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Conventional and new ways of remediating soils polluted with heavy metals

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ABSTRACT

Heavy metals pollution is amongst the commonest form of environmental pollution. These metals have accumulated over time from the smelting and mining activities of man, from poor waste disposal practices and from modernization. Of recent the impact of heavy metal pollution of the environment is stirring up serious concerns since the discovery that some edible plants accumulate these metals to a level, toxic to both themselves and to the animals that consumes them. Common features of heavily polluted soil includes barrenness, desertification, erosion, and this usually result in developmental stagnation in areas with such pollution. More researches have recently been stepped up in the field of remediating soils polluted with heavy metals. Traditional method includes, excavation of the top soil, capping of the soil, stabilization of the polluting heavy metals, soil washing. In recent time, emphases have been drawn to the use of plants that has high metal accumulating and tolerating capacity to remediate metal contaminated soil. This mini review highlights the different conventional and recent practices in the control of heavy metal pollution.

INTRODUCTION

Over 7900 papers has been devoted to the study of the pollution of the environment with heavy metals till date, as evident from the search conducted in the NCBI database on July 2008, using the keyword “Heavy metal pollution”. This underscores the important consequence and implication of heavy metal pollution.

Heavy metals are found naturally in the soil mostly in its complexed or bound form such as in ZnS04, ZnCl and Zinc Oxides. They enter the environment by human activities such as mining, purification of Zinc, lead and cadmium, steel production, coal burning, burning of wastes, discharges from industrial effluents, excessive use of fertilizer, pesticide application and use of raw sewage waste in farming (Lone et al., 2008; Okoronkwo et al., 2005; Jing et al., 2007).

The sad thing about the pollution of the environment with heavy metals is that they can’t be biologically degraded, they can only be transformed from one oxidation state or organic complex to another (Lone et al., 2008; Jing et al., 2007). Once the environment becomes polluted with Zinc, it begins it journey to man’s body (Islam et al., 2007; Okoronkwo et al., 2005) by been readily absorbed by plants (Kos et al., 2003) which are subsequently consumed by man.

In view of the inadvertent toxicity heavy metals to man and plants, efforts are been made to remediate already polluted soil and to check against further pollution of the soil by indiscriminate disposal of wastes, use of sewage sludge in farming.

Remediation of metal polluted soil aims to achieve either the removal or stabilization of the polluting metal (Kiikkila, 2002). Lone et al. (2008) classified the different approaches used to reclaim already metal polluted soils into physicochemical and biological approaches.

PHYSIOCHEMICAL METHODS OF REMEDIATING METAL POLLUTED SOIL

The physiochemical approaches involved in soil remediation includes:

A. **Excavation Method:** These involves the excavation and reburial of polluted soils in special landfills (Conder et al., 2001; Jing et al., 2007; Lombi et al., 2001; Neilson et al., 2003; Bennett et al., 2003) This even as the commonest means of reclaiming contaminated soil (Lombi et al., 2001) does not actually remediate the soil (Neilson et al., 2003).

B. **Capping Of the Polluted Soil.** (Neilson et al., 2003) This involves top soiling of the polluted soils with uncontaminated soils from offsite to a depth that would minimize uptake of heavy metals by vegetation (Okoronkwo et al., 2005). Still, this does not give a permanent solution to the problem since the metal can still be leached into the underground water.

C. **Fixation and Inactivation (Stabilization) Of the Polluting Heavy Metals** (Lone et al., 2008; Kiikkila, 2002; Conder et al., 2001). This involves the conversion of the polluting heavy metals to forms that are less mobile and available for plants and micro flora (kiikkilla, 2002). Usually, the essence of stabilization is to reduce the amount of phytoavailable metal and thus reduce their toxicities to plants, animal., and soil organisms. Some commonly used chemical immobilization agent includes zeolite, gravel sludge, beringite (kiikkilla, 2002), alkaline materials, organic material (sewage sludge and compost) phosphate (Conder et al., 2001) and lime stabilized municipal biosoilds (stuczynski et al., 2007; Conder et al., 2001). Even with this, the polluting substance are still present in the soil and could become available overtime as agents that enhances their phytoavailability are introduced into the soil.

D. **Soil Washing.** This technique involves the use of acids (HCI and HN03), chelators (EDTA, Nitriloacetic acid, DTPA etc) and other anionic surfactant (bio surfactant) (Neilson et al., 2003) to solubulise the polluting metals. It may take the form of in-situ treatments which involves soil flushing with pumps (Neilson et al., 2003) or ex-situ treatment which involves washing an excavated portion of the contaminated site with these agents followed by the return of clean soil residue to the site (Lone et at, 2008). This method is generally expensive and its fraught with lots of side effects (Lone et al., 2008). For instance, Greman (2005) reported that in-situ application of chelating agents can cause ground water pollution by uncontrolled metal dissolution.

Other physicochemical method includes: Thermal treatment (Jing et al., 2002), precipitation or flocculation followed by sedimentation, Ion exchanges, reverse osmosis and micro filtration (Lone et al., 2008). These physicochemical approaches are not suitable for practical purposes because of their high cost, low efficiency, destruction of soil structure and fertility (Lone et al., 2008; Jing et al 2007)

BIOLOGICAL APPROACHES OF REMEDIATING METAL POLLUTED SOILS

The biological approaches involved in soil remediation includes:

I) Use of microorganisms to detoxify metal by valence transformation (Lone et al., 2008)

II) Use of special type of plants to decontaminate soil or water by inactivating metals in the rhzosphere or translocating them in their aerial parts. This approach is called Phytoremediation.

These new techniques are cheaper, efficient and a more environment friendly means of remediating metal polluted soils (Lone et al., 2008; Jing et al., 2007).

Phytoremediation Of Heavy Metal Polluted Soil

This techniques involves the use of green plants to decontaminate soils, water and air. Its application spans through both the remediation of both organic and inorganic pollutants (Lone et al., 2008). The phytoremediation of heavy metal contaminated site essentially aims to extract or inactivate metals in the soil (Lombi et al., 2001; Bennett et al., 2003). There are different categories of phytoremediation, these includes: phytoextraction, phytofiltration, phytostabilisation and phytovolatisation (Lone et al., 2008).

Phytoextraction involves the use of plants that has the ability to concentrate the heavy metal in their shoot tissue, to remediate contaminated lands. Usually, the shoot biomass are harvested for proper disposal in special site or are burnt to recover the metal (Bennett et al., 2003; Islam et al., 2007; Peciulyte et al., 2006).

Phytofiltration (Rhizofilteration) involves the use of plants to absorb, concentrate or precipitate metals from aqueous waste (Jing et al., 2007).

Phytostabilisation is the use of plants to reduce the mobility of heavy metal through absorption and precipitation by plants, thus reducing their bio availability (Jing et al., 2008; Bennett et al., 2003).

Phytovolatisation is the uptake and release into the atmosphere of volatile material such as mercury or arsenic containing compound (Jing et al., 2007; Lone et al., 2008).

In recent times, efforts are being made to increase the efficiency of decontaminating polluted soils with plants; such strategies as suggested by Bennett et al (2003) include:

1. Identification of novel plants capable of hyper accumulating heavy metals through screening studies (Tu et al., 2002; Kos et al., 2003).
2. Optimization of agronomic practices for enhanced biomass production and metal uptake (claus et al., 2007).
3. Breeding of selected plant species for the desired property through classical breeding or genetic engineering.

Lombi et al (2001) suggested two approaches for the phytoextraction of heavy metals. The first is the continuous or natural phytoextraction. This involves the use of natural hyper accumulate plants with exceptional metal accumulating capacity to remediate the soil. More than 400 plant species are known to hyper accumulate heavy metals of much more than half are Nickel hyper accumulator (Tu et al., 2002; Lone et al., 2008). The set backs in using this method includes the production of low biomass by these plant species, the long time required to clean up a polluted site and the reduced bio availability of metals in polluted site (Lombi et al., 2001).

The 2nd approach as suggested by Lombi and his colleagues is the chemically enhanced phytoextraction. This involves the use of high biomass crops that are induced to take up large amount of metal when their mobility in soil is enhanced by chemical treatment. The chemicals employed are mostly chelating agents such as EDTA, NTA, citric acid (Lombi et al., 2001).

Even though lots off successes has been recorded with this latter method, there is concerned over enhanced mobility of metals in the soil after chelates application and also the potentials risk of leaching of these metals into ground water (Lombi et al., 2001; Greeman, 2005; Evangelon et al., 2007). Their is also the issue of the persistence of the metal–EDTA complex in the soil after chelate application (Lombi et al., 2001; Greeman, 2005).

Researches are ongoing to discover new chelating agents that won't cause the contamination of ground water. Kos et al (2003) reported that ethylenediamine–dissuccinic acid (a biodegradable chelant) is able to prevent leaching of heavy metal by placing a horizontal permeable barrier below the layer of treated soil. Earlier this year, Chen and his colleague reported that heat treatment can increase the phytoextraction of metals at reduced chelant application. Despite all the advances made in this direction, a satisfactory solution to the fears raised over the use of chelant assisted phytoextraction has so far not been found (Evangelon et al., 2007).

CONCLUSIONS

There is ongoing effort to remediate heavy metal polluted soil. Traditional techniques often used to effect these remediation processes includes; top soiling contaminated soil with uncontaminated ones, stabilization of the polluting heavy metals to prevent leaching into ground water, soil washing, excavating top layers of polluted soil amongst others.

Biological techniques used to remediate metal contaminated soil essentially involve the use of plants and organisms to remediate this soils. It includes phytovolatisation, phytostabilisation, phytofiltration, and phytoextraction processes.

Even though some of this methods have some side effects, appreciable success has been recorded from their practice and implementation. More enquires is expected to continue into the study of good and efficient bio remediating agents in years to come

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