HEAVY METAL CONTAMINATION

Priya Gupta, K. L. Sharma

ABSTRACT

Heavy metal contaminations that affect human health are mainly associated to metals lead, cadmium, mercury and arsenic. Exposure to these metals can pose serious health hazards. This paper is a review of these health hazards caused by heavy metal contamination and/or poisoning. A treatment review and ways of avoiding heavy metal poisoning.

Keywords: Poisoning, detoxification, chelation, chelating agents, lead, mercury, arsenic, and cadmium.

Abbreviation: The Agency for Toxic Substances and Disease Registry (ATSDR), Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH).
INTRODUCTION

"Heavy metals" are chemical elements with a specific gravity at least 5 times that of water example arsenic (5.7), cadmium (8.65), iron (7.9), lead (11.34), and mercury (13.546) (Lide 1992) (Sp.gravity of water is 1 at 4°C (39°F)

Some heavy metals are nutritionally essential which are trace elements (eg, iron, copper, manganese, and zinc) found in foodstuffs, fruits, and vegetables, and available as multivitamin products commercially (CIS 1999).

Exposure through food, water, air, absorption through the skin in agriculture, pharmaceutical, industrial manufacturing, and housing settings, is common in adults.

- Ingestion.
- Inhalation.
- Absorption via skin/mucous membranes.
- Acute poisoning through materials at work place due to inhalation of vapours, dust, or fume.

Heavy metals become toxic when they are not metabolized by body and accumulate in soft tissues. Heavy metals competing with other ions bind with proteins which lead to impaired enzymatic activity resulting in damage of organs throughout the body.

In children

Ingestion is most common route, (Roberts 1999) occurring through hand-to-mouth activity (contact with contamination soil and objects like dirt or paint chips) (Dupler 2001).

Exposure through radiological procedure, or not administering an appropriate dose during monitoring intravenous (parenteral) nutrition, a broken thermometer (Smith 1997), or a suicide or homicide attempt (Lupton 1985).

Agencies like (ATSDR) The Agency for Toxic Substances and Disease Registry (ATSDR) located in Atlanta, Georgia which is a part of the US. Department of Health and Human Services was established by congressional mandate.

Functions of ATSDR

Assessing the waste sites and providing education and training regarding hazardous substances and providing health information, (ATSDR Mission Statement 2001).

A priority list called "Top 20 Hazardous Substances" was compiled by ATSDR in 2001 in cooperation with the U.S. Environmental Protection Agency.
The heavy metals arsenic (1), lead (2), mercury (3), and cadmium (7) appear on this list.

**Presentation**

Depends on age of the age of the individual, the metal absorbed, and whether this was the result of acute exposure - eg, vapour inhalation, or exposure over a more prolonged period of time.

**Differential diagnosis**

Depends on the symptoms and signs displayed, but may include causes of encephalopathy, dementia, substance abuse and causes of vomiting and diarrhoea.

**Investigations**

Full history of a person that include his professional history, age of residency, source of water if known, examination, FBC and film - basophilic stippling with lead and arsenic poisoning. Anemia which is normochromic or microcytic with lead toxicity. Blood levels monitoring and 24-hour urine collection for lead, mercury and arsenic levels. Long bone X-ray in children - horizontal metaphyseal lines which are lead bands caused by failure of the bones to remodel, not seen in adults. CXR – An injection of mercury may show radiodense pulmonary emboli.

**CADMIUM**

**Occurrence, exposure and dose**

There are numerous sources of exposure to Cadmium but mainly cadmium occurs in ores of zinc, lead, and copper, used as stabilizers in PVC products, colour pigment, several alloys and, in re-chargeable nickel–cadmium batteries, metallic cadmium, anticorrosion agent (cadmiation), as a pollutant in phosphate fertilizers, industrial emissions and the application of fertilizer and sewbage sludge to farm land common source of cadmium exposure. Cigarette smoking is a major source and may cause significant increases in blood cadmium (B-Cd) levels on biologic monitoring. Food is the most important source of cadmium exposure in the general non-smoking population.

Toxicity of cadmium occurs through inhalation and ingestion and rarely occurring through absorption from skin. Cadmium fume fever, an occupational illness occurring during welding due to exposure to fumes. Symptoms occur typically after 12 to 36 hours.

The person with cadmium poisoning presents with:
Metallic taste and increased salivation, nausea, vomiting, diarrhoea, impaired sensation, difficulty breathing, cough, and chest pain.

Poisoning at a complicated stage may include pneumonitis and pulmonary oedema. Chronic exposures causes anemia, renal failure, and emphysema. Treatment is mostly supportive and symptomatic as there is no effective therapy, however some newer chelating agents may help in reducing cadmium levels in body.

**Cadmium laboratory testing**

24-hour urine collection, CBC, clippings of hair and fingernail. Recent exposure can be predicted by blood levels whereas urine levels can predict both recent and earlier exposure (ATSDR). Blood levels of cadmium above 5 mcg/dL and creatinine in urine above 10 mcg/dL suggest cadmium toxicity (Dupler 2001). However, these tests are considered as unreliable by ATSDR.

**MERCURY**

The mercury compound cinnabar (HgS), was used in pre-historic cave paintings for red colours, and metallic mercury/white lead used as cosmetic to lighten skin in ancient Greece. In medicine, as a cure for syphilis, as diuretics [calomel (Hg₂Cl₂)], and mercury amalgam used for filling teeth. Metallic mercury is used in thermometers, barometers and instruments for measuring blood pressure. A major use of mercury is in the chlor-alkali industry, in the electrochemical process of manufacturing chlorine, where mercury is used as an electrode. The largest occupational group exposed to mercury is dental care staff. Inorganic mercury is converted to organic compounds, such as methyl mercury, commonly used for control of fungi on seed grain. The general population is primarily exposed to mercury via food, fish being a major source of methyl mercury exposure, and dental amalgam. Mercury in urine is primarily related to (relatively recent) exposure to inorganic compounds, whereas blood mercury may be used to identify exposure to methyl mercury. The toxic dose for mercury compounds is about 10-50 mg/kg. Ingestion is harmless (a single dose, e.g. broken thermometer causes no problems). It is poorly absorbed from the gut and slowly absorbed through the skin but can cause contact dermatitis.

**Historical incident**
Minamata in Japan, people suffered from chronic mercury poisoning due to pollution from local factory (Minimata disease). Incident occurred in mid-1950s to 1968.

Hatmakers using mercuric nitrate to soften hair of animal hides suffered from disease called 'Mad as a hatter' which results due to mercury poisoning.

**Acute poisoning:**

- An acute pneumonitis (± adult respiratory distress syndrome (ARDS)), flu-like symptoms, irritability, myalgia, gastrointestinal upset, subsequent peripheral neuropathy, hepatic dysfunction or renal failure may develop,

**Chronic poisoning:**

- Headache, Irritability, peripheral neuropathy, personality changes, memory problems, ataxia, coma, respiratory problems (pneumonitis and ARDS), gastrointestinal upset, (abdominal pain, gingivitis and stomatitis, nausea, vomiting), renal problems include acute renal failure, acute tubular necrosis, and nephrotic syndrome

**Treatment**

An intravenous injection of hydrocortisone for the pulmonary complications and chelating agent d-penicillamine in case of inorganic mercury poisoning.

**Mercury laboratory testing**

A 24-hour urine specimen, chest x-rays, abdominal x-rays, blood and urine samples are carried out to reveal exposure to elemental, inorganic mercury, pulmonary embolism, and mercury poisoning in cases if mercury was swallowed. Exposure to methymercury is usually carried out through determination of scalp hair. In case of severe exposure, liver and kidney function tests are important. Levels of mercury in blood should not exceeded 50 mcg/L.

**LEAD**

The most common exposure to lead is through air and due to food which originated from pots used for storage and cooking. Lead acetate was previously used to sweeten port wine. Over 50% of lead emissions are originating from petrol. Exposure to inorganic lead occurs through occupations like mines, smelters, welding of lead painted metal, battery plants, glass industry, where exposure is low.

Airborne lead gets deposited on soil and water thus ultimately reaches human through the food chair and upto 50% inhaled inorganic lead may be absorbed in the lungs. Through food, adults may take up to 10–15% of lead and children
may absorb 50% via GI tract. In blood, lead is bound to erythrocytes and eliminated slowly via urine. Lead also gets accumulated in the skeleton, which is slowly released. Half-life of lead in blood is about 1 month and in the skeleton 20–30 years.

Inorganic lead does not penetrate the blood–brain barrier in adults. The BBB is not fully developed in children hence they are more susceptible to brain damage. Body and cell membrane penetration is possible for organic lead compounds. Tetramethyl lead and tetraethyl lead penetrate the skin easily which may also cross the blood–brain barrier in adults and thus adults may suffer from lead encephalopathy which is result of acute lead poisoning.

Health effects
Symptoms of acute lead poisoning mainly include headache, irritability, and abdominal pain. Lead encephalopathy is mainly characterized by sleeplessness and restlessness. Behaviour disturbances occur in children. Learning and concentration difficulties may also occur in children. Severe cases of lead encephalopathy may include acute psychosis, confusion and reduced consciousness. Long time exposure to lead may cause memory deterioration. Peripheral nerve symptoms occur when blood levels are below 3 μmol/l accompanied with reduced nerve conduction velocity and dermal sensibility. Permanent lesions may occur in case of severe neuropathy, a dark blue lead sulphide line at the gingival margin. Disturbance of haemoglobin synthesis is obvious sign of lead poisoning leading to anemia on a long term exposure.

Lab Testing
Blood testing, if blood lead levels in children are higher than 10 mcg/dL it is of great concern whereas symptoms in adults may not occur until blood lead levels exceed 80 mcg/dL (Dupler 2001). Medical treatment is usually necessary in case of children when their blood lead levels are 45 mcg/dL however, lower levels of 30 mcg/dL in children can cause mental retardation or cognitive and behavioral problems (ATSDR ToxFAQs for Lead). Red blood cells abnormalities (basophilic stippling ) can be detected by a complete blood count (CBC). Lead lines, indication of failure of bone to rebuild can be detected by long-bone x-rays. These band do not indicate lead concentrations but bone abnormalities. This is not showed by adults. Abdominal x-rays may show swallowed objects like paint chips, fishing sinkers, curtain weights, or bullets (Ferner 2001). Measurement of lead in teeth is a less common test. Children with brain-related symptoms should be considered for lead toxicity (ATSDR ToxFAQs for Lead).

ARSENIC

Sources of arsenic poisoning include:
Contaminated drinking water (as above). Some ayurvedic medicines\textsuperscript{[5]} and Chinese herbal medicines, Pesticides, Herbicides. Fungicides. Wood preservatives. Ceramic enamels. Paints. Tobacco (there may be as much as 6 mcg per pack). Burning of fossil fuels as arsenic is a contaminant. In the USA, illicit whiskey (‘moonshine’).\textsuperscript{[6]}

**Occupational exposure can occur in:**

- The smelting industry (arsenic is a byproduct of ores containing lead, gold, zinc, cobalt and nickel). The microelectronics industry (as gallium arsenide). Coal power plants. Manufacture of glass and fireworks. Use of pesticides. Contact with wood treated with arsenic as a preservative.

Fish and seafood, which have organic arsenics are nontoxic and hence are not a source of arsenic poisoning but the long-term exposure with the cutting and burning of wood preserved with copper chrome arsenate leads to elevated blood levels but no signs or symptoms of toxicity.

Concentrations of arsenic or related metabolites in hair, nails, urine, and blood are used as biomarkers of exposure. These are useful indicators of arsenic exposure in the past. If care is taken to avoid external arsenic contamination of the samples. Before urine sampling to check contamination with arsenic, consumption of certain sea food should be avoided as they may confound estimation of inorganic arsenic.

**Acute poisoning**

Arsenic exists in compounds in organic or inorganic form and in three metallic forms, alpha or yellow, beta or black and gamma or grey. Poisoning usually occurs through ingestion, inhalation and dermal absorption. Toxicity of inorganic compounds is more than organic compounds. Least toxic is elemental arsenic. Trivalent arsenic is 60 times more toxic than pentavalent arsenic due to more absorption. Arsine gas is highly toxic.

Arsenic mainly affects cell enzymes which affects metabolism and DNA repair. Arsenic get deposited in many body tissues and excreted through urine.

Arsenic has been used in medicines and pesticides. Arsenic toxic features are similar to other heavy metals mercury and lead. Arsenic is used in production of glass and semiconductors. Arsenic is found in seafood and water supplies.

**Symptoms of Acute poisoning**

Moderate-to-severe abdominal pain, vomiting, encephalopathy which is common in children characterized by delirium, coma, seizure, death, hepatitis, and lethargy caused due to hemolytic anemia.
Chronic poisoning

- Abdominal pain, mild in nature, aggression, antisocial behaviour, headaches., hearing loss, Subfertility, foot drop caused due to motor peripheral neuropathy. Wrist drop that is a late sign, carpal tunnel syndrome, gout, and autonomic dysfunction.

Arsenic laboratory testing

Blood, urine, hair, and fingernails are analysed for arsenic levels. As it clears rapidly from blood it is not such a worth full test (Dupler 2001). Urine tests are most reliable to detect exposure within the past few days while hair and fingernail testing is mostly useful to detect exposure within several months (ATSDR ToxFAQs for Arsenic). Metallic fragments can be revealed by abdominal x-rays (Ferner 2001).

CHELATION THERAPY

Chelation is a chemical process where chelating agent binds to metal and removes it from the tissues ((Dr. Joseph F. Smith Medical Library 2001). Chelation therapy is used in many fields, water purification, medical field for treatment of cardiovascular disease, heavy metal toxicity, and in genetic disorders where metal deposits in the body tissues. Chelating agent is specific for drug used and is given orally, intramuscularly, or intravenously. Once the metal binds to chelating agent and leaves the tissue, it enters the bloodstream from where it is filtered in the kidneys and eliminated through urine (Dupler 2001). A professional consultation is always considered before using chelation therapy along with poison control center or medical toxicologist.

Chelating Agents


PREVENTION OF METAL POISONING

Three agencies within the US that offer guidance and information regarding heavy metal contamination those involving industrial hazards are Occupational Safety and Health Administration (OSHA), National Institute for occupational Safety and Health (NIOSH), and Agency for Toxic Substances and Disease register (ATSDR). native health departments, regional poison management centers, and clinics that concentrate on occupational and environmental health conditions may also offer valuable resources and guidance.
Avoid smoking, eating, or drinking in work areas, appropriate protective clothing should be provided which would remain at the facility and worn only during work in the facility. Showering facilities should be provided. Work clothes and street clothes should not be mixed. Least harmful products should be used. Labels on the product should be read to know the potential hazards. Read labels of products to know potential hazards of products. Products should be stored in original container. Accidental spill or ingestion should be avoided by reading the label every time the product is used. Household chemicals should not be stored in food container even though if it is relabelled.

One should be familiar with symptoms and first aid procedures in case of ingestion of toxic metals. Many herbs and supplements have natural chelating characteristics and properties that help detoxify the body.

**Antioxidants**

Ascorbic acid, vitamin E, and A, alpha-lipoic acid, lactoferrin, glutathione, chemical element and metallic element are necessary antioxidants that aid overall health by increasing protection from oxidative stress.

**Herbs**

Herbs and flavoring extracts have been used and studied for years, particularly in Europe and China (Huang 1993). Many modern medication have been derived either directly or indirectly from flavoring origin. Herbs are often complexed (combined) to assist in blood purification and detoxification (eg, herbaceous plant root, sarsparilla, yellow dock root, licorice, echinacea, garlic, green tea, and cilantro).

Minerals like metal, Essential Amino AcidsL-cysteine and therefore the acetylated kind, N-acetyl-cysteine (NAC), act as antioxidants and liver protectants. Taking ascorbic acid in conjunction with either L-cysteine or NAC will facilitate maintain their powerful free radical-suppressing effects.

**CONCLUSION**

Acute heavy metal toxicity is not of a great concern except for certain groups of people who are at higher risk

- People living in homes that have lead pipes and are painted lead-based paints are exposed to high levels of environmental mercury, iron, or aluminium.
- People working Batteries, pesticides, and fertilizers manufacturing industries.
- People working in metal finishing industries.
- People handling chemical either in chemical laboratories or industries.

Heavy metal exposure can be acute or chronic. Illness may result if toxicities are not recognized and not treated well in time, which may affect quality of life. Testing is necessary and if test indicate positive results, treatment by either
conventional methods or natural medical methods should be considered as early as possible. Many natural chelating,
detoxifying, anti-inflammatory, and antioxidant products can aid in detoxifying the toxic effects of heavy metal.

REFERENCES


