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# Impact of Heavy Metals on Human Health and Environment: An Overview

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**ABSTRACT:** Environmental pollution has exposed humans to various contaminants such as pesticides, heavy metals or polycyclic aromatic hydrocarbons [1]. Unlike most organic pollutants, heavy metals are not removed from ecosystems by natural processes. They tend to accumulate in biotic and abiotic environments reaching toxic levels [2, 3, 4]. The introduction of heavy metals into the environment can result from natural events as volcanic eruptions, soil erosion and forest fires or anthropogenic activities including mining operations, industrial and domestic effluents and fertilizers application [3]. A number of heavy metals are considered essential for human health. They are important constituents of several key enzymes and play a crucial role in various biochemical reactions [5]. An insufficient supply of these elements leads to various deficiency syndromes. However, these micronutrients can become toxic from a threshold content in the body. Other elements are not beneficial for health and can be highly toxic even at very low levels. This is the case of lead, cadmium and mercury that are among the list of 10 chemicals of major public concern due to their high water solubility, toxicity, and carcinogenesis. Acute and chronic exposure to these elements affects human health and could cause incurable diseases leading to death [2, 3, 6, 7].

**KEYWORDS-**heavy,metals,environment,human,health,pollution

### I. INTRODUCTION

Heavy metals are well-known environmental pollutants owing to their toxicity, longevity in the atmosphere, and ability to accumulate in the human body via bioaccumulation. The pollution of terrestrial and aquatic ecosystems with toxic heavy metals is a major environmental concern that has consequences for public health. Most heavy metals occur naturally, but a few are derived from anthropogenic sources. Heavy metals are characterized by their high atomic mass and toxicity to living organisms. Most heavy metals cause environmental and atmospheric pollution, and may be lethal to humans. Heavy metals can become strongly toxic by mixing with different environmental elements, such as water, soil, and air, and humans and other living organisms can be exposed to them through the food chain. Plenty of experimental studies were performed to appraise the promising treatment options from natural products. Additionally, nanotechnology based treatment options are being constantly developed. As an emerging field, nanotechnology is making substantial advances in the analysis and removal of heavy metals from complicated matrices. [1,2,3] Removal of heavy metal has been accomplished by the use of a variety of nanomaterials, including graphene and its derivatives, magnetic nanoparticles, metal oxide nanoparticles, and carbon nanotubes, to name a few. Using nanotechnology for heavy metal analysis and removal from food and water resources provides many benefits over traditional methods. These advantages include a broad linear range, low detection and quantification limits, a high sensitivity, and high selectivity. Therefore this review aimed to explore the environmental consequences of the heavy metals, toxicity to the human health, as well as novel therapeutics development from the natural resources.

Any substance with the potential to produce a negative biological effect can be considered a toxic agent. There are several distinct and intricate classification systems for toxic substances, each based on different standards depending on the desired application. They are classified as pesticides, solvents, food additives, metals, and war gases based on their target purpose. Furthermore, classification based on the chemical structure of toxicants includes metals, non-metals, acids and bases, and organic toxicants, while analytical characterization divides them into volatile

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toxicants, extractives, metals, and metalloids. Therefore, metal toxicity is regularly encountered in a variety of forms, making the analytical assessment of heavy metals (HMs) highly important in the context of public health [1].

HMs are found naturally in the environment, in volcanic eruptions or soil, but they are also the result of various human activities, such as mining, automobile emissions, and industrial waste, etc. The term toxic metals is often synonymous with the term HMs, but there are also light metals which, through accumulation, or in certain forms or doses, become toxic [2]. They adversely affect living organisms, the environment and are non-biodegradable. The criteria for assigning the term HMs are as follows: atomic weight, atomic number, position in the periodic table, and specific gravity  $>5 \text{ g/cm}^3$  (i.e., five times that of water) [3,4,5]. HMs are substances with high electrical conductivity, luster, malleability, and the property to split electrons, forming cations.

Concern over HMs contaminating the ecosystem has grown steadily, addressing the issues of environmental and global public health. As a consequence of their use increasing exponentially in a variety of manufacturing, agricultural, residential, and technical applications, human exposure has also increased significantly [6]. Based on the contamination of the air and water, or the accumulation of HMs in plants and meat, the population can be exposed to HMs directly by ingestion, inhalation, or direct skin contact. Furthermore, exposure to HM toxicity is more likely to occur in certain occupations [7].

Critical contaminants with the possibility of harming both human health and the ecological balance are non-essential metals. The toxicity manifested by non-essential HMs is different for each chemical element. Effects increase from a low level, as in the case of Barium (Ba), Lithium (Li), Aluminum (Al), and Tin (Sn) to elements with a high degree of toxicity, including Lead (Pb), Arsenic (As), Cadmium (Cd), and Mercury (Hg), responsible for numerous negative health consequences [8].

Among the most toxic HMs (affecting human health), the following can be mentioned: As, Al, Hg, Pb, Ni, and Cd. Although they are extremely toxic, the population's exposure to them is constantly increasing [15]. The HMs pathways into the human body are:

- ingestion (via food or water, reaching the bloodstream and various organs, such as the pancreas, and liver, etc., through the absorption process), as is the case for As, Pb, Hg, and Cd;
- inhalation (through the inhalation of air, vapors or aerosols, toxic metals enter the respiratory tract, reach the lungs and then the bloodstream), as is the case for Pb, Hg, and Al;
- and by dermal absorption for As
- It is increasingly recognized that HMs have an increased affinity for certain target organs (i.e., liver, brain, kidneys, and the bones). The accumulation and toxic effect of HMs depends on several factors, such as concentration, chemical form, sex, age, and the time of exposure. Most of them, once ingested, are distributed through the bloodstream to various organs and tissues, where they cause damage in different systems and organs. HMs' harmful action derives from stimulating the formation of free radicals and reactive oxygen derivatives, which cause lipid peroxidation and oxidative stress in the body [17,18]. Furthermore, it must be considered the excess of HMs in the human body which may lead to neurological disorders and adverse emotional changes[5,7,8]

## II. DISCUSSION

The potential of HMs to damage DNA and membranes, as well as to interfere with the activity of proteins and enzymes has demonstrated that they represent a significant risk to human health.

At the present moment, AAS is the dominant analytical technique for the detection of trace elements (metals, and oligo-elements) in the human body, and we are witnessing a more and more evident shift from flame-electro thermal atomic spectrometry to ICP-MS, a more modern and effective method. However, the choice of the analytical method used for the detection of the different metals will remain at the discretion of the toxicologist/chemist who considers the metals to be detected, their number, the analyzed matrix (biological samples), the concentration of the analyte in the matrix, and the intended purpose (toxicological/nutritional screening, therapeutic purpose, and prevention, etc.).

It is of great importance for monitoring the health of the population, not only for studying the effects of occupational exposure, but also for health in general, by determining both nontoxic minerals in the human body and toxic minerals (HMs). This diagnostic method cannot accurately, clearly, and realistically determine what causes an

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abnormal concentration of minerals in the hair. However, it can be stated that the results in conjunction with laboratory biochemical analyses (i.e., determination of  $\delta$ -aminolevulinic acid (ALA), coproporphyrin/Pb poisoning, or determination of As acute hemolytic anemia, the dark color of urine, detection of plasma Hg, coproporphyrin or DMPS challenge test etc.) can lead to an accurate diagnosis in terms of the disorders that the patient suffers from, possible intoxication or possible procedures that the patient undergoes [22].

In the case of an HM detection in forensic practice, it is extremely important to collect as many biological fluids, tissues, and organs as possible, to process them as quickly as possible and to analyze them with modern high-performance equipment. All of these factors, together with a histopathological examination and an investigation into possible diseases and habitual behaviors, can lead to the most accurate determination of the cause of death.

Hyphenated techniques, which combine multimodal detectors with chromatographic separative methods, are becoming effective substitutes with potential use in the evaluation of HMs.

Given the fact that HMs are toxic elements for both human health and the environment, and due to the high degree of bioaccumulation in the human body, it would be advisable to monitor them continuously. Nowadays, due to the modernization of laboratories, the development of biological methods of identification and quantification, using biomarkers it is possible to establish certain criteria and standards that would help protect human health and the environment from HM contamination.[9,10,11] The high-performance laboratory analysis, can be considered a vital barometer of the population's health, as it creates a true mapping of all the biochemical reactions in the body, which through their disturbances can trigger various diseases or even intoxications.

### III. RESULTS

Heavy metal poisoning is the accumulation of heavy metals, in toxic amounts, in the soft tissues of the body. Symptoms and physical findings associated with heavy metal poisoning vary according to the metal accumulated. Many of the heavy metals, such as zinc, copper, chromium, iron and manganese, are essential to body function in very small amounts. But, if these metals accumulate in the body in concentrations sufficient to cause poisoning, then serious damage may occur. The heavy metals most commonly associated with poisoning of humans are lead, mercury, arsenic and cadmium. Heavy metal poisoning may occur as a result of industrial exposure, air or water pollution, foods, medicines, improperly coated food containers, or the ingestion of lead-based paints. Some heavy metals have bio-importance as trace elements but the biotoxic effects of many of them in human biochemistry are of great concern. Hence, there is a need for proper understanding of mechanism involved, such as the concentrations and oxidation states, which make them harmful. It is also important to know their sources, leaching processes, chemical conversions and their modes of deposition in polluting the environment, which essentially supports life. Literature sources point to the fact that these metals are released into the environment by both natural and anthropogenic means, especially mining and industrial activities, and automobile exhausts. They leach into the underground waters, moving along water pathways and eventually depositing in the aquifer, or are washed away by run-off into surface waters thereby resulting in water and subsequently soil pollution. Poisoning and toxicity in ecosystem occur frequently through exchange and co-ordination mechanisms. When ingested, they form stable biotoxic compounds, thereby mutilating their structures and hindering bioreactions of their functions[12,13,15]

In general the toxicity of metal ions to mammalian systems is due to chemical reactivity of the ions with cellular structural proteins, enzymes and membrane system. The target organs of specific metal toxicities are usually those organs that accumulate the highest concentrations of the metal in vivo. This is often dependent on the route of exposure and the chemical compound of the metal i.e. its valiancy state, volatility, lipid solubility etc. Besides the general toxicities of metals, we are today also concerned with the potential carcinogenicity of metal compounds. Certain metals such as chromium and nickel have been linked with cancers in exposed human populations

1 Arsenic: Soluble inorganic arsenic can have immediate toxic effects. Ingestion of large amounts can lead to gastrointestinal symptoms such as severe vomiting, disturbances of the blood and circulation, damage to the nervous system, and eventually death. When not deadly, such large doses may reduce blood cell production, break up red blood

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cells in the circulation, enlarge the liver, color the skin, produce tingling and loss of sensation in the limbs, and cause brain damage. Long-term exposure to inorganic arsenic in drinking water in Taiwan has caused black foot disease, in which the blood vessels in the lower limbs are severely damaged, resulting eventually in progressive gangrene. The relationship between arsenic exposure and other health effects is less clear. The evidence is strongest for high blood pressure, heart attacks and other circulatory disease. The evidence is weaker for diabetes and reproductive effects; it is weakest for strokes, longterm neurological effects, and cancer at sites other than lung, bladder, kidney and skin. as well as other skin changes such as hyperkeratosis and pigmentation changes. These effects have been demonstrated in many studies using different study designs. Exposure–response relationships and high risks have been observed for each of these end-points. The effects have been most thoroughly studied in Taiwan but there is considerable evidence from studies on populations in other countries as well. Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been reported to be associated with ingestion of drinking-water at concentrations  $\leq 50\mu\text{g}$  arsenic/litre. Occupational exposure to arsenic, primarily by inhalation, is causally associated with lung cancer. Exposure–response relationships and high risks have been observed. Increased risks have been observed at cumulative exposure levels  $\geq 0.75$  ( $\text{mg}/\text{m}^3$ )  $\times$  year (e.g. 15 years of exposure to a workroom air concentration of  $50\mu\text{g}/\text{m}^3$ ). Effects on human health Lead is a toxic heavy metal even at very low levels of exposure in humans. Its effect on the human body can be both acute and chronic depending on dose and exposure scenarios. Lead targets multiple organs in the body due to its systemic toxicity which can cause neurological, cardiovascular, renal, gastro-intestinal, haematological and reproductive effects. Human exposure to lead is usually tested through blood sampling. The lead stored in the bones can emerge as a remobilised form of lead exposure late in the life of the individual. Exposure occurs primarily through inhalation of dust particles, air contaminated with lead and ingestion of foodstuffs, water and dust. Inhalation is an important exposure pathway for people in the vicinity of point sources such as lead contaminated sites, countries where leaded fuel is still used and areas where waste from products containing lead is burnt as well as secondary lead recovery operations. Apart from ingestion of lead on foodstuffs and in drinking water a major exposure source is leaded paint. Dust in homes containing leaded paint can be inhaled by adults and children and ingested by children through pica behaviour.

2 Cadmium: Effects on human health Humans are exposed to cadmium by inhalation and ingestion although the main health impacts recorded in the literature are through dietary exposure (kidney and bone damage) and inhalation from smoking tobacco and occupational exposure (lung damage). Dietary intake accounts for 90% of all exposure in non-smokers. Cadmium in the environment is toxic to plants and animals and many micro-organisms. Cadmium does not degrade in the environment to less toxic products which contributes to its bioaccumulation in the kidneys and liver of vertebrates and invertebrates. Cadmium enters the environment from a variety of anthropogenic sources. Wastewater is key source of environmental cadmium contamination and diffuse pollution occurs through industrial air emissions and widespread use of fertilizers on agricultural soils. Plants (including rice and tobacco) that are grown in contaminated soils take up cadmium and lead to human dietary (and inhalation) exposures. However, human exposure also occurs when cadmium contaminated soils are disturbed and the dust is inhaled. Diets high in meat (especially liver and kidneys) or products from marine mammals may result in a particularly high intake of cadmium.<sup>72</sup> Cadmium is not considered essential for biological function in humans. The main human organ impacted by cadmium exposure is the kidney in both the general population and the occupationally exposed. Tobacco smokers are considered to be at particular risk as are people with low iron levels. A secondary critical effect is skeletal damage as a secondary response to kidney damage or direct action on the bone cells by the cadmium.[17,18,19]

3 Mercury: Main effects of Mercury on Human Health and the environment effects on human health Toxicity of mercury is dependent on whether it takes the form of elemental mercury, inorganic mercury or organic mercury compounds (particularly alkylmercury compounds such as methylmercury and ethylmethyl salts and dimethylmercury). Accordingly, the exposure scenario varies considerably for these different forms of mercury and complicates toxicity assessment. In terms of methylmercury, dietary ingestion is the major source of human exposure, especially for seafood and fish. Around 80% of inhaled elementary mercury vapour is retained in the tissue of the lungs where it goes on to penetrate the blood-brain barrier where neurological effects take place. Ingestion of elementary mercury does not

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always lead to high levels of absorption but deaths have been reported. Inhalation of elementary mercury vapour has been observed to lead to symptoms including tremors, emotional lability, insomnia, memory loss, neuromuscular changes, and headaches as well effects on the kidney and thyroid. High exposures have led to death but the critical effects are neurotoxic and renal.<sup>94</sup> The main route of exposure to inorganic mercury for humans is dietary although for some sub-sections of the population products such as skinlightening creams, soaps and the use in traditional medicine and/ritualistic practices can result in significant exposures to both inorganic and elemental mercury. Methylmercury is a well known potent neurotoxin which causes adverse impacts on the developing human brain. It passes readily through the placental barrier and the blood-brain barrier making any exposure during pregnancy of great concern. Methylmercury is considered possibly carcinogenic by the International Agency for Research on Cancer.

4 Copper: Copper is a naturally-occurring metallic element that occurs in soil at an average concentration of about 50 parts per million (ppm). It is present in all animals and plants and is an essential nutrient for humans and animals in small amounts. The major sources of environmental copper releases include the mining, smelting and refining of copper, industries producing products from copper such as wire, pipes and sheet metal, and fossil fuel combustion. Water pipes are often made of copper and bath fixtures may be made from brass and bronze alloys that contain copper. The principal source of copper in drinking water results from the leaching of copper from pipes and bath fixtures due to acidic water. Blue-green stains left in bath fixtures are a sign of the presence of copper in water. Other releases of copper to the environment include agricultural use against plant diseases and treatments applied to water bodies to eliminate algae. Health Effects Absorption/Metabolism Studies investigating oral absorption of copper have found the percentage absorbed ranging from 24-60 percent. Factors affecting the amount absorbed include the amount of copper in the diet and competition with other metals found in food such as iron and zinc. There are no studies examining inhalation exposure to copper. The amount of dermal absorption is also not known, but a few studies indicate that it is very low. Beneficial Effects Copper is a component of several enzymes necessary for normal metabolic functions in humans. The Recommended Daily Allowance (RDA) of copper for adults is 0.9 milligrams (mg). The median intake of copper from the typical U.S. diet ranges from 1 to 1.6 mg/day. The safe highest level of intake for an extended period of time (chronic exposure) is 10 mg/day. [20,21,22] Food sources rich in copper include shellfish, organ meats, nuts, beans and cocoa. Effects of copper deficiency can include anemia, low numbers of white blood cells, osteoporosis in infants and children, and defects in connective tissue leading to skeletal problems. Short-Term (Acute) Effects Acute poisoning from ingestion of excessive copper can cause temporary gastrointestinal distress with symptoms such as nausea, vomiting, and abdominal pain. Liver toxicity was seen in doses high enough that resulted in death. High levels of exposure to copper can cause destruction of red blood cells, possibly resulting in anemia. Long Term (Chronic) Effects Mammals have efficient mechanisms to regulate copper stores in the body such that they are generally protected from excess dietary copper levels. However, at high enough levels, chronic overexposure to copper can damage the liver and kidneys. Wilson's disease is an inherited (genetic) disorder in which copper builds up in the liver. Symptoms of liver toxicity (jaundice, swelling, pain) usually do not appear until adolescence. Carcinogenicity (ability to cause cancer) although some studies of workers exposed to copper have shown increased cancer risks, they were also exposed in the workplace to other chemicals with carcinogenic potential. Increased cancer risk has not been found in animal studies. Copper is currently categorized by the EPA as a Group D carcinogen (inadequate evidence to classify) and has not yet been reviewed for placement into one of the new cancer classification categories. Reproductive/Developmental Effects There are no reports of developmental effects occurring in humans exposed to elevated levels of copper. Developmental effects have been observed in a few studies of animals given high doses of copper, including delayed growth and development, delayed bone formation, and decreased litter size and body weights

5 Nickel: Nickel is a compound that occurs in the environment only at very low levels. Humans use nickel for many different applications. The most common application of nickel is the use as an ingredient of steel and other metal products. It can be found in common metal products such as jewelry. Foodstuffs naturally contain small amounts of nickel. Chocolate and fats are known to contain severely high quantities. Nickel uptake will boost when people eat large quantities of vegetables from polluted soils. Plants are known to accumulate nickel and as a result the nickel uptake from vegetables will be eminent. Smokers have a higher nickel uptake through their lungs. Finally, nickel can be

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found in detergents. Humans may be exposed to nickel by breathing air, drinking water, eating food or smoking cigarettes. Skin contact with nickel-contaminated soil or water may also result in nickel exposure. In small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. An uptake of too large quantities of nickel has the following consequences: Higher chances of development of lung cancer, nose cancer, larynx cancer and prostate cancer. Sickness and dizziness after exposure to nickel gas. Respiratory failure, Lung embolism, Birth defects, Asthma and chronic bronchitis, Allergic reactions such as skin rashes, mainly from jewelry, Heart disorders. Nickel fumes are respiratory irritants and may cause pneumonitis. Exposure to nickel and its compounds may result in the development of a dermatitis known as "nickel itch" in sensitized individuals. The first symptom is usually itching, which occurs up to 7 days before skin eruption occurs. The primary skin eruption is erythematous, or follicular, which may be followed by skin ulceration. Nickel sensitivity, once acquired, appears to persist indefinitely.

6 Tin: Scientists use many tests to protect the public from harmful effects of toxic chemicals and to find ways for treating persons who have been harmed. One way to learn whether a chemical will harm people is to determine how the body absorbs, uses, and releases the chemical. For some chemicals, animal testing may be necessary. Animal testing may also help identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method for getting information needed to make wise decisions that protect public health. Scientists have the responsibility to treat research animals with care and compassion. Scientists must comply with strict animal care guidelines because laws today protect the welfare of research animals. Because inorganic tin compounds usually enter and leave your body rapidly after you breathe or eat them, they do not usually cause harmful effects. However, humans who swallowed large amounts of inorganic tin in research studies suffered stomachaches, anemia, and liver and kidney problems. Studies with inorganic tin in animals have shown similar effects to those observed in humans. There is no evidence that inorganic tin compounds affect reproductive functions, produce birth defects, or cause genetic changes. Inorganic tin compounds are not known to cause cancer. Inhalation (breathing in), oral (eating or drinking), or dermal exposure (skin contact) to some organotin compounds has been shown to cause harmful effects in humans, but the main effect will depend on the particular organotin compound. There have been reports of skin and eye irritation, respiratory irritation, gastrointestinal effects, and neurological problems in humans exposed for a short period of time to high amounts of certain organotin compounds. Some neurological problems have persisted for years after the poisoning occurred. Lethal cases have been reported following ingestion of very high amounts. [23,25,27]

7 lead: Most of the studies looking for a possible link between lead exposure and cancer have focused on workers with high levels of occupational (work-related) exposure to inorganic lead. People with heavy workplace exposures to lead have been found to have blood lead concentrations many times higher than the average blood lead concentration in the general population. Several studies have looked for a link between exposure to lead in the workplace (mainly among battery workers and smelter workers) and lung cancer. Some of these studies have found a small increase in lung cancer risk. However, most of these studies were limited in that they didn't take into account other factors that might affect lung cancer risk, such as smoking or exposures to arsenic or other heavy metals that typically also occur along with lead exposures in industrial settings. Some studies looking at blood lead levels in the general population have also found a small increased risk of lung cancer in people with higher lead levels. Several of these same workplace studies also looked at stomach cancer risk. Most of the studies found an increased risk of stomach cancer with higher lead exposure. Although it is unlikely these results would be affected by smoking or arsenic exposure, the studies didn't take into account other factors that could also have affected stomach cancer risk. Studies have also looked at possible links between workplace exposures to lead and other cancers, including cancers of the brain, kidney, bladder, colon, and rectum. The results of these studies have been mixed. Some studies have found links, while others have not. The link between lead exposure and cancer is clearly a concern, and more research is needed to better define the possible link between lead exposure and a number of cancers.

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### IV. CONCLUSIONS

Conclusively, based on experimental studies, the advances of toxicology has improved our knowledge about human exposure to toxic elements (metals and metalloids) and their health effects, such as developmental retardation, several types of cancer, kidney damage, endocrine disruption, immunological, neurological effects and other disorders. The ongoing research works throw more light onto new insights and biochemical and molecular mechanisms involved in the development of pathological conditions in human. [29,30]

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