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Review Article

Phytoremediation Prospect in Clean Up of Contaminated Environment with Heavy Metals

Usman Umar Zango[1, *], Aminu Abubakar[2], Halima Ibrahim Mukhtar[1], Sadiq Adamu Minjibir[1]

[1]Department of Biology, School of Science Education, Sa'adatu Rimi College of Education, Kumbotso, Nigeria

[2]Department of Trypanosomiasis, Kano Liaison Office, Infectious Diseases Hospital, Kano, Nigeria

Email address:
uumarzango@gmail.com (U. U. Zango)
[*]Corresponding author

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Abstract: Heavy metals contamination of global environment arises from natural sources directly or indirectly from anthropogenic activities such as rapid industrialization, urbanization, energy generation, improper waste management and other local anthropogenic sources. Phytoremediation is a green emerging technology used to remove pollutants from environment components. Phytoremediation, an emerging cost-effective, non-intrusive, and aesthetically pleasing technology, that uses the remarkable ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues, appears very promising for the removal of pollutants from the environment. Within this field of phytoremediation, the utilization of plants to transport and concentrate metals from the soil into the harvestable parts of roots and above ground shoots, i.e., phytoextraction, may be, at present, approaching commercialization. Due to its great potential as a viable alternative to traditional contaminated land remediation methods, phytoremediation is currently an exciting area of active research. This paper highlighted the sources and effects of heavy metals. The paper also discussed the meaning, concept, advantages, and limitations of phytoremediation.

Keywords: Phytoremediation, Heavy Metals, Soil, Anthropogenic, Phytoextraction

1. Introduction

Numerous industries such as petroleum refinery, soap and detergent, food and beverage, brewery, textiles, building materials, timber products, wood and leather works, metal works, chemicals and plastics, industries were established in Nigeria [1]. Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (such as, changes in precipitation inputs, erosion, weathering of crustal materials) degrade surface waters and impair their use for drinking, industrial, agricultural, recreational or other purposes [2]. Akaninwor *et al.,* [3] reported that, industrial activities and urbanization in developing countries including Nigeria has gradually led to the deterioration of the environment in recent years. This situation has invariably increased the problem of waste disposal. Untreated wastes from processing factories located in cities are discharged into inland water bodies resulting to stench, discoloration and a greasy oily nature of such water bodies [3]. Over the years, the improper disposal of industrial wastewater effluents has been a major problem and a source of concern to both government and industrialists. In most cases, the disposal or discharge of effluents, even when these are technologically and economically achievable for particular standards, do not always comply with pretreatment requirements and with applicable toxic-pollutant-effluent limitations or prohibitions. The consequence of these anomalies is a high degree of environmental pollution, leading to serious health hazards [1]. Paul and James [4] noted that, dumping of various industrial waste products into water sources, and improper handling of industrial wastes, often result in polluting water sources. Such water pollution disturbs the balance of the ecosystem inside, resulting in the death of various animal and plant species present in the water. Pollution also reduces the potential of water as a resource for the various uses [4]. The waste water or sewage water thrown out from industries is either used for irrigation purposes or it runs off to natural sources of water. If these effluents are not treated before their disposal they can be harmful for human consumption as well as for other uses too [5].

Heavy metal pollution has been attracting considerable public concern, due to the magnitude of the problem in the environment [6]. Heavy metals contamination of global environment arises from natural sources directly or indirectly from anthropogenic activities such as rapid industrialization, urbanization, energy generation, improper waste management and other local and/or regional anthropogenic sources [7, 8]. The toxicity heavy metals ions to living organisms involves oxidative and/or genotoxic mechanisms [9]. Brennan [10] reported that, based on their chemical and physical properties, there are three different distinct molecular mechanisms of heavy metal toxicity: (i) production of reactive species by auto oxidation and Fenton reaction (Fe, Cu), (ii) blocking of essential functional groups in biomolecules (Cd, Hg) and (iii) displacement of essential metal ions from biomolecules. Heavy metal contaminated soils are very difficult to remediate. Current technologies resort to soil excavation and either land filling or soil washing followed by physical or chemical separation of the contaminants. Although highly variable and dependent on the contaminants of concern, soil properties, site conditions can result in high cost of the procedures of reclaiming the soils. Traditional physicochemical methods of cleanup are very tedious and not economically feasible, due to the fact that large area of the land is normally contaminated with the heavy metals. Therefore, some methods are developed to keep the metals in the soil but reduce the risks related to this presence (by decreasing bioavailability by in situ immobilization processes) [11].

2. Phytoremediation

Paz-Alberto and Sigua [12] described phytoremediation as a natural process carried out by plants and trees in the cleaning up and stabilization of contaminated soils and ground water. It is actually a generic term for several ways in which plants can be used for these purposes. It is characterized by the use of vegetative species for *in situ* treatment of land areas polluted by a variety of hazardous substances [12]. According [13] phytoremediation is a green emerging technology used to remove pollutants from environment components. Mechanisms used to remediate soils contaminated by heavy metal are: phytoextraction, phytostabilisation, phytovolatilization and rhizofiltration. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water [12]. Vasavi et al., [14] stated that, phytoremediation is a method which green plants use for cleaning up contaminated hazardous wastes sites. Phytoremediation has applied Ex-situ and In-Situ, continually and induces to clean up contaminated terrain of toxic metals. Phytoremediation as a technology uses plants to clean up contaminated environment. It is a low cost, long term, environmentally and aesthetically friendly method of immobilizing/stabilizing, degrading, transferring, removing, or detoxifying contaminants, including metals, pesticides, hydrocarbons and chlorinated solvents [15, 16, 17]. Weber et al., [18] sees phytoremediation as the use of plants to extract, sequester, and/or detoxify pollutants, which has been reported to be an effective, non-intrusive, inexpensive, aesthetically pleasing, socially accepted technology to remediate polluted soils. The US phytoremediation market is expected to expand more than ten-fold between 2000 and 2012, to over $415 million [19]. The work of [20] revealed the synergistic effect of *Thalia geniculate* and water hyacinth during phyto-treatment of domestic wastewater. The Results showed that the, combination of *Thalia geniculata* and water hyacinth provides a better clarification of gray water. Abdullahi et al., [21] conducted a research to determine the efficiency of Jatropha (*Jatropha curcas),* Neem (*Azadirachta indica*) and Baobab (*Adansonia digitata*) in accumulating heavy metals from contaminated soils in Challawa industrial areas. And recommended that, all the three plant species are potentially useful for remediating heavy metals contaminated soils for these metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn).

Table 1. *Phytoremediation Plants and the Heavy metals removed from contaminated Soil.*

Botanical name	Tolerant Heavy metals
Eichhornia crasspes	Cd, Cr, Pb, Hg
Avena strigose	Cd, Cu, Pb
Bacopa monneiri	Cr, Hg, Pb, Cu
Agrostic capillaries	Mn, Cu, Zn
Brassica juncea	Au, Se, As, Cu
Brassica napus	Se, Hg, Zn, Cr
Thlaspi caerulescens	Cd, Cr, Co, Cu
Azolla spp	Cr, Cd, Zn
Vallisneria americana	Mn, Cd, Pb
Halinthus annuus	Cu, Cd, Cd, Hg
Hydrilla verticillata	As, Cu, Zn
Lemna minor	Pb, Cu, Zn, Mn
Pistra stratioles	Cu, Hg, As, Cu
Tagetes erecta	Zn, Mn, Pb
Cocos nucifera	Cr, Cd, Zn
Vicia faba	Hg, Pb, Se

3. Hyperaccumulators

Hyperaccumulators are the plants that accumulate high concentrations of metals in their foliage and other parts of the plant tissues [22]. Plants that growing on metalliferous soils are grouped into three categories:

(1) Excluders, where metal concentrations in the shoot are maintained, up to a critical value, at a low level across a wide range of soil concentration [23].
(2) Hypoaccumulators, where metals are concentrated in above-ground plant parts from low to high soil concentrations [23].
(3) Indicators, where internal concentration reflects external levels [23].

In general terms, metal concentrations in hyperaccumulators are about 100–1000-fold higher than those found in normal plants growing on soils with background metal concentrations [23]. Hyperaccumulator plants show a highly efficient transport of metals from roots to shoots, whereas non-hyperaccumulators usually have higher metal concentrations in roots than in shoot [23, 24,].

Most phytoremediation studies have considered metal extraction efficiency in relation to metal concentration of bulk soil samples or metal concentration of the soil solution, but little is known about the effect of various metal-bearing solids on metal extraction by hyperaccumulators as shown in table 1. In fact, it has been shown that it is essential to consider the nature of the metal-bearing solids to better predict the efficiency of plant extraction [25]. Besides, it is also important to consider that metal bioavailability changes between the bulk soil and the rhizosphere, the latter being a microbiosphere which has quite different chemical, physical and biological properties from bulk soils [26]. In this respect, recently, it has been reported that root growth is a more sensitive endpoint of metal availability than chlorophyll assays [27]. In order to improve phytoremediation of heavy metal polluted sites, the speciation and bioavailability of the metals in the soil, the role of plant-associated soil microorganisms and fungi in phytoremediation, and that of plants have to be elucidated. In the recent research it revealed that, phytoremediation has been combined with electrokinetic remediation, applying a constant voltage of 30 V across the soil, concluding that the combination of both techniques represents [28].

Table 2. *Plants used in phytoremediation.*

Botanical name	English name
Eichhornia crasspes	Water hyacinth
Avena strigose	New oat
Bacopa monneiri	Water hyssop
Agrostic capillaries	Bent grass
Brassica juncea	Mustard
Brassica napus	Rape seed
Thlaspi caerulescens	Alpine pennycress
Azolla spp	Fern
Vallisneria americana	Tape grass
Halinthus annuus	Sun flower
Hydrilla verticillata	Hydrilla
Lemna minor	Duck weed
Pistra stratioles	Water lettuce
Tagetes erecta	African tall
Cocos nucifera	Coconut palm
Vicia faba	Horse bean

4. Phytoremediation

4.1. Advantages of Phytoremediation

Phytoremediation has great advantage over other nonbiological and biological technologies [29]. Here are some of the advantages of phytoremediation;

In phytoremediation, variety of organic and inorganic compounds are amenable to the phytoremediation process. Phytoremediation can be used either as an *in situ* or *ex situ* application. Phytoremediation is a novel, less expensive, efficient, environment and eco-friendly remediation strategy with good public acceptance [30]. Phytoremediation does not require expensive equipment or highly specialized personnel. In large scale applications the potential energy stored can be utilized to generate thermal energy [31]. Phytoremediation is suitable for sites with shallow contaminants. It is environmentally friendly, suitable for a wide range and concentration [32].

4.2. Limitations of Phytoremediation

Phytoremediation may be a time-consuming process, and may take at least several growing seasons to clean up a site. The products formed from those organic or inorganic contaminants may be cytotoxic to plants. It is limited by the growth of the plants. Phytoextraction or degradation need several years to accomplish. Phytoremediation might be suited for rural/remote areas where human contact is limited or where soil contamination does not require an intermediate response. Success of phytoremediation may be limited by factors such as growing time, climate, root depth, soil chemistry and level of contamination [8, 33, 34].

5. Conclusion

Phytoremediation needs interdisciplinary approach with inputs from many fields such as botany, plant physiology, biochemistry, geochemistry, agricultural engineering, agronomy, soil science, genetic engineering to come up with strategic measures for the future phytoremediation that will become a widely acceptable technology for the plants to remove pollutants especially heavy metals from the environment which is very fascinating field of research. Thus, phytoremediation is considered as one of the most effective method of environmental control.

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