IMPACT OF HEAVY METAL CONTAMINATION ON HUMAN HEALTH

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ABSTRACT

Heavy metal contamination has become a growing concern worldwide due to its detrimental effects on human health. This paper aims to provide a comprehensive review of the impact of heavy metal contamination on human health. The paper begins by discussing the bioaccumulation, toxicity, sources, and pathways through which heavy metals enter the human body, including industrial activities, agricultural practices, and environmental pollution. It highlights common heavy metals of concern, such as lead, mercury, cadmium, arsenic, and chromium, outlining their sources, distribution, and toxicological properties.

The research shows that natural processes and interactions between people, including industrial processes, mining, agriculture, and poor waste management, all contribute to heavy metal pollution. It has been shown that the most common ways heavy metals surround people are inhalation, ingestion, and skin contact. Arsenic has been related to many types of cancer and cardiovascular illness, whereas mercury has been connected to neurological issues after long-term exposure. Nickel exposure in the workplace has been linked to respiratory issues and certain forms of cancer, while lead exposure is linked to neurodevelopmental difficulties and kidney damage. Lung cancer and other breathing problems have both been linked to hexavalent chromium exposure.

Keywords – *Human health, Potential health impacts, Heavy metal pollution, Neurodevelopmental*

I. INTRODUCTION

Human health is severely impacted by heavy metal pollution, which has recently emerged as a global issue. The extensive occurrence of heavy metals is a result of both natural events and human activities. Heavy metals, including mercury, arsenic, lead, nickel, and iron, are just a few examples. The widespread availability of these potentially dangerous drugs poses serious health risks to individuals and communities everywhere (Mitra, 2022). Academics, legislators, and public health specialists have all paid increasing attention to the extent of the poisoning of heavy metal and its consequences during the last several years. Disturbing numbers highlight the urgency of the need to address this issue. For instance, according to the WHO, surrounding 1.8 billion people worldwide drink dirty water (Arain, 2015), putting them at risk for exposure to various heavy metals. The UN Environment Programme (UNEP) also reports that almost 200 million people are in danger of heavy metal exposure in the workplace. The following diagram shows the issue of contamination for heavy metals.

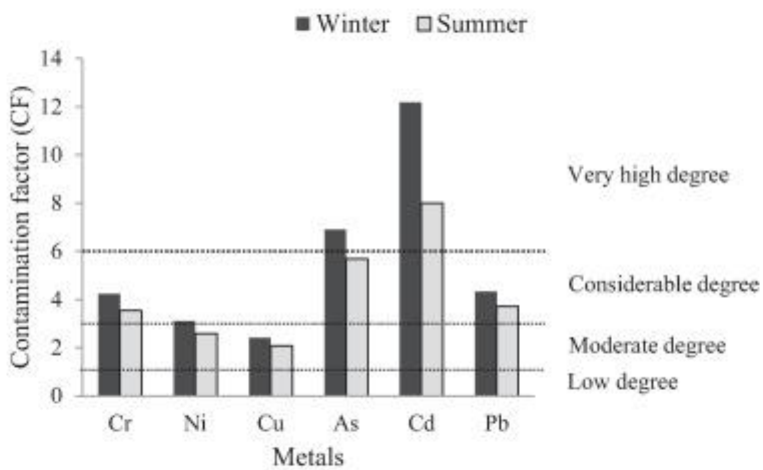

Fig1: Water contamination levels in heavy water

Source: Islam MS et al., "2022https://www.sciencedirect.com/science/article/pii/S1470160X14003719."

Lead, arsenic, mercury, cadmium, zinc, chromium, and nickel are only some of the heavy metals that may be found in tap water, and other sources of water, including the ground and the surface, are also analyzed. Heavy metals may enter the environment via a variety of pathways, a portion of that may be detrimental. The measured levels were too high, as stated by authoritative national and international agencies such as the World Health Organization (2008), the Environmental Protection Agency of the US (EPA), the European Union Union, and the US Environmental Protection Agency (EUC). Emissions from rapidly expanding industrial zones, mine exit, the disposal of massive aluminum wastes, lead-based fuel, and coatings, agricultural use of fertilizers, compost that is sewage sludge, chemical fertilizers, irrigation with wastewater, rock, and electronic waste all contribute to the accumulation of heavy metals and metalloids in water sources, which can lead to contamination. The enormous variety of health issues that heavy metal poisoning may induce have made it an issue of great concern for quite some time. The negative effects of specific metals continue to prevent human bodies' proper operation, notwithstanding their lack of biological significance.

This review study is significant because it offers an all-encompassing look at how heavy metal exposure affects human health. Through a methodical analysis of the available literature, this review strives to consolidate our understanding of the pollution sources, exposure pathways, and health effects associated with heavy metal toxicity. By learning more about how people get introduced to the chemicals and the potential health risks caused by these poisons, academics, individuals, and doctors may better protect the public from the damaging impacts of heavy metals.

This manuscript provides more information on some of the most concerning heavy metals, such as mercury, lead, nickel, and chromium. These metals were selected because of their widespread presence, high toxicity, and well-documented effects on human health. This evaluation may be useful for choosing choices since it focuses on certain metals.

II. BIOACCUMULATION AND HEAVY METAL TOXICITY

The buildup of chemicals inside a creature over time is called bioaccumulation. Bioaccumulation occurs when an organism takes in a substance faster than it can break down and discard it via breakdown and excretion. Exposure to low levels of a toxin in the environment is more dangerous than exposure to larger amounts of the chemical in the short term because the risk of chronic poisoning increases in relation to the bio half-life of a substance (Sharma, 2010).

Heavy metal accumulation in the body is harmful to human health. Elements such as Cadmium, lead cobalt, nickel, and silver have been linked to interference with blood cell growth. Liver and kidney damage, as well as problems with the circulatory system (which moves blood throughout the body) and the transmission of nerve impulses, have all been linked to heavy metal buildup. Furthermore, certain types of cancer are associated with exposure to certain heavy metals. Heavy metal bioaccumulation is seen in the following diagram.

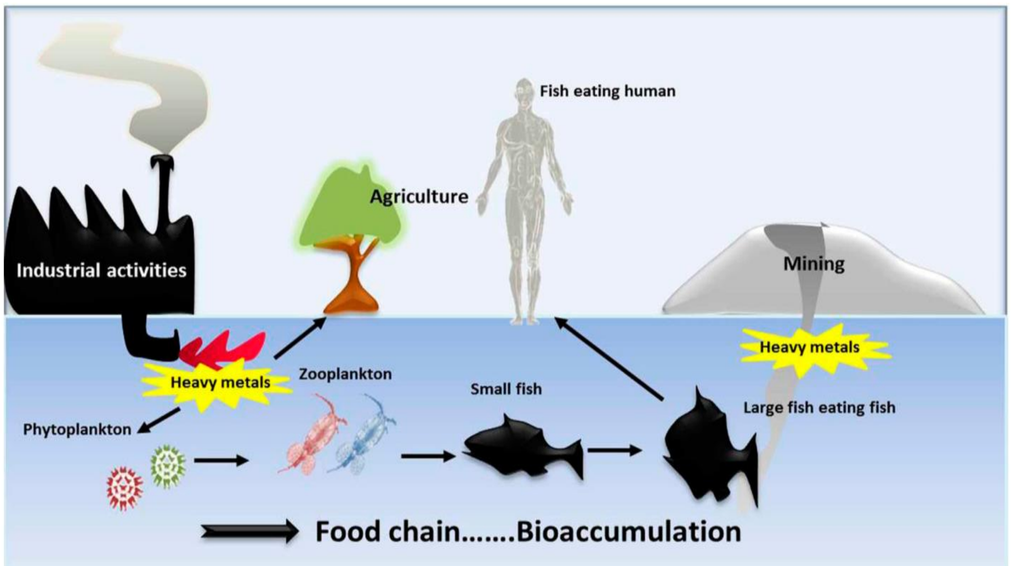

Fig 2.1: Bioaccumulation of heavy metals in humans.

Heavy Metals Toxicity: Heavy metal toxicity, also known as toxicity, may occur as a consequence of exposure to metals, including lead, arsenic, and mercury (Sundseth et al., 2017). The heavy metals bind to cellular components, preventing them from performing their normal tasks. Heavy metal poisoning may cause potentially fatal symptoms and long-lasting health problems if not treated (Sharma, 2020).

The deposition of metals such as mercury in the soft tissues of the human body in toxic amounts is the cause of heavy metal poisoning. The symptoms and physical findings of toxic metal poisoning vary depending on the metal that was loaded. Zinc, copper, chromium, iron, and titanium are just a few of the heavy metals the body needs in very small amounts to function correctly. However, serious damage may occur if these metals accumulate to the point where they cause poisoning (Sundseth et al., 2017). Arsenic, mercury, and cadmium are the most common heavy metals associated with human toxicity. Proximity to harmful metals (Sundseth et al., 2017) in job environments, air or water pollution, foods, medications, insufficiently protected food containers, or absorption of lead-based paints may all contribute to heavy metal poisoning. The toxicity of heavy metals is shown in a straightforward visual below.

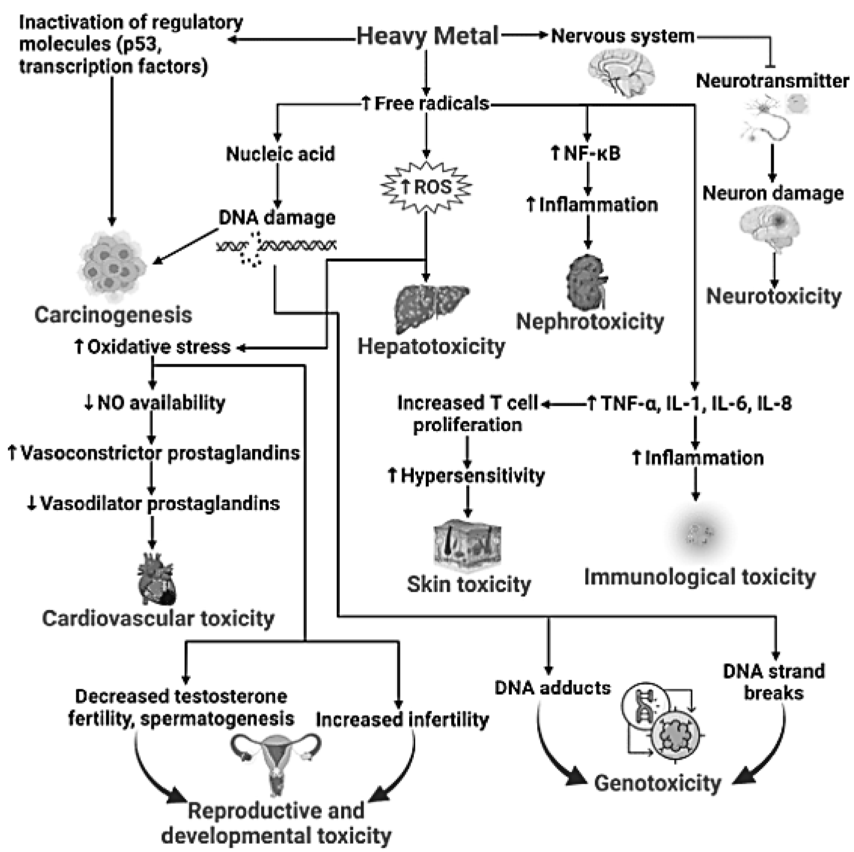

Fig 2.2: Heavy metal Toxicity

IV. SOURCES OF DIFFERENT HEAVY METALS AND THEIR IMPACTS ON HEALTH

Heavy metals can originate from various sources, including natural processes and human activities. Each heavy metal has unique sources and pathways of exposure, which ultimately affect human health. Here are some common heavy metals, their sources, and their impacts on health. Each major heavy metal is represented by its own part of the findings. The paradigm is shown graphically in Fig 3, which is presented below.

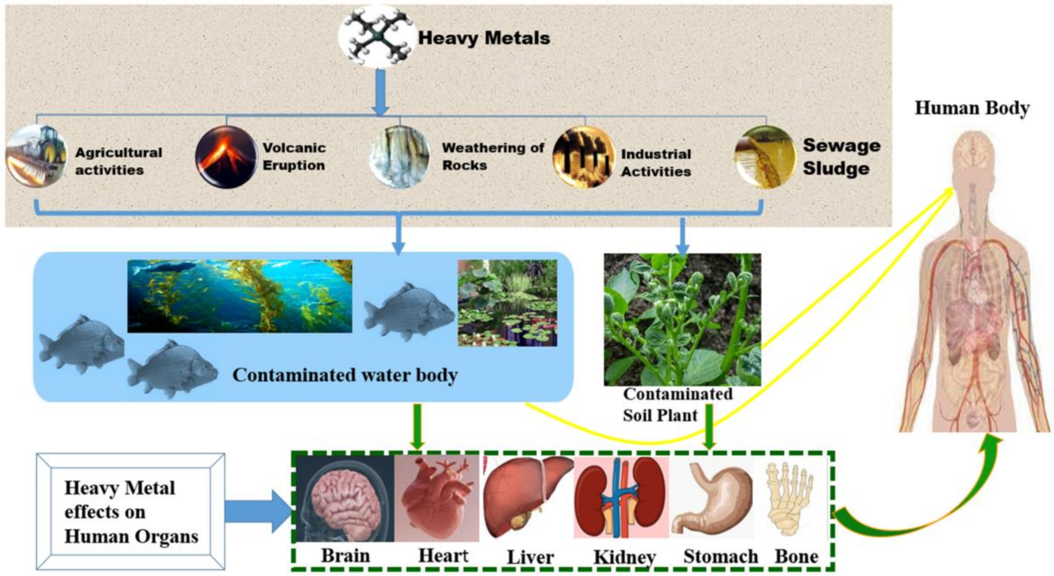

Fig 3: Sources and impact of heavy metals.

Seaweeds have been shown to be effective in removing harmful metals from toxic aqueous solutions, according to a review published in 2021 in Sustainability by Foday Jr., Bo, and Xu.

Mercury

Sources of contamination: Researchers found that thermometers, barometers, and blood pressure monitors often contain metallic mercury. Mercury is used extensively as an electrode in the chloralkali industry's electrochemical method of producing chlorine. Studies have shown that most of the population is exposed to mercury predominantly via their diet, with fish being the main source of information on methyl mercury ingestion (Sankhala et al., 2016; Ha el. al., 2017). Multiple experimental research has shown that amalgam fillings produce mercury vapour, with some evidence suggesting that chewing speeds up the release rate (Ha et al., 2017).

Impact on health: Metallic lead is an allergen that has been linked to contact with the condition, and lead from amalgam dental restorations has been linked to oral lichen, according to a number of studies. Some research (Mitra et al. 2022) suggests that silver in amalgam may have negative health effects. However, this so-called "amalgam disease" is contentious, and although some writers have claimed that their symptoms improved after having dental amalgam fillings removed, there is no research to support this (Ha et al., 2017). After acute exposure, it might take up to a month for symptoms related to nervous system injury to manifest (Mitra et al., 2022; Sharma, 2019).

Parestesias and tingling or numbness in the extremities of the body are the first signs. Coordination issues and visual field constriction may emerge with auditory problems later on. In extreme cases, death might occur 2–4 weeks after the first signs of illness.

Different instances of widespread mercury poisoning have been highlighted by many studies (Sundseth et al., 2017; Ha et al., 2017). The Minamata crisis of the 1950s in Japan was attributed to acute mercury poisoning, in which mercury from fish polluted by mercury leaks into the surrounding water (Mitra et al., 2022). The consumption of bread made with mercury-contaminated grain poisoned over 10,000 Iraqis in the 1970s, resulting in several thousand deaths. The only people in danger from total mercury exposure are those who regularly consume large amounts of fish, while the rest of the population is not at risk. It has been speculated that consuming a lot of fish raises the chance of developing coronary heart disease due to the mercury in the fish.

Recent case-control studies have examined the association between mercury levels in foot trims and adipose tissue fatty acid levels in men's risk of having their first myocardial infarction (Sharma, 2019). Myocardial infarction was associated with a 2.16 (95% CI, 1.09-4.29; P for trend = 0.006) higher adjusted hazard ratio among those in the highest magnesium quintile compared to those in the lowest magnesium quintile. The patients had a 95% confidence interval (CI) of 15% higher mercury levels than the controls.

Lead

Source of contamination: According to a meta-analysis of many studies, lead exposure occurs most often in both indoor air and ingested food. Pots used for preparing and storing food have historically been the source of lead in food, and lead-based acetate was formerly used to enrich port wine. The lungs may absorb up to 50% of the inorganic lead that is breathed. Mines, smelters, welders of lead-painted metal, and battery facilities all pose risks of industrial exposure to inorganic lead. The manufacturing of glass may expose workers to low or moderate levels of risk. It has been shown that whereas adults only absorb around 10% of the lead in food, children may absorb as much as 50%.

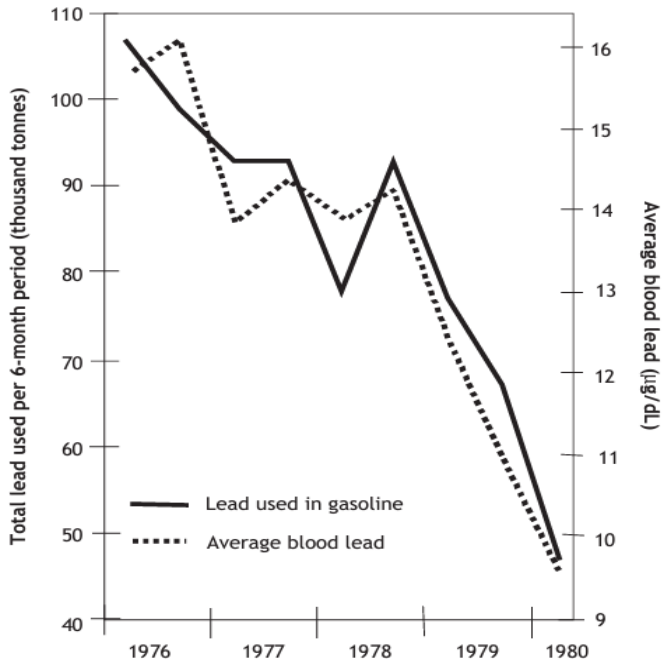

Fig 4 : Lead concentrations in petrol and children's blood

National Academies of Sciences/National Research Council (1989) cites Annest (1983).

Impact on health: Multiple studies have shown that erythrocyte binding to lead in the blood is the mechanism through which lead poisoning occurs. The skeleton is a major storage site for lead, and the metal is only slowly eliminated from there. Lead has a one-month half-life in the blood and a twenty- to thirty-year half-life in the skeleton.

In recent studies, long-term, low-level contact with lead in children has been linked to lower IQ. The mean levels of lead in the blood level over an amount of years are shown in a meta-analysis in Fig 3. The data reveals that an increase of 0.48 mol/l (10 g/dl) in hemoglobin level is associated with a weighted mean decline in IQ of 2 points (95% confidence range, 0.3 to 3.6).

Headache, irritability, stomach discomfort, and other nervous system symptoms have been consistently identified as signs of acute poisoning of lead across investigations. Insomnia and agitation are hallmark symptoms of lead encephalopathy. It's possible that kids will have trouble focusing and learning as a result of this. Lead encephalopathy may cause abrupt psychosis, disorientation, and loss of consciousness in severely afflicted individuals. Long-term lead exposure has been linked to cognitive impairment, including memory loss, slower reflexes, and worse comprehension.

According to several studies of the blood and neurological system associated with lead poisoning, even with typical blood lead levels below 3 mol/l, people may exhibit peripheral nerve symptoms, including slower nerve conduction speed and less cutaneous sensitivity. Severe cases of neuropathy may cause lifelong nerve damage. The gingival edge in the classic image has a dark blue line of lead sulphide. Modification of hemoglobin synthesis is the most noticeable symptom of lead poisoning, and prolonged exposure may cause anemia.

Arsenic

A new meta-analysis of data on poisoning from (Soza-Ried et al., 2019) demonstrates that lead is one of the most worrisome metals from both a societal and human health standpoint. Oxides, sulfides, iron, calcium, magnesium, sodium, copper, etc. salts make it easily accessible (Sankhala, 2016; Chowdhury, 2022). It is semimetallic in nature, very toxic and carcinogenic, and widely distributed in nature. Toxic to the environment and living things, inorganic arsenic includes elements like arsenic and compounds like arsenate. Accidental, inadvertent, or industrial exposure to arsenic might cause health problems (Rahman, 2018; Chowdhury, 2022).

Many studies have looked at the health impacts of arsenic and found that suicide attempts or accidental intake by children may also lead to cases of acute poisoning (Ozturk et al., 2022; Xue et al., 2020; Zhu et al., 2023; Chowdhury, 2022). Because of its effects on respiration within cells, enzymes, and mitosis, especially in the sulphydryl accumulation inside cells, arsenic is classified as a protoplastic poison (Chowdhury, 2022).

Nickel and Chromium

Sources: According to the study, alloys, nickel plating as a corrosion preventative, and battery manufacturers are the three most prevalent use of nickel. An excessive amount may be hazardous to human health, despite the fact that it qualifies as a required trace metal. Both farming and industrial operations contribute to chrome and nickel water pollution in the studied areas. The presence of metals, including cobalt, copper, iron, and zinc, might increase water's toxicity. Several studies on the susceptibility of people to nickel poisoning have been published.

Impact: Multiple studies have linked patients with hair loss to drinking water contaminated with nickel and chromite. It causes cancer in people; therefore, avoid it at all costs. Much additional research has attempted to determine whether or not cutaneous irritation is related to nickel exposure. This is the first research to reveal a link between nickel and balding. According to certain studies, high levels of nickel have been linked to an increase in eczema severity in humans. Nickel is linked to dermal toxicity in sensitized persons and is a possible cause of hair loss in patients exposed to contaminated drinking water. In contrast, chromium is required for normal body function in both animals and humans.

Hexavalent chromium, when present in high enough concentrations, may be hazardous. Pigments made from chromium are utilized in a wide variety of media, including paints, mortar, paper, rubber, and more. Cr dust has been speculated to be a possible cause of lung cancer, and chromic acid spray released during electroplating may cause direct injury to the skin and lungs. Dermatitis and perforation of the skin have been linked to subchronic and chronic use of chrome oxide (U.S. EPA, 1999). Kidney and liver damage and damage to blood vessels and nerves may result from chronic exposure. Since chromium tends to build up in aquatic organisms, there is an increased risk associated with consuming fish that might have recently been exposed to toxic quantities of the element.

It is important to note that the impacts on health can vary depending on the level and duration of exposure to these heavy metals. Chronic exposure to even low concentrations can have significant health consequences. Implementing measures to reduce heavy metal emissions, improving waste management practices, and promoting uncontaminated food and water consumption are crucial for minimizing human health risks associated with heavy metal contamination.

V. IMPACTS OF HEAVY METALS ON PLANT HEALTH

Heavy metals can have detrimental effects on plant health, impacting their growth, development, and overall physiological processes. Here are some examples of the impacts of heavy metals on plants -

Inhibition of seed germination: Heavy metals such as lead (Pb), cadmium (Cd), and copper (Cu) can inhibit seed germination in plants. They can affect various physiological processes during germination, including water uptake, enzyme activity, and nutrient mobilization (Khanna & Chopra, 2013)

Stunted growth and reduced biomass production: High concentrations of heavy metals in the soil can impair root growth and inhibit the development of shoots, resulting in stunted growth and reduced biomass production in plants (Gupta, D. K. et al, 2013).

Disruption of nutrient uptake and transport: Heavy metals can interfere with the uptake and transport of essential nutrients in plants, leading to nutrient imbalances. For example, excess concentrations of zinc (Zn) can hinder the uptake of iron (Fe) and manganese (Mn) in plants (Seregin, I. V. et al, 2006).

Oxidative stress and cellular damage: Heavy metals can induce oxidative stress in plants by generating reactive oxygen species (ROS), which can damage cellular components such as lipids, proteins, and DNA. This oxidative damage can disrupt cellular processes and lead to plant cell death (Hasanuzzaman, M et al, 2012).

Altered photosynthesis and chlorophyll degradation: Heavy metals can impair photosynthesis in plants by affecting chloroplast structure and function. They can inhibit chlorophyll synthesis and accelerate chlorophyll degradation, leading to reduced photosynthetic efficiency (Pilon-Smits et al., 2010).

VI. CONCLUSION

The findings emphasize the significance of understanding heavy metals' sources, pathways, toxicological properties, and their impact on various organ systems. It also highlights that heavy metal contamination arises from both natural processes and human activities, including industrial operations, agricultural practices, and environmental pollution. Lead, mercury, cadmium, arsenic, and chromium are identified as common heavy metals of concern due to their widespread distribution and toxicological effects.

It underscores the importance of monitoring and assessing heavy metal contamination in different environmental compartments to ensure public health safety. This paper concludes by emphasizing the need for integrated strategies that encompass pollution prevention, effective waste management, and public awareness. Collaborative efforts between policymakers, scientists, and health professionals are crucial to minimize heavy metal contamination and safeguard human health. Overall, this paper contributes to understanding the detrimental effects of heavy metal contamination on human health and provides valuable insights into preventive measures and future research directions. By raising awareness and promoting sustainable practices, it advocates for protecting public health from the harmful impacts of heavy metals.

REFERENCES

1. Arain, S.S., Kazi, T.G., Afridi, H.I., Talpur, F.N., Kazi, A.G., Brahman, K.D., Naeemullah, Arain, M.S. and Sahito, O.M., 2015. Estimation of nickel in different smokeless tobacco products and their impact on human health of oral cancer patients. *Nutrition and cancer*, *67*(7), pp.1063-1074.
2. Chowdhury, U., 2022. Groundwater arsenic contamination status and its impact on humans' health in Bangladesh. *Academic Research Journal of Nature and Public Health*, *1*(1), pp.1-12.
3. Gupta, D. K., Chatterjee, S., Datta, S., Veer, V., Walther, C., & Rosenkranz, F. (2013). Heavy metals and their impact on plants and the environment. In: Gupta, D. K., Chatterjee, S., & Walther, C. (Eds.), Metal Toxicity in Plants: Perception, Signaling and Remediation (pp. 1-29). Springer.
4. Ha, E., Basu, N., Bose-O'Reilly, S., Dórea, J.G., McSorley, E., Sakamoto, M. and Chan, H.M., 2017. Current progress on understanding the impact of mercury on human health. *Environmental research*, *152*, pp.419-433.
5. Hasanuzzaman, M., Nahar, K., Alam, M. M., Roychowdhury, R., & Fujita, M. (2012). Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. International Journal of Molecular Sciences, 13(9), 9643-9684.
6. Kang, D.H.P., Chen, M. and Ogunseitan, O.A., 2013. Potential environmental and human health impacts of rechargeable lithium batteries in electronic waste. *Environmental science & technology*, *47*(10), pp.5495-5503.
7. Khanna-Chopra, R. (2013). Heavy Metal Toxicity to Plants: From Molecular to Ecosystem Responses. Springer, pp. 49-70.
8. Mahurpawar, M., 2015. Effects of heavy metals on human health. *Int J Res Granthaalayah*, *530*, pp.1-7.

9. Mitra, S., Chakraborty, A.J., Tareq, A.M., Emran, T.B., Nainu, F., Khusro, A., Idris, A.M., Khandaker, M.U., Osman, H., Alhumaydhi, F.A. and Simal-Gandara, J., 2022. Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science*, p.101865.
10. Ozturk, M., Metin, M., Altay, V., Bhat, R.A., Ejaz, M., Gul, A., Unal, B.T., Hasanuzzaman, M., Nibir, L., Nahar, K. and Bukhari, A., 2022. Arsenic and human health: genotoxicity, epigenomic effects, and cancer signaling. *Biological trace element research*, pp.1-14.
11. Prakash, S. and Verma, A.K., 2021. Arsenic: It's Toxicity and Impact on Human health. *International Journal of Biological Innovations, IJBI*, *3*(1), pp.38-47.
12. Pilon-Smits, E. A. H., & Quinn, C. F. (2010). Mechanisms of metal hyperaccumulation and phytoremediation. Annual Review of Plant Biology, 61, 517-534.
13. Rahman, M.A., Rahman, A., Khan, M.Z.K. and Renzaho, A.M., 2018. Human health risks and socio-economic perspectives of arsenic exposure in Bangladesh: a scoping review. *Ecotoxicology and environmental safety*, *150*, pp.335-343.
14. Sharma S., Prasad F.M., "Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India)." Journal of Chemistry, vol. 7. Article ID 678589, pp 1-10. (2010). https://doi.org/10.1155/2010/678589
15. Sharma S., Dhingra P., Sisodia NS. (2020). Contamination of Heavy Metals in Human Fingernails due to Occupational Exposure in Agra, India. Trans Indian Inst Met. 73, 2239-2245. https://doi.org/10.1007/s12666-020-02029-0
16. Sankhla MS., Kumari M., Nandan M., Kumar R., Agrawal P., 2016. Heavy Metals Contamination in Water and their Hazardous Effect on Human Health-A Review.*Int.J.Curr.Microbiol.App.Sci.* *5*(10):759-766.
doi: http://dx.doi.org/10.20546/ijcmas.2016.510.082
17. Sadeghfam, S., Abdi, M., Khatibi, R. and Nadiri, A.A., 2021. An investigation into uncertainties within Human Health Risk Assessment to gain an insight into plans to mitigate impacts of arsenic contamination. *Journal of Cleaner Production*, *311*, p.127667.
18. Sall, M.L., Diaw, A.K.D., Gningue-Sall, D., Efremova Aaron, S. and Aaron, J.J., 2020. Toxic heavy metals: impact on the environment and human health, and treatment with

conducting organic polymers, a review. *Environmental Science and Pollution Research*, *27*, pp.29927-29942.

19. Sharma, B.M., Sáňka, O., Kalina, J. and Scheringer, M., 2019. An overview of worldwide and regional time trends in total mercury levels in human blood and breast milk from 1966 to 2015 and their associations with health effects. *Environment international*, *125*, pp.300-319.
20. Sonwani, S., Madaan, S., Arora, J., Suryanarayan, S., Rangra, D., Mongia, N., Vats, T. and Saxena, P., 2021. Inhalation exposure to atmospheric nanoparticles and its associated impacts on human health: a review. *Frontiers in Sustainable Cities*, *3*, p.690444.
21. Soza-Ried, C., Bustamante, E., Caglevic, C., Rolfo, C., Sirera, R. and Marsiglia, H., 2019. Oncogenic role of arsenic exposure in lung cancer: A forgotten risk factor. *Critical reviews in oncology/hematology*, *139*, pp.128-133.
22. Sundseth, K., Pacyna, J.M., Pacyna, E.G., Pirrone, N. and Thorne, R.J., 2017. Global sources and pathways of mercury in the context of human health. *International journal of environmental research and public health*, *14*(1), p.105.
23. Xue, L., Zhao, Z., Zhang, Y., Liao, J., Wu, M., Wang, M., Sun, J., Gong, H., Guo, M., Li, S. and Zheng, Y., 2020. Dietary exposure to arsenic and human health risks in western Tibet. *Science of the Total Environment*, *731*, p.138840.
24. Zambelli, B. and Ciurli, S., 2013. Nickel and human health. Interrelations between essential metal ions and human diseases, pp.321-357.
25. Zambelli, B., Uversky, V.N. and Ciurli, S., 2016. Nickel impact on human health: An intrinsic disorder perspective. *Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics*, *1864*(12), pp.1714-1731.
26. Zhang, Y., Xu, B., Guo, Z., Han, J., Li, H., Jin, L., Chen, F. and Xiong, Y., 2019. Human health risk assessment of groundwater arsenic contamination in Jinghui irrigation district, China. *Journal of environmental management*, *237*, pp.163-169.
27. Zhu, Y., Yang, Q., Wang, H., Yang, J., Zhang, X., Li, Z. and Martín, J.D., 2023. A hydrochemical and isotopic approach for source identification and health risk assessment of groundwater arsenic pollution in the central Yinchuan basin. *Environmental Research*, p.116153.