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Perspective

Use of Nanotechnology in Remediation of Heavy Metals Polluted Soils

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Description

Heavy metals polluted soils are a significant worldwide environmental problem. The crops cultivated in polluted soils often contain significant levels of heavy metals that can impair human health. The current technologies such as removing up of pollutants, stabilization/solidification of pollutants, verification, soil capping, etc., used in remediation of polluted soils are not adequate. Smarter and cheaper techniques still to be addressed to decontaminate polluted soil. In the present study, nanotechnology has been adopted to immobilize heavy metals in polluted soil, in which Nano-particles; Nano-scale zero valiant iron, bentonite-nZVI, Nano alginate, Nano carbon and dendrites are used as immobilizing agents. Six soil samples collected from different locations in Egypt which have been polluted by either sewage sludge, industrial wastes, or vehicle exhausts, are treated with Nano-immobilizing agents, at three rates of 0.1, 0.5 and 1%. The treated soil samples are incubated for two months which were subjected to eight wetting and drying cycles. At the end of the incubation period, the soils were analysed for the determination of total, plant available as extracted using DTPA solution, and various chemical fractions of Cd and Pb. The results showed that all Nano-immobilizing agents proved high efficiency to reduce the level of DTPA extractable-Cd and Pb. The magnitude of the reduction varied as both agent and rate of application varied. The efficiency of the tested Nano-agents to immobilize Cd and Pb increased as the rate of application increased. The sequential extraction experiment showed that, nano immobilizing agents successfully altered Cd and Pb from mobile to immobile form as the exchangeable Cd and Pb significantly decreased in all tested soils, whereas, carbonate- and oxides- bound-Cd and-Pb significantly increased. Also, the results of the pot experiment showed that application of nano-materials to polluted soils at rates of 1% and 2% significantly increased fresh and dry weight of crop Garden Rocket (Eruca sativa) and decreased uptake of Cd and Pb.

Heavy Metal Polluted Soils

Heavy metals are elements that exhibit metallic properties such as ductility, malleability, conductivity, stability, and ligand specificity. They are characterized by relatively high density and high relative atomic weight with an atomic number greater than 20. Some heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms. However, excessive amounts of these elements can become harmful to organisms. Other heavy metals such as Pb, Cd, Hg, and as (a metalloid but generally referred to as a heavy metal) do not have any beneficial effect on organisms and are thus regarded as the "main threats" since they are very harmful to both plants and animals.

Metals exist either as separate entities or in combination with other soil components. These components may include exchangeable ions sobbed on the surfaces of inorganic solids, nonexchangeable ions and insoluble inorganic metal compounds such as carbonates and phosphates, soluble metal compound or free metal ions in the soil solution, metal complex of organic materials, and metals attached to silicate minerals. Metals bound to silicate minerals represent the background soil metal concentration and they do not cause contamination/ pollution problems compared with metals that exist as separate entities or those present in high concentration in the other 4 components .

Soil properties affect metal availability in diverse ways. Harter reported that soil pH is the major factor affecting metal availability in soil. 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 complexion with ligands, and the soil's relative surface area. The

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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, Mcbride and Martínez reported 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.

Effect of Heavy Metal Polluted Soil on Plant Growth

The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilized by root exudates. Although plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals. As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly.

Bioremediation of Heavy Metal Polluted Soils

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. Blaylock .Reported 50% to 65% saving when bioremediation was used for the treatment of 1 acre of Pb polluted soil compared with the case when a conventional method (excavation and landfill) was used for the same purpose. Although bioremediation is a no disruptive method of soil remediation, it is usually time consuming and its use for the treatment of heavy metal polluted soils is sometimes affected by the climatic and geological conditions of the site to be remediated.