Evaluation of Heavy Metals Bioaccumultion Potentials of Plants Grown on Waste Contaminated Soils

Mary B Ogundiran and Oladele Osibanjo

Department of Chemistry, University of Ibadan, Ibadan, Nigeria

E-mail: mbogundiran@yahoo.com

Introduction

Environmental pollution by heavy metals is a global issue that has generated a lot of concern in all parts of the world and which requires both local and universal attention to stem the growing threat it poses to survival on earth. Pollution generated in one part of the world can have far reaching and serious detrimental effects both locally and across the globe. Heavy metal pollutants reach and contaminate the environment from myriad of sources, the common ones being metallurgical processes, industrial activities, agricultural practices, waste disposal sites, sewage sludge and automobiles. These are potential sources of heavy metals that are known to cause distortions in human systems, in vegetations, in livestock and in wild animals. Heavy metals are chemical elements with a specific gravity of about 5.0g/dm^3 or greater (Bolan and Duraisamy, 2003). Examples of heavy metals include Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Cobalt (Co), Lead (Pb), Manganese (Mn) Mercury (Hg), Nickel (Ni), Iron (Fe), Selenium (Se), Thallium (Th) and Zinc (Zn). Some well-known toxic heavy metals with a specific gravity that is greater than 5.0 g/dm^3 are arsenic, 5.7 g/dm^3 ; cadmium, 8.65 g/dm^3 ; iron, 7.9 g/dm^3 ; lead, 11.34 g/dm^3 ; and mercury, 13.5 g/dm^3.

Unlike organic contaminants, heavy metals once entered into soil, cannot be degraded but can be cleaned up from environmental media. This is termed remediation. Environmental remediation involves removal or reduction in heavy metal bioavailability. Two major approaches have been employed to decontaminate or ameliorate heavy metal contaminated soils: these include ex situ and in situ remediation techniques. Ex situ technique involves removal and transportation of contaminated soil to an authorized landfill site for cleaning, detoxification and physical or chemical destruction of contaminants while in situ technique involves cleaning on site. In-situ techniques whenever feasible are always preferred over ex-situ techniques due to low cost and less disruption on the ecosystem. Many methods have been used to decontaminate metals-contaminated soils thereby making the soils relatively safe for the environment and humans. The commonly employed methods include containment, chemical treatment, electrokinetics, biological treatments (bioremediation), mechanical and pyrometallurgical separation, solidification/stabilisation and immobilization. Many of these conventional technologies are expensive and not environment friendly but negatively impact ecosystem. Recently, phytoremediation, a type of biological treatment, has been identified as soil heavy metal decontamination technique. Low cost, little or no landscape disruption, wide applicability, preservation of ecosystem including soil fertility, generation of recyclable heavy-metal rich plant residues, applicability to a range of toxic heavy metals, public acceptance have been identified as advantages of phytoremediation (Ogundiran and Osibanjo, 2008).

Phytoremediation

Phytoremediation is a biotechnology that employs the use of plants and trees for in-situ removal, degradation or immobilisation of contaminants in organic (pesticides, polyaromatic hydrocarbons, crude oil) or inorganic (metals) contaminated tailings, soils and waters. Plant degrades organic pollutants and immobilises/stabilises metal contaminants. The phytoremediation process could be through the natural biological, chemical or physical activities of the plants and trees. The plants and the trees are grown on the contaminated media for a required period of time and thereafter could be harvested, processed and disposed off in designated landfills.

In phytoremediation of heavy metal contaminated soil or tailings/waste, the heavy metals contaminants are gradually removed from the soil by plant uptake and harvesting, thereby reducing the toxic effects of heavy metals on health of all living organisms and the environment. This remediation method has attracted attention in the recent years due to low cost of execution when compared to other remediation techniques and environmental friendliness. Out of Phytoremediation technologies available, phytostabilization and phytoextraction have been widely researched to mitigate metals-contaminated soils.

Phytostabilization

Phytostabilization technique involves the use of plants to contain or restrict the movement of heavy metals out of the polluting source thus preventing bioavailability of metals through leaching into the environment. Plant species that are used to stabilise heavy metals in polluted waste or soil are characterized with high tolerance of metals in surrounding soils, low accumulation of metals in the plant and dense root system (Ghosh and Singh, 2005). They function primarily on the contaminated soil by preventing soil erosion, percolation of rainwater through the soil, formation of heavy metal contaminated leachate and distribution through agents of rain and wind. However, this technique may only be used as an interim containment strategy until other remediation (Evanko and Dzombak, 1997). This is due to the fact that the amounts of the toxic metal contaminants remain relatively unchanged in soil. As hyperaccumulators have been applied in phytoextraction, excluders have been identified for phytostabilisation of heavy metal contaminants in soil. Excluders are plants that limit the levels of heavy metal translocation within them and maintain relatively low concentrations in their shoot in the presence of highly polluted soil/waste. They are employed in regenerating heavy metal contaminated soils (Baker, 1981). Many authors have measured heavy metals concentration in plants growing on heavy metal contaminated soils and mine tailings and have identified metal tolerant plants, excluders and accumulators (Franco-Hernandez *et al.*, 2010; Haque *et al.*, 2008; Del Rıo-Celestino *et al.*, 2006; Dahmani-Muller *et al.*, 2000; Wenzel and Jockwer, 1999).

Phytoextraction

Phytoextraction is based on the use of natural hyperaccumulator plants with exceptional metal-accumulating capacity to reduce the levels of bioavailable metal in heavy metal contaminated soils. These plants have several beneficial characteristics such as the ability to accumulate metals in their shoots and an exceptionally high tolerance to heavy metals (Kidd and Monterroso, 2005). Hyperaccumulators have been defined as plant species which contain more than 0.1% (1,000 mg/kg) of copper, lead, nickel chromium or cobalt, cadmium>100 mg/kg in their dried tissues. In the case of zinc and Mn, a threshold of 1% (10,000 mg/kg) is proposed (Yanqun *et al.*, 2004; Boularbah *et al.*, 2006). In addition, a hyperaccumulator is regarded as plant which the concentrations of heavy metal in its above ground part are 10–500 times more than that in usual plant (Shen and Liu, 1998). In hyperaccumulator plants, the metal concentrations in shoots are greater than in roots, showing a special ability of the plant to accumulate and transport metals and store them in their above-ground part. The process of phytoextraction generally requires transportation of heavy metals to the shoots which can be easily harvested and disposed off. In some cases, root can be harvested as well. Several growth and harvesting of the plant is repeated until soil concentrations of heavy metals are reduced to environmentally acceptable levels. The metal-enriched plants can be harvested using standard agricultural methods, dried, ashed or composted plant residues highly enriched in heavy metals may be isolated as hazardous waste or recycled as metal ore (Kumar *et al.*, 1995).

Phytoextraction can be achieved via two means. Natural hyperaccumulation, in this case hyperaccumulators naturally accumulate heavy metal contaminants from the soil unassisted. Secondly induced hyperaccumulation, in which a chelator is added to soil to increase metal solubility which makes it easier for plants to absorb. To date, more than 450 plant species of metal hyperaccumulator plants have been reported in the literature and most of them (about 300) hyperaccumulate Ni (Boularbah *et al.*, 2006). Majority of the excluders for phytostabilisation and hyperaccumulators for phtoextraction have been identified through investigation into metal contaminated mine wastes (tailings) or soils.

Accumulators concentrate heavy metals in their shoots at both low and high soil metal concentrations and are utilized in extracting heavy metals from contaminated soils (Rotkittikhun *et al.*, 2006). Many field studies have investigated the accumulating capacity of plants that grew naturally on metalliferous wastes and on contaminated soils. It has been observed from such surveys that some plant species accumulate levels of heavy metals more than the normal levels encountered generally in plants (Boularbah *et al.*, 2006; Kidd and Monterroso, 2005; Yanqun *et al.*, 2004; Walter *et al.*, 2003; Bunzl *et al.*, 2001; Escarre *et al.*, 2000; Smith and Bradshaw, 1979) thereby proposing that such plants can be used as decontaminants of heavy metal polluted soils. In Nigeria, there is paucity of information about such metal tolerant plants locally and yet there are heavy metals contaminated sites all over the nation.

Hence in our study, we looked at the levels of heavy metals in soils and plants from four sites contaminated by abandoned secondary Pb slag dumpsites in Ibadan, Nigeria. Identification of plant species that accumulated exceptionally large concentration of Pb and Cd in shoots was the focus of the study. 26 plant samples of 20 species belonging to 12 families and 26 waste samples on which the plants were growing were collected. 12 out of the 26 plant samples demonstrated the features of Pb hyperaccumulators while 7 of the plants accumulated Cd. Enrichment coefficient of all the plant samples was lower than 1 for Pb except for *Andropogon tectonium(1.99). Clome viscose, Gomphrena celosiodies, Elusine indica, andropogon, gayanus and urera lobata* are few of the plants that the results of this work identified as potential hyperaccumulators for Pb and Cd. These observed Pb and Cd accumulating plants could be used in bioremediation of lead and cadmium contaminated soils after further research into the accumulation mechanism. Field application of this technology will foster decrease in the risk of heavy metals to human, living organism and the environment as a whole.

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