

## Health effects caused by metal contaminated ground water

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### Abstract

The main threats to human health are associated with the exposure to heavy metals like lead, cadmium, zinc, manganese, copper, nickel, chromium, mercury and arsenic. Even though adverse health effect due to heavy metals is known, still exposure continues the same in most of the developing countries. Cadmium found in low concentration in rocks, coal, and petroleum, enters the groundwater and surface water through industrial discharge, metal painting by which it replaces the zinc biochemically in the body and causes high blood pressure, liver and kidney damage and anemia. Cadmium emission is increasing dramatically as it is not recycled and often dumped along with the household waste. The general population is exposed to mercury through food; fish is the major source of methyl mercury exposure and dental amalgam. Lead enters environment from industry, mining and as a water additive; Affects red blood cell chemistry, delays normal physical and mental development in babies and young children, increase in blood pressure in some adults. In ground water used as drinking water, arsenic concentrations ranged from 0.1–1340  $\mu\text{g L}^{-1}$ . Exposure to the arsenic is mainly through food and drinking water which has the high risk of cancer of lung, skin, bladder and kidney, skin lesions such as hyperkeratosis and pigmentation changes.

**Keywords:** heavy metals, health effects, metal toxicity

### 1. Introduction

Heavy metals constitute a very heterogeneous group of elements widely varied in their chemical properties and biological functions. Heavy metals are kept under environmental pollutant category due to their toxic effects on plants, animals and human being. Anthropogenic activities such as mining, smelting operation and agriculture have locally increased the levels of heavy metals such as Cd, Co, Cr, Pb, As and Ni in soil up to dangerous levels. Heavy metals have largest availability in soil and aquatic ecosystems and to a relatively smaller proportion in atmosphere as particulate or vapors. Several heavy metals are considered toxic metals due to adverse human health effects, when taken in excess.

Heavy metal toxicity in plants vary with plant species, specific metal, concentration, chemical form, and soil composition and pH, as many heavy metals are considered to be essential for plant growth few metals like Cu and Zn serve as the co-factor and activators for the enzyme reactions. Some of heavy metal such as Cd, Hg and As etc. are strongly

poisonous to metal sensitive enzymes, resulting in growth inhibition and death of organisms. Heavy metals which are categorized as class B metals that come under non-essential trace elements, which are highly toxic elements such as Hg, Ag, Pb, Ni. These heavy metals are persistent, bio accumulative and do not readily breakdown in the environment or not easily metabolized. Such metals accumulate in ecological food chain through uptake at primary producer level and then through consumption at consumer levels. Heavy metals such as Cd, Ni, As and Cr pose a number of hazards to humans.

Heavy metals are also potent carcinogens. Mercury intake leads to mina Mata disease and Arsenic causes poisoning due to drinking water contamination. The essential heavy metals (Cu, In, Fe, Mn and Mo) play biochemical and physiological functions in plants and animals. Two major functions of essential heavy metals are: (a) Participation in redox reaction, and (b) Direct participation, being an integral part of several enzymes. Vapor form of heavy metals such as As, Cd, Cu, Pb, and Sn

combine with water in the atmosphere to form aerosols. Heavy metal toxicity is reported to increase the activity of enzymes such as, glucose-6-phosphate dehydrogenase and peroxidase in the leaf of plants grown in polluted soil.[2] Mercury, Cu and Zn ions have changed the hydrolytic activity of chlorophylls in rice leaves, with Hg increasing the activity maximally out of the three metals. In drinking water presence of Zn is 5.0 mg/l where as Cd is 0.001mg/l.

## 2. Distribution of Heavy Metals

Heavy metals pose hazards to human health because these are persistent in nature and have accumulation tendency in biological systems. Heavy metals can be divided into four major groups based on their health importance (1) Essential metals such as Cu, Zn, Co, Cr, Mn and Fe, (2) Non-essential metals such as Ba, Al, Li and Zr, (3) less toxic metals such as Sn and As and (4) highly toxic metals such as Hg, Cd and Pb.

### 2.1 Zinc

The recommended Daily Dietary Allowance of Zn is 15 mg for adults and 20 to 25 mg for pregnant and lactating women. Acute Zn toxicity in human includes vomiting, dehydration, drowsiness, lethargy, electrolytic imbalance, abdominal pain, nausea, lack of muscular coordination, and renal failure. Chronic dose of Zn increases the risk of developing anemia, damage to the pancreas, lowers down HDL cholesterol levels and raises LDL cholesterol levels and possibly enhances the symptoms of the Alzheimer's disease. Workers exposed to Zn fumes from smelting or welding have suffered from a short-term illness called metal fume fever.[3-5]

### 2.2 Lead

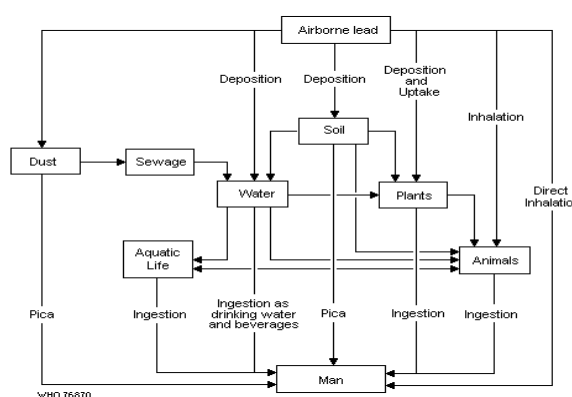
The general population is exposed to Pb from air and food. Children are particularly susceptible to Pb exposure due to high gastrointestinal uptake, and the permeable blood brain barrier leading to neurotoxin effects even at low level of exposure.[4] The toxicity of Pb is caused by its direct interference with activity of different enzymes or displacing essential metal ions from metalloenzymes. The major exposure pathway of inorganic Pb is via ingestion and adsorption through the gastrointestinal tract, respiratory tract and inhalation. Kidney and liver are considered potential targets of Pb toxicity before storage in bones. Depending on the level of exposure, Pb has potential to cause a variety of biological effects such as decreased hemoglobin synthesis, impairment of neurobehavioral and psychological functions, peripheral neuropathy, indirect effect on heart, renal

tubular damage and reproductive problems.[8,9] Plumbism is the main disease caused by exposure to the pollutants of lead. Reticulocyte percentage, stipple cell counts, and polychromatophilia estimations tended to be higher in lead affected men. All three sets of values increased with increasing lead concentration. Albuminuria was twice as frequent among the lead affected group. Severe microcytic hypochromic anemia with low plasma iron and percent iron saturation can be seen in affected children and adults. The total iron binding capacity was lower in the lead poisoning individual. The most noted finding was a great increase in the free erythrocyte protoporphyrin.[6] Reduced glomerular filtration rate can be seen by the urinary excretion of more than 1,000 µg of lead per day. renal biopsies and kidney damage is confirmed by lead nephropathy.[7]

Figure 1: Effect of lead on health



Figure 2: Contribution of airborne lead to total lead intake



### 2.3 Copper

Copper is essential for the formation of enzyme in human beings. Intake of excessively large doses of Cu leads to severe mucosal irritation and corrosion, wide spread capillary damage, hepatic and renal damage and central nervous system irritation followed by depression. [10] Copper toxicity includes blue green diarrhea stool and saliva and acute haemolysis and abnormalities of kidney functions. Wilson's disease is an inborn error of metabolism where the inherited defect lies in the incorporation of

Cu<sup>2+</sup> into apocerplasmin to form ceruloplasmin and also impaired ability of the liver to excrete Cu into the bile which leads to Cu accumulation in tissues of liver, brain, kidney and cornea resulting in organ damage. The safe and adequate daily dietary allowance for Cu is 2 to 3 mg for adults and 1 to 3 mg the children.[4]

#### 2.4 Cadmium

Cadmium (Cd) has been in industrial use for a long period of time. Its serious toxicity moved into scientific focus during the middle of the last century. Food and cigarette smoking are the most important sources of Cd apart from water. Daily dietary intake of Cd ranges from 40 to 50  $\mu\text{g}$  day. Cd accumulates within the kidney and liver over long time. Long-term low-level exposure leads to cardiovascular disease and cancer. It is known to primarily affect renal tubular function of reabsorbing protein, sugar and amino acids. Cadmium exposure in conjunction with Ca, Fe, Zn, protein, fat and vitamin D deficiencies, led to ostomalacia and bone fractures in postmenopausal women in polluted Jintsu valley, Japan commonly referred to as Itai-Itai disease. Cadmium can affect calcium, phosphorus and bone metabolisms in both industrial workers and people exposed to Cd in general Environment. [11-12]

#### 2.5 Nickel

Daily intake of nickel through food is approximately 300 $\mu\text{g}$ . Nickel induces embryo toxic and population from exposure to coins, jewellery, watchcases, clothing and fasteners. It causes conjunctivitis, eosinophilic pneumonitis, asthma and local or system reaction to Ni containing prostheses such as joint replacements, pins, cardiac valve replacements, cardiac pacemaker wires and dental inlays[4]. Nickel is a potential carcinogen for lung and may cause skin allergies, lung fibrosis and cancer of respiratory tract in occupationally exposed populations.[13]

#### 2.6 Arsenic

Arsenic and arsenic containing compounds are human carcinogens. Exposure to arsenic is mainly through intake of food and drinking water, food being the most important source in most populations. Long-term exposure to arsenic in drinking-water is mainly related to increased risks of skin cancer, hyperkeratosis and pigmentation changes. Occupational exposure is by inhalation which causes lung cancer.[14] Intake of 70 to 80 mg of trivalent arsenic (III) oxide has been reported to be fatal for man (WHO, 1987). Inorganic arsenic produces acute, sub acute and chronic toxic effects, which may be either local or system. Acute toxic effects include abdominal cramping, hyperesthesia in extremities,

abdominal patellar reflexes and abdominal electrocardiograms.[16] Such effects generally occur at the levels of exposure equal to 50  $\mu\text{g}$  weight/day. However, chronic poisoning of As includes anemia, liver - and kidney damage, hyper pigmentation and keratosis Le. Skin damage. Other effects of arsenic include peripheral vascular disturbances resulting in gangrene and a disease termed Black foots disease .In groundwater used as drinking water, arsenic concentrations ranged from 0.1–1340  $\mu\text{g L}^{-1}$ , with 37% of the studied wells exceeding the WHO guidelines of 10  $\mu\text{g L}^{-1}$  arsenic. Chronic arsenic poisoning is the most serious health risk for the  $\sim$ 2 million people drinking this groundwater without treatment, followed by malfunction in children's development through excessive manganese uptake. Government agencies, water specialists and scientists must get aware of the serious situation. Mitigation measures are urgently needed to protect the unaware people from such health problems. [15]

#### 2.7 Chromium

Average daily intake of chromium ranges between 100 and 300  $\mu\text{g}$ /day (.). The harmful effects of Cr to human are mostly associated with its hexavalent form. Chromium toxicity includes liver necrosis, membrane ulcers and cause dermatitis by skin contact. Differentiation between the biological effects caused by Cr+6 and Cr+3 is difficult because after penetration through membrane the Cr+6 gets reduced into Cr+3 form. A similar has potent carcinogenic effects on human beings and other animals. [17]

#### 2.8 Mercury

Generally population are not much effected by the methyl mercury, in certain cases high consumption of fish with high mercury concentration may attain blood levels associated with a low risk of neurological damage to adults. The safe daily intake of mercury as suggested by WHO is 43  $\mu\text{g}$ . Since there is the high risk in fetus, pregnant women should avoid high intake of certain fishes like shark, swordfish, tuna fish taken from polluted fresh water.[19] The effect of Hg poisoning depends on its different forms. Maximum toxicity results due to methyl mercury or mercury vapor. Mercury toxicity includes neurological and renal disturbances. Mercury intake led to minimata disease, where liver accumulated substantial amounts of Hg. Fishes's contain more than 0.4 ppm Hg are unfit for human consumption. The critical urinary concentration of Hg has been suggested as 1 to 2  $\mu\text{g/ml}$ . Minimata disease is characterized by symptoms of fatigue, loss of memory and concentration, tremours constriction

of visual field, cortical blindness, etc. Mercury passes through placental barrier and may cause intra-uterine death, fetal resorption and stillbirth. The alkyl derivatives are particularly phototoxic.[18]

### 2.9 Manganese

Mn is an essential nutrient and its daily requirement is estimated to be between 2.5 to 5.0 mg for 310 adults.[4] It is a metal having relatively low toxicity to human being, and causes acute poisoning effect at higher concentrations. The neurological disorder known as manganese results from exposure of Mn dust fume to occupational workers.[19] Effects of Mn are decrease in systolic blood pressure, disturbed excretion of 17-ketosteroids, change in erythropoiesis and granulocyte formation.[20]

## 3. Remediation

- The selection of the most appropriate soil and sediment remediation method depends on the site characteristics, concentration, types of pollutants to be removed, and the end use of the contaminated medium. The approaches include isolation, immobilization, toxicity reduction, physical separation and extraction.
- Many of these technologies have been used full-scale. Contaminants can be isolated and contained to minimize further movement, to reduce the permeability of the waste to less than  $1 \times 10^{-7}$  m/s (according to U.S. guidelines) and to increase the strength or bearing capacity of the waste. Physical barriers made of steel, cement; bentonite and grout walls can be used for isolation and minimization of metal mobility.
- Another method is solidification /stabilization, which contains the contaminants in an area by mixing or injecting agents. Solidification encapsulates contaminants in a solid matrix while stabilization involves formation of chemical bonds to reduce contaminant mobility. Another approach is size selection processes for removal of the larger, cleaner particles from the smaller more polluted ones. To accomplish this, several processes are used.
- They include: hydro cyclones, fluidized bed separation and flotation. Addition of special chemicals and aeration in the latter case causes these contaminated particles to float. Electro kinetic processes involve passing a low intensity electric current between a cathode and an anode imbedded in the contaminated soil. Ions and small charged particles, in addition to water, are transported between the electrodes.
- This technology has been demonstrated in the U.S. full-scale, in a limited manner but in

Europe, it is used for copper, zinc, lead, arsenic, cadmium, chromium and nickel. The duration of time that the electrode remains in the soil and spacing is site-specific. Techniques for the extraction of metals by biological means have been not extensively applied up to this point. The main methods include bioleaching and phytoremediation.

- Bioleaching involves *Thiobacillus* sp. bacteria which can reduce sulphur compounds under aerobic and acidic conditions (pH 4) at temperatures between 15 and 55°C. Plants such as *Thlaspi*, *Urtica*, *Chenopodium*, *Polygonum sachalase* and *Alyssim* have the capability to accumulate cadmium, copper, lead, nickel and zinc and can therefore be considered as an indirect method of treating contaminated soils. This method is limited to shallow depths of contamination.
- Soil washing and in situ flushing involve the addition of water with or without additives including organic and inorganic acids, sodium hydroxide which can dissolve organic soil matter, water soluble solvents such as methanol, nontoxic cations, complexing agents such as ethylene diamine tetraacetic acid (EDTA), acids in combination with complexation agents or oxidizing/reducing agents.
- Research has indicated that biosurfactants, biologically produced surfactants, may also be promising agents for enhancing removal of metals from contaminated soils and sediments. The main techniques that have been used for metal removal are solidification/stabilization, electro kinetics, and in situ extraction. Site characteristics are of paramount importance in choosing the most appropriate remediation method. Phytoremediation and bioleaching can also be used but are not as well developed[21].

## 4. Conclusion

Anthropogenic activities greatly influence the availability of heavy metals in the environment. Since heavy metals are not naturally degraded, they are progressively accumulated in plants and soil. Copper, Fe, Mn and Zn cause growth reductions at high concentrations, whereas Cd, Ni, Pb and Cr cause growth reductions at lower levels of accumulation. Heavy metals interfere with physiological processes such as gaseous exchange, CO<sub>2</sub> fixation, respiration, and nutrient absorption and photosynthetic translocation. Heavy metal uptake is not linear in response to the increasing concentrations. Wide species variations are recorded for the accumulative

efficiency for different heavy metals. The difference in metal accumulation is not correlated with tolerance to the heavy metal. Heavy metals pose a number of hazards to human health. Therefore their concentration in the environment and their effects on human health must be regularly monitored. More researches are required to understand the mechanisms Metal induced defense response at molecular level need to be worked out for understanding the cascade of chemical mechanisms of heavy metal tolerance.

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