



Essentials of
Environmental Health

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Chapter 6
Toxic Metals and Elements

Toxic Metals

- Include:
 - Heavy metals (e.g., lead, mercury, nickel)
 - Other metallic compounds (e.g., aluminum, iron, tin)
- Featured in the CERCLA Priority List of Hazardous Substances

CERCLA Priority List of Hazardous Substances

- The Agency for Toxic Substances and Disease Registry (ATSDR) has identified a list of the top 20 hazardous substances, known as the CERCLA Priority List of Hazardous Substances.
- This list is revised every two years.

Characteristics of Hazardous Substances on the CERCLA Priority List

- Pose the most significant potential threat to human health because they:
 - Have known or suspected toxicity **and**
 - Have potential for human exposure at NPL sites
- A substance can be on the NPL if there is a high frequency of occurrence and potential for human exposure **even if it is not among the most toxic substances.**

Top 20 Hazardous Substances from the 2003 CERCLA Priority List of Hazardous Substances

1. Arsenic
2. Lead
3. Mercury
4. Vinyl chloride
5. Polychlorinated biphenyls
6. Benzene
7. Cadmium
8. Polycyclic aromatic hydrocarbons
9. Benzo(a)pyrene
10. Benzo(b)fluoranthene
11. Chloroform
12. DDT, P, P'
13. Aroclor1254
14. Aroclor260
15. Dibenzo(a,h)anthracene
16. Trichloroethylene
17. Chromium, hexavalent
18. Dieldrin
19. Phosphorus, white
20. Chlordane

National Priorities List (NPL)

- This is the “EPA’s list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund.”
- Sites are scored based on the Hazard Ranking System and updated annually.

Definition: Heavy Metals

- A heavy metal has a high atomic weight with a specific gravity that exceeds the specific gravity of water by five or more times at 4° C.

Classification of Toxic Effects of Metals

- Major toxic metals with multiple effects
- Essential metals with potential for toxicity
- Metals related to medical therapy
- Minor toxic metals

Bioaccumulation

- Toxic substances such as heavy metals become more concentrated and potentially more harmful as they move up the food chain.

Modes of Exposure

- Lungs (through inhalation of dusts, metal fumes, and vapors)
- Skin (through contact with dusts)
- Mouth (by ingestion)

High and Low Level Contacts

- Contact with high concentrations of toxic metals is most likely to occur in an occupational setting, e.g., among persons who work with metals.
- Lower-level exposures may result from contact with the ambient environment (e.g., children may ingest toxic metals present in paint).

Acute Toxic Metal Poisoning

- The symptoms of acute poisoning from exposure to metals generally have rapid onset—from a few minutes to approximately one hour.

Symptoms of Acute Poisoning from Toxic Metals

- Depending upon portal of entry, symptoms may consist of gastrointestinal effects (vomiting and stomach pain) and neurological effects (headaches, suppression of normal breathing, and convulsions).

Symptoms of Long-Term Exposure at Lower Levels

- Reduced cognitive functioning
- Mimicking of chronic disease symptoms

Potential Exposure Media

- Air
- Soil/dust
- Water
- Biota/food

Gender Differences and Heavy Metal Exposure Effects

- The health effects of exposure to heavy metals (e.g., nickel, cadmium, lead, and mercury) are different for women than they are for men.
- These differences have been attributed to hormonal and metabolic processes related to menstruation, pregnancy, and menopause.

Children and Exposure to Heavy Metals

- For fetuses, infants, and children (especially young children), heavy metals are known to present serious hazards, which can include impairment of physical and mental development, damage to internal organs and the nervous system, some forms of cancer, and even mortality.

Children and Exposure to Heavy Metals (continued)

- Nervous system damage
 - Memory impairment
 - Difficulty in learning
 - Range of behavioral problems, such as hyperactivity syndrome and overt aggressiveness

Heavy Metal Exposure among Children Versus Adults

- Because a child's body weight is smaller than that of adults, children consume more food in proportion to their body weight and consequently receive higher doses of heavy metals that may be present in their food.

Fetal Exposure Effects

- Lead and mercury have the capacity to cross the placental barrier, causing potential fetal brain damage.

Major Toxic Metals with Multiple Effects

- Arsenic
- Beryllium
- Cadmium
- Chromium
- Mercury
- Lead
- Nickel

Arsenic

- Varies in toxicity depending upon its chemical form
- Byproduct of refining gold and other metals
- Used in pesticides, wood preservatives, and in manufacturing processes
- Exposure can come from ingestion and inhalation.

Standards for Arsenic

- In 2001, the EPA announced the standard of 10 μg of arsenic per liter of drinking water with the year 2006 set as the compliance date for this standard.
- This standard has been lowered from 50 μg of arsenic per liter of water.

Potential Health Effects of Arsenic Exposure

- Skin, bladder, kidney, and liver cancer when ingested
- Lung cancer when inhaled
- Peripheral vascular disease
- Cerebrovascular disease
- Cardiovascular disease, e.g., hypertensive heart disease
- Diabetes (long-term exposure)
- Adverse pregnancy outcomes--spontaneous abortions, stillbirths, and preterm births

Beryllium

- Used widely in industry because of its special properties (lighter than aluminum and stronger than steel)
- Employees in the metal processing industry most likely to be exposed
- Inhalation is most common method of exposure
- Class A carcinogen

Occupational Exposures to Cadmium

- Occupational exposure to cadmium comes from the production of nickel cadmium batteries, zinc smelting, manufacture of paint pigments, soldering, and from employment in metal factories.

Cadmium and the General Population

- Primary sources of cadmium exposure for the general population are cigarette smoke and dietary cadmium.
- Cadmium bioaccumulates in shellfish and is found in some species of mushrooms.

Effects of Cadmium Exposure

- Osteoporosis in women
- Height loss in men
- Kidney damage
- Elevated blood pressure
- Cardiovascular diseases
- “Itai-Itai” disease

Chromium

- Naturally occurring element in the earth's crust (e.g., in rocks, soils, and materials of volcanic origin)
- Most common forms are:
 - chromium(0)
 - chromium(III): an essential nutrient
 - chromium(VI): classified as a carcinogen

Erin Brockovich

- Advocated for residents of Hinkley, California, against an electric power company accused of contaminating the town's water with chromium

Effects of Hexavalent Chromium(VI) Exposure

- Digestive problems and damage to organs such as the kidney and liver when ingested.
- Produces skin ulcers when applied to the skin.
- Inhaling chromium(VI) in high concentrations may cause respiratory problems, for example, nose bleeds, perforation of the nasal septum, and runny nose.

Mercury

- Naturally occurring metal that is highly toxic
- Released into the environment as a by-product of industrial processes

Exposure to Mercury

- At low levels, mercury represents a hazard to human health because it becomes deposited in the beds of lakes, rivers, and other bodies of water.
- Microorganisms ingest these small amounts of mercury.
- The process of bioaccumulation causes the mercury to become more concentrated in aquatic invertebrates.

Legacy of Mercury Contamination

- Minamata disease
- Water contamination around the New Almaden mine in California

Lead

- Sources of environmental lead include leaded gasoline, tap water from soldered pipes, and painted surfaces in older buildings.
- Another common source of household lead exposure is imported pottery that is used in food service.

Lead Exposure

- Serious central nervous system (CNS) effects and other adverse health consequences occur even when ingested at low levels.
- Lead poisoning is one of the most common environmental pediatric health problems in the United States.

Nickel

- Classified as a heavy metal, nickel is one of the constituents of the earth's crust.
- Human exposure to low levels of nickel is probably universal and unavoidable.
- Employed in the production of many of the appliances and tools that are used in everyday life, such as nickel cadmium batteries.

Effects of Nickel Exposure

- One of the most common reactions to skin contact with nickel is nickel allergy, manifested as contact dermatitis.
- Cardiovascular-related and renal diseases as well as fibrosis of the lungs
- Potential carcinogenic action

Essential Metals with Potential for Toxicity

- Copper, zinc, and iron are essential for human nutrition, but can be toxic if ingested in excessive amounts.
- A narrow range of these essential metals is necessary to maintain health.

Copper and the Environment

- Copper appears in electrical wires, pipes, in combination with other metals to form alloys, as a mildew inhibitor, and as a wood and leather preservative.
- The ATSDR estimates that in the year 2000 alone, approximately 1.4 billion pounds of copper were released into the environment during industrial processing.

Exposure to Copper

- Occurs by inhalation, ingestion of copper-containing foods and water, and direct contact with the skin.
- Small amounts may dissolve into tap water from copper piping, causing copper levels to become more concentrated when the water remains in the pipes overnight.

Effects of Copper Exposure

- Concentrated amounts (far above trace levels) can produce respiratory and gastrointestinal disturbances.
- Respiratory effects from dust include irritation of the respiratory tract (e.g., nose and mouth).
- Very high levels are known to cause liver damage, renal damage, and death.

Zinc

- A frequently occurring element found in the earth's crust, zinc permeates air, soil, water and, to some degree, all foods.
- Used commercially as a coating for rust inhibition, as a component of batteries, and in combination with other metals to make brass, bronze, and other alloys
- A nutritional element that is important for maintaining health

Negative Effects of Excessive Amounts of Zinc

- Consumption of large quantities is associated with gastrointestinal problems such as stomach cramps, nausea, and vomiting.
- Zinc also can cause anemia and damage to the pancreas.
- Breathing high concentrations of zinc in the workplace causes a disease known as metal fume fever. This condition appears to be an immune-mediated response that originates in the lungs.

Iron

- One of the most ubiquitous metals in the earth's crust
- Vital to human health, iron is important to the growth of cells and the transport of oxygen within the circulatory system.

Effects of Excessive Amounts of Iron

- Acute iron intoxication (accidental iron poisoning) is among the most common childhood poisonings.
- Other groups at risk from iron overload (iron toxicity) include adult men and postmenopausal women.

Metals Used in Medical Therapies

- Aluminum
- Bismuth
- Gallium
- Gold
- Lithium
- Platinum

Aluminum

- This silver-white metal is used widely in food and beverage containers, in pots and pans, and in construction sites.
- An ingredient in various medicines and cosmetics, for example, buffered aspirin and antiperspirants
- Concern about possible association with Alzheimer's disease