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Heavy metal toxicity of drinking water: A silent killer

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Abstract

Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning.

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms. These metals are essential to maintain various biochemical and physiological functions in living organisms when in very low concentrations, however they become noxious when they exceed certain threshold concentrations. The most commonly found heavy metals in waste water include arsenic, cadmium, chromium, and copper, lead, nickel, and zinc, all of which cause risks for human health and the environment. Heavy metals enter the surroundings by natural means and through human activities. Various sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops etc.

Some heavy metals, i.e. arsenic, lead, mercury, cadmium, chromium, aluminium causes drastic harmful effect on the environment and living organisms, mainly human beings.

Keywords: Heavy metals; Toxicity; Water pollution; Cadmium toxicity; Arsenic; Mercury; Chromium

1. Introduction

Water pollution occurs when harmful substance like chemicals or microorganism contaminate a stream, river, lake, ocean, underground water, or other body of water, hence degrading water quality and rendering it toxic to humans or the environment.

According to the most recent surveys on national water quality from the Environmental Protection Agency (EPA), nearly half of the rivers and streams and more than one-third of lakes are polluted and unfit for swimming, fishing, and drinking even in developed countries and situation is even worst in developing countries contribute Major share of toxins to the water bodies is contributed by municipal and industrial waste discharges , besides the random junk that industry and individuals dump directly into waterways.

When contamination originates from a single source, it's called point source pollution, like wastewater (also called effluent) discharged legally or illegally by a manufacturer, oil refinery, or wastewater treatment facility, as well as contamination from leaking septic systems, chemical and oil spills, and illegal dumping. The EPA regulates point source pollution by establishing limits on what can be discharged by a facility directly into a body of water. While point source pollution originates from a specific place, it can affect miles of waterways and ocean.

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Used water is wastewater. It comes from our sinks, showers, and toilets inform of sewage and from commercial, industrial, and agricultural activities as toxic sludge having metals and solvents etc.

According to the United Nations, More than 80 percent of the world's wastewater flows back into the environment without being treated or reused and this figure tops to 95 percent in some least-developed countries.

To put it bluntly it can be said that Water pollution kills. In fact, it causes millions of deaths each year globally. Contaminated water can also make you ill. Every year, unsafe water sickens about 1 billion people. And low-income communities are disproportionately at risk because their homes are often closest to the most polluting industries.

Waterborne pathogens, in the form of disease-causing bacteria and viruses from human and animal waste, are a major cause of illness from contaminated drinking water. Diseases spread by unsafe water include cholera, giardia, and typhoid, salmonellosis, or shigellosis dysentery, hepatitis etc. Even in wealthy nations, accidental or illegal releases from sewage treatment facilities, as well as runoff from farms and urban areas, contribute harmful pathogens to waterways. Millions of people across the world are sickened every year by severe water borne diseases. While acute illnesses like diarrhea, dysentery, cholera, hepatitis A, typhoid can manifest early due to their symptoms and public at large and health care providers are to some extent are aware of these contaminations, it is the heavy metal toxicity which is becoming a silent killer and major cause of morbidity and mortality to vast number of humanity with the passing time as the symptoms appear late and patients present in advance stage of disease.

Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. The toxic effects of these metals, even though they do not have any biological role, remain present in some or the other form harmful for the human body and its proper functioning.

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms. These metals are essential to maintain various biochemical and physiological functions in living organisms when in very low concentrations, however they become noxious when they exceed certain threshold concentrations. Although it is acknowledged that heavy metals have many adverse health effects and last for a long period of time, heavy metal exposure continues and is increasing in many parts of the world. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons. The most commonly found heavy metals in waste water include arsenic, cadmium, chromium, and copper, lead, nickel, and zinc, all of which cause risks for human health and the environment. Heavy metals enter the surroundings by natural means and through human activities. Various sources of heavy metals include soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff, sewage discharge, insect or disease control agents applied to crops etc.

These metals bind with protein sites which are not made for them by displacing original metals from their natural binding sites causing malfunctioning of cells and ultimately toxicity.

2. Effects of heavy metals on humans

There are 35 metals that are of concern for us because of residential or occupational exposure, out of which 23 are heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc. These heavy metals are commonly found in the environment and diet. In small amounts they are required for maintaining good health but in larger amounts they can become toxic or dangerous. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long-term exposure can lead to gradually progressing physical, muscular, and neurological degenerative processes that imitate diseases such as multiple sclerosis, Parkinson's disease, Alzheimer's disease and muscular dystrophy. Repeated long-term exposure of some metals and their compounds may even cause cancer. The toxicity level of a few heavy metals can be just above the background concentrations that are being present naturally in the environment. Hence thorough knowledge of heavy metals is rather important for allowing to provide proper defensive measures against their excessive contact.

2.1. Arsenic

Arsenic contaminations have occurred as a result of both natural geologic processes and the activities of man. Anthropogenic sources of arsenic include human activities such as mining and processing of ores. The smelting process, both the ancient and a recent one, can release arsenic to the air and soil. Such types of sources can affect the quality of surface water through groundwater ejection and runoff. Another way of ground water contamination is through geologic sources such as arsenic minerals. Most of the paints, dyes, soaps, metals, semi-conductors and drugs contain arsenic. Certain pesticides, fertilizers and animal feeding operations also release arsenic to the environment in higher amounts. The inorganic forms of arsenic such as arsenite and arsenate are found to be more dangerous to human health. They are highly carcinogenic and can cause cancer of lungs, liver, bladder and skin. Humans are exposed to arsenic by means of air, food and water. Drinking water contaminated with arsenic is one of the major causes for arsenic toxicity in more than 30 countries in the world. If the arsenic level in ground water is 10–100 times the value given in the WHO guideline for drinking water (10 μg/L), it can be a threat to human health. Water may get contaminated through improperly disposed arsenical chemicals, arsenical pesticides or by natural mineral deposits. Arsenic toxicity can be either acute or chronic and chronic arsenic toxicity is termed as arsenicosis. Most of the reports of chronic arsenic toxicity in man focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic arsenic toxicity.

2.2. Lead

Human activities such as mining, manufacturing and fossil fuel burning has resulted in the accumulation of lead and its compounds in the environment, including air, water and soil. Lead is used for the production of batteries, cosmetics, metal products such as ammunitions, solder and pipes, *etc.* Lead is highly toxic and hence its use in various products, such as paints, gasoline, *etc.*, has been considerably reduced nowadays. The main sources of lead exposure are lead based paints, gasoline, cosmetics, toys, household dust, contaminated soil, industrial emissions. Lead poisoning was considered to be a classic disease and the signs that were seen in children and adults were mainly pertaining to the central nervous system and the gastrointestinal tract. Lead poisoning can also occur from drinking water. The pipes that carry the water may be made of lead and its compounds which can contaminate the water. According to the Environmental Protection Agency (EPA), lead is considered a carcinogen. Lead has major effects on different parts of the body. Lead distribution in the body initially depends on the blood flow into various tissues and almost 95% of lead is deposited in the form of insoluble phosphate in skeletal bones. Toxicity of lead, also called lead poisoning, can be either acute or chronic. Acute exposure can cause loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations and vertigo. Acute exposure mainly occurs in the place of work and in some manufacturing industries which make use of lead. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death. Although lead poisoning is preventable it still remains a dangerous disease which can affect most of the organs. The plasma membrane moves into the interstitial spaces of the brain when the blood brain barrier is exposed to elevated levels of lead concentration, resulting in a condition called edema. It disrupts the intracellular second messenger systems and alters the functioning of the central nervous system, whose protection is highly important.

2.3. Mercury

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 by the activities of various industries such as pharmaceuticals, paper and pulp preservatives, agriculture industry, and chlorine and caustic soda production industry. Mercury has the ability to combine with other elements and form organic and inorganic mercury. Exposure to elevated levels of metallic, organic and inorganic mercury can damage the brain, kidneys and the developing fetus. 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 biomembranes 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.

2.4. Cadmium

Cadmium is a metal of the 20th century. It is a byproduct of zinc production. Soils and rocks, including coal and mineral fertilizers, contain some amount of cadmium. Cadmium has many applications, *e.g.* in batteries, pigments, plastics and metal coatings and is widely used in electroplating. Cadmium and its compounds are classified as Group 1 carcinogens for humans by the International Agency for Research on Cancer. Cadmium is released into the environment through natural activities such as volcanic eruptions, weathering, river transport and some human activities such as mining, smelting, tobacco smoking, incineration of municipal waste, and manufacture of fertilizers. Although cadmium emissions have been noticeably reduced in most industrialized countries, it is a remaining source of fear for workers and people living in the polluted areas. Cadmium can cause both acute and chronic intoxications. Cadmium is highly toxic to the kidney and it accumulates in the proximal tubular cells in higher concentrations. Cadmium can cause bone mineralization either through bone damage or by renal dysfunction. Studies on humans and animals have revealed that osteoporosis (skeletal damage) is a critical effect of cadmium exposure along with disturbances in calcium metabolism, formation of renal stones and hypercalciuria. Inhaling higher levels of cadmium can cause severe damage to the lungs. If cadmium is ingested in higher amounts, it can lead to stomach irritation and result in vomiting and diarrhea. On very long exposure time at lower concentrations, it can become deposited in the kidney and finally lead to kidney disease, fragile bones and lung damage. Cadmium and its compounds are highly water soluble compared 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. Tobacco is the main source of cadmium uptake in smokers as tobacco plants, like other plants, can accumulate cadmium from the soil. Non-smokers are exposed to cadmium via food and some other pathways. Premature birth and reduced birth weights are the issues that arise if cadmium exposure is high during human pregnancy.

2.5. Chromium

Chromium is present in rocks, soil, animals and plants. It can be solid, liquid, and in the form of gas. Chromium compounds are very much persistent in water sediments. They can occur in many different states such as divalent, four-valent, five-valent and hexavalent state. Cr (VI) and Cr (III) are the most stable forms and only their relation to human exposure is of high interest. Chromium (VI) compounds, such as calcium chromate, zinc chromates, strontium chromate and lead chromates, are highly toxic and carcinogenic in nature. Chromium (III), on the other hand, is an essential nutritional supplement for animals and humans and has an important role in glucose metabolism. The uptake of hexavalent chromium compounds through the airways and digestive tract is faster than that of trivalent chromium compounds. Occupational sources of chromium include protective metal coatings, metal alloys, magnetic tapes, paint pigments, rubber, cement, paper, wood preservatives, leather tanning and metal plating. It has been reported that cigarettes contained 390 g/kg of Cr, but there has been no significant report published on the amount of chromium inhaled through smoking. When broken 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. Exposure to higher amounts of chromium compounds in humans can lead to the inhibition of erythrocyte glutathione reductase, which in turn lowers the capacity to reduce methemoglobin to hemoglobin. Results obtained from different *in vitro* and *in vivo* experiments have shown that chromate compounds can induce DNA damage in many different ways and can lead to the formation of DNA adducts, chromosomal aberrations, sister chromatid exchanges, alterations in replication and transcription of DNA.

2.6. Aluminium

Aluminium is the third most common element found on the earth's crust. The main routes of aluminium consumption by humans are through inhalation, ingestion and dermal contact and sources of exposure are drinking water, food, beverages, and Aluminium containing drugs. Aluminium is naturally present in food. Aluminium and its compounds are poorly absorbed in humans, although the rate at which they get absorbed has not been clearly studied. Symptoms that indicate the presence of higher amounts of Aluminium in the human body are nausea, mouth ulcers, skin ulcers, skin rashes, vomiting, diarrhea and arthritic pain. Aluminium exposure is probably a risk factor for the onset of Alzheimer disease (AD) in humans, as hypothesized by the WHO. Contact dermatitis and irritant dermatitis were seen in persons who were exposed to aluminium in their place of work. Aluminium showed adverse effects on the nervous system and resulted in loss of memory, problems with balance and loss of co-ordination. People suffering from kidney diseases find it difficult to eliminate aluminium from the body, resulting in aluminium accumulation in the body leading to bone and brain damage. Some factors that would likely be the reason for the development of aluminium toxicity are life in dusty environments, long-term intravenous nutrition, and diminished kidney function, hemodialysis, drinking or ingesting substances that are high in aluminium content, working in an environment that contains high levels of aluminium. Higher levels of aluminium exposure can change the evolution of secondary hyperparathyroidism, leading to other diseases such as aluminium-induced a dynamic bone disease and aluminium-induced osteomalacia, both of which are characterized by low-bone remodeling. Some of the other complications associated with aluminium toxicity are lung problems, anemia, impaired iron absorption, nervous system problems, *etc*.

3. Conclusion

Hence it is concluded that some heavy metals, i.e. arsenic, lead, mercury, cadmium, chromium, aluminium causes drastic harmful effect on the environment and living organisms, mainly human beings. Effective legislation, guidelines and detection of the areas where there are higher levels of heavy metals contamination are necessary. Failure to control the exposure will result in severe complications in the future because of the adverse effects imposed by heavy metals. 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 of potentially killer diseases and safety of humanity at large.

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