinking water
- Food and Drug Administration (FDA) – concentration in bottled drinking water should not exceed 0.005 ppm (5 ppb).
- OSHA – an average of 5 micrograms per cubic meter of workplace air for an 8-hour workday, 40-hour work week.

Chromium

Chromium is found in rocks, animals, plants, and soil and can be a liquid, solid, or gas. Chromium compounds bind to soil and are not likely to migrate to ground water but, they are very persistent in sediments in water. Chromium is used in metal alloys such as stainless steel; protective coatings on metal (electroplating); magnetic tapes; and pigments for paints, cement, paper, rubber, composition floor covering and other materials. Its soluble forms are used in wood preservatives.

Health effects

Chromium (VI) compounds are toxins and known human carcinogens, whereas Chromium (III) is an essential nutrient.

- Breathing high levels can cause irritation to the lining of the nose; nose ulcers; runny nose; and breathing problems, such as asthma, cough, shortness of breath, or wheezing.

- Skin contact can cause skin ulcers. Allergic reactions consisting of severe redness and swelling of the skin have been noted.
- Long term exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation.

Regulatory limits

- EPA– 0.1 ppm (parts per million) in drinking water.
- FDA – should not exceed 1 milligram per liter (1 ppm) in bottled water.
- OSHA – an average of between 0.0005 and 1.0 milligram per cubic meter of workplace air for an 8-hour workday, 40-hour workweek, depending on the compound.

Lead

As a result of human activities, such as fossil fuel burning, mining, and manufacturing, lead and lead compounds can be found in all parts of our environment. This includes air, soil, and water. Lead is used in many different ways. It is used to produce batteries, ammunition, metal products like solder and pipes, and X-ray shielding devices. Lead is a highly toxic metal and, as a result of related health concerns (see below), its use in several products like gasoline, paints, and pipe solder, has been drastically reduced in recent years. Today, the most common sources of lead exposure in the United States are lead-based paint and possibly water pipes in older homes, contaminated soil, household dust, drinking water, lead crystal, lead in certain cosmetics and toys, and lead-glazed pottery.

Health effects

EPA has determined that lead is a probable human carcinogen. Lead can affect every organ and system in the body. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system; weakness in fingers, wrists, or ankles; small increases in blood pressure; and anemia.

- Exposure to high lead levels can severely damage the brain and kidneys and ultimately cause death.
- In pregnant women, high levels of exposure to lead may cause miscarriage.
- High level exposure in men can damage the organs responsible for sperm production.

Regulatory limits

- EPA – 15 parts per billion (ppb) in drinking water, 0.15 micrograms per cubic meter in air.

Mercury

Mercury combines with other elements to form organic and inorganic mercury compounds. Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings, switches, light bulbs, and batteries. Coal-burning power plants are the largest human-caused source of mercury emissions to the air in the United States. Mercury in soil and water is converted by microorganisms to methylmercury, a bioaccumulating toxin.

Health effects

The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens.

- The nervous system is very sensitive to all forms of mercury.
- Exposure to high levels can permanently damage the brain, kidneys, and developing fetuses. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems.
- Short-term exposure to high levels of metallic mercury vapors may cause lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.

Regulatory limits

- EPA – 2 parts per billion parts (ppb) in drinking water
- FDA – 1 part of methylmercury in a million parts of seafood.
- OSHA – 0.1 milligram of organic mercury per cubic meter of workplace air and 0.05 milligrams per cubic meter of metallic mercury vapor for 8-hour shifts and 40-hour work week.

Selenium

Selenium is a trace mineral widely distributed in most rocks and soils. Processed selenium is used in the electronics industry; as a nutritional supplement; in the glass industry; in plastics, paints, enamels, inks, and rubber; in the preparation of pharmaceuticals; as a nutritional feed additive for poultry and livestock; in

pesticide formulations; in rubber production; as an ingredient in antidandruff shampoos; and as a constituent of fungicides. Radioactive selenium is used in diagnostic medicine.

Health effects

Selenium is toxic in large amounts, but trace amounts of it are necessary for cellular function in most, if not all, animals. For humans, selenium is an essential trace nutrient. For example, selenium plays a role in the element functioning of the thyroid gland. The Tolerable Upper Intake Level is 400 micrograms of selenium per day. Consumption above that level can lead to selenosis (see below).

- Short-term oral exposure to high concentrations can cause nausea, vomiting, and diarrhea.
- Chronic oral exposure to high concentrations can produce selenosis. Major signs of selenosis are hair loss, nail brittleness, and neurological abnormalities.
- Brief exposures to high levels in air can result in respiratory tract irritation, bronchitis, difficulty breathing, and stomach pains. Longer-term exposure can cause respiratory irritation, bronchial spasms, and coughing.

Regulatory limits

- EPA – 50 parts per billion of selenium (50 ppb) in drinking water.
- OSHA – 0.2 mg per cubic meter of workroom air for an 8-hour work shift.

Silver

Silver usually combines with other elements such as sulfide, chloride, and nitrate. Silver is used to make jewelry, silverware, electronic equipment, and dental fillings. Silver metal is also used in electrical contacts and conductors, in brazing alloys and solders, and in mirrors. Silver compounds are used in photographic film. Dilute solutions of silver nitrate and other silver compounds are used as disinfectants and as an antibacterial agent. Silver iodide has been used in attempts to seed clouds to produce rain.

Health effects

According to EPA, silver is not classifiable as a human carcinogen.

Health effects

- Exposure to high levels for a long period may result in a condition called argyria, a blue-gray discoloration of the skin and other body tissues. Argyria appears to be a cosmetic problem that may not be otherwise harmful to health.
- Exposure to high levels of silver in the air has resulted in breathing problems, lung and throat irritation, and stomach pains.
- Skin contact with silver can cause mild allergic reactions such as rash, swelling, and inflammation in some people.

Regulatory limits

- EPA – recommends concentration in drinking water not to exceed 0.10 parts per billion (ppb). Requires that spills or accidental releases of 1,000 pounds or more be reported.
- OSHA – in workplace air, 0.01 milligrams per cubic meter (0.01 mg/m³) for an 8-hour workday, 40-hour workweek.

Bioaccumulation

Bioaccumulation is the accumulation of substances or chemicals in an organism. There are a small number of plants that easily absorb high levels of metals from the surrounding soil. These are called hyperaccumulators. If these plants are harvested for human use, exposure to harmful levels of metals can happen. Normally, this is a concern only if plants are collected from areas with high concentrations of metals in the soil. Metals uptake by plants is dependent on soil acidity (pH). The higher the acidity, the more soluble and mobile the metals become, and the more likely they are to be taken up and accumulated in plants.

In general, humans are more likely to be exposed to metal contamination from soil that sticks to plants than from bioaccumulation. This is because it is very difficult to wash all soil particles off of plant materials before preparing and ingesting them. Root crops (like potatoes and carrots), leafy vegetables (like spinach and lettuce), and parts of plants that grow near the soil (like strawberries) are a higher risk for exposure to metal contamination than the higher portions of plants, like fruits or berries.

Stressed plants may be a sign of metal contamination. Look for unusual changes in the coloring or growth pattern of plants as an indicator of a stressful growth environment (like drought) combined with high metals concentrations in the soil. These kinds of conditions make it more likely that the plants are bioaccumulating (or uptaking) metals. Deficiencies in the plant (like a low level of zinc) can also influence a plant's likelihood to accumulate metals.

Animals can accumulate metals as well by eating plants, fish, or drinking water with elevated metal concentrations. These metals are not excreted by the animals; rather, they accumulate mostly in the organs as well as the skin, hair, and bones. Fish accumulate metals from the water they live in as well as from organisms they eat. Bottom feeders are particularly susceptible to metals bioaccumulation as they can ingest sediments laced with metals. For fish consumption advisories, please visit this website, <http://www.epa.gov/waterscience/fish/>

Seaweed accumulates metals from the surrounding water as well as the sediments it grows in.

In addition to ingesting metals via food, there are a number of ways to be exposed to metal contamination through plant use. They include:

- inhaling contaminants from burning plant materials (like smudging),
- inhaling contaminants from smoking plant materials (like tobacco or jimson weed),
- volatilization (turning into a gas) of contaminants in plant materials in enclosed areas (like sweat lodges or work areas),
- ingestion, inhalation, or skin contact from handcrafts using plants, and
- daily use of plant materials as tonics to promote health (like ginseng or sage)

Table 2. Bioaccumulation Risks

Metal	Bioaccumulation risk	Special considerations
Arsenic	Generally not absorbed or limited to roots. Fish and shellfish can accumulate arsenic. Fish consumption advisories: http://www.epa.gov/waterscience/fish/	<ul style="list-style-type: none"> • Toxic to plants at levels not harmful to humans and animals. • Be primarily concerned with roots or contamination from soil on lower portion of plant.
Barium	Rarely accumulated in plants, but accumulates in certain plants, seaweed, and fish.	Readily accumulated in brazil nuts
Cadmium	Fish, plants and animals bio-accumulate. Examples: liver, kidney, meat, mushrooms, shellfish, mussels, cocoa powder and dried seaweed. Fish consumption advisories: http://www.epa.gov/waterscience/fish/	<ul style="list-style-type: none"> • Be primarily concerned with roots or contamination from soil on lower portion of plant (dust). • Under certain conditions (high soil levels plus plant stress) can accumulate to levels harmful to humans. • Rice plants are particularly vulnerable.
Chromium	High potential for uptake by aquatic life, especially bottom-feeders. Fish consumption advisories: http://www.epa.gov/waterscience/fish/ Possible uptake by plants.	Be primarily concerned with roots.
Lead	Generally not absorbed or limited to roots.	<ul style="list-style-type: none"> • Be primarily concerned with roots and contaminated soil adhering to lower portion of plant. • Without phosphates, lead can move from roots to plant tissues.
Mercury	Plants tie up mercury in a form that is not readily bioavailable to animals and humans. Mercury bioaccumulates in fish, shellfish and animals eating fish. Fish consumption advisories: http://www.epa.gov/waterscience/fish/	<ul style="list-style-type: none"> • Greatest risks are from contaminated soil particles on plants or from using contaminated plants in sweat lodges where metals may volatilize into the air. • The older and larger the fish are, the more methylmercury they may contain.
Selenium	Biocaccumulates readily; Indicator plants for high selenium concentrations in soils are: milkvetch or locoweed (<i>Astragalus</i>), prince's plume (<i>Stanleya</i>), woody aster (<i>Xylorhiza</i> , sp.) and false goldenweed (<i>Oonopsis</i> , sp.) These plants require high selenium levels to thrive. High concentrations are found in kidney, tuna, crab and lobster. Fish consumption advisories: http://www.epa.gov/waterscience/fish/	Plants under certain conditions (for example high soil concentrations of selenium plus drought) can accumulate higher levels, potentially harmful to humans.
Silver	May be absorbed at low concentrations, but usually does not enter the shoots of plants at levels that would be harmful to people.	

Units of Measurement

1 ppm = 1 part per million \cong 1 milligram/liter (mg/l)

1 ppb = 1 part per billion = 0.001 ppm \cong 1 microgram/liter (μ g/l)

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