PHYTOREMEDIATION AS AN ALTERNATIVE TECHNOLOGY TO CLEANS UP ENVIRONMENTAL CONTAMINATION IN JIGAWA STATE. NIGERIA: A REVIEW

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Abstract: Bioremediation is a technology that utilizes the metabolic potential of microorganisms to clean up contaminated environments. The purpose of this review is to assess the current state of. Phytoremediation as an innovative technology and to discuss its usefulness and potential in the remediation of various impacted sites. Since the dawn of industrial revolution and Agricultural activities mankind has been introducing numerous hazardous compound in the environment at an exponential rate. This hazardous pollutant consists of a variety of organic compound, fertilizer, and heavy metals, which pose serious risk to human health. Heavy metals are primarily more concerned because they cannot be destroyed by degradation frequently, the remediation of contaminated soils, ground water, and surface water is not common due to inability to decompose as a result of microbial activities. Therefore, there is need for the prevention and control of this pollution from contaminated areas in Jigawa state. Phytoremediation is useful in these circumstances because natural plants or transgenic plants are able to bioaccumulate this contaminant in the above ground parts which are then harvested for removal. Phytoremediation is a green technology, and when properly implemented it could minimizes disturbance of the soil and surrounding environment and reduce the spread of contamination via air and waterborne. Phytoremediation does not require expensive equipment. However, the greatest advantage of phytoremediation is its low cost and environmentally friendly compared to conventional clean up technologies. Despite all the important of phytoremediation in the preventing and control of pollutant, their use in developing countries like Nigeria is limited. Therefore, this review aimed at providing an innovative economical and environmentally- friendly approach to removing contaminant from wastes sites.

Keywords: Bioremediation, Phytoremediation, Contaminant, Soil, Water.

Introduction

The Anthropogenic inputs of environmental contaminants have increased rapidly since the dawn of industrial revolution and Agricultural activities which result into the emergence of newly innovative technology in some developed countries to overcome the situation. However, this technology is going to be of advantage in reducing the *environmental pollution if properly handled* in some developing countries like, Nigeria. This remediation process will be effectively used in Northern part of the country, especially Jigawa due to availability of land for effective phytoremediation process.

Bioremediation is one of the top 10 Biotechnologies that utilizes the metabolic potential of microorganisms to clean up contaminated environments (Wantanaba and Baker, 2000). One important characteristic of bioremediation is that it is carried out in non-sterile open environments that contain a variety of organisms (bacteria), such as those capable of degrading pollutants, usually have central roles in bioremediation, whereas other organisms are fungi and grazing protozoa which affect the process. A deeper understanding of the microbial ecology of

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contaminated sites is therefore necessary to further improve bioremediation processes. In the past two decades, molecular tools, exemplified by rRNA approaches, have been introduced into microbial ecology; these tools have facilitated the analysis of natural microbial populations without cultivation. Microbiologists have now realized that natural microbial populations are much more diverse than those expected from the catalogue of isolated microorganisms (Wantanaba and Baker, 2000). This is also the case for pollutant-degrading microorganisms, implying that the natural environment harbors a wide range of unidentified pollutant-degrading microorganisms that have crucial roles in bioremediation. Bioremediation can occur on its own (natural attenuation or intrinsic bioremediation) or can be spurred on via the addition of fertilizers to increase the bioavailability within the medium (biostimulation). However, other microorganisms that enhance bioremediation involved *α-Proteobacteria* and the genus *Alcanivorax* showed accelerated growth (Chang *et al.*, 2000). These studies have indicated that some groups of bacteria commonly occur in oil-contaminated marine environments. Recent advancements have also proven successful via the addition of matched microbe strains to the medium to enhance the resident microbe population's ability to break down contaminants. Microorganisms used to perform the function of bioremediation are known as bioremediators (Diaz, 2008). However, not all contaminants are easily treated by bioremediation using microorganisms. For example, heavy metals such as cadmium and lead are not readily absorbed or captured by microorganisms. The assimilation of metals such as mercury into the food chain may worsen matters. Phytoremediation is useful in these circumstances because natural plants or transgenic plants are able to bioaccumulate these toxins in their above-ground parts, which are then harvested for removal (Diaz, 2008). However, the heavy metals in the harvested biomass may be further concentrated by incineration or even recycled for industrial use. The elimination of a wide range of pollutants and wastes from the environment requires increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds, and they will certainly accelerate the development of bioremediation technologies and biotransformation processes (Lovley, 2003).

Phytoremediation

Phytoremediation describes the treatment of environmental problems through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere (Rupassara *et al.*, 2002). Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them (Greger and Landberg, 1999).

Phytoremediation is the use of green plants to clean up contaminated hazardous wastes site (Chang *et al.*, 2000). The idea of using metal accumulating plants to remove heavy metals and other compound was first introduced in 1983, but the concept has actually been implemented for the past 300 years on waste water discharges (Chang *et al.*, 2000). Phytoremediation has the potential to clean an estimated 30,000 waste sites contaminated throughout the US, according to the EPA's comprehensive environmental response compensation liability information system (CERCLIS). Sites included in this estimate are those that have either been owned or contaminated by battery manufacturer, electroplating, metal fishing and mining companies. Also included in the estimate are producers of solvent, coated glass, paint leather and chemicals. However, bioremediation (Phytoremediation) involves biological components in the remediation or clean up of a specific site. A study conducted in Ogbogu located in one of the largest oil producing regions of Nigeria has utilized two plant species to clean up spills. The first stage of clean up involves *Hibiscus cannabinus*, a plant species indigenous to West Africa. *H. cannabinus* is an annual herbaceous plant originally used for pulp production. This specie has high rates of absorbency and can be laid down on top of the water to absorb oil. The oil saturated plant material is then removed and sent to a safe location where the hydrocarbons can be broken down and detoxified by microorganisms. The second stage of bioremediation involves a plant known as *Vetiveria zizanioides*, a perennial grass species. *V. zizanioides* has a deep fibrous root network that can both tolerate chemicals in the soil and can also detoxify soils through time requiring little maintenance. The people of Ogbogu hope to use these methods of bioremediation to improve the quality of drinking water, soil conditions, and the health of their surrounding environment. Within the Imo State of Nigeria, a study was conducted in the city of Egbema to determine the microfloral communities present at the site of an oil spill. These microorganisms have the ability to break down the oil, decreasing the toxic conditions. This is recognized as another method of bioremediation and scientists are trying to determine whether the properties these microorganisms possess can be utilized for the cleanup of future spills (Okereke *et al.*, 2007).

However, bleak this situation may seem for the Niger Delta region, there are clearly alternatives that can be implemented to save it from future contamination. Satellite imagery combined with the use of Geographical Information Systems (GIS) can be put to work to quickly identify and track spilled oil. To hasten the cleanup of spills, regional cleanup sites along the problem areas could help contain spills more quickly. To make these tasks feasible more funding must be provided by the stakeholders of the oil industry. Non-governmental organizations will keep fighting the damaging effects of oil, but will not win the battle alone (Nwilo *et al.*, 2007). However, other reported work using different type of bioremediation involved the use of fungal mycelium which reported that in one conducted experiment, a plot of soil contaminated with diesel oil was inoculated with mycelia of oyster mushrooms; traditional bioremediation techniques (bacteria) were used on control plots. After four weeks, more than 95% of many of the PAH (polycyclic aromatic hydrocarbons) had been reduced to non-toxic components in the mycelial-inoculated plots. It appears that the natural microbial community participates with the fungi to break down contaminants, into carbon dioxide and water. Wood-degrading fungi are particularly effective in breaking down aromatic pollutants (toxic components of petroleum), as well as chlorinated compounds certain persistent pesticide.

Phytoremediation aimed at providing an innovative, economical, and environmentally- approach to removing toxic metals from hazardous wastes sites. The foundation of Phytoremediation is built upon the microbial community and the contaminated soil/water environment. Complex biological, physical and chemical interactions that occur within the soil allow for the remediation of contaminated sites. Of major importance is the interaction that takes place in the soil adjacent to the roots called the rhizosphere, It has been shown that the rhizosphere contains 10-100 times the number of microorganism per gram than unvegetated soil. Plants exude from their roots a variety of organic compounds that support the microbial community and facilitate the uptake of some metals. The complex interactions among the roots, microbes' metals and solid make Phytoremediation a highly site –specific technology. The agronomic principles of each site must also be reviewed in order to accomplish an effective application of the technology (USEPA, 2000).

Application of Phytoremediation

Phytoremediation may be applied wherever the soil or static water environment has become polluted or is suffering from ongoing chronic pollution. Examples where Phytoremediation has been used successfully include the restoration of abandoned metal-mine workings, reducing the impact of an area where polychlorinated biphenyls have been dumped during manufacture and mitigation of on-going coal mine discharges. Phytoremediation refers to the natural ability of certain plants called hyper accumulators to bioaccumulate, degrade, or render harmless contaminants in soils, water, or air. Contaminants such as metals, pesticides, solvents, explosives (Rupassara *et al.,* 2002), crude oil and its derivatives, have been mitigated in Phytoremediation projects worldwide. Many plants such as mustard plants, pennycress, hemp, and pigweed have proven to be successful at hyper accumulating contaminants at toxic waste sites.

Phytoremediation is considered a clean, cost-effective and non-environmentally disruptive technology, as opposed to mechanical cleanup methods such as soil excavation or pumping polluted groundwater. Over the past 20 years, this technology has become increasingly popular and has been employed at sites with soils contaminated with lead, uranium, and arsenic. However, one major disadvantage of Phytoremediation is that it requires a long-term commitment, as the process is dependent on plant growth, tolerance to toxicity, and bioaccumulation capacity (Mendez and Maier, 2008).

Various Phytoremediation Process and their Application

Phytoextraction

Phytoextraction (or phytoaccumulation) uses plants or algae to remove contaminants from soils sediments or water into harvestable plant biomass (stem and leaves etc.) organisms that take larger-than-normal amounts of contaminants from the soil are called hyper accumulators. A hyper accumulator is a plant species capable of accumulating 100 times more metals then a common non accumulating plant. Thus a hyper accumulator will concentrate more than 1000fg/g (0.1%) of Co, Cu, Cr, Pb,or 1% Zn and Ni in their leaf dry matter. Phytoextraction has been growing rapidly in popularity worldwide for the last twenty years or so. In general, this process has been tried more often for extracting heavy metals than for organics. At the time of disposal, contaminants are typically concentrated in the much smaller volume of the plant matter than in the initially contaminated soil or sediment. 'Mining with plants, or phytomining, is also being experimented with. The plants absorb contaminants through the root system and store them in the root biomass or transport them up into the stems or leaves. A living plant may continue to absorb contaminants until it is harvested. After harvest, a lower level of the contaminant will remain in the soil, so the growth/harvest cycle must usually be repeated through several crops to achieve a significant cleanup. After the process, the cleaned soil can support other vegetation. (Burken, 2004).

Advantages of Phytoextraction

The main advantage of Phytoextraction is environmental friendliness and is among the Traditional methods (Phytoextraction, Phytostabilization, Phytotransformation, Phytostimulation, Phytoscreening, Rhizifiltration and Phytovolatilization) that are used for cleaning up heavy metal-contaminated soil disrupt soil structure and reduce soil productivity, where as Phytoextraction can clean up the soil without causing any kind of harm to soil quality. Another benefit of Phytoextraction is that it is less expensive than any other clean-up process, and can prevent erosion.

Disadvantages of Phytoextraction

As this process is controlled by plants, it takes more time than anthropogenic soil clean-up methods.

Two versions of Phytoextraction:

- **Natural hyper-accumulation**, where plants naturally take up the contaminants in soil unassisted
- **Induced or assisted hyper-accumulation**, in which a conditioning fluid containing a chelator or another agent is added to soil to increase metal solubility or mobilization so that the plants can absorb them more easily. In many cases, natural hyper accumulators are metallophyte plants that can tolerate and incorporate high levels of toxic metals.

Phytoextraction Process

- Arsenic, using the Sunflower (*Helianthus annuus*), or the Chinese Brake fern (*Pteris vittata*), a hyper accumulator. Chinese Brake fern stores arsenic in its leaves.
- Cadmium, using willow (*Salix viminalis*): In 1999, one research experiment performed by Maria Greger and Tommy Landberg suggested willow has a significant potentiality for Phytoextraction of Cadmium (Cd), Zinc (Zn), and Copper (Cu), as willow has some specific characteristics like high transport capacity of heavy metals from root to shoot and huge amount of biomass production; can be used also for production of bio energy in the biomass energy power plant(Greger and Landberg, 1999).
- Cadmium and zinc, using Alpine pennycress (*Thlaspi caerulescens*), a hyper accumulator of these metals at levels that would be toxic to many plants. On the other hand, the presence of copper seems to impair its growth
- Lead, using Indian Mustard (*Brassica juncea*), Ragweed (*Ambrosia artemisiifolia*), Hemp Dogbane (*Apocynum cannabinum*), or Poplar trees, which sequester leads in their biomass.
- Salt-tolerant (moderately halophytic) barley and/or sugar beets are commonly used for the extraction of Sodium chloride (common salt) to reclaim fields that were previously flooded by sea water.
- Caesium-137 and strontium- 90 were removed from a pond using sunflowers after the Chernobyl accident.
- Mercury, selenium and organic pollutants such as polychlorinated biphenyls (PCBs) have been removed from soils by transgenic plants containing genes for bacterial enzymes.

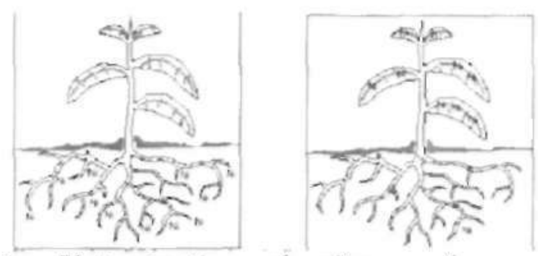

Fig 1: Phytoextraction of nitrogen from contaminated soil. (Greger and Landberg, 1999).

Phytostabilization

Phytostabilization focuses on long-term stabilization and containment of the pollutant. Example, the plant's presence can reduce wind erosion; or the plant's roots can prevent water erosion, immobilize the pollutants by adsorption or accumulation, and provide a zone around the roots where the pollutant can precipitate and stabilize. Unlike Phytoextraction, Phytostabilization focuses mainly on sequestering pollutants in soil near the roots but not in plant tissues. Pollutants become less bioavailable, and livestock, wildlife, and human exposure is reduced. (Mendez and Maier, 2002).

Phytotransformation

In the case of organic pollutants, such as pesticides, explosives, solvents, industrial chemicals, and other xenobiotic substances, certain plants, such as Cannas, render these substances non-toxic by their metabolism. In other cases, microorganisms living in association with plant roots may metabolize these substances in soil or water. These complex and recalcitrant compounds cannot be broken down to basic molecules (water, carbon-dioxide, etc.) by plant molecules, and, hence, the term Phytotransformation represents a change in chemical structure without complete breakdown of the compound. The term "Green Liver Model" is used to describe Phytotransformation, as plants behave analogously to the human liver when dealing with these xenobiotic compounds (foreign compound/pollutant) [Burken, 2004] .After uptake of the xenobiotics, plant enzymes increase the polarity of the xenobiotics by adding functional groups such as hydroxyl groups [-OH]. (Subramanian *et al.*, 2006).

Phytostimulation

Enhancement of soil microbial activity for the degradation of contaminants, typically by organisms that associate with roots This process is also known as Phytostimulation can also involve aquatic plants supporting active populations of microbial degraders, as in the stimulation of atrazine degradation by hornwort (Rupassara *et al.*, 2002).

Phytovolatilization

This is the removal of substances from soil or water with release into the air, sometimes as a result of Phytotransformation to more volatile and/or less polluting substances.

Rhizifiltration: - filtering water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots.

Phytoscreening

As plants are able to translocate and accumulate particular types of contaminants, plants can be used as biosensors of subsurface contamination, thereby allowing investigators to quickly delineate contaminant plumes (Burken *et al.*, 2004). Chlorinated solvents, such as trichloroethylene, have been observed in tree trunks at concentrations related to groundwater concentrations (Vroblesky, 2008). To ease field implementation of Phytoscreening, standard methods have been developed to extract a section of the tree trunk for later laboratory analysis, often by using an increment borer (Vroblesky, 2008). Phytoscreening may lead to more optimized site investigations and reduce contaminated site cleanup costs.

Advantages and Limitation of Phytoremediation.

Advantages of Phytoremediation

(1) The cost of the Phytoremediation is lower than that of traditional processes both *in situ* and *ex situ*
(2) The plants can be easily monitored
(3) The possibility of the recovery and re-use of valuable metals (by companies specializing in "phyto mining")
(4) It is potentially the least harmful method because it uses naturally occurring organisms and preserves the environment in a more natural state.

Limitations of Phytoremediation

(1) Phytoremediation is limited to the surface area and depth occupied by the roots.
(2) Slow growth and low biomass require a long-term commitment with plant-based systems of remediation; it is not possible to completely prevent the leaching of contaminants into the groundwater (without the complete removal of the contaminated

ground, which in itself does not resolve the problem of contamination)

(3) The survival of the plants is affected by the toxicity of the contaminated land and the general condition of the soil.

Conclusion

Bioremediation is a proven alternative treatment tool that can be used in clean up environmental contamination. Phytoremediation is the use of green plants to clean up hazardous waste sites. According to the EPA's Comprehensive Environmental Response Compensation Liability Information System [CERCLIS], Phytoremediation has the potential to clean up an estimated 30,000 hazardous waste site in US (USEPA, 2000). Phytoremediation is amenable to a variety of organic and inorganic compounds and may be applied either *insitu* or *ex situ.In situ* applications decrease soil disturbance and the possibility of contaminant from spreading via air and water, reduce the amount of waste to be land filled (up to 95%) and a low cost compared with the other treatment methods. In addition to this, it is easily to maintain, and environmentally friendly.

The use of Phytoremediation to clean up contaminant from environment has shown promising result, but is still in the research and development stage. Phytoremediation is considered to be an innovative technology and hopefully by increasing our knowledge and understanding of this intricate clean up method, it will provide as a cost effective, environmentally friendly alternative to conventional clean up methods.

Recommendation

The paper recommends that, there is need for the application of Phytoremediation technology across the state for the management of waste and sustainable development in the state, because it is environmentally friendly and easy to adopt.

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