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Phytoremediation (Series 3a): exploring the phytomitigation option of environmental management as an ecological response clean-up technique

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ABSTRACT

The prospects of phytoremediation of oil polluted sites in areas where is oil exploration, extraction and transport are evaluated in this study in relation to environmental degradation and public health. The study revealed that phytoremediation of oil polluted sites has some prospects and is likely to attract policy makers to enforce its application in the maintenance of environmental quality. What is necessary is a sound phytoapplication technique and approach to future implementation through modeling for a sustainable grass root environmental development.

INTRODUCTION

The environment is that unit or component of ecological system in which interactions and changes between and among biotic and abiotic components occur. The environment is a complex of the atmosphere, lithosphere and hydrosphere. They can easily be polluted by all forms of liquid and solid waste excesses, substances and other forms of hazardous materials, noxious and non-noxious, degradable and non-degradable pollutants, that are potentially pathogenic to the general well being and socio-ecological implication of our society and environs. Industrial development has grossly increased these environmental threats. Among the recorded ecological disasters in our society, particularly in the rural areas, oil pollution either from point or non-point source has been an environmental problem faced by the society, as in spillages in course of extraction, production and transportation activities.

Oil spillage refers to its spread on the surface of either water or soil and its attendant polluting effects on the atmosphere. Such spillage (particularly crude oil) on the immediate environment is one of the anticipated problems in oil exploration and production activities, which may not have been given adequate management attention. Crude oil spillages interfere negatively with the natural balance in ecological processes within the affected environment.

The nuisance engendered by crude oil pollution has led to the enactment and implementation of laws and regulations intended to reduce spillage and consequent human ill health and environmental hazard (Wardley-Smith, 1979).

Similarly in the last four decades oil spills have given rise to increased scientific knowledge of the behaviour of hydrocarbons and development of new intervention methods. It has also led to growing industrial sectors dedicated to the clean up of contaminated environmental media using physical and chemical methods otherwise suitable for aerial and aquatic media but with no significant impact on the terrestrial ecosystem. In acknowledging the fact that pollution has posed severe threat to environment (both in the rural and urban areas) various governments, organizations and interest groups have proposed numerous action plans aimed at protecting our global and common heritage – *the terrestrial environment.* The initiatives promote the practice of bioremediation, which is being carried out in various part of the world, but may not have yielded the desired goals due to some short comings (Muclure, 1972, Yall, 1979; Song *et al* , 1990 and Jones and Greenfield, 1991). Phytoremediation is being currently practiced in various countries of the world (Environment watch, 2000). This study examines the significance and prospects of embracing phytoremediation as an environmental mitigation option for grass root sustainable development. The was carried out by examining past and related works obtained from the internet, journals, books, newspapers and magazines besides personal communications.

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The rationale for exploring phytoremediation as a necessary option for grassroots sustainable development (An overview).

In the last two decades much progress has been made in the cleanup of contaminated soils, sediments, ground water and aerial environmental media. But the existing methods (both physical, chemical and mechanical approaches) have proven to be very costly or limited in various ways. It is evident that clean up of sites with existing and conventional technologies will continue to be demanding, very expensive and sophisticated. With these inadequacies for the containment of terrestrial pollution, there is growing ecological awareness that has led to research and development of new technologically sound soil rehabilitation programs that meet many remediation needs around the globe (Personal communication).

Many processes and techniques (Physicochemical approach) of pollutant disposal simply engender the transmigration and transboundary movement of pollutants from one environment to another and thus remain without containment. There have been unexpected pollutant threats posing new challenges to the society, as in the recently discovered problem of methyl ter-butyl ether (MTBE) contamination of soil and groundwater (FCE, 2003). Risk analysis may provide a basis for some site to go unremediated, but uncertainties in this nascent science of risk analysis may foster public and scientific uneasiness.

There has been a call for bioremediation application for terrestrial pollution management, and series of it are being practiced in America, Asia, European countries, and other African countries, but which seem not to have yielded the desired goals (Envt. Watch, 2000). Oil spillages have been effectively treated with booms, skimmers and chemical barrier or dispersant but these options are usually ineffective in terrestrial habitats (Cox and Cowell. 1979). Song *et al*, (1990) investigated the bioremediation potential of pollutants and noted that this process was only fit for fuel distillates. Attempts have been made to degrade recalcitrant molecules in polluted soils with strains of micro-organisms (commercial innoculum), including treatment with fertilizers (Muclure, 1972, Yall 1979, Jones and Greenfield, 1991). These innovations could result in population explosion and possibly health hazards may ensue, as most microorganisims are potential vertebrate pathogens.

Genetic engineering is being utilized to increase the biodegradation capabilities of microbes. Many have questioned the release of genetically engineered organisms into the environment, because the behaviour of these organisms may alter the environment and mutation could take place, subsequently resulting in harmful organisms.

Another potential problem with using genetically engineered microbes is that they could compete with microbes naturally present in polluted sites. These naturally occurring microbes are often more effective, and do not exhibit any positive effect from the addition of genetically engineered microbes (*Online-life: // A:* bioremediation of oil spill. htm). Initially it was hoped that microbial bioremediation would provide such a breakthrough, but microbial activities have proven to be limited. After nearly 20 year of intensive research in microbial bioremediation, enthusiasm for this approach has noticeably waned. Different and better ways are needed to deal with soil pollution problems. In the early 80's a new technology- *Phytoremediation,* the use of plants to remediate environmental toxicity emerged with promises of significant economics reminiscent of those initially proposed for bioremediation.

Some plants growing in areas contaminated with metals such as nickel accumulate metals and thus the use of plants to extract and accumulate toxic metals. It was proposed that toxic organic compounds might be degraded by the action of microorganisms peculiar to the rhizosphere of plants. In the last five years it has become clear that phytoremediation using conventional plants has some potential for use in remediation (UWCFR, 2003). The potential of genetic engineering for enhancing the biodegradation of xenobiotic compounds has been justifiably recognized since the early 80's. Initially there was hope that transgenic bacteria would provide powerful methods for remediation of environmental problems but this approach failed due to two factors:

(i) Inconsistent survival of genetically modified microorganism in soil and water environments, and the reluctance by regulatory authorities to approve the release of genetically modified microbes into the environment.

(ii) Such reluctance could stem from the high growth and small size of bacteria and ease of horizontal gene transfer among dissimilar prokaryotes, (UWCFR, 2003).

These problems can be overcome by using plants rather than microorganisms as the delivery systems for genetically engineered environmental clean up of biosystems. Primarily by virtue of their size, vascular plants are more easily controlled than microorganisms. Selecting sterile plants and controlling propagation by harvesting the plants prior to flowering can prevent uncontrolled genetic releases from phytoremediation plantation. Thus by using plants, the promise of genetically engineered phytoremediation environmental clean up system can be achieved (UWCER, 2003). The potential economic benefits of using plants for remediation are impressive. Plants are robust and solar powered. Their root systems permeate soil and sediment environments with an extensive and active membrane system.

The soil near their roots has microbial population orders of magnitude greater than non-root-soil. These benefits are provided with little or no maintenance requirements. Furthermore. Plant based systems are welcomed by the public due to their superior aesthetics, the societal and environmental benefits that their preserve provides. Many scientists and other hazardous waste site managers believe that it is more efficient to use trees as a solar driven pump and in long-term treatment process for categories of pollutants in the environmental media.

An overview of global trend of phytoremediation technology

Phytoremediation is the name given to a set of technologies that clean contaminated sites using plants. Plants may remediate homogenic contaminants through several mechanisms. Some plants destroy organic pollutants by degrading them directly, while some other plants aid in degrading indirectly by supporting microbial communities. Other plants take up inorganic contaminants from soil or water and concentrate them in the plant tissue or root. Thus Phytoremediation can be applied as containment, degradation or an extraction technique. It has been applied in point and non-point source hazardous waste pollution control, and has been used in soil, surface water, ground water, sediments and atmospheric medium. The cost of phytoremediation techniques is estimated to be from 50% to less than 20% of physical, chemical or thermal techniques on applicable sites (Steven, 2004).

As earlier indicated its application to polluted environments is being carried out in so many countries including the United State of America, China, India, Thailand, Brazil, European countries and in some African nations. When pollution prevention fails phytoremediation can help improve the environmental quality as part of balanced program to enhance natural cleaning processes. Therefore, Phytoremediation is an important approach for the remediation or reclamation of derelict terrestrial environments.

Phytoremediation has been used to clean up metals, pesticides, solvents, explosives, crude oil, polyaromatic hydrocarbons and land fill leachates plants can use contaminants as nutrients, nitrate contamination of ground water can serve as a Nitrogen source for plants (Steve and Daniel, 1996). Albeit, some phytoremediation technology applications are slower than conventional methods like the use of chemical and mechanical techniques. Despite the limited depths that may be within reach of plants roots macrophytes can still be effectively utilized in phytoremediation applications. This can be in combination with other clean up approaches as a “finishing” of “polishing” step for a sustainable and quality environmental management.

Many plants transport significant quantities of water and also remediate several years of chronic pollution problem in a terrestrial environment. Plants such as the phreatophytes (Willow and poplar plants) are noted as phytometer for remediation, (Steve and Daniel, 1996). Some plants extract and accumulate metals in tissues. Metals such as Pb. Cd, Cr, Ni, Co, Cu, Zn, Uranium and Selenium can be extracted from the soil by the accumulators. Phytoremediation has been used to reduce concentrations of hydrocarbons from spills and leaking underground storage tanks, polychlorinated biphenyls from transformers, pentachlorophenol and creosote from wood preserving sites, Nitrates, pesticides and herbicides from agricultural runoff and chlorinated solvents like trichloroethylene (TCE) from industrial processes (Steve & Daniel, 1996).

Generally, phytoremediation utilization is limited to sites with low to medium contaminant concentration and contamination in shallow soils, streams and ground water. Currently studies have substantiated that using trees (rather than smaller plants) looks more durable and gives credibility to a sustainable environmental quality. Since it allows for deeper decontamination treatment.

Integrating phytoremediation in environmental management programme for sustainable development of the grassroot.

The World Commission on Environment and Development sees sustainable development as: (i) ensuring equity for human generations yet to come, whose interest are not represented by standard economic analysis or by market forces that discount the future. (ii) equity for people living now who do not have equal access to natural resources or to socio-economic goods. (iii) It is simply the path of human progress, which meet the needs and aspirations of present generations without compromising the ability of future generations to meet their needs (AAS, 1993). The World Conservation Union sees sustainable development as the improvement of supporting ecosystems.

The application of macrophytes in environmental management and remediation of a contaminated environment (particularly terrestrial and aquatic habitats) could be pivoted around four major facets, viz:

i) *The policies and procedures that govern phytoremediation systems*

ii) The methods and techniques to be used in applying phytoremediation to the environmental programme or project.

iii) The prospects for socioeconomic and sustainable development.

iv) Grassroot participation for sustainable development

POLICIES AND PROCEDURES

Should a polluted environment be allowed to undergo natural self-remediation by fallow method, this takes a long time. Therefore contaminated environments need human intervention to accelerate the recovery process. It becomes pertinent to seek out macrophytes of high potential for habitat remediation. The screening of macrophytes should aim at identifying and evaluating the potentials of using the most appropriate species in various plant families. Such screening will also determine and assess the effect of such pollutant on the phytometer and subsequently, their level of tolerance and potential ecological impact on the contaminated environment Results obtained will help produce a remediation technology package for such a polluted terrestrial environment. The initial concentrations of pollutants may be toxic to an unknown proportion of macrophytes thus underestimating their degrading potentials.

The screening, use and management of tree plants (macrophytes) for use in phytoremediation of polluted sites should consider the following factors:

1. The most appropriate phytoremediation intervention considerations should be:

(i) Levels of pollution (light, medium and high).

(ii)Types of pollutants (crude oil or some other pollutant)

(iii) Period of pollution (e.g., 7days of post-pollution or more).

2. The purpose of such intervention and priorities of set objective (e.g. intercropping or solely for soil management).

Most plants grow roots to about 2 meters deep or less, but some plants can reach far deeper under good conditions. It might be desirable for phytoremediation macrophytes to have certain ecological characteristics and which ever will be of interest depends on the role expected of such trees or shrubs on any of the phytoremediation intervention priorities (Edwin-Wosu, 2002). Such ecological attributes of macrophytes include:

i. Providing well ramified and buttress root for soil erosion control.

ii. Providing enough root for creation of voids and rhizospheric environment for microbial colonization and habitation.

iii. Fast growth, erect stems and coppicing ability.

iv. High productivity of branches and leaves and increase in rooting pattern.

v. The plant should be resistant to pests and disease infestation.

vi. Spreading dense hedge and ability to recover rapidly upon heavy pollarding.

vi. High soil enrichment potentials, for organic matter return nitrogen fixation and high decontaminating potentials.

vii.The plant should have well-ramified and very deep down root system for efficient soil binding, aeration and maximum water uptake in such polluted terrestrial habitat.

Phytoapplication techniques

Consideration should be given to the general experimental design, which could involve experimental pollution of the study site with crude oil, post-pollution habitat reclamation treatment using plant species, assessment of biological recovery of the polluted sites and statistical assessment of the remediation performance for the species in question. Pollutants including petroleum products (e.g. gasoline, diesel, fuel, creosote, etc), which pollute soil and H_2O may also be removed using hydrocarbon-degrading macrophytes. Often times nutrients and /or election acceptors may be introduced in such sites to stimulate the growth and activities of these macrophytes. Moreover, since such abiotic processes as dilution, leaching, volatilization, sorption or chemical and photochemical oxidation can be responsible for pollutant disappearance, other biotic criteria could be used to assess macrophyte response, and the effectiveness of the various abiotic treatments.

Increase in the biological performance of the degrading macrophyte on polluted sites would provide evidence that they are response for pollutant disappearance. In a pilot scale experiment, crude oil polluted microplots of loam soil were used to study the effectiveness of agro-forestry species on hydrocarbon degradation, (Edwin-Wosu, 2002). When the crude oil formed cakes at the surface, it became impermeable to water and air movement, and thus reduce the ability of such macrophytes in root formation and absorption of nutrients, besides loss of efficacy for hydrocarbon degradation. It has been suggested that not all plant in the family fabaceae used in agro-forestry practice have the potential for remediation (Edwin-Wosu, 2002).

Phytoremediation prospect for sustainable development

The phenomenon of crude oil spillage is both natural and anthropogenic in nature. Spillages have continued to ravage over 60% of the rural populace in oil producing areas (Environmental watch 2000). The existing control techniques, which are highly capital intensive and often saddled with complicated implementation approaches, exclude the participatory initiative of the local population. Of the many remediation methods (peating, dispersant treatment, skimming/booming, microbial seeding) currently in use or under development phytoremediation is viewed as one of the most promising technologies in terrestrial pollution. Phytoremediation will enhance the use of *Leucaena leucocephala* as effective oil absorbent for moping up oil spills and to achieve an integrated soil restoration and pollution control biofilter in oil producing area. *Leucaena leucocephala* is of the Fabaceae family, exotic species from Tropical America. It was introduced into Nigeria and have naturalised. It is easily available and accessible for ornamental and agro-forestry purposes. It is an internationally recommended, selected and accepted species among the many agro-forestry species, with special reference to their extent of naturalization, perennial and multipurpose qualities by the

International Institute of Tropical Agriculture (I.I.T.A.) Ibadan (Odigie,1990).

Phytoremediation technology is less expensive to install and maintain, has economic prospects and very high prospects for land recovery for building and agriculture. In this way, phytoremediation can play a significant role in national development. With phytoremediation, after the plants have grown to maturity, they are harvested and either incinerated or composted to cycle the metals. The incinerated plant will generate less than 10% ash compared to the volume that would be created if the contaminated soil were dug up for treatment (AFCEE / ERT, 2002). It is a passive technology, with minimal environmental disturbance, aesthetically pleasing and permanent. Noise and vibration created by the pump and treatment systems, which affect neighbourhoods around the treatment site is not applicable to phytoremediation. Phytoremediation can be used to clean up sites with shallow, low to moderate levels of contamination. The technique can be used along with or in some cases in place of mechanical clean up methods. It is useful and applicable for treating a wide variety of environmental contaminants / pollutants including metals; pesticides, solvent, explosives, crude oil, polyaromatic hydrocarbons (PAH) and land fill leachates (USEPA 1998). It can clean chronic pollution sources, though it may take at least 2-3 years for total clean up. Phytoremediation technology is a promising clean up solution for a wide variety of pollutants and sites. It is an *in situ* passive, solar driven, and costs 10%-20% of mechanical treatment. It is a phenomenon with faster transfer than natural attenuation, high public acceptance, fewer air and water emissions, generates less secondary wastes. Soils remain in place and are usable following treatment.

Bioremediation and Participatory local initiatives for sustainable development of the environment

Historically, local communities are induced to participate in externally initiated environmental projects. There have been reference cases where local people are vigorous participators in the determination of their own future and that of the environment. Local initiatives in resource management and development requires that local communities, NGOs and CBOs enjoy genuine autonomy, have control over resources and in some cases provided with financial and technical assistance to restore their resource base and re-establish control over resources.

The rationale for local initiatives in sustainable ecological development and resource management is the fate of the environment in the rural areas will be determined by the interactions between the local dwellers and the natural resources from which they derive their livelihood. The local people in communities have deep and intimate knowledge of the local ecology, the flora and fauna, a knowledge born out of centuries of constant interaction with the environment and transferred from generation to generation. Such traditional knowledge is indispensable in evolving responses to hanging material conditions in order to preserve and enhance environmental quality. Some activities of the local communities contribute to the degradation of environmental resources. The local communities have a stake in the health and integrity of their environment, inspite of any external responses and assistance.

For solutions and interventions to succeed it must not only be technically sound, but also socio-economically acceptable to the rural populace. External assistance should be pivoted toward the building up of local capabilities that respond to priorities established by the local communities.

Present techniques in combating oil spillage in the oil producing areas is capital intensive, sophisticated and required trained personnel, and thus not suited for application in local communities. With the call for poverty alleviation in Nigeria by different sectors of the economy, there is need for environment friendly innovation on how to meet the needs of the poor and their environs. Participation of the local populace in bioremediation activities will aid the development of communities and their environments for better and cautious management of their resources to ensure long term and sustainable economic empowerment.

CONCLUSION

The exploitation of degradative capacities and effectiveness of macrophytes is a *sine-qua-non* for environmental decontamination currently in use of under development. Consequently, irrespective of the nature of the polluted habitat and the type of treatment system applied, for a sustainable development of the grassroots area to tae effect via a successful and effective bioremediation applications, this calls for an imperative grassroots participation initiative, hence the development of such technological innovation is on a cost-effective, efficient and a sound environment friendly and prospective ecological status in coherent to the philosophy of sustainable Development.

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