

**A REVIEW ON TOXICITY OF MAJOR HEAVY METALS****Pushpraj Singh\*<sup>a</sup> and Babita Kumari<sup>b</sup>**

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**ABSTRACT**

In the recent years, the pollution of the environment by heavy metals has become a crucial problem across the world. Heavy metals consist of a group of metals and metalloids which have atomic density greater than  $4000 \text{ kg m}^{-3}$ . Heavy metals normally occur in nature and play a very important role in various metabolic processes of plants, animals and microorganisms but can become toxic through accumulation in organisms. Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Mercury (Hg) and Lead (Pb) are the most common heavy metals

which can pollute the environment. Heavy metals may gain entrance into the human body through consumption of contaminated drinking water or ingestion of soil or crops grown on contaminated land. Heavy metals such as lead, mercury, cadmium and copper are collective poisons, which causes environmental hazards and are reported to be exceptionally toxic. These metals are important sources of oxidative stress in the cell and play an important role in an etiology of diverse human pathologies such as carcinogenesis. Exposure to heavy metal toxicity leads to brain damage, mental retardation, cerebral palsy, lung cancer, gastrointestinal abnormalities, dermatitis and death of the unborn fetus. Many metals have been shown to directly modify and/or damage DNA by forming DNA adducts that induce chromosomal breaks. The unrestricted access to the dumpsite means that each day, scavengers search for raw materials, much of which eventually finds its way back to neighborhoods as animal feed and even human food. Stray chicken, pigs, goats, dogs and cats

roam the dumpsite eating the toxic matter and becoming vectors of pests and parasites that are eventually transferred to the surrounding home and hence causing diseases to both animals and human beings. This review gives details about some heavy metals and their public health effects.

**KEYWORDS:** Heavy metals, metal toxicity, pollution, environment, drinking water.

## 1. INTRODUCTION

Metals are substances with high electrical conductivity, malleability and luster which voluntarily lose their electrons to form cations. Metals are found naturally in the earth's crust and their compositions vary among different localities, resulting in spatial variations of surrounding concentrations. Metals are found all over the earth including the atmosphere, earth crust, water bodies and can also accumulate in biological organisms including plants and animals. There 35 naturally existing metals, 23 of them have high specific density above  $5\text{g/cm}^3$  with atomic weight greater than 40.04 and are called heavy metals.<sup>[1]</sup> Heavy metals include: Antimony, tellurium, bismuth, tin, thallium, gold, arsenic, cerium, gallium, cadmium, chromium, cobalt, copper, iron, lead, mercury, manganese, nickel, platinum, silver, uranium, vanadium and zinc. Heavy metals are not just popular because of their specific high densities, they are also importantly known for their adverse effect on the ecosystem and living organisms. Heavy metals are essential nutrients that are needed for various physiological and biochemical functions in the body and may lead to various deficiency diseases or syndromes if not available in adequate amounts but when present in large doses they may result to acute or chronic toxicities. In the recent years, heavy metal pollution has become a crucial problem across the world. For ecological, evolutionary, nutritional and environmental reasons, Heavy metals are important environmental pollutants and their toxicity is a problem of flourishing significance.<sup>[2]</sup> Heavy metals gain access into the environment by natural means and through human activities. Soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops, and many others are peculiar sources of heavy metals.<sup>[3]</sup> Bioaccumulation of heavy metals develops as a result of different processes causing negative effects. These heavy metals are conveyed and compartmentalized into body cells and tissues binding to proteins, nucleic acids destroying these macromolecules and disrupting their cellular functions in the human body.<sup>[4]</sup> The oxidative deterioration of biological macromolecules has been found by research to be primarily due to binding of heavy metals to

the DNA and nuclear proteins.<sup>[5]</sup> Heavy metal toxicity in essence, can have several repercussions in the human body. The central nervous function can be affected leading to mental disorder, damage the blood constituents and may damage the lungs, liver, kidneys and other vital organs promoting several disease conditions.

This review focuses on the varied sources of heavy metals and the processes that encourage their exposure and bioaccumulation in the human body. It will also focus on the metabolism and mechanisms that leads to heavy metal toxicity. Toxic effects, signs and symptoms of heavy metals on human body will be discussed.

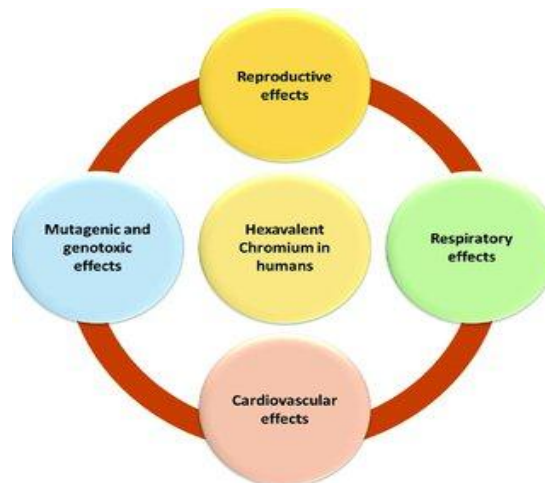
## **2. Heavy Metal Sources and their Toxicological Effects**

Metals has important role in biological systems because a living cell cannot exist without metal ions. There are several heavy metals that are important for human health and many of them like Zn, Cu, Ni, Fe and Mn are essential metal ions for living organisms in trace amount. However, if metals accumulate at high level or are ingested in large amounts, they can cause serious health problems.<sup>[6-7]</sup>

### **2.1. Chromium (Cr)**

Chromium (Cr) is popularly known as the two-faced metal, its ability to be of advantage or disadvantage humans and animals largely depends on its oxidation state and concentration. Chromium, which mostly originates from several industries, occurs in different oxidation states but Cr (III) and Cr (VI) are the most significant. Cr (III) is regarded a trace element vital for proper functioning of living organisms.<sup>[8]</sup> It is broadly used in industries such as electroplating, paint and pigment manufacturing, textile, fertilizer and leather tanning. Most of these industries indiscriminately expel trivalent and hexavalent chromium with waste effluent to the soil and surface water. Hexavalent chromium is acutely toxic, mutagenic, and carcinogenic. Additionally, Cr (VI) is soluble in nature which makes it highly mobile in most environments. In spite of the heavy metals being acutely toxic to most microbes, there are metal-tolerant bacteria. In the aspect of nutrition, at reduced concentrations, Cr (III) is a valuable component of a much-needed human and animal diet for impeding negative effects in the metabolism of glucose and lipids, example, impaired glucose tolerance, increased fasting insulin, increased cholesterol and triglycerides, and hypoglycemic symptoms. Cr (III) at huge concentrations can interfere with several metabolic processes due to its high capacity to coordinate numerous organic compounds leading to inhibition of some metal-enzyme systems.<sup>[9]</sup> Hexavalent chromium is known to have carcinogenic and mutagenic properties

affecting mammals including human beings. Chromium causes cancer of bladder, allergic dermatitis and nasopharyngeal cancer.<sup>[10]</sup> Schroeder *et al* revealed that cigarettes contained 390 g/kg of Cr, but there has been no concrete report published on the quantity of chromium inhaled through smoking.<sup>[11]</sup> When injured skin comes in contact with any type of chromium compounds, a deeply penetrating hole will be formed. Exposure to chromium compounds can result in the formation of ulcers, which will persist for months and heal very slowly. Ulcers on the nasal septum are very common in case of chromate workers. Humans, being exposed to considerably huge amounts of chromium compounds can bring about the inhibition of erythrocyte glutathione reductase, which as a result, lowers the capacity to reduce methemoglobin to hemoglobin. Conclusion gotten from different *in vitro* and *in vivo* experiments have shown that chromate compounds can incite DNA damage in many different ways and can lead to the development of DNA adducts, chromosomal aberrations, sister chromatid exchanges, alterations in replication and transcription of DNA.<sup>[12]</sup>



**Fig 1: Health Effects of Chromium.**

## 2.2. Zinc (Zn)

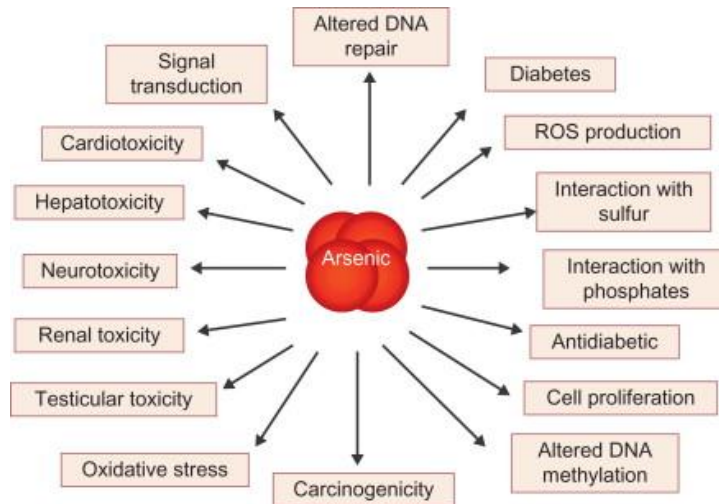
Zinc (Zn) is a member of group II-B of the periodic table and it is relatively abundant. Zn is a bluish-white lustrous metal and is averagely reactive. It combines with oxygen and other non-metals. The well-known oxidation state of zinc is  $Zn^{2+}$ . Zn is frequently used in corrosion-resistant steel coatings, brass alloys, paint pigments, wood preservatives, dry-cell batteries, cosmetics and pharmaceuticals.<sup>[13]</sup> Large quantity of Zn has found various applications in the industries such as the production of die-castings, which promotes its release to the atmosphere, water and soil. Major sources of Zn contamination in the environment are industrial wastes, metal plating and acid mine drainage. Zn is a vital trace element required

for life of animals, plants and bacteria. It is noticed that human proteins contain Zn which portrays a valuable role in the catalytic activity of proteins. This crucial trace metal is used in several biological processes, is valuable for the proper maturation of sex organs and bone growth, most importantly in the fetuses. On the other hand, Zn at elevated levels becomes injurious to health.<sup>[14]</sup> Evidence portraying Zn deficiency in animals are as follows; hair loss, skin lesions, diarrhea and growth depression. Typical indications of zinc deficiency in plants are interveinal chlorosis, impaired growth, and malformation of stems and leaves. Despite Zn being an essential element, excess of this metal causes reduced weight in animals, reduced iron function, impaired immune system, and nausea. High concentrations of Zn can also interact with thiols and block essential reaction on the cell.<sup>[15]</sup>

### 2.3. Arsenic (As)

Arsenic (As) is an element of group V-A of the periodic table. It is a very poisonous metalloid; it is chemically very similar to phosphorus and forms colorless crystalline oxides like  $As_2O_3$  and  $As_2O_5$  readily soluble in water. Arsenic compounds have various applications such as insecticides, example, lead hydrogen arsenate, Scheele's green and more recently monosodium methyl arsenate. Arsenic has application in pyrotechnics, in bronzing and for hardening other metals. Other current uses include doping agent in solid-state devices and as a laser material (gallium arsenide) to change electricity into coherent light. Arsenic is gotten naturally and artificially as a result of weathered volcanic rocks, fossil fuels, agricultural chemicals, wood preservatives, medicinal products and industrial activities.<sup>[16]</sup> Arsenic pollution of the environment stems from the use of herbicides, fungicides and fertilizers. Arsenite and arsenate are examples of inorganic arsenic that has been disclosed to be threatening to the general wellbeing of humans.<sup>[17]</sup> They are known to be extremely carcinogenic and can lead to malignant growth of lungs, liver, bladder and skin. Arsenic gains access into the human body system through air, food and water. Portable drinking water soiled with arsenic is part of the critical reasons for arsenic detrimental effects in excess of 30 nations on the planet Earth. Cases whereby the arsenic level in ground water is 10-100 times above the value provided in the WHO guideline for drinking water (10  $\mu\text{g/L}$ ), it can be injurious to human health.<sup>[18]</sup> Contamination of water may occur through indiscriminate disposal of arsenical chemicals, arsenical pesticides or by natural mineral deposits. Arsenic toxicity can be either acute or chronic. Chronic arsenic toxicity is known as arsenicosis. Majority of the research on chronic arsenic toxicity in man is focused on its effect on the skin because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions

that show chronic arsenic toxicity. Although arsenic is highly toxic and cancer-causing, a few forms of this element have been adapted in the treatment of some diseases namely syphilis and cancer.<sup>[19]</sup>



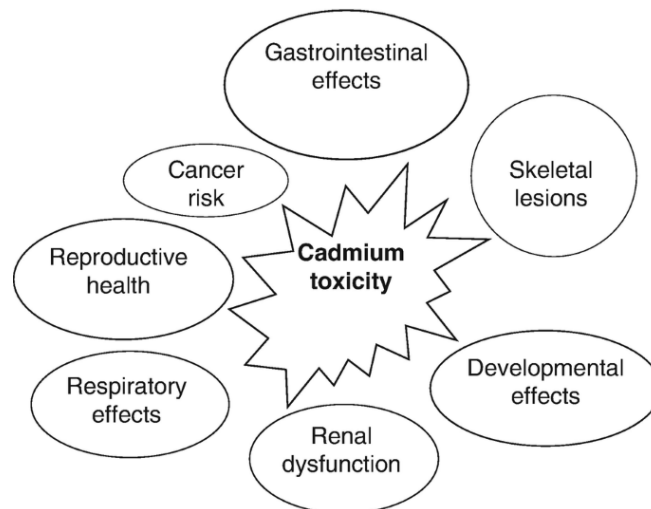
**Fig 2: Health Effects Arsenic.**

#### 2.4. Cadmium (Cd)

Cadmium (Cd) is a member of group II-B of the periodic table and is a nearly uncommon metal which makes it rare in most natural soil and water. The production of this metal has increased expeditiously in the past few years. Cadmium is major component in semiconductors, nickel-cadmium batteries, electroplating, PVC, various alloys, pigments and control rods for nuclear reactors. Contamination of soil and water by Cadmium originates from mining and smelting industries, atmospheric pollution, sewage sludge application and burning of fossil fuels.<sup>[20]</sup> Symptoms characterized by the diseases caused by cadmium are bone pain, pathological fractures and signs of renal impairment. Cadmium toxicity targets organs such as liver, placenta, kidneys, lungs, brain and bones. Various researches on humans and animals have disclosed that osteoporosis (skeletal damage) is a significant effect of human exposure to cadmium together with disruptions in calcium metabolism, formation of renal stones and hypercalciuria. Depending on the severity of exposure, the symptoms of effects include nausea, vomiting, abdominal cramps, dyspnea and muscular weakness. Severe exposure may result in pulmonary oedema and death. Pulmonary effects (emphysema, bronchiolitis and alveolitis) and renal effects may occur following sub chronic inhalation exposure to cadmium and its compounds.<sup>[21,22]</sup> Cadmium and its compounds are highly water soluble in comparison to other metals. Their bioavailability is very high and hence it tends to bioaccumulate. Long-term exposure to cadmium can result in morphopathological changes in



the kidneys. Smokers are more susceptible for cadmium intoxication than non-smokers. Presence of cadmium in smokers is as a result of tobacco. Tobacco plants, like other plants, have the ability to accumulate cadmium from the soil. Non-smokers are exposure is through food and some other pathways. Still, cadmium uptake through other pathways is much lower.<sup>[23]</sup> Cd is also affiliated with a disease called Itai-Itai, meaning “it hurts” in Japanese. Many clinical conditions namely; anosmia, cardiac failure cancers, cerebrovascular infarction, emphysema, osteoporosis, proteinuria cataract formation in the eyes have been more or less affiliated with cadmium. Cadmium interacts with essential nutrients through which it causes its toxicity effects. Experimental analysis in animals has shown that 50% of cadmium gets absorbed in the lungs and less in the gastrointestinal tract. Premature birth and reduced birth weights are the issues that arise if cadmium exposure is high during human pregnancy.<sup>[24]</sup>

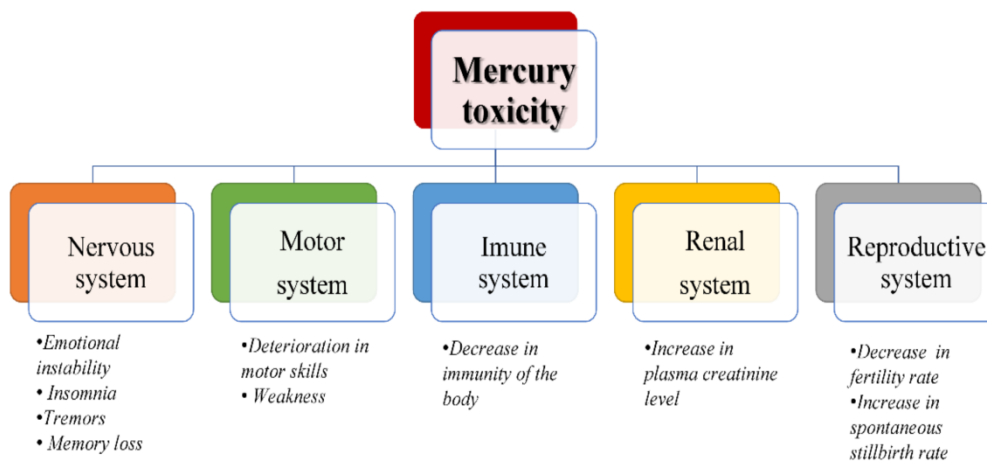


**Fig 3: Health Effects of Cadmium.**

### 2.5. Mercury (Hg)

Mercury is considered the most toxic heavy metal in the environment. Mercury poisoning is referred to as acrodynia or pink disease. Mercury is released into the environment through the daily running of various industries such as pharmaceuticals, paper and pulp preservatives, agriculture industry, and chlorine and caustic soda production industry.<sup>[25]</sup> Organic and inorganic mercury can be produced through its capability to combine with other elements. Continuous exposure to increased levels of metallic, organic and inorganic mercury can maim the brain, kidneys and the developing fetus.<sup>[26]</sup> Mercury is present in most foods and beverages in the range <1 to 50 µg/kg. In marine foods it is often seen at higher levels. Organic mercury can easily permeate across the bio membranes and since they are lipophilic

in nature, mercury is present in higher concentrations in most species of fatty fish and in the liver of lean fish. Micro-organisms convert the mercury present in soil and water into methyl mercury, a toxin which can accumulate with fish age and with increasing trophic levels. EPA has declared mercuric chloride and methyl mercury to be highly carcinogenic. The nervous system is very sensitive to all types of mercury. Increased exposure of mercury can alter brain functions and lead to shyness, tremors, memory problems, irritability, and changes in vision or hearing. Exposure to metallic mercury vapors at higher levels for shorter periods of time can lead to lung damage, vomiting, diarrhea, nausea, skin rashes, increased heart rate or blood pressure. Symptoms of organic mercury poisoning include depression, memory problems, tremors, fatigue, headache, hair loss, *etc.* Since these symptoms are common also in other conditions, it may be difficult to diagnose such cases. Due to the excess health effects associated with exposure to mercury, the present standard for drinking water has been set at lower levels of 0.002 mg/L and 0.001 mg/L by the Environmental Protection Act and World Health Organization.<sup>[27]</sup>



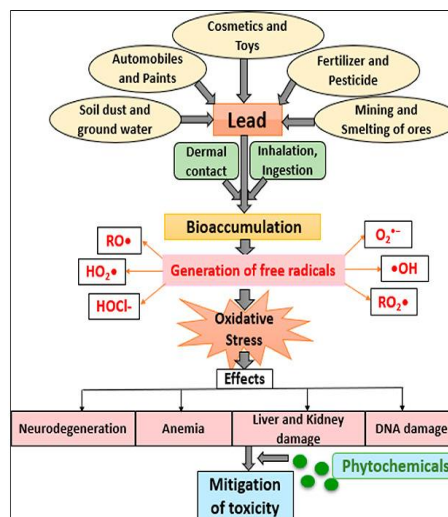
**Fig 4: Health Effects of Mercury.**

## 2.6. Lead (Pb)

Lead (Pb) is a member of carbon family (IV-A) of periodic table and it is biologically non-essential. This metal is a notable pollutant that is found in soil, water and air as a hazardous waste. It is highly toxic to human, animals, plants and microbes.<sup>[28]</sup> The notable sources of lead are petroleum, electronic industries, battery, paint, stained glass and biocide preparation. The use of leaded gasoline in cars is one of the major sources of Pb pollution in metropolis around the world. According to research, an estimated value of over a thousand tons Pb is produced by road traffic each year, as a result of lead additives in petrol. Soils, plants and



food are major receptacles for these atmospheric emissions. Only 3% of Pb in soil is translocated through the root to the shoot of plants while the rest is through foliage. Research on smoked fish food exposed to highways indicated a relationship between the vehicular traffic volume and the fish Pb levels<sup>[29]</sup> which is a potential threat to the health, security and safety of such food items. Lead is one of the dangerous heavy metals found in environment. This metal affects systems of the human body. Lead on low doses cause developmental disorder in fetuses, infants and young children, brain damage, respiratory problems, intoxication of central nervous system and male infertility.<sup>[30]</sup> Lead toxicity is targeted towards the memory and learning processes of the brain and can be mediated through three processes. Lead can impair learning and memory in the brain by inhibiting the N-methyl-d-aspartate receptor (NMDAR) and can block neurotransmission by inhibiting neurotransmitter release, block the neuronal voltage-gated calcium ( $\text{Ca}^{2+}$ ) channels (VGCCs) and reduce the expression of brain-derived neurotrophic factor (BDNF).



**Fig 5: Health Effects of Lead.**

### 3. CONCLUSION

In this survey, we evaluated the impacts of some heavy metals, for example arsenic, lead, mercury, cadmium, chromium, aluminum and iron, on nature and living life forms, for the most part humans. Effective laws, rules and discovery of the territories where there are more elevated levels of heavy metals are fundamental. Inability to control the presence of heavy metals will bring about extreme inconveniences in future due to the unfriendly impacts forced by them. Work related presentation to heavy metals can be diminished by creating working solutions. Monitoring the exposure and probable intervention for reducing additional

exposure to heavy metals in the environment and in humans can become a momentous step towards prevention. National as well as international co-operation is vital for framing appropriate tactics to prevent heavy metal toxicity.

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