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Heavy Metals Contamination and Remediation

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Abstract

Heavy metals normally occur in Earth's crust, but the human way of life can trigger the concentration to increase, posing serious health risks to humans and other organisms. Remediation, the process of cleaning up environmental contamination, is necessary to mitigate these risks. Several methods can be used for heavy metal remediation, including physical, chemical, and biological approaches, with the choice of the method depending on factors, namely the type of heavy metal, the concentration of heavy metals present, and the potential risks to the health of the environment. Combined methods or multipurpose methods may be used to achieve the desired results.

Keywords: Bioremediation, Hazards, Phytoremediation, Pollution

Introduction

Heavy metals exhibit unique chemical and physical properties, and their behavior in the environment can be complex and diverse, can be toxic to living organisms in low or high concentrations, and can accumulate in the environment through natural processes or human activities, such as industrial pollution, mining, and agricultural runoff. They can accumulate in the food chain and cause biomagnification. The toxicity of heavy metals can cause damage to organs, nerves, and bones, as well as developmental and reproductive problems in humans and other animals.

What is Heavy Metal?

Heavy metals are a group of transition elements with high atomic weight and density with at least one unpaired electron in their outermost shell, such as lead, cadmium, mercury, arsenic, and chromium (Prabakaran, 2023).

According to the data obtained from the World Health Organization (WHO) in the year 2017, exposure to lead is estimated to cause the death of about 1.06 million and about 24.4 million years of loss of healthy life with the majority of exposure occurring in poor and developing countries. Another heavy metal, cadmium is a carcinogenic substance (Group I) that can cause kidney damage as listed by International Agency for Research on Cancer (IARC). In addition, mercury exposure can cause neurological damage and has been linked to developmental problems in children.

Understanding the behavior of heavy metals in the environment is essential to developing effective remediation strategies and reducing their impact on human health and the environment. This includes studying factors such as their mobility, bioavailability, and persistence in soil and water systems. Through ongoing research and collaboration between scientists, policymakers, and industry experts, we can work towards reducing heavy metal contamination and promoting a healthier and more sustainable future.

Atomic Weight of Heavy Metals

The atomic weight of heavy metals varies depending on a specific element. The atomic weights of Lead, Mercury, Cadmium, Arsenic, and Chromium are noted as 207.2, 200.59, 112.41, 74.92, and 51.99 g atomic mass, respectively.

The atomic weight of an element (relative atomic mass) is not only the factor that determines its toxicity or potential health effects. Other factors such as solubility, bioavailability, and chemical form can also influence the behavior and effects of heavy metals in the surrounding and within living organisms.

Article History

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Chromium as Heavy Metal

Chromium (Cr) is a heavy metal that has an atomic weight of 51.99. It is commonly found in the environment as Cr III (trivalent) and Cr VI (hexavalent) forms. Trivalent chromium is an essential nutrient for human beings and animals, while hexavalent chromium acts as a potent carcinogen and is toxic to living organisms.

Hexavalent chromium is often found in industrial processes such as electroplating, welding, and stainless steel production. Exposure to hexavalent chromium can occur through inhalation, ingestion, or skin contact, and can lead to lung disorders, inflammation, and the likelihood of developing lung cancer.

Even though trivalent chromium is an essential nutrient, more contact with trivalent chromium can similar effects as that of hexavalent chromium. Damage to the respiratory system and liver, as well as skin irritation and allergic reactions, may occur due to excessive contact with trivalent chromium.

It is important to monitor and regulate the levels of both trivalent and hexavalent chromium in the environment and in industrial processes to prevent more contact and excessive and protect human health and the environment.

Chromium from Tannery

Tanneries use chromium in the leather tanning process, which can lead to the release of significant amounts of chromium into the environment if not properly managed.

Itai-Itai Disease

The name "itai-itai" comes from the Japanese word for "pain-pain," reflecting the severe pain experienced by those affected by the disease. Itai-itai disease is a condition that was first reported in the mid-20th century in Japan, primarily affecting women in rural areas. Long-term exposure to cadmium, discharged into rivers by mining companies causes the disease that is characterized by severe bone pain, fractures, and deformities, as well as kidney damage.

Today, the incidence of itai-itai disease has decreased significantly due to improved regulation of industrial practices and better public awareness of the risks associated with heavy metal exposure. Nonetheless, the enduring impact of the ailment acts as a cue to the catastrophic outcomes that can arise from uncontrolled industrial contamination and emphasizes the significance of continued endeavours to safeguard human and ecological well-being.

Heavy Metals from e-Waste

Discarded electronic devices such as computers, televisions, and cell phones, collectively known as e-waste, hold a substantial quantity of heavy metals, such as lead, cadmium, mercury, and chromium. Improper disposal of e-waste can result in the leaching of these metals into the environment, polluting soil and water sources, and creating a threat to both human and ecological health.

An instance of this is lead, which is frequently present in cathode ray tubes (CRTs) utilized in older computer monitors and televisions. Mercury is another transition metal found in e-waste, primarily in fluorescent light bulbs and certain types of batteries.

The impact of heavy metals from e-waste on human and environmental health has been documented in various studies and case studies. Here are some examples:

1. Agbogbloshie, Ghana: Agbogbloshie is a community in Ghana that has become known as a dumping ground for e-waste from developed countries. The burning and dismantling of electronic devices have resulted in high levels of lead, cadmium, and other heavy metals on the land as well as in the atmosphere. A study of children living in the area found elevated levels of lead in their blood, which can cause developmental delays, neurological damage, and other health problems.

2. Guiyu, China: Guiyu is another community that has become known for its e-waste recycling activities. Studies have found high levels of lead, cadmium, and other transition metals in the land and atmosphere, as well as in the blood of workers and local residents. Workers in Guiyu have reported a range of health problems, including respiratory problems, skin disorders, and neurological damage.

3. Bangladesh: A study of e-waste recycling workers in Bangladesh found high levels of lead and other heavy metals in their blood, as well as in the soil and water in their communities. The study also found that workers were not using proper protective equipment, putting them at risk of exposure to hazardous materials.

4. India: A study of e-waste recycling workers in India found high levels of lead, chromium, and other heavy metals in their blood. Workers reported a range of health problems, including respiratory problems, skin disorders, and neurological damage.

These case studies highlight the importance of responsible e-waste management practices, including proper recycling and disposal. Encouraging sustainable e-waste management practices that safeguard human and environmental health is a shared responsibility among governments, industries, and consumers alike.

Proper disposal and recycling of e-waste are essential to prevent heavy metal contamination in the environment. This includes measures such as implementing regulations on e-waste disposal, developing safe and sustainable e-waste recycling practices, and promoting public awareness and education on the importance of responsible e-waste management.

Heavy Metals from Sewage

Inadequate treatment and disposal of sewage can lead to substantial amounts of heavy metals present in it, posing a threat to human and environmental health. Here are a few illustrations of heavy metals detected in sewage.

- ***Lead***: Sewage sludge can contain high levels of lead, which can contaminate soil and water if not properly disposed of.

- ***Cadmium*** is commonly found in sewage, particularly from industrial sources such as battery manufacturing and metal plating processes.

• ***Mercury*** can enter the sewage system from dental offices and medical facilities, as well as from consumer products such as batteries and fluorescent light bulbs. Mercury exposure can cause neurological damage, particularly in developing foetuses and young children.

• ***Copper*** is often found in sewage from corrosion of copper pipes and fittings. High levels of copper can be toxic to aquatic life and cause gastrointestinal problems in humans.

• ***Zinc*** is also commonly found in sewage, often from industrial sources such as metal plating and galvanizing. High levels of zinc can be toxic to aquatic life and cause gastrointestinal problems in humans.

Heavy Metals from Mines

Mining activities can release significant amounts of heavy metals into the environment, posing a risk to human and environmental health. Heavy metals from mines can enter waterways, soils, and the air, leading to contamination and pollution. Here are some examples of heavy metals that can be released from mines: Small-scale gold mining operations frequently use mercury to extract gold from ore. Mercury can enter the water supply and accumulate in fish, posing a risk to human health if consumed. Lead is often found in mine tailings, the waste materials left over after ore is extracted. Lead can contaminate soil and water, posing a risk to human health if consumed. Arsenic is found in many minerals and can be released from mines during the extraction process. Arsenic can contaminate water and soil and pose a risk to human health if consumed. Cadmium is often found in zinc and copper ores and can be released from mines during the extraction process. Cadmium and Nickel through soil and water exposure can contaminate and pose a health risk to human if consumed.

Minimizing the release of heavy metals into the environment can be achieved through efficient management and monitoring of mining activities. Implementation of measures such as tailing storage facilities, water treatment systems, and proper waste management can help to mitigate the risk of contamination. Conducting regular environmental monitoring is also crucial to evaluate the impact of mining activities on both the environment and human health.

Heavy Metal Pollution Remediation

Remediation is the process of cleaning up environmental contamination, including heavy metal pollution. Several methods can be used for heavy metal remediation, including physical, chemical, and biological approaches.

Physical methods involve the physical removal of heavy metal contaminants from the environment. Examples include excavation and disposal, dredging and soil washing.

Chemical methods involve the use of chemicals to immobilize or transform heavy metals into less harmful forms. Examples include precipitation, ion exchange, and electrochemical methods.

Phytovolatilization

Phytovolatilization is the process by which plants absorb and uptake heavy metals or other contaminants and release them as vapour into the atmosphere in a gaseous form. Here are some examples of phytovolatilization of heavy metals:

1. Mercury: Some plants, such as willows and poplars, can absorb mercury from contaminated soil and release it into the atmosphere as volatile elemental mercury.

2. Arsenic: Some plant species, such as Indian mustard, can take up arsenic from contaminated soil and release it into the atmosphere as volatile arsenic compounds.

3. Selenium: Some plant species, such as Stanleyapinnata, can take up selenium from contaminated soil and release it into the atmosphere as volatile selenium compounds.

Bioremediation

Bioremediation is the use of microorganisms to degrade, detoxify, or remove pollutants, including heavy metals, from contaminated environments. Here are some examples of bioremediation of heavy metal pollution:

1. Biosorption: This method uses microorganisms to absorb heavy metals on their cell surfaces. For example, some bacterial strains have been shown to remove lead and cadmium from contaminated water.

2. Bioleaching: This is the use of microorganisms to solubilize metals from solid substrates. For example, acidophilic bacteria can be used to extract metals from low-grade ores.

3. Biomineralization: This is the use of microorganisms to precipitate metals in the form of insoluble minerals. For example, sulfate-reducing bacteria can be used to precipitate heavy metals as metal sulfides.

4. Biodegradation: This is the use of microorganisms to break down organic pollutants that may be associated with heavy metal contamination. For example, some bacterial strains can degrade organic pollutants that are often found in conjunction with heavy metal contamination.

Phytoremediation

Phytoremediation, as defined by Greipsson (2011), involves utilizing plants to extract, immobilize, or detoxify pollutants, including heavy metals, from polluted soil or water. Followings are some instances of phytoremediation of heavy metals:

• ***Hyperaccumulating plants***: Certain plant species possess a unique characteristic of efficiently absorbing and accumulating high concentrations of heavy metals, thereby making them well-suited for phytoremediation applications. For instance, *Pteris vittata*, a fern species, has demonstrated remarkable efficacy in removing arsenic from polluted soils.

• ***Phytostabilization***: Certain plants are capable of immobilizing heavy metals in soil, thereby decreasing their accessibility for plant uptake or groundwater leaching. Indian mustard (*Brassica juncea*), for instance, can amass significant amounts of heavy metals in its roots, contributing to the stabilization of these pollutants in soils.

• ***Rhizofiltration***: The utilization of plants for removing contaminants from polluted water is known as phytoremediation. An instance of this is the use of water hyacinths (*Eichhornia crassipes*) to eliminate heavy metals from wastewater.

• ***Phytodegradation***: Some plants can break down or detoxify pollutants, including heavy metals. For example, sunflowers have been shown to break down organic pollutants in the soil.

Phytoremediation can be an efficient and environmentally friendly strategy to cleaning up contaminated sites. However, it is important to carefully select the appropriate plants for a specific site and to ensure that the remediation process does not result in the spread of pollutants to other areas. Additionally, the effectiveness of phytoremediation can depend on factors such as soil type, climate, and the specific contaminants present in the soil.

Conclusion

Several factors, such as the concentration and type of heavy metals present, accessibility and location of the site, and the probable risks to environmental and human health, determine the selection of an appropriate remediation strategy. A combination of methods may also be employed to attain the desired remediation outcomes.

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