Chapter

Heavy Metal Sources and Their Effects on Human Health

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Abstract

Heavy metals are defined in many ways, based on various factors such as density and atomic weight. Some of the heavy metals are essential as nutrients for humans such as iron, cobalt and, zinc in small quantities but are toxic in higher quantities. But few metals, such as lead, cadmium and, mercury are poisonous even in small quantities. The toxicity of heavy metals is depending on concentration,period of exposure and route of exposure. Heavy metal exposure takes place on human beings through inhalation from the atmosphere, intake through drinking water and, ingestion through the skin by dermal contact. The present chapter describes the definition of heavy metals, sources of these heavy metals, toxicity and, their impact on various environmental segments, such as air, water and, soil.

Keywords: heavy metals, heavy metal toxicity, sources, exposure, environmental impacts

1. Introduction

Heavy metals, the name has so many definitions based on various parameters. Based on density the metals which are having a density values greater than 5 g/cm^3 are considered as heavy metals [1]. According to this study, the heavy metals which would consider as most threat to human beings are lead, cadmium, mercury, and arsenic. Duffs [2] reviewed the usage of the term heavy metals from the history and finally, he concluded that using the term "heavy metals" is meaningless. He established that there is no relation between the density of the metal and to the usage of the term. In the case of heavy metals, metalloid arsenic also included, from this the term heaviness means may be toxicity.

Some of the heavy metals are having so much of biological importance in trace amounts [3] particularly the elements that are present in the 4th period in the modern periodic table. The biological importance of these metals is enzyme functioning (vanadium and manganese), hormone functioning, production (selenium), cellular growth (nickel), and metabolic growth (arsenic). But these metals are required for the human in trace amounts only if their amount in the body increases they cause adverse effects on human health. Overall the heavy metal should be considered as having high density and also biological importance in trace amounts.

There is a lot of importance for the determination of heavy metals in the various environmental segments, such as air, water, and soil due to their carcinogenic and toxic nature. The IARC (International Agency for Research on Cancer) declared arsenic, hexavalent chromium, cadmium, and nickel and their compounds as

group 1 carcinogens (proven carcinogens). Arsenic and their compounds cause urinary bladder, liver, and lung cancers. Hexavalent chromium causes lung cancer and nickel and its compounds cause nasal cavity and lung cancers. All these elements cause cancers to human beings by the route of exposure is through inhalation and ingestion [4]. Regarding the availability of various heavy metals in the earth's crust is about 5%, among which iron occupies nearly 95% [5].

Due to their toxicity and carcinogenic nature, most of the researchers all over the world are reported about the determination and health implications of heavy metals in the environment. Some of them are discussed hereunder.

Jyothi and Mohamed Farook [6] reported the sources, exposure, and toxicity of mercury. Suvarapu et al. [7] reviewed the heavy metal concentrations in ambient air. This study is limited to the estimation of toxicity of heavy metals in the Indian atmosphere and another study [8] they reviewed the heavy metal determination in ambient air all over the world. Kim et al. [9] reviewed heavy metal toxicity and chelating therapeutic strategies. Giller et al. [10] reviewed the toxicity of heavy metals in microorganisms in agricultural soils. This study found that the microorganisms in soil are much sensitive to heavy metal toxicity than animals and plants. Yabe et al. [11] summarized heavy metal pollution and its impact on the environment and the human population in Africa. Das et al. [12] reviewed the toxicity of cadmium in plants. Proshad et al. [13] reviewed the toxicity of heavy metals in soils of Bangladesh. In this study, they concentrated on the impact of industrialization on the concentration of heavy metals in soil. Su et al. [14] reported the heavy metal contamination in soil worldwide. In this study, they mentioned the current situation of contamination and remediation methods.

The present chapter describes the heavy metal sources, exposure, and the impact of their toxicity on various environmental segments. Based on the toxicity and non-biodegradable nature of lead, cadmium, mercury, and arsenic, the present study mainly focused on these metals.

2. Types of heavy metals

Based on the survey of literature the metals that are considered as heavy metals are chromium, lead, cadmium, iron arsenic, cobalt, mercury, copper and zinc are the Heavy metal. According to Kim et al. [9] studies heavy metals have been classified in to two types as essential and non- essential (**Table 1**). Essential Heavy metals are less toxic at low concentrations and they act as coenzyme in biological process. For example Hemoglobin and Myoglobin consist of Iron, Vitamin B12 consist of cobalt. Non-essential heavy metals are highly toxic even at very low concentrations, they are non -biodegradable and cause severe toxic effects to living organisms.

ESSENTIAL (Harmless)	NON ESSENTIAL (Toxic)
Zinc (Zn)	Chromium (Cr)
Copper (Cu)	Lead (Pb)
Iron (Fe)	Arsenic (As)
Cobalt (Co)	Mercury(Hg)
	Cadmium (Cd)

Table 1.
Classification of heavy metals.

2.1 Heavy metal toxicity

Some heavy metals are essential to the human biological process, but depending upon their dosage intake leads some unexpected hazardous effects on health and the physiological system. According to [9] studies shows that despite of its beneficiary health effects, heavy metals are acting as carcinogenic agents. Dissolved forms of these metals through different forms as soil pollutants, water pollutant and air pollutants entering into food chain and finally ending in humans, these are leading to severe damage to the cellular system and leading to expose towards cancer. According to the reports of the International agency for research on cancer non-essential heavy metals (As, Cd, Cr) are major cancer- causing agents [9].

2.2 Sources, exposure, and environmental impacts of lead

The sources of lead varies with different countries based on old and new usage of lead products. It is not limited to the processing of gold ore and recycling of used lead products. It is found that the decrease in blood lead levels in the population of the countries in which unleaded gasoline is in usage [15].

A recent study [16] has reported elevated blood levels in pregnant women in a rural village in Bangladesh. In this study, they found more than 30% of women they sampled were had lead levels in blood in the range of above 5 μg/dL. They found the major source of lead exposure to these women were identified as food storage cans. Nearly 18% of food storage cans (out of the tested) were having lead soldering insides and are responsible for lead contamination in these women. Another study in China [17] determined the blood lead levels (BLL's) in children who are taking treatment in lead specialty clinics. In this study, they found the BLL's ranging from 5 to 126 μg/dL. The major reasons they found for the higher lead levels in their blood as industrial sources and folk medicine which is popular in China. Another important thing was determined as it is difficult to find lead poisoning in children due to non-specific symptoms. A very recent study from Australia [18] determined the higher lead levels in children due to the high concentration of lead in soil and pretty dish dust at their premises. This study found that the population who are living in old houses built before 1940 are diagnosed with higher lead levels due to pretty dish dust.

In Nigeria, lead poisoning in the population was observed in the area of Zamfara state which contains gold mining activities. Mahuta [19] reported that in Nigeria, the sources of the lead include mining of gold, lead pipes used for drinking water, and cultural usage of lead.

Based on the studies in all parts of the world it is assumed that the sources of lead are historical usage of lead, industrial activities, and leaded gasoline. Major studies reported that children are the most common victims of lead poisoning. The way of exposure includes the inhalation through the nose and ingestion through drinking water and soil.

There are several ways to minimize the lead levels in the environment such as remediation techniques (in soil), using adsorbents (in water), and using unleaded gasoline (the air). After the identification of leaded gasoline as a source of lead poisoning by US EPA, a major decline in their levels was found by replacing it with unleaded gasoline. Dongre [20] reported the toxicological profile, remedial solutions for lead levels in water by using polymeric materials, such as chitin and chitosan.

Zaltauskaite and Kniuipyte [21] reported the impact of lead concentration in soil on *Eisenia fetida* (earthworm). They found that lead in soil inhibits the growth of earthworms. Lead in soil can enter into human food by the vegetation in the contaminated soil [22]. The Types of carcinogenic effects of lead toxicity was explained in **Figure 1**. The lead toxicity in humans causes intestinal cancer, lung cancer, and central nervous system.

Figure 1.
Carcinogenic effect of Lead.

2.3 Sources, exposure and environmental impacts of cadmium

The major exposure of cadmium by human beings is through contaminated food and water. Cigarette smoke is the way of exposure through the inhalation route. The toxicity of cadmium is due to accumulation in plants and animals for nearly 25–30 years. Microbial fermentation is one of the effective methods to remove cadmium from food [23]. Another major source of cadmium in the environment is phosphate fertilizers and the waste incineration process. Blood cadmium levels are having a huge difference between smokers and non-smokers of cigarettes [1].

The presence of lead and cadmium in the human body can reach the brain and can cause Alzheimer's disease [24]. After the exposure to the cadmium, in human, it can accumulate at the kidney, due to this reason urinary cadmium levels has been considered as biomarkers for cadmium levels in humans [25].

In case of occupational exposure to cadmium includes the workers at battery production, pigment industries, and electroplating. Because of long time accumulation in the human body even in small quantities is toxic and carcinogenic [26]. Another important source of cadmium in the soil is sewage sludge which can make the cadmium almost the same amount as fertilizers consumption (https://www.osti.gov/biblio/5478006, accessed on 1st October/2020). The types of carcinogenic effects of cadmium toxicity were explained in **Figure 2**. Cadmium shows its toxic effects on the gastric system and leads to gastric cancer, breast cancer, lung cancer, and it also affects the excretory system and leads to renal cancer.

2.4 Sources, exposure, and environmental impacts of mercury

Mercury is the metal widely studied all over the world due to its toxic nature and easily entering into the food chain. An extensive review report was published by Jyothi and Mohamed Farook [6] regarding the sources, exposure, and toxicity

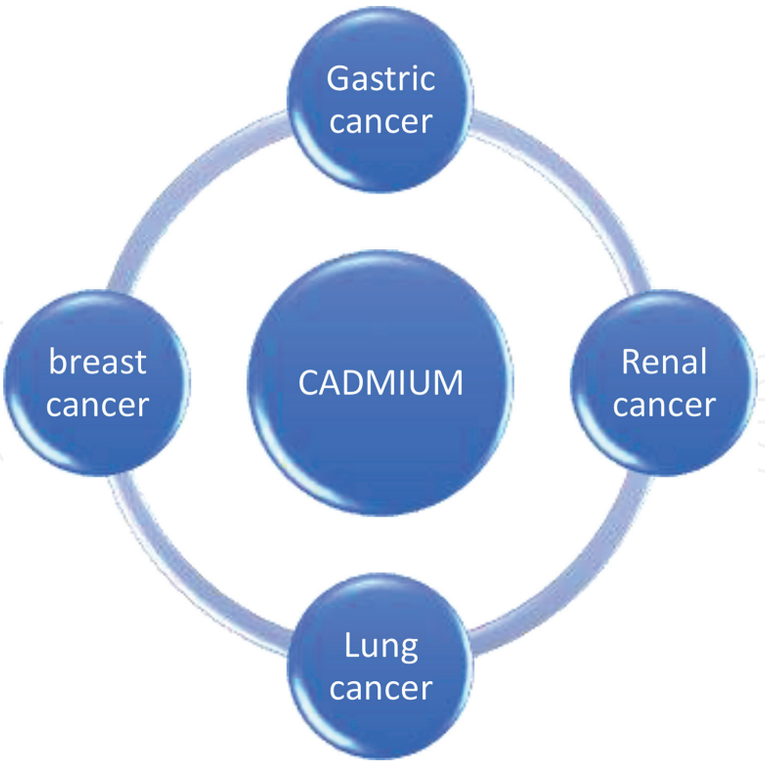

Figure 2.
Carcinogenic effect of cadmium.

of mercury. The toxicity of mercury depends on its chemical composition. Methyl mercury is more toxic than inorganic mercury. Due to its toxic nature and historical incidents like Minamata so many authors were published various facts regarding the sources, transport, and fate of mercury in the environment. Both volcanoes and forest fires are natural sources of mercury in the atmosphere. The burning of fossil fuels in power plants is one of the major anthropogenic sources of mercury (https://www.epa.gov/mercury/basic-information-about-mercury; accessed on 15th October/2020). Because of easy transportation, it is considered a global pollutant [27].

Even exposure to small quantities, shows toxic effects on various physiological systems, such as nervous and digestive systems and organs like lungs and kidneys. Due to this reason WHO declares mercury as one of the top most priority toxic metals (https://www.who.int/news-room/fact-sheets/detail/mercury-and-health; accessed on 20th October/2020). When it enters into water it largely affects the aquatic animal's life and through them, it can enter into the food chain to reach human beings.

Yokoyama [28] reported the methylmercury poisoning control measures and the current situation of its effects on fetuses and infants particularly. In this study, they addressed the global cycle of methyl mercury also. Strode et al. [29] studied the emission of mercury into the North American atmosphere due to gold and silver mining in the 19th century. The types of carcinogenic effects of mercury toxicity was explained in **Figure 3**. Mercury toxicity effects on the rectal system and leads to colorectal cancer. It shows vast effects on the central nervous system leads to brain cancer and lung cancer.

2.5 Sources, exposure, and environmental impacts of arsenic

Arsenic is a metalloid but due to its toxic and carcinogenic nature, it is discussed under the heading of heavy metal toxicity. Abdul et al. [30] reviewed the health effects of arsenic exposure to human beings. According to this study, the majority of

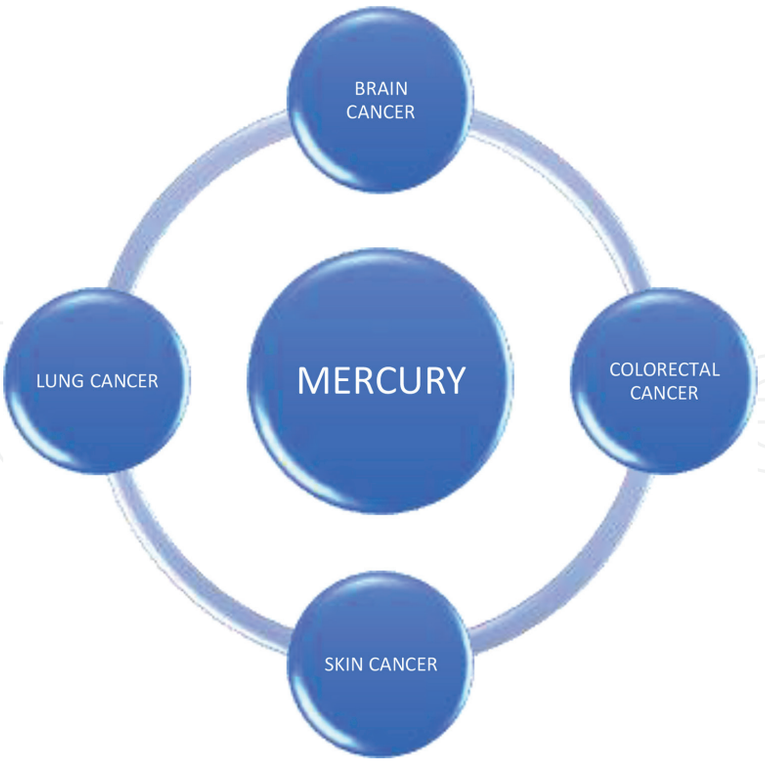

Figure 3.
Carcinogenic effect of mercury.

Figure 4.
Carcinogenic effect of arsenic.

the population expose to this toxic metal through atmospheric air, groundwater, and certain kind of foods. The health effects are not limited to damage to cardiovascular, endocrine, renal, and reproductive systems. In various parts of the world such as India, Pakistan, and Bangladesh it was observed that major exposure to the arsenic is through groundwater. Shahid et al. [31] reported about the sources and health

effects of arsenic through the exposure of groundwater in Pakistan. This study predicts nearly 47 million people of Pakistan at risk due to arsenic contamination in groundwater. They found that over 50% of the well they studied are having higher arsenic levels than WHO recommended levels in drinking water. A recent study [32] describes the occurrence and mobilization of arsenic in the groundwater of Bangladesh. In this study, they found that intensive usage of land for agriculture and usage of agrochemicals are the major reasons for arsenic contamination in groundwater of Bangladesh. Ahmed et al. [33] reported the situation of arsenic contamination in groundwater in a village in Bangladesh. For this purpose, they discussed 20 years situation of its exposure. Based on their results they found that the cancer risk to the population who are exposing to arsenic has 40% more than the non-exposures. The Types of carcinogenic effects of arsenic toxicity was explained in **Figure 4**. Sources and health effects of all the above discussed heavy metals are summarized in **Table 2**. Arsenic has its toxic carcinogenic effect on prostate glands and cause prostate cancer, leukemia and cause lesions in hepatic regions leads to cause of cancer of the liver.

	Heavy metal	**Sources**	**Health Effects**
Essential heavy metal	Zinc (Zn)	Oil Refining Plumbing Brass manufacturing	Gastrointestinal disorders, Kidney & Liver abnormal functioning
	Copper (Cu)	Copper polishing Plating Printing	Abdominal disorders, Metabolic activity abnormalities
	Iron (Fe)	High intake of iron supplements & oral consumption	Vomiting Diarrhea Abdominal pain Dehydration & lethargy
	Cobalt (Co)	Hip alloy replacement case	Haemotological Cardiovascular Hepatic Endocrine
Non Essential heavy metal	Chromium (Cr)	Steel fabrication Electroplating Textile	Lung disorders (bronchitis,cancer), Renal and reproductive system
	Lead (Pb)	Batteries Coal combustion Paint industry	Serious effect on mental health (Alzheimer s disesase), Nervous system
	Arsenic (As)	Atmospheric deposition Mining pesticides	Highly effects dermal region (Cancer), Brain & Cardiac problems
	Mercury (Hg)	Coal combustion Fish Mining Paint industry Paper industry Volcanic eruption	Sclerosis Blindness Minamata disease Deafness Gastric problems Renal disorders
	Cadmium (Cd)	Plastic Fertilizers pesticides	Osteo related problems Prostate cancer Lung diseases Renal issues

Table 2.
Sources and health effects of heavy metals.

	US EPA			WHO			OSHA	
	Ambient Air	**Drinking Water**	**Soil**	**Ambient Air**	**Drinking Water**	**Soil**	**Air at work place**	**Blood**
Pb	0.15[1] μg/m^3	15[1] μg/L	400 ppm[1] (play areas); 1200 ppm non-play areas	—	15[2] μg/L	—	30[1] μg/m^3	40[1] μg/dL
Cd	6.5–130[6] ng /m^3	0.005[3] mg/L	85[4] mg/Kg	—	0.003[3] mg/L	—	5[4] μg /m^3	—
As	50[6] μg/m^3	0.01[2] mg/L	—	—	0.01[2] mg/L	—	10[5] μg /m^3	—
Hg	5[7] mg /m^3	0.002[2] mg/L	4–16[7] mg/Kg	—	0.001[2] mg/L	—	—	—

[1]*https://www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=8#:~:text=EPA's%20action%20level%.*
20for%20lead, systems%20is%2015%20%C2%B5g%2FL.
[2]*Ebrahimi et al. [34].*
[3]*https://www.wqa.org/portals/0/technical/technical%20fact%20sheets/2015_cadmium.pdf*
[4]*https://www.atsdr.cdc.gov/csem/csem.asp?csem=6&po=7#:~:text=OSHA%20has%20established %20workplace%20levels,people%20occupationally%20exposed%20to%20*
cadmium.&text = Permissible%20Exposure%20Limit%2D%20TWA%20 (PEL, %2Fm3%20(fumes).
[5]*https://www.atsdr.cdc.gov/csem/csem.asp?csem=1&po=8#:~:text=The%20permissible%20 exposure%20limit%20for, OSHA%202,001%3B%20NIOSH%202,005%5D.*
[6]*https://ec.europa.eu/environment/archives/air/pdf/pp_as_cd_ni.pdf*
[7]*Ye et al. [35].*

Table 3.
Permissible limits of different toxic elements in environmental matrices.

The permissible limits of lead, cadmium, arsenic, and mercury in different environmental matrices suggested by various international reputed agencies such as US EPA (Environmental Protection Agency), WHO (World Health Organization), and OSHA (Occupational Safety and Health Administration) are presented in **Table 3**.

3. Conclusions

The heavy metal toxicity and their environmental impact is a global issue due to their transportation through air, soil, and water. Based on various factors such as concentration and different major sources are the possible ways of entering the heavy metals through drinking water, air and foods. In minimum traces these metals are required for cellular, metabolic and hormonal functioning in humans but if the limitation exceeds its leads to the cause of severe hazardous effects in health. The toxicity of these metals is affecting the soil vastly by killing microorganisms present in soil which are very helpful to enhance fertility and nutrition levels of soils. According to the IARC, arsenic toxic effects are the cause of cancers in prostate glands, liver, blood, and skin. Mercury is the major reason for causing carcinogenic effects on the brain, lung, skin, and colorectal parts. The adverse effects of lead are the reason for intestinal, central nervous system, and lung cancers. The toxic effects of cadmium cause gastric, breast, lung, and renal cancers in humans.

Another diagnosis was identified in china, extreme high levels of lead toxicity in children were due to the pretty dish and in women, high lead levels in the blood is due to the usage of food storage cans. Cadmium is the major cause of Alzheimer disease and due to high usage of phosphate fertilizers they are accumulating in soils and entering into food chains. WHO states that mercury is hazardous toxic metal affecting aquatic life severely and consumption such mercury affected foods by human leads to several harmful diseases such as Minamata and cause several physiological effects.

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