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Research Article

Heavy Metal and environmental pollution

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Abstract

In recent years, environmental contamination caused by heavy metals has become a global problem as it impacts public health. Particularly when anthropogenic activities such as factories and urbanisation continue to increase, releasing contaminants into the atmosphere without solutions for control and effects. Heavy metals are naturally formed in the soil system as a result of the parent materials' pedogenetic weathering processes, as well as through anthropogenic sources such as coal and fuel combustion. Metals accumulated in the soil can be converted and transmitted up the food chain, from plants to animals and people..By affecting the metabolic processes of vital organs and glands, excessive heavy metal levels may be detrimental to the organism and plants. They also displace from their original position the necessary nutritional minerals, thereby hindering their biological role. As a result of growing anthropogenic activities, it is vital that heavy metal levels in the atmosphere be regularly measured and monitored for human exposure assessment and a healthy environment.The goal of this study is to discuss heavy metal contamination in the environment, as well as the pharmacokinetic and toxicological processes involved. .

Introduction

The setting is the world where all species reside or function. The hydrosphere, lithosphere, biosphere and the atmosphere are composed of it. Industrialization has evolved at a rapid pace over the last hundred years. The rise in traffic activity contributes significantly to the accumulation of heavy metals in the atmosphere due to the rapid trend of industrialization and urbanisation. Heavy metals are those that have a high density or high atomic weight. As a result of growing anthropogenic activities, it is vital that heavy metal levels in the atmosphere be regularly measured and monitored for human exposure assessment and a healthy environment.[Tchounwou et al., 2012; Duffus, 2002 and Wang, 2009]. Via suspended dust or direct contact, heavy metal pollutants can easily affect people living within the vicinity of the source [Martin and Johnson, 2012]. If they join the food chain because of any significant health threats they cause in any way. Because of their toxicity, persistence and non-degradability features, managing the quantities of heavy metals in our atmosphere is of major importance.

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Occurrence and properties of Heavy metal

Human activities, notably metal mining, smelting, foundries, and other metal-based enterprises, such as landfills and roadworks, contribute to heavy metal pollution... The agriculture sector's usage of herbicides, insecticides, fertilizers, and other goods has resulted in heavy metal contamination. Volcanic activity, metal degradation, and geological weathering can all enhance heavy metal emissions...[Masindi and Muedi, 2018; Walker, 2012; Tchounwou et al., 2012; Shallari, 1998 and He et al., 2005].Heavy metals, such as copper, lead, and zinc, are among the traditional transition metals, according to Nies[1999]. Generally, densities above 5g/cm3 are not degradable or destructible. according to Singh [2009]. Transition metals, lanthanides, and actinides, some of which are metalloids, are among them. Heavy metals, such as copper, lead, and zinc, are among the most common transition metals, according to Mcintyre[2003]. "Tchounwou et al.[2012] defined heavy metals as metallic elements with a relatively high density compared to water. Assuming that heaviness and toxicity are related, metalloids such as arsenic are included in heavy metals and can cause toxicity at low exposure levels. Heavy metals are metals or metalloids (elements with both metal and nonmetal properties) [Singh, 2009]." "Cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin, and thallium" are elements of great significance since they are found in all regions of the environment. [Nies, 1999].

Metallicoids form lipophilic ions and compounds, and when they bind to non-metallic elements of cellular macromolecules, they can produce toxic effects.. [Masindi, and Muedi, 2018 and walker et al., 2012]..Metals are difficult to degrade since they are not biodegradable.Metal ions can be detoxified by encapsulating them in a protein or storing them in an insoluble state within intracellular granules, where they can be expelled or stored for long periods of time. They bioaccumulate in our systems until we consume or inhale them. This bioaccumulation is harmful to biological and physiological systems. Because of their involvement in a wide range of biochemical and physiological processes, certain heavy metals are required for living and are referred to as essential elements..[Tchounwou et al., 2012; Duffus, 2002 and Wang, 2009]. Three categories of elements exist: essential elements, macrominerals, and trace elements. Seven significant macrominerals, which are integral elements that maintain the ionic balance of structural components include "amino acids, and nucleic acids include sodium, magnesium, phosphorous, sulphur, chlorine, potassium, and calcium", in order of their atomic number. "The last group consists of thirteen trace elements: silicone, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, molybdenum and iodine, based on their atomic number. For the maintenance of skeletal structure formation, acid-base equilibrium control, colloidal system maintenance, the critical elements are important." They are also critical as components of crucial enzymes, structural proteins, and hormones [Tchounwou et al., 2012 and Villanueva, P. Bustamante, 2006]. Nonessential metals play no major role in the body, but they can induce toxicity in the body. [Walker et al., 2012].

Heavy metals have been shown to impact cellular organelles and components such as lysosomes, mitochondria, nuclei, cell membranes, and enzymes.Metal ions have been demonstrated to interact with DNA and nuclear proteins, resulting in DNA damage, cell cycle disruption, apoptosis, and carcinogenesis. . [Tchounwou et al., 2012]. "The heavy metal, on the other hand, causes 'indirect' harm resulting from the production of species of reactive oxygen and nitrogen comprising hydroxyl and superoxide radicals, hydrogen peroxide, nitric oxide and other endogenous oxidants." It has been noted that heavy metals cause signalling pathways [Valko et al., 2005]. Metal toxicity allows free radicals to form, causing damage to DNA, sulphydryl homeostasis modification, and lipid peroxidation. Fornickel, iron, copper, chromium and cadmium, free radical formation has mostly been studied. For carcinogenic properties, the last three metals are recognised [Valko et al., 2005].

The reactions of Fenton are mainly associated with mitochondria, microsomes and peroxisomes [Valko et al., 2005]. Mutagenicity of DNA base changes is mediated by metal-induced free radicals, establishing a link between carcinogenesis and oxidative stress.. Cadmium, nickel, and arsenic have all been shown to obstruct the following DNA repair mechanisms "(I)base modification by chromium and nickel (ii) crosslinking by nickel, copper and oxidant, iron and oxidant (iii) nickel, cadmium, chromium and oxidant strand splitting; and (iv) copper, chromium, and nickel depuration are all examples of DNA oxidative effects." [Valko et al., 2005].

The spectrum of antioxidants, which can be enzymatic and nonenzymatic, offers defence by "(I) preventing molecular oxygen and/or peroxide reactions and ferrous ion chelation; (ii) preserving iron chelation and the redox state, rendering iron unable to reduce molecular oxygen; and (iii) trapping the created radicals." Thiol molecules, like glutathione, are among the most potent groups, trapping radicals, preserving the redox state of the cell, and decreasing peroxide, so safeguarding the cell. Vitamin E is a "non-enzymatic antioxidant" that has been shown in vitro and in animals to protect against damage caused by metals containing iron, copper, and cadmium, as long as the daily intake does not exceed 400 IU, which is deadly.... [Valko et al., 2005].

Pollution from Heavy Metal

Any metal (or metalloid) species that appears in an unwelcome location, or in a shape or concentration that has a negative human or environmental impact, may be deemed a 'pollutant.' Metals/metalloids include "lead, cadmium, mercury, arsenic, chromium, copper, selenium, nickel, silver, and zinc." [Mcintyre, 2003]. In recent years, environmental pollution by these metals has been correlated with a rising ecological and global public health problem. Heavy metals are among the many environmental toxins that play an essential role since their concentrations in air, soil, and water are constantly growing as a result of anthropogenic activity. [Gray et al., 2003]. In most major metropolitan areas, the issue of environmental contamination due to toxic metals is of great concern. Geoaccumulation, bioaccumulation and biomagnification may result from toxic metals entering the environment [Abdulmajeed et al., 2013 and Domingo et al., 2001]. Heavy metal contamination in the natural environment is a global issue, for it inflicts harmful effects on living organisms[Ghrefat and Yusuf, 2006].

A crucial concern in determining the environmental effects of heavy metals on the atmosphere is the distribution of metals between soil and vegetation [Addo et al., 2012]. Heavy metals such as "copper, lead, and zinc contribute to environmental pollution through sources such as leaded fuel, industrial waste, and acid rain, which results from metal ions seeping from the soil into lakes and rivers." [Bi et al., 2010]. In point-source areas such as mining, foundries and smelters and other metal-based manufacturing activities [Halim et al., 2002], environmental pollution is very prominent. It is the responsibility of rapid industrialization and the addition of hazardous chemicals to the atmosphere to change the ecosystem [Clayton and Clayton, 1982]. Natural processes such as weathering and volcanic eruptions have also been implicated in a large contribution to heavy metal emissions..[Duffus, 2002].

Factors associated with heavy metals accumulation in an environment

Numerous elements, including parent material and soil characteristics, as well as human activities such as industrial processing, trafficking, agriculture, and irrigation, all influence heavy metal buildup in the environment.Heavy metals emitted by smelters, waste incinerators, industrial waste water, and the application of sludge or municipal manure, pesticides, and fertilizers have the potential to damage vast areas of land.. [Hu et al., 2013]. [Ratko et al., 2001; Zehetner et al., 2009].Natural concentrations of heavy metals in soil are mostly influenced by the composition of the parent material. “Chemical factors that regulate speciation at thermodynamic equilibrium, complexion kinetics, lipid solubility, and octanol/water partition coefficients are all impacted.[Hamelink et al., 1994].” Biological aspects such as species differences, trophic interactions, and biochemical/physiological flexibility are also important. [Morkunas et al., 2018],

Pharmacokinetic and toxicology processes of some heavy metals

Chromium: - The properties of chromium particles impact the absorption of inhaled chromium. “In the bloodstream, Cr6+ is processed at a higher rate than Cr3+. Chromium, which is not consumed by the lungs, will then reach the gastrointestinal tract as mucociliary clearance cleanses it. It is consumed mainly in the yeyunum. Factors that impact the degree of absorption [ATSDR Toxicological Profile for Chromium, 2012] are oxidation state and metal formulation. The gastrointestinal tract does not absorb Inorganic Cr3+ well. After oral exposure, Cr6+ is absorbed to a higher degree than Cr3+, while gastric juices in the gastrointestinal tract are seen to reduce it to Cr3+. The liver, blood, lung, erythrocytes, epithelial fluid, peripheral parenchyma cells, and alveolar macrophages will reduce Cr6+ to Cr3+ [ATSDR Toxicological Profile for Chromium, 2012]. Cr3+ binds to transferrin once it reaches the bloodstream, and after it has been absorbed, Cr6+ is taken up by erythrocytes and then decreased to the trivalent form. The spleen, bone marrow, lungs, lymph nodes, liver and kidney are mostly consumed. The organs that take up the most chromium are the lungs.” The metal is primarily excreted by urine, but is also removed in nails, hair, milk and sweat by bile excretion and smaller amounts [Valko et al., 2005].

A dynamic process is the mechanism of toxicity and chromium carcinogenicity. Intermediates are involved in both the intracellular reduction of Cr6+ and Cr3+ and the oxidative process [“ATSDR Toxicological Profile for Chromium, 2012”]. “DNA lesions such as DNA-protein crosslinks, Cr-DNA adducts, DNA-DNA crosslinks, cell signaling pathway shifts, and DNA strand breaks are caused by complexes within the cell made up of Cr3+ and peptides, DNA and proteins, all of which may play a role in chromium compound toxicity and carcinogenicity [ATSDR Toxicological Profile for Chromium, 2012; Valko et al., 2005].” Cr6+ is more hazardous than the trivalent oxidative state because “(i) has a larger redox potential; and (ii) is more likely to infiltrate cells. Cr6+ is found at physiological pH in a tetrahedral chromate anion with a structure comparable to other natural anions such as phosphate and sulphate, which are permeable via nonselective membrane channels [Valko et al., 2005]. Cr3+, on the other hand, has an octahedral complicated structure that prevents it from easily passing through the channels.”.Once the hexavalent form of chromium and its intermediates Cr4+ and Cr5+ reach the cell, redox mechanisms convert Cr6+ to Cr3+. As a result of the reaction, Cr4+ is generated, which has a larger hazard potential than Cr3+. The reactions will involve ascorbate, amino acids, and glutathione [ATSDR Toxicological Profile for Chromium, 2012]. The ability of radical scavengers to protect chromium cells has been demonstrated, implying that oxygen radicals play a significant role in chromium toxicity.[ATSDR Toxicological Profile for Chromium, 2012]..

Cobalt: - In the absorption of cobalt inhalation, biological solubility plays a critical role. Simple particles of physiologically insoluble cobalt are transported through phagocytosis and mucociliary, thereby providing a small systemic macrophage. Cobalt is eliminated in the feces and bile primarily by urine and, to a lesser extent, through bile. [Simonsen et al., 2012]. Soluble forms of the metal enter the bloodstream via the bronchial and alveolar walls. Other factors, such as iron shortage and hunger, may be dependent on cobalt oral absorption, which enhances cobalt absorption. Iron and cobalt fight for the absorptive route in the intestine, but ferritin is not present to absorb cobalt. The metal's solubility can also hinder oral absorption. The more the metal's solubility, the more it gets absorbed. Dermal absorption is affected by whether or not the skin is intact. “When the skin is intact, cobalt absorption is lower, however when the skin is fractured, cobalt absorption is higher” [ATSDR - toxicological profile: Cobalt, 2014]. Cobalt has been reported to have a high sulphydryl group affinity, causing essential enzymes to be inhibited. Animal studies have established that Cr2+ is carcinogenic. The generation of free radicals by cobalt has resulted in toxicity and carcinogenicity.. [Valko et al., 2005].

Nickel: - Nickel is absorbed via the gastrointestinal tract as a lipophilic, low-molecular-weight compound. Nickel absorption in the stomach would be harmed by the presence of ions and complex ligands. Nickel in low concentrations, when combined with enhanced diffusion, can be absorbed via active transport in mammals.. Nickel forms a complex with albumin and is transported into the bloodstream along with ultra-filterable ligands such as amino acids and small polypeptides. Nickel competes with copper for albumin binding sites. [ATSDR - toxicological profile: Nickel, 2017]. According to in vitro research on rats, nickel is absorbed into the liver via calcium channels located in hepatocytes. Nickel is normally excreted through the urine. [Valko et al., 2005].

Nickel has been shown to activate the transcription factor NF-B throughout the inflammatory phase of nickel, as well as during the apoptotic process. Another nickel-activated transcription factor is ATF-1 (a member of the ATF/CREB family), which activates the protein kinase cascade in response to a rise in calcium, hence mediating ATF/CREB phosphorylation. Nickel activation of ATF-1 has been demonstrated to result in a reduction in the TSP I regulator, which increases angiogenesis and thus tumor formation. [Valko et al., 2005].

Mercury: -Mercury:

Metallic mercury, accompanied by ingestion, is consumed mainly by inhalation. Metallic mercury accumulates in a variety of physiological tissues, including the thyroid, heart, breast, muscles, liver, adrenal glands etc. “Additionally, the metal exhibits a strong affinity for T cell surfaces and sulphydryl groups, impairing the function of T cells. The majority of metallic mercury is discharged as mercuric mercury.[Bernhoft, 2012]. Calomel (Hg2+) is weakly soluble in water and is little absorbed by the intestine, however certain amounts of a more absorbable form are oxidised.” The intermediate phase of metallic and mercuric mercury is mercury mercury. [Bernhoft, 2012].

When tin animals are exposed to both types of mercury, as demonstrated in in vivo and in vitro experiments, oxidative stress is frequently generated. Due to the high affinity of mercury ions for thiol binding sites, intracellular thiols, notably glutathione, are depleted, leading in oxidative stress in proximal tubular cells as a result of an indirect or direct cause or predisposition.. [Valko et al., 2005].. Hg2+ depletes mitochondrial GSH at low concentrations and enhances hydrogen peroxide production in kidney mitochondria due to reduced transit of respiratory chain electrons. The increased generation of H2O2 can produce oxidative tissue damage, as demonstrated in mercury-induced nephrotoxicity, such as lipid peroxidation. [Valko et al., 2005]. Because of the oxidative damage caused to the kidneys, a number of biochemical changes can occur. Porphyrinuria [ATSDR - toxicological profile: Mercury, 1999] may be included in the updates. Mercury contaminations has invreasingly been linked with growing cardiovascular diseases. the mercury concentration can diminish the beneficial impact of acquatic resources. [Valko et al., 2005].

Lead: - The amount of lead absorbed by the gastrointestinal tract is determined by numerous factors in the ingested media, including the person's age, nutrition, and diet, as well as the physiological properties of the metal. The duodenum is frequently used for saturable route absorption into the gastrointestinal tract. When it comes to inorganic lead absorption, the cutaneous route is not very effective, whereas absorption boosts hand-to-mouth behavior.[Abadin et al., 2013]. Pregnancy, menopause, lactation, and osteoporosis are all circumstances that might increase bone resorption and consequently blood lead levels. Lead is primarily found in red blood cells. Lead is transferred from the mother to the fetus through nursing. [Abadin et al., 2013]. Complexes with a variety of protein ligands, such as albumin, and non-protein ligands, such as sulphydryls, are generated during inorganic metal metabolism. “ALAD is a significant intracellular ligand that is present in red blood cells. Additionally, the metal forms interactions with proteins in the cytosol and nucleus of the cell. In the case of organic lead, alkyl lead compounds are actively processed in the liver by oxidative dealkylation catalyzed by cytochrome P-450.” Complexes with a variety of protein ligands, such as albumin, and non-protein ligands, such as sulphydryls, are generated during inorganic metal metabolism. [Abadin et al., 2013].

Nitric oxide deficiency, which is essential for peripheral and central blood pressure control, is also related with lead-induced hypertension in rats.NO is produced as a result of oxidative stress and is associated with increased ROS activity and NO reactivity. Lead is also triggered by alterations in the cell signaling pathways found in endothelial cells, which disrupt NO vasodilatory functions. The soluble expression of guanylate cyclase is downregulated as a result of lead exposure. Cyclic GMP is formed by this enzyme, which promotes vasodilation induced by NO. Lead-induced hypertension is associated with irregularities in the adrenergic system, including elevated activation in the central sympathetic nervous system, reduced vascular β-adrenergic receptor density, and increased norepinephrine plasma. “The ‘renin-angiotensinaldosterone system’ is activated directly or indirectly by sympathetic nervous system stimulation.” Hypertension is also linked to changes in the regulation of the kallikrein-kinin system, as well as the generation of vasodilator hormones.Constrictive effects of lead on vascular smooth muscles are induced by Na-K-ATPase inhibition or activity, as well as an increase in Ca2+ levels in the cells, potentially due to protein kinase C activation. [Abadin et al., 2013].

Remediation technologies of Heavy Metal: -

Excessive levels of several metals can degrade soil quality, reduce crop yields, and reduce the quality of agricultural products, regardless of where the metals originated in the environment, posing major risks to human, animal, and ecosystem health. [Mishra et al., 2017]. Therefore, the removal of the accumulated metals becomes important. Different lo-cost adsorbents "(Fe2O3, Fe3O4, FeS, steel wool, Mg pellets, Cu pellets, Zn pellets, Al pellets, Fe pellets, and coal") were investigated to extract single heavy metals such as "Co and Zn" from aqueous solutions [90]. [Wang, 2008]. Phytoaccumulation, phytoextraction, phytovolatilization, phytodegradation, and phytostabilization are pathways proposed to be involved in transitional metal accumulation by plants [Wang, 2008, Singh et al., 2011].

Conclusion

The planet is contaminated with heavy metals in so many ways, mainly due to human pollution, that it affects so many people's health. Both of these diagnoses should assist to raise awareness of the dangers that these metals pose.Systematic remediation technologies for heavy metal polluted areas should be utilised to eliminate the stored metals.

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