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Review Article

# Heavy Metals in Soil: A Review

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**Abstract**

Environmental contamination by heavy metals is an issue of global health concern. With the incessant rise in various anthropogenic activities: the release of various organic and inorganic contaminants has continued to rise. Some of these activities include industrialization, agricultural activities, and vehicular emissions amongst others. Amongst the various categories of pollutants, heavy metals have been identified as one of the priority groups because they pose deleterious effects on plants, animals and the environment at large. Heavy metals are not biodegraded by microbial activities; rather they persist and are transmitted along the food chain with a high degree of bioaccumulation. Although heavy metals are ubiquitous, and present in all segments of the environment, their concentrations in soil have continued to rise, since the soil acts as a natural reservoir of these metals in the environment. Hence metals from other parts of the environment usually are found within the soil. This review provides details on heavy metals. It discusses their sources, distribution and environmental and health impact on the future trends in heavy metals investigations based on recent studies.

## INTRODUCTION

The soil is one of the vital components of the ecosystem. The vulnerability of soil to heavy metals pollution is due to its emitting and absorbing potentials. The emergence of heavy metals in soil has been attributed to various natural and anthropogenic means inherent in industrialization, urbanization as well as agricultural activities [1,2].

It has been established that at a global scale, the land mass polluted by heavy metals is higher than twenty million hectares (ha) of land. Various studies have documented the primary heavy metals present in the soil to include the highly toxic and carcinogenic categories such as arsenic, mercury, cadmium and lead as well as other trace elements such as chromium, copper, and cobalt which are of concern at relatively higher concentrations. Based on documentation from the Agency of Toxic Substances and Diseases Registry (ATSDR), there are four major heavy metals that have been marked to be highly toxic for animals, plants and humans [3,4]. These are mercury, lead, cadmium and Arsenic. Heavy metals have a remarkable tendency of bio accumulating and being passed along the food chain, which further heightens their concern as environmental pollutants. Heavy metals are of serious concern because they are not easily acted upon by activities of microorganisms hence they persist in the soil for a very long period [5,6].

Heavy metals when present in trace concentrations are needed for the proper functioning of plants, however at higher concentrations, they constitute serious harm to plants and animals. Metals such as copper, manganese, cobalt, zinc, nickel, and iron function are micronutrients that are vital for the growth of plants. Other metals such as mercury, cadmium, lead and arsenic, however, do not have any known function but rather are toxic even at a low concentration. It has been well documented that various metals such as manganese, iron, chromium, cobalt, selenium, nickel and are needed in trace concentration and hence known as an essential nutrients. Their non-availability for plant uptake has been linked to various deficiency diseases [7]. The essential heavy metals play physiological and biochemical roles in animals and plants. They are vital components of various key enzymes and are also paramount in various oxidation and reduction processes in biological systems. Some of the metals are also vital as co-factors in various oxidative processes involving enzymes such as ferroxidases, dopamine, cytochrome, dismutase, superoxide, and monoamine. When present in biological systems, these metals have been documented to influence numerous cellular components such as mitochondria, cell membrane, nuclei, reticulum and lysosome [8,9].

The availability of heavy metals at biological levels is influenced by numerous factors which include phase equilibrium and association, temperature, sequestration, and adsorption. It is also affected by other factors that are inherent in the kinetics and thermodynamics of biochemical processes in the environment.

This review presents details on heavy metals in soil. It highlights their sources, distribution, and environmental and health impact on plants, microorganisms and humans.

## CONCEPT OF HEAVY METALS

Heavy metals are elements that are naturally occurring and possess a large atomic weight with a density that is up to 5 times higher than the density of water. Their wide distribution on a global scale has risen due to their application in industries,

agriculture, and other areas within the environment. The recent concern about their presence in the environment has been due to their rising concentrations from reports in various studies [1]. The toxicity due to heavy metals is affected by various factors which include their chemical specie, exposure dose, the pathway of exposure, and other factors relating to the individual exposed to the metal such as nutritional status, age, duration of exposure, prevailing health condition [5].

## SOURCES OF HEAVY METALS IN SOIL

Heavy metals are ubiquitous. They are found in abundance naturally in the earth crust. There are numerous natural sources of heavy metals in the environment which include processes such as volcanic eruption, soil erosion, and re-suspension of sediments, weathering, and corrosion of metals [10,11].

Anthropogenic activities have contributed to the rapidly rising concentrations of heavy metals in soil, with industrialization being the major one. Numerous human activities contribute to pollution by heavy metals which include smelting, sewage discharge, mining, foundries, production of leaded paint, spillage, and combustion of fossil fuels and various materials, automobile discharge, irrigation using wastewater, amongst others. The above mention constitutes the primary sources of heavy metals [9,12]. Secondary sources of heavy metals [Figure 1] also exist which include the use of various agricultural products for the improvement of agricultural yield such as fertilizers, pesticides, herbicides, etc [3].

### Uses of heavy metals

Heavy metals though well known for their toxicity also have some beneficial applications which have also contributed to their increasing concentration in soil. The specific use of heavy metals is depended on their physicochemical properties such as mechanical strength, density, durability, reflectivity and conductivity. They are also employed in mechanical engineering, sports, nuclear science and military ordnance which is due to their high density. These metals are used as ballast in airplanes, boats as well as vehicles. Since denser materials usually absorb higher doses of radioactive materials, heavy metals are therefore used in radiation shielding.

Generally, heavy metals from soil get back into the air as aerosols [7].

## DETERMINATION OF HEAVY METALS CONCENTRATION IN SOIL

Some instrumental techniques for heavy metals determination require pre-treatment processes such as the digestion of the soil samples. The essence of the digestion step is to free the metal atoms in a form that they are readily detected. In some other techniques, the metals of interest are quantified directly without digestion. Similarly, some instrumental techniques make it possible for multi-elemental analysis while others do not permit it. Numerous instrumental techniques have been employed for the quantification of heavy metals in soil. Some of the instrumental approaches that have been well documented include atomic absorption spectroscopy (AAS), inductively coupled plasma atomic emission spectroscopy (ICP-ES), and inductively coupled plasma mass spectroscopy (ICP-MS) amongst others [11].

## ENVIRONMENTAL AND HEALTH IMPACTS OF HEAVY METALS

The health effects of heavy metals have been well-documented in various studies. They have been reported to be highly toxic to microorganisms, human's cells and plants. The phytotoxicity of heavy metals brings about developmental and structural impairment of the various cells in the plant. When plants are directly exposed to heavy metals, there is protein denaturation as well as damage to DNA which have been linked to oxidative stress.

Heavy metals get into the food chain through uptake by plants. These metals when in soil tend to form highly stable inorganic abducts with various organic compounds present in soil which induces the alteration of the physicochemical properties of the soil such as porosity, particle size distribution, color, and pH [5].

### Effects on plants

HMs alters the growth and development of plants. Heavy metals get into the plant through the roots and bring about the

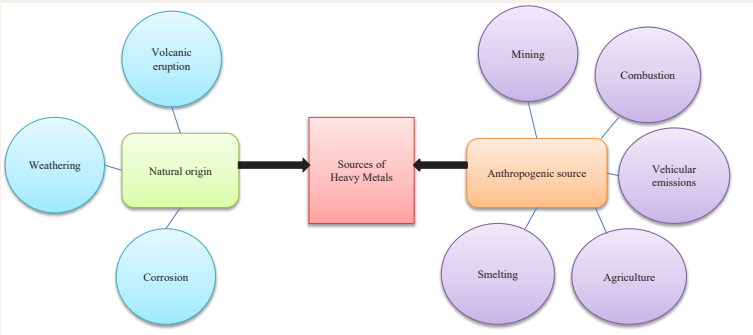


**Figure 1** Sources of heavy metals.

reduction of growth and interference with various biochemical processes such as photosynthesis which affect the health of the plant [7]. HMs toxicity affects the uptake of vital nutrients from the soil. A high concentration of chromium in the soil inhibits the absorption of other mineral nutrients such as magnesium, phosphorus, calcium and iron thereby resulting in the formation of complexes that are insoluble through the masking of the sites of absorption. There is also a rise in oxidative stress at the cellular level when there is a high concentration of lead in the soil. This can induce the deterioration of various bimolecular such as nucleic acids, and proteins. This also disrupts cellular activities and damages the nucleus, chloroplast and cell membrane [1]. In their study reported that a high-stress level emerging from the high concentration of lead in soil brought about a reduction in the growth of *coriandrum sativum*, while a high concentration of Nickel resulted in stunted growth in the crop.

### Effects on humans

Poisoning of humans by heavy metals can take place through ingestion, inhalation, or direct contact with the skin. Some heavy metals have been associated with most of the recent cases of poisoning in humans, which include mercury, cadmium, arsenic and lead. Their major sources to humans include industrial exposure at workplaces, coating in food packaging, and ingestion of leaded paint. Human exposure to heavy metals has been connected to various diseases such as Alzheimer, cancer, Parkinson, respiratory problems, vision impairment, depression, neurological disorders as well as dementia [9]. In their work reported that high concentrations of cadmium exposed to humans for a long duration resulted in the mortality of sperm cells, reduction of the quality of the semen, as well as disruption of hormonal balance. Cadmium's toxicological effects have been linked to the rising occurrence of kidney stones, dysfunction of the liver, diseases of the lungs, and failure of the heart amongst others. Exposure to arsenic in high concentrations contributes to the rise in the formation of free radicals in biological cells as well as oxidative stress. This has also been connected to renal dysfunction, and disruption of enzymatic activities amongst others [1].

### Effect of heavy metals microorganisms

Toxicity based on heavy metals includes several mechanistic routes, some of which have not been well investigated and comprehended. It is however established that each metal possesses its special character as well as physicochemical properties which also influence its toxicological impacts and profile [13,9]. The presence of heavy metals in soil affects the growth of microorganisms present in the soil since microorganisms are involved in various biochemical processes taking place in the soil which influences the formation of soil organic matter as well as the overall quality of the soil. The pollution of soil by these metals affects various soil microbial parameters such as pH, organic matter, etc. The presence of high content of heavy metals in soil reduces respiration rate thereby affecting the release of carbon dioxide. Microbial activities are affected by severe contamination of heavy metals in soil. High contents of heavy metals reduce soil enzymatic activities. Heavy metals impact the quantity and quality of microorganisms in the soil [3]. Microorganisms are highly sensitive to stress emerging from heavy metals pollution and hence have been employed widely as biological monitors or indicators for heavy metals pollution. Such microorganism also quickly indicates a change in soil quality level [14].

## CONCLUSION

The presence in all components of the environment has been well documented. Heavy metal toxicity in the soil is one of the problems of remarkable priority in the world. Heavy metals are toxic to plants, the soil, as well as human health at high concentrations. It is therefore paramount to continually monitor the contents of heavy metals in various environmental matrices, most especially the soil since the soil is the natural storeroom for various environmental contaminants.

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