International Journal of Multidisciplinary Research and Growth Evaluation
ISSN: 2582-7138
Received: 26-09-2021; Accepted: 13-10-2021
www.allmultidisciplinaryjournal.com
Volume 2; Issue 6; November-December 2021; Page No. 77-82

The effect of heavy metal pollution on the health of human beings in the environment

Augustine Bai Kamara [1*], Musa Tarawally [2], Hassan Rogers [3]

[1] Department of Basic Sciences, Faculty of Basic and Health Sciences, Ernest Bai Koroma University of Science and Technology (EBKUST), Makeni, Sierra Leone

[2] Department of Science Education, Faculty of Education, Ernest Bai Koroma University of Science and Technology (EBKUST), Makeni, Sierra Leone

[3] Department of Public Health, Microbiology, and Immunology, Faculty of Basic and Health Sciences, Ernest Bai Koroma University of Science and Technology(EBKUST), Makeni, Sierra Leone

Corresponding Author: **Augustine Bai Kamara**

Abstract

The environment and its compartments are heavily polluted by heavy metals and expected to continue through the twenty centuries in developing countries. As a result, threatening the health of humans, animals, and plants reduces the environment's ability to forester life. Heavy metals such as arsenic, lead, mercury, cadmium, chromium, and trace elements are in the first place according to their availability in the environment. Although some of these heavy metals, such as vanadium, can be harmful to the body at high doses, other heavy metals such as cadmium, mercury, lead, chromium, and small amounts of arsenic are detrimental to humans. There is, thus, a need to focus research, especially in developing countries such as Sierra Leone. As such, this paper advances a discussion and review on the effect of heavy metals on human health in the environment. As the outcome will make researchers to develop strategies to be monitoring the impact of heavy metals on human health especially in developing countries.

Keywords: Heavy Metals. Chromium, Vanadium, Environment, Human Beings

1. Introduction

The environment can be related to the surrounding in which human beings exist (Masindi & Muedi, 2018) [31]. It consists of the earth, the water, the earth's atmosphere, Microorganisms, plants, and animals. The earth's system is defined by the four spheres: the biosphere (living things), the atmosphere (air), the lithosphere (earth), and the hydrosphere (water), all of which work together in harmony. Industrialization has increased over the last hundred years. Thus, the demand for exploiting the earth's natural resources has risen carelessly, exacerbating the World's pollution problem (Gautam, Gautam, Banerjee, Chattopadhyaya, & Pandey, 2016) [14]. The environments are heavily polluted by inorganic ions, organic contaminants, organometallic compounds, radioactive isotopes, gaseous pollutants, and nanoparticles (Walker, Sibly, & Peakall, 2005) [43]. Of all the pollutants, heavy metals have received the most attention from environmental chemists due to their toxic nature. Heavy metals are generally present in traces in natural waters, but many of them are toxic even at low concentrations (Herawati, Suzuki, Hayashi, Rivai, & Koyama, 2000) [20]. Metals are also natural components found in the environment. They are substances with a high electrical conductivity that voluntarily give up their electrons to form cations. Heavy Metals are found throughout the World, including the atmosphere, the earth's crust, bodies of water, and can also accumulate in biological organisms such as plants and animals. Among the 35 natural metals, 23 have a high specific gravity greater than 5g/cm3 with an atomic weight of more than 40.04 and are commonly known as heavy metals (Duffus, 2002; Lajçi, Sadiku, Lajçi, Baruti, & Nikshiq, 2017) [9, 23]. They are utilized in, for example, golf clubs, cars, antiseptics, self-cleaning ovens, plastics, solar panels, mobile phones, and particle accelerators. The staggering increase in heavy metals has led to an imminent rise in metallic substances in both terrestrial and aquatic environments (Gautam *et al*., 2016) [14]. Heavy metal contamination is due to anthropogenic activities that are the main source of contamination, mainly from mining, foundries, foundries, and other metal industries leaching of metals from various sources such as landfills, waste dumps, excreta, livestock, and garbage for chickens, sewers, automobiles, and road work. The use of heavy metals in agriculture has been the secondary source of Exposure to heavy metals, such as the use of pesticides, insecticides, fertilizers, and more.

Natural causes can also increase heavy metal contamination, such as volcanic activity, corrosion of metals, evaporation of metals from soil and water, and sediment turbulence, soil erosion, geological weathering (Shallari, Schwartz, Hasko, & Morel, 1998; Tchounwou, Yedjou, Patlolla, & Sutton, 2012) [39, 41]. The health of human beings is at great risk because of the pollution of heavy metals in the aquatic environment of which, if steps are not taken, will lead to the death of so many people. Heavy metals can enter a human in four ways; Intake of contaminated food; inhale from the atmosphere, drink contaminated water; and due to contact with the skin of agricultural, pharmaceutical, manufacturing, residential and industrial areas (Masindi & Muedi, 2018) [31]. Heavy metals accumulate in vital organs of the human body such as kidneys, bones, and liver, leading to numerous serious health effects, including neurotoxic and carcinogenic effects (Duruibe, Ogwuegbu, & Egwurugwu, 2007; Vickers, 2017) [10, 42]. Studies have shown that inorganic pollutants such as heavy metals occur as natural materials, but human production has modified them to increase their numbers in the environment. Inorganic substances enter the environment through various anthropogenic activities such as mine drainage, smelting, metallurgical and chemical processes, and natural processes. These pollutants are toxic due to their accumulation in food chains (Förstner, Mader, & Salomons, 1995) [12]. In Sierra Leone, industries dispose of untreated industrial waste directly into rivers. The Rivers are the most polluted in Sierra Leone (Marcantonio, Field, Sesay, & Lamberti, 2021) [30] (Nouri *et al*., 2009), which is increasingly polluted with vast amounts of toxic waste from thousands of industrial plants and sewerage lines (Girardet, 2019) [16]. However, a variety of heavy metals come from the disposal of industrial waste, batteries, lead paint, and gasoline from mechanized cargo, cans and cans, traffic and improper disposal of household garbage, etc. in water, sediments, and fish in various rivers, including Buriganga (Begum *et al*. 2013; Ahmed *et al*. 2010b; Mohiuddin *et al*. 2011; Saha and Hossain 2011). Studies reporting risk assessments with a special focus on human health, are very scanty. As such,there is need for such study to understand

The health of human beings is at significant risk because of the pollution of heavy metals in the aquatic environment of which, if steps are not taken, will lead to the death of so many people.

Considering that some metalloid elements' environmental effects and harmful actions are like those of heavy metals, certain metalloid elements have been included in the research on the environment and the health of humans.

Furthermore, heavy metal pollutants in the aquatic environment are the main causes of human diseases entering the human body through drinking water, living water, enrichment in plants and aquatic animals, production water, etc. Hence study on the relationship between heavy metals in the marine environment and human health serves as an important reference for heavy metal pollution—supervision and governance and prevention and treatment of diseases in Sierra Leone.

Due to Sierra Leone's industrial and agricultural development, which is coupled with the continuous increase of heavy metal content in pollutants discharged by various enterprises into the waters, leading to that heavy metal pollution constantly worsens the aquatic environment with mercury (Hg), cadmium (Cd), Chromium (Cr), lead (Pb), arsenic (As) being identified as main pollutants.

Wang *et al*. have researched the content of trace heavy metals in part of rivers, lakes, seas of China and their changes, and found out that rivers have higher such content than lake areas and suffer severer pollution. In contrast, the distribution of heavy metals in seawater is dependent on complex factors like runoff, salinity, PH, and the properties of the seawater itself.

Frequent occurrence of river heavy metal pollution incidents in recent years has been greatly concerned by the Government among which Cd and Pb pollution incidents are the most serious. Meanwhile, the detection technologies for heavy metals applied in the aquatic environment and clinical trials were discussed to provide theoretical support for containing ecological risk from heavy metals in the marine environment.

2. Categories of Heavy Metals

There are many heavy metals in the environment. Most can be toxic health that can negatively influence people's health. Certain metalloid elements are included in environmental and health studies because some metalloid elements' harmful and ecological effects are similar to those of heavy metals (J.-J. Li, Pang, Wu, & Zeng, 2018) [25]. Numerous toxic, semi-metallic elements, including arsenic and mercury, Lead, Chromium (Cr), Cadmium (Cd), and Vanadium (V): are discussed below:

2.1 Arsenic (As)

As is a chemical element with the symbol As and the atomic number 33. Arsenic is found in many minerals and is mainly combined with sulfur and metals, but it also exists as pure elemental crystals. Arsenic is a metalloid. In general, As levels are deficient in clean air, water, and food, and high levels of As are detected in air in coal-burning areas, groundwater in each area, and seafood (Bencko, 2011) [4]. Currently, As is produced from two sources, one is a natural source, including rock weathering, arsenic-volcano-magma eruptions, etc. This explains why the arsenic content of springs and groundwater is high in individual regions. The other is mainly due to the human activity of people, including mining, smelting, coal burning, and the use of pesticides (L. Li, Zhang, Liu, Xiang, & Wei, 2009) [26]. Arsenic is mainly used in lead alloys (such as car batteries and ammunition). Arsenic is an n-type dopant commonly used in electronic semiconductor devices. It is also part of the IIIV compound semiconductor gallium arsenide. As and its compounds, especially trioxides, produce pesticides, treated wood products, herbicides, and pesticides.

2.2 Mercury

Mercury is a chemical element with the symbol Hg and atomic number 80. Commonly known as hydrargyrum. Mercury is mainly generated in deposits around the World as cinnabar. Red pigmented cinnabar is obtained by grinding natural cinnabar or synthetic mercury sulfide. Natural mercury sources in the environment include elemental mercury vapors from volcanoes and forest fires and the release of inorganic mercury due to weathering and movement of water (Bose-O'Reilly, McCarty, Steckling, & Lettmeier, 2010) [5]. Anthropogenic sources include burning coal and fossil fuels, mining mercury, refining precious metals, manufacturing electrical and automotive parts, and chemical treatment, waste incineration, landfill, and emissions from industrial pollution of water systems.

Mercury uptake, transport, and detoxification depend on the species of mercury. For elemental and inorganic mercury, inhalation of mercury vapor is the most important sink, with up to 80% of the inhaled vapor entering the bloodstream. Once absorbed, the elemental mercury penetrates all tissues and accumulates in the central nervous system and kidneys. Inorganic mercury has low solubility of lipid and does not easily penetrate cell membranes. All forms of mercury are toxic to the human body, but the toxicity pattern depends on its chemical structure, exposure route, amount of duration, and time of exposure (Yang *et al*., 2020) [45] and (Liu, Shi, Yu, Goyer, & Waalkes, 2008) [27].

2. 3 Lead (Pb): Pd is a chemical element with the symbol Pb and the atomic number 82. It is a heavy metal with a higher density than the most common materials. Lead is soft and malleable and has a relatively low melting point. Freshly cut lead is silvery and bluish. When exposed to air, it turns dull gray. The increase in lead levels in our environment is due to the activities of people, including the burning, mining, and manufacturing of fossil fuels. Presently, in Sierra Leone, Pb is discharged mainly from manufacturing industries, printing, and car exhaust, etc. In the United States, lead-containing paints are the most common source of exposure for lead-poisoned children, but most adults are associated with the workplace. Pb occurs naturally in the environment. However, most of the Pb concentrations found in the environment are due to human activity. The use of Pb in gasoline creates an unnatural lead cycle. In automobile engines, Pb burns, producing Pb salts (chlorine, bromine, oxides). Pb is one of the four metals that have the most detrimental effects on human health (Wasserman, Staghezza-Jaramillo, Shrout, Popovac, & Graziano, 1998) [44].

2.4 Chromium (Cr), Chromium is mainly used for metal alloys such as metal ceramics and stainless steel and is used as chrome plating. It is highly regarded for its high-gloss polish, durable and rust-resistant coatings for rugged applications. Cr has long been known as a toxic, mutagenic, and carcinogenic metal. Toxic to microorganisms, plants, animals, and humans. Chromium occurs in two stable forms in the environment: Cr (VI) and Cr (III). Cr (III) is less toxic and insoluble, while Cr (VI) is very toxic and easily soluble. Chromium is used in many industrial applications but poses a threat to the local environment (Coetzee, Bansal, & Chirwa, 2018) [7].

2.5 Cadmium (Cd), Cadmium is a chemical element with Cd and atomic number 48. This soft silvery-white metal is chemically similar to the other stable metals in Group 12, zinc and mercury. Over the past century, various forms of cadmium exposure have been detected, and cadmium is present in the environment through many human activities (Rahimzadeh, Rahimzadeh, Kazemi, & Moghadamnia, 2017) [37]. The constant cause of cadmium contamination is related to its industrial use as a corrosive reagent and its use as a stabilizer for PVC products, color pigments, and NiCd batteries (Genchi, Carocci, Lauria, Sinicropi, & Catalano, 2020) [15]. Cd is widely used in chemical engineering, galvanization, nuclear industry, etc., as one of the heavy metal pollutants for the environment.

2.6 Vanadium (V): V is a Chemical element with the symbol V and atomic number 23. It is a complex, silver-gray, malleable transition metal. Elemental metals rarely occur in nature, but when artificially separated, the formation of an oxide layer stabilizes some free metals against further oxidation. It's widely used because its addition improves steel's hardness, formability, and fatigue resistance (Fortoul *et al*., 2014) [13]. It also provides metal fracture resistance to extreme temperature modulation. Vanadium is also used to manufacture synthetic rubber for automobile engines because it helps increase heat resistance. The main concern about this factor is the increase in occupational and environmental exposure sources over the last decade. The well Known occupational activities where exposure occurs are processing and refining vanadium ore, producing products containing vanadium, burning of high vanadium fuels, and various processes of the chemical industry (Ehrlich *et al*., 2008). Other causes of vanadium exposure were derived from inhalation of particulate matter produced by combustion products made by the smelter and from vanadium-rich petroleum such as Venezuela, Mexico, Iraq, and Iran. V can have many effects on human health if taken too much.

3. Effect of Heavy Metals on Humans

Some heavy metals are naturally present in the crust and are used for various industrial and economic purposes. Some of these heavy metals have direct or indirect effects on the human body. Since is exposed to home or occupation, there are 35 metals of concern, 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, zinc (Mosby, Glanze, & Anderson, 1996) [32]. These heavy metals are common in the environment and food. Small doses are needed to stay healthy, but large quantities can be toxic or dangerous. Heavy metal toxicity reduces energy levels and can impair the function of the brain, lungs, kidneys, liver, blood composition, and other vital organs. Long-term exposure can lead to progressive physical, muscular, and degenerative neurological processes that mimic multiple sclerosis, Parkinson's disease, Alzheimer's disease, and muscular dystrophy. Repeated long-term exposure to some metals and their compounds can even cause cancer (Järup, 2003) [22].

For instance, Mercury is a dangerous metal, and its toxicity was a common cause of 3,596 acute heavy metal poisonings by the American Association of Toxicological Control Centers in 1997. Methyl mercury is a neurotoxic compound involved in the destruction of microtubules, mitochondrial damage, lipid peroxidation, and the accumulation of neurotoxic molecules such as serotonin, aspartic acid, and glutamate (Patrick, 2002) [35]. According to both the Environmental Protection Agency and the National Academy of Sciences, it is estimated that 8-10% of American women have mercury levels that cause neuropathy in their offspring (Haley, 2005) [18]. Animals exposed to the toxic mercury showed neurologically and behaviorally detrimental changes. After exposure to a mercury vapor concentration of 28.8mg/m^3 for 1-13 weeks, the rabbits showed vague pathological changes, marked cell degeneration, and brain necrosis (Ashe, Largent, Dutra, Hubbard, & Blackstone, 1953; Haley, 2005) [2, 18].

Human exposure to sufficiently high concentrations of chromium can be potentially harmful due to its toxic, genotoxic, and carcinogenic effects (De Flora *et al*., 2016; Stanin, 2005; Zohdi, Emami, & Shahverdi, 2012) [8, 40, 46].

Chromium is one of the eight metals in the Top 50 Most Toxic Substances in the World, according to data released by the Agency for Toxic Substances and Disease Registry (ATSDR). WHO classifies chromium as carcinogenic to people (Lucchetti *et al*., 2015; Organization, 1993) [28, 34].

Many quantitative studies have shown that the ionic form of chromium exhibits higher absorption than the less soluble form—chromium in the form of a diabetic supplement (Achmad & Auerkari, 2017) [1]. The lower the daily oral intake, the higher the gastrointestinal chromium absorption rate (Achmad & Auerkari, 2017) [1]. Upon absorption, Cr (VI) is reduced to Cr (III), which is done at the expense of cell damage. Chromium metabolism The process induces oxidation stress by glutathione radicals to oxidize the environment, attacking adenine and guanine in DNA to produce DNA adducts (Pechova & Pavlata, 2007) [36]. DNA damage and/or incomplete DNA repair can lead to carcinogenesis (Graham, 1999) [17]. Chromium-related cancers commonly occur in the respiratory tract and mainly lung, nasal, and sinus cancers (Levina & Lay, 2011) [24].

As is absorbed primarily by inhalation or ingestion and is rarely absorbed through the skin. When is taken orally, the absorption rate of arsenic in the gastrointestinal tract is 90%, which is higher than that of other heavy metals. Absorbed arsenic binds to red blood cells and deposits in the liver, kidneys, muscles, bones, hair, skin and nails, but is mainly excreted in the urine. Inorganic arsenic compounds suppress the activity of various enzymes involved in cellular respiration, glutathione metabolism, and DNA synthesis. They may cross the placenta and affect the development of the fetal nervous system (Hanlon & Ferm, 1977) [19]. Arsenic has increased the risk of lung cancer over the last few decades, and extensive exposure to arsenic in the environment has attracted the attention of scientists. A cohort study of 654 people in Taiwan showed an observed incidence of skin cancer of 14.7 per 1000 person-years (Hsueh *et al*., 1997) [21]. In addition, the incidence of skin cancer was determined by length of stay in areas infected with black foot disease, duration of drinking water, arsenic concentration in drinking water, and cumulative exposure to arsenic (Hsueh *et al*., 1997) [21]. Recentky, studies have reported an association between skin cancer and vascular disease (Luster & Simeonova, 2004).

Furthermore, Pb poisoning is a major environmental disease, and its effects on the human body are devastating. Exposure to high levels of lead can Pb to anemia, weakness, and kidney and brain damage. Very high levels of Pb can be fatal, and Pb can cross the placental barrier. In other words, pregnant women exposed to Pb are also exposed to the foetation. Lead can damage the nervous system of developing babies. In a recent study, the authors showed that sodium selenite reduced the toxic effects of Pb nitrate on blood cells in rats. They also showed that the results of lead nitrate were more harmful in diabetic rats than in non-diabetic rats (Baş, Kalender, Pandir, & Kalender, 2015) [3]. Oxidative stress has been studied through low lead exposure in first-year children in Uruguay, suggesting a potentially adverse effect on oxidative stress (Roy *et al*., 2015) [38].

Also, Cd, a by-product of zinc production, is one of the most toxic elements humans may be exposed to at work and in the environment. Cd is released into the atmosphere through natural activities such as volcanic eruptions, weathering, river transport, and human activities such as mining, smelting, smoking tobacco, burning municipal waste, and fertilizer production. Cadmium emissions have been significantly reduced in most developed countries, but Cd remains a source of concern for workers and people living in contaminated areas. Cd can cause acute and chronic poisoning (Chakraborty, Dutta, Sural, Gupta, & Sen, 2013) [6]. Cd is highly toxic to the kidney and accumulates in high concentrations in proximal tubular cells. Cd can cause bone mineralization through either bone damage or renal dysfunction. Studies in humans and animals have shown that osteoporosis, along with disorders of calcium metabolism, kidney stone formation, and hypercalcemia, are significant effects of cadmium exposure. Inhalation of high concentrations of cadmium can cause severe lung damage. Ingesting large amounts of cadmium can cause stomach irritation, vomiting, and diarrhea. Several studies have reported that mortality is associated with low levels of cadmium exposure. It was concluded that the available evidence was insufficient to allow a causal interpretation of the association seen between these effects when reported for cadmium exposure and low exposure. The UNEP contains a report on initiatives and countermeasures to control cadmium release and its exposure (Nordberg *et al*., 2018) [33].

Finally, As already mentioned, acute exposure to vanadium compounds, especially vanadium oxide, is for occupational exposure, including mining and crushing vanadium ore, metallurgy with Ferro vanadate, catalysts, batteries, and glass melt additive based production. Limited to inhalation in context. About cleaning vanadium oxide and oil-burning boilers. Inhaled vanadium oxide causes pulmonary dysfunction such as rhinitis, airway inflammation, bronchitis, pneumonia, and asthma. Plants, in particular, ingest large amounts of heavy metals through water, increasing food chain pollution and causing severe health problems for humans. This phenomenon affects agricultural land and economically important crops around the World. Therefore, heavy metal issues are getting worrisome and should be addressed.

4. Conclusion

Heavy metals are important to humans in many ways, especially in manufacturing certain important products intended for human consumption. Heavy metal pollution is a major source of anthropogenic activities, mainly metal mining, smelting, foundries, and other metal-based industries, landfills, excreta, cattle, and chicken manure. It results from metal leaching from the source. However, some of the effects of heavy metals can be acute or chronic after prolonged exposure, damaging various organs such as the brain, lungs, liver, and kidneys, leading to illness in the body. Reducing the burden on local communities due to the impact of heavy metals on human health leads to a healthy life. Therefore, the Government needs to develop a strong strategy for enforcing environmental legislation that evaluates the production and manufacture of heavy metals. Reducing the usage of toxic heavy metals is very important.

References

1. Achmad RT, Auerkari EI. Effects of chromium on the human body. Annual Research & Review in Biology, 2017, 1-8.
2. Ashe W, Largent E, Dutra F, Hubbard DM, Blackstone M. Behaviour of Msrcury in the Animal Organism following Inhalation. Arch. Indust. Hyg. & Occupational Med. 1953; 7(1):19-43.

3. Baş H, Kalender Y, Pandir D, Kalender S. Effects of lead nitrate and sodium selenite on DNA damage and oxidative stress in diabetic and non-diabetic rat erythrocytes and leucocytes. Environmental toxicology and pharmacology. 2015; 39(3):1019-1026.
4. Bencko V. Hearing Changes in Children Exposed to Arsenic in Neurotoxicity Context Environmental Heavy Metal Pollution and Effects on Child Mental Development Springer, 2011, 85-100.
5. Bose-O'Reilly S, McCarty KM, Steckling N, Lettmeier B. Mercury exposure and children's health. Current problems in pediatric and adolescent health care. 2010; 40(8):186-215.
6. Chakraborty S, Dutta AR, Sural S, Gupta D, Sen S. Ailing bones and failing kidneys: a case of chronic cadmium toxicity. Annals of clinical biochemistry. 2013; 50(5):492-495.
7. Coetzee J, Bansal N, Chirwa E. Chromium in Environment, Its Toxic Effect from Chromite-Mining and Ferrochrome Industries, and Its Possible Bioremediation. Exposure and Health. 2018; 12:51-62.
8. De Flora S, Camoirano A, Micale RT, La Maestra S, Savarino V, Zentilin P, *et al*. Reduction of hexavalent chromium by fasted and fed human gastric fluid. I. Chemical reduction and mitigation of mutagenicity. Toxicology and applied pharmacology. 2018; 306:113-119.
9. Duffus JH. Heavy metals a meaningless term?(IUPAC Technical Report). Pure and applied chemistry. 2002; 74(5):793-807.
10. Duruibe JO, Ogwuegbu M, Egwurugwu J. Heavy metal pollution and human biotoxic effects. International Journal of physical sciences. 2007; 2(5):112-118.
11. Ehrlich VA, Nersesyan AK, Hoelzl C, Ferk F, Bichler J, Valic E, *et al*. Inhalative exposure to vanadium pentoxide causes DNA damage in workers: results of a multiple end point study. Environmental Health Perspectives. 2008; 116(12):1689-1693.
12. Förstner U, Mader P, Salomons W. Heavy Metals: Problems and Solutions: Springer, 1995.
13. Fortoul T, Rojas-Lemus M, Rodriguez-Lara V, Gonzalez-Villalva A, Ustarroz-Cano M, Cano-Gutierrez G, *et al*. Overview of environmental and occupational vanadium exposure and associated health outcomes: an article based on a presentation at the 8th International Symposium on Vanadium Chemistry, Biological Chemistry, and Toxicology, Washington DC, August 15–18, 2012. Journal of immunotoxicology. 2014; 11(1):13-18.
14. Gautam PK, Gautam RK, Banerjee S, Chattopadhyaya M, Pandey J. Heavy metals in the environment: fate, transport, toxicity and remediation technologies. Nova Sci Publishers. 2016; 60:101-130.
15. Genchi G, Carocci A, Lauria G, Sinicropi MS, Catalano A. Nickel: Human health and environmental toxicology. International journal of environmental research and public health. 2020; 17(3):679.
16. Girardet H. The metabolism of cities: Routledge, 2019.
17. Graham N. Disinfection By-products in Drinking Water–Current Issues; M. Fielding and M. Farrimond (Eds.); The Royal Society of Chemistry, Elsevier, 1999.
18. Haley BE. Mercury toxicity: genetic susceptibility and synergistic effects. Medical Veritas. 2005; 2(2):535-542.
19. Hanlon D, Ferm V. Placental permeability of arsenate ion during early embryogenesis in the hamster. Experientia. 1977; 33(9):1221-1222.
20. Herawati N, Suzuki S, Hayashi K, Rivai I, Koyama H. Cadmium, copper, and zinc levels in rice and soil of Japan, Indonesia, and China by soil type. Bulletin of environmental contamination and toxicology. 2000; 64(1):33-39.
21. Hsueh YM, Chiou HY, Huang YL, Wu WL, Huang CC, Yang MH, *et al*. Serum beta-carotene level, arsenic methylation capability, and incidence of skin cancer. Cancer Epidemiology and Prevention Biomarkers. 1997; 6(8):589-596.
22. Järup L. Hazards of heavy metal contamination. British medical bulletin. 2003; 68(1):167-182.
23. Lajçi N, Sadiku M, Lajçi X, Baruti B, Nikshiq S. Assessment of major and trace elements of fresh water springs in village Pepaj, Rugova region, Kosova. Journal of International Environmental Application and Science. 2017; 12(2):112-120.
24. Levina A, Lay PA. Metal-based anti-diabetic drugs: advances and challenges. Dalton transactions. 2011; 40(44):11675-11686.
25. Li JJ, Pang LN, Wu S, Zeng MD. Advances in the effect of heavy metals in aquatic environment on the health risks for bone. Paper presented at the IOP Conference Series: Earth and Environmental Science, 2018.
26. Li L, Zhang G, Liu H, Xiang M, Wei X. Migration and impact of Antimony and Arsenic in water environment of the Dachang multi-metalliferous mine area, Guangxi, China. Geochimica et Cosmochimica Acta Supplement. 2009; 73:A754.
27. Liu J, Shi JZ, Yu LM, Goyer RA, Waalkes MP. Mercury in traditional medicines: is cinnabar toxicologically similar to common mercurials? Experimental biology and medicine. 2008; 233(7):810-817.
28. Lucchetti MC, Fratto G, Valeriani F, De Vittori E, Giampaoli S, Papetti P, *et al*. Cobalt-chromium alloys in dentistry: An evaluation of metal ion release. The Journal of prosthetic dentistry. 2015; 114(4):602-608.
29. Luster MI, Simeonova PP. Arsenic and urinary bladder cell proliferation. Toxicology and applied pharmacology. 2004; 198(3):419-423.
30. Marcantonio RA, Field SP, Sesay PB, Lamberti GA. Identifying human health risks from precious metal mining in Sierra Leone. Regional Environmental Change. 2021; 21(1):1-12.
31. Masindi V, Muedi KL. Environmental contamination by heavy metals. Heavy metals. 2018; 10:115-132.
32. Mosby C, Glanze W, Anderson K. Mosby Medical Encyclopedia, The Signet: Revised Edition. St. Louis. 1996; 16:875-882.
33. Nordberg GF, Bernard A, Diamond GL, Duffus JH, Illing P, Nordberg M, *et al*. Risk assessment of effects of cadmium on human health (IUPAC Technical Report). Pure and Applied Chemistry. 2018; 90(4):755-808.
34. Organization WH. Guidelines for drinking-water quality: World Health Organization, 1993.
35. Patrick L. Patrick L. Mercury toxicity and antioxidants: Part 1: role of glutathione and alpha-lipoic acid in the treatment. Alternative Medicine Review. 2002; 7(6):456-471.
36. Pechova A, Pavlata L. Chromium as an essential nutrient: a review. Veterinární medicína. 2007; 52(1):1.
37. Rahimzadeh MR, Rahimzadeh MR, Kazemi S,

Moghadamnia AA. Cadmium toxicity and treatment: An update. Caspian journal of internal medicine. 2017; 8(3):135.
38. Roy A, Queirolo E, Peregalli F, Mañay N, Martínez G, Kordas K. Association of blood lead levels with urinary F2-8α isoprostane and 8-hydroxy-2-deoxy-guanosine concentrations in first-grade Uruguayan children. Environmental research. 2015; 140:127-135.
39. Shallari S, Schwartz C, Hasko A, Morel JL. Heavy metals in soils and plants of serpentine and industrial sites of Albania. Science of the total environment. 1998; 209(2-3):133-142.
40. Stanin FT. The transport and fate of chromium (VI) in the environment: CRC Press, Florida, USA, 2005.
41. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metal toxicity and the environment. Molecular, clinical and environmental toxicology, 2012, 133-164.
42. Vickers NJ. Animal communication: when i'm calling you, will you answer too? Current biology. 2017; 27(14):R713-R715.
43. Walker CH, Sibly R, Peakall DB. Principles of ecotoxicology: CRC press, 2005.
44. Wasserman GA, Staghezza-Jaramillo B, Shrout P, Popovac D, Graziano J. The effect of lead exposure on behavior problems in preschool children. American Journal of Public Health. 1998; 88(3):481-486.
45. Yang L, Zhang Y, Wang F, Luo Z, Guo S, Strähle U. Toxicity of mercury: Molecular evidence. Chemosphere. 2020; 245:125586.
46. Zohdi H, Emami M, Shahverdi H. Galvanic corrosion behavior of dental alloys. Environmental and Industrial Corrosion: Practical and Theoretical Aspects: In Tech, 2012.