A Study on the Methods to Prevent Soil Toxicology

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Abstract* – *Soil pollutants can be solid, liquid or gaseous. They deteriorate the quality and mineral content of soil and disturb the biological balance of organisms in the soil. Causes of soil pollution include an increase in urbanization, domestic waste, dumping industrial waste on soil and improper agricultural activities. You can prevent soil pollution by minimizing or eliminating waste at the source and substituting nontoxic options for hazardous materials.

Plants require soil nutrients such as nitrogen, calcium and phosphorous for growth and development. Also, crops come under attack from rodents, insects and bacteria, so farmers require pesticides to protect the plants. The use of fertilizers and pesticides in agriculture, however, leads to other problems. Some raw materials can contaminate the soil. For instance, copper and boron in fertilizers, and organochlorine in pesticides, can harm the environment and create health risks when products are used in wrong proportions or over a long period of time.

To prevent such damage, farmers should use composted manure and bio-fertilizers -- biologically active products such as algae and bacteria that can help initiate nitrogen fixation in soil. Biological methods of pest control such as importation – introducing a pest's natural enemy in a location where they do not naturally occur — also minimize soil pollution.

Keywords: Prevent, Soil, Toxicology

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INTRODUCTION

Forests and grassland vegetation bind soil to keep it intact and healthy. They also support many habitats that contribute to a complete ecosystem. Construction, cutting of timber and mining, on the other hand, leave the soil bare and expose soil to contaminants. Restoring forests by planting more trees protects the soil from floods and soil erosion. It also improves the fertility of the soil and increases biodiversity.

Dumping solid waste such as domestic refuse, garbage and industrial materials on soil increases the level of toxicity and hazardous substances in soil. Waste also alters the chemical and biological properties of soil such as its alkalinity levels. Through chemical treatment methods such as acid-base neutralization, municipalities can alter the pH level of solid waste before dumping it in landfills. Degrading insoluble waste by using methods such as adding chemicals or enzymes under a controlled environment before disposing of it also reduces soil pollution.

To reduce solid waste pollution on soil, you can reuse materials such as cloth, plastic bags and glass in your home rather than disposing of them. By recycling, you reduce the amount of solid refuse going to landfills and also make a contribution toward saving natural resources. For example, according to the U.S. Environmental Protection Agency, when a company recycles 1 ton of paper, it saves an equivalent of 17 trees.

Soils polluted with heavy metals have become common across the globe due to increase in geologic and anthropogenic activities. Plants growing on these soils show a reduction in growth, performance, and yield.

Bioremediation is an effective method of treating heavy metal polluted soils. It is a widely accepted method that is mostly carried out in situ; hence it is suitable for the establishment/reestablishment of crops on treated soils.

Microorganisms and plants employ different mechanisms for the bioremediation of polluted soils. Using plants for the treatment of polluted soils is a more common approach in the bioremediation of heavy metal polluted soils. Combining both microorganisms and plants is an approach to bioremediation that ensures a more efficient clean-up of heavy metal polluted soils. However, success of this approach largely depends on the species of organisms involved in the process.

Although heavy metals are naturally present in the soil, geologic and anthropogenic activities increase the concentration of these elements to amounts that are harmful to both plants and animals. Some of these activities include mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge, and municipal waste disposal.

Growth reduction as a result of changes in physiological and biochemical processes in plants growing on heavy metal polluted soils has been recorded. Continued decline in plant growth reduces yield which eventually leads to food insecurity. Therefore, the remediation of heavy metal polluted soils cannot be overemphasized.

Various methods of remediating metal polluted soils exist; they range from physical and chemical methods to biological methods. Most physical and chemical methods (such as encapsulation, solidification, stabilization, electrokinetics, vitrification, vapor extraction, and soil washing and flushing) are expensive and do not make the soil suitable for plant growth.

Biological approach (bioremediation) on the other hand encourages the establishment/reestablishment of plants on polluted soils. It is an environmentally friendly approach because it is achieved via natural processes. Bioremediation is also an economical remediation technique compared with other remediation techniques.

METHODS TO PREVENT SOIL TOXICOLOGY

Soil properties affect metal availability in diverse ways. Availability of Cd and Zn to the roots of Thlaspi caerulescens decreased with increases in soil pH. Organic matter and hydrous ferric oxide have been shown to decrease heavy metal availability through immobilization of these metals. Significant positive correlations have also been recorded between heavy metals and some soil physical properties such as moisture content and water holding capacity.

Other factors that affect the metal availability in soil include the density and type of charge in soil colloids, the degree of complexation with ligands, and the soil's relative surface area. The large interface and specific surface areas provided by soil colloids help in controlling the concentration of heavy metals in natural soils.

In addition, soluble concentrations of metals in polluted soils may be reduced by soil particles with high specific surface area, though this may be metal specific. For instance, it is said that addition of amendment consisting of hydroxides with high reactive surface area decreased the solubility of As, Cd, Cu, Mo, and Pb while the solubility of Ni and Zn was not changed. Soil aeration, microbial activity, and mineral composition have also been shown to influence heavy metal availability in soils.

Conversely, heavy metals may modify soil properties especially soil biological properties. Monitoring changes in soil microbiological and biochemical properties after contamination can be used to evaluate the intensity of soil pollution because these methods are more sensitive and results can be obtained at a faster rate compared with monitoring soil physical and chemical properties.

Heavy metals affect the number, diversity, and activities of soil microorganisms. The toxicity of these metals on microorganisms depends on a number of factors such as soil temperature, pH, clay minerals, organic matter, inorganic anions and cations, and chemical forms of the metal .

There are discrepancies in studies comparing the effect of heavy metals on soil biological properties. While some researchers have recorded negative effect of heavy metals on soil biological properties, others have reported no relationship between high heavy metal concentrations and some soil (micro)biological properties.

Some of the inconsistencies may arise because some of these studies were conducted under laboratory conditions using artificially contaminated soils while others were carried out using soils from areas that are actually polluted in the field. Regardless of the origin of the soils used in these experiments, the fact that the effect of heavy metals on soil biological properties needs to be studied in more detail in order to fully understand the effect of these metals on the soil ecosystem remains. Further, it is advisable to use a wide range of methods (such as microbial biomass, C and N mineralization, respiration, and enzymatic activities) when studying effect of metals on soil biological properties rather than focusing on a single method since results obtained from use of different methods would be more comprehensive and conclusive.

The presence of one heavy metal may affect the availability of another in the soil and hence plant. In other words, antagonistic and synergistic behaviours exist among heavy metals.

It is also observed that the inhibitory effect of Mn on the total amount of mineralized C was antagonized by the presence of Cd. Similarly, Cu and Zn as well as Ni and Cd have been reported to compete for the same membrane carriers in plants. In contrast, Cu was reported to increase the toxicity of Zn in spring barley.

Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress. An example of indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants. Further, the negative influence heavy metals have on the growth and activities of soil microorganisms may also indirectly affect the growth of plants.

For instance, a reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to decrease in organic matter decomposition leading to a decline in soil nutrients. Enzyme activities useful for plant metabolism may also be hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decline in plant growth which sometimes results in the death of plant.

DISCUSSION

The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process. For metals such as Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, adverse effects have been recorded at very low concentrations of these metals in the growth medium.

Reduced tiller and panicle formation also occurred at this concentration of Hg in the soil. For Cd, reduction in shoot and root growth in wheat plants occurred when Cd in the soil solution was as low as 5 mg/L. Bioremediation is the use of organisms (microorganisms and/or plants) for the treatment of polluted soils. It is a widely accepted method of soil remediation because it is perceived to occur via natural processes. It is equally a cost effective method of soil remediation.

Bioremediation can also occur indirectly via bioprecipitation by sulphate reducing bacteria (Desulfovibrio desulfuricans) which converts sulphate to hydrogen sulphate which subsequently reacts with heavy metals such as Cd and Zn to form insoluble forms of these metal sulphides.

Most of the above microbe assisted remediation is carried out ex situ. However, a very important in situmicrobe assisted remediation is the microbial reduction of soluble mercuric ions Hg (II) to volatile metallic mercury and Hg (0) carried out by mercury resistant bacteria.

Making the soil favorable for soil microbes is one strategy employed in bioremediation of polluted soils. This process known as biostimulation involves the addition of nutrients in the form of manure or other organic amendments which serve as C source for microorganisms present in the soil.

The added nutrients increase the growth and activities of microorganisms involved in the remediation process and thus this increases the efficiency of bioremediation. Although biostimulation is usually employed for the biodegradation of organic pollutants, it can equally be used for the remediation of heavy metal polluted soils. Since heavy metals cannot be biodegraded, biostimulation can indirectly enhance remediation of heavy metal polluted soil through alteration of soil pH.

The ability of biochar to increase soil pH unlike most other organic amendments may have increased sorption of these metals, thus reducing their bioavailability for plant uptake. It is important to note that, since the characteristics of biochar vary widely depending on its method of production and the feedstock used in its production, the effect different biochar amendments will have on the availability of heavy metals in soil will also differ.

Other amendments that can be used for phytostabilization include phosphates, lime, biosolids, and litter. The best soil amendments are those that are easy to handle, safe to workers who apply them, easy to produce, and inexpensive and most importantly are not toxic to plants. Most of the times, organic amendments are used because of their low cost and the other benefits they provide such as provision of nutrients for plant growth and improvement of soil physical properties.

CONCLUSION

Bioremediation can be effectively used for the treatment of heavy metal polluted soil. It is most appropriate when the remediated site is used for crop production because it is a nondisruptive method of soil remediation. Using plants for bioremediation (phytoremediation) is a more common approach to bioremediation of heavy metal compared with the use of microorganisms. Plants employ different mechanisms in the remediation of heavy metal polluted soils. Phytoextraction is the most common method of phytoremediation used for treatment of heavy metal polluted soils. It ensures the complete removal of the pollutant. Combining both plants and microorganisms in bioremediation increases the efficiency of this method of remediation. Both mycorrhizal fungi and other PGPR have been successfully incorporated in various phytoremediation programmes. The success of the combined use of these organisms depends on the species of microbe and plants involved and to some extent on the concentration of the heavy metal in soil.

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