ENVIRONMENTAL SOIL PHYTOREMEDIATION USING MANGROVE PARTS FOR CRUDE OIL AND HEAVY METAL REMEDIATION IN SELECTED SITES IN RIVERS STATE, NIGERIA

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Article History

Submitted: 06.10.2023
Accepted: 10.10.2023
Published: 11.10.2023

Journal homepage:
https://www.iiarpub.org

ABSTRACT

The study investigates the use of mangrove parts (branch, leaves, stem and root) as a tool for crude oil remediation in selected sites in Rivers State, Nigeria. The study tends to determine the physicochemistry of soils phytoremediated with different plant parts and to determine the THC increase or decrease in each of these soils over time in order to determine the plant parts with highest remediation power based on soil THC and microbial load. Random sampling was used in obtaining soil samples at the Jetty Mangrove site. The different sampling points were homogenized to form a true representative of the mangrove soil. The Mangrove parts were oven dried to constant weight for 72 hours at 60ºC before being homogenized with plastic mortar and pestle prior to the experiment. EPA Method 418 was used to determine the Total Hydrocarbon Content (THC). Heavy metals such as Cadmium, Lead and Zinc were determined using AAS- Atomic Absorption Spectrometry method while the microbial load was estimated using the plate viable count method. Results showed that all the mangrove plant parts phytoremediated the soils in the order root > leaf > branch > stem with values 21.5, 18.6 and 26.3 for root, 16.0, 11.9 and 143.9 for stem, 94.2, 80.6 and 15.8 for leaf and 28, 34.8 and 217.8 for branch respectively. The research which was observed for six months at two months intervals showed progressive decrease in THC and the Heavy metal composition and an increase in the microbial load. Hence, mangrove parts especially the roots are potential tools for bioremediation of polluted soils and if explored can serve as a cheap, available and effective source of materials for phytoremediation.

Keywords: Phytoremediation, Heavy metals, Total Hydrocarbon Content (THC), physicochemistry, Mangrove parts.

INTRODUCTION

Oil spills contribute to degradation and destruction of the mangrove forest and endangered species such as Delta elephant, the white monkey, the river hippopotamus, and crocodiles are increasingly threatened by the activities of the oil companies (Anyanwu and Tanee, 2008). The resulting ecological devastation as a result of oil exploration and related activities are enormous. Farm lands are lost, drinking water and air are made unsafe for human consumption. The resulting impact on the residents is enormous. Mangroves are salt-tolerant trees, also called halophytes, and are adapted to life in harsh coastal conditions, immersion and wave action. They are adapted to the low oxygen conditions of waterlogged mud (Flowers and Colmer, 2015).

The Niger Delta region of Nigeria has witnessed an intermittent discharge of crude oil into its environment since the inception of crude oil exploration and exploitation; this has led to the destruction of its farmlands, aquaculture, rivers and creeks with hydrocarbon compounds (Eze and Okpokwasili, 2010).

The Niger Delta consists of highly diverse ecosystems supportive of numerous species of terrestrial and aquatic fauna and flora and is the largest wetland in Africa. Crude oil pollution is a serious multi-dimensional problem as it affects all aspects of the environment. The effects depend on the amount of oil spill, type of oil, extent of oil coverage, oil composition and season of the spill (Pezeshki *et al*., 2000). Its effects include suffocation and death of aquatic lives as it prevents oxygen diffusion into water. Crude oil has also been known to affect plant through inhibition of germination, reduction in plant growth (height and stem diameter) and photosynthetic rate and complete mortality (Pezeshki *et al*., 2000; Tanee and Anyanwu, 2007; Anyanwu and Tanee, 2008). Crude oil has also been known to reduce nutrients (especially nitrogen and phosphorus) availability (Xu and Johnson, 1997; Tanee and Kinako, 2008). A number of plant species have been reported extinct as protracted effect of crude oil environmental pollution. This affects the livelihood of the indigenous people who depend on the ecosystem services for survival leading to increased poverty and displacement of people. The oil industry located within this region has contributed immensely to the growth and development of the country which is a fact that cannot be disputed but unsustainable oil exploration activities has rendered the Niger Delta region polluted. The total oil revenue generated into the federation account from 2000 to 2009 amounted to 34.2 trillion Naira representing 82.36% of total revenue of the nation (OPEC, 2019). One of the five most severely petroleum damaged ecosystems in the world. However, according to Shell Nigeria, the largest producer of oil in the country, about 85 % of the spills (95 % by volume) are as a result of sabotage, and the remaining portion is the result of operational activities (SPDC, 2013). Statistics have shown that during 1976-1980, the majority of oil spill incidents occurred in the purely mangrove zones and the offshore areas of the Niger-Delta, which constitute the most productive biological areas of the region. Within six (6) months, mangrove vegetation started dying in the contaminated waters. Crabs, mollusks and periwinkles died while associated fire hazard spreading to about 25ha of land occurred (Nwankwo and Ifeadi, 2019). In this research, we intend to use the withstanding potency of the mangrove plant as a tool for crude oil remediation on mangrove soil from Jetty community in Okrika in Rivers State, Nigeria. Bioremediation of heavy metals and polycyclic aromatic hydrocarbons can be achieved through the activities of bacteria and other microflora in the soil. Addition of nutrients helps in the enhancement of biodegradation of polycyclic aromatic hydrocarbons and reduction of heavy metal ion concentration on crude oil polluted soil due to stimulation of native microorganisms. This research will help to discover other organic waste matter with heavy metals absorbent potentials and the enhancement of hydrocarbon degradation in natural sites on oil polluted soil

The aim of this study is to investigate the use of mangrove parts (leaves, branches, roots and stems) as a tool for crude oil remediation in selected sites in Port

Harcourt, Rivers State. The specific objectives of this study include,

(1) To determine the THC increase or decrease in different soil with plant parts over time

(2) To determine the plant parts with highest remediation power based on soil heavy metal toxicological load.

MATERIAL AND METHOD

Description of Study Area

Jetty is a community in Okrika popularly known for the presence of an oil refinery. Oil exploration and processing is the major activity Jetty is known for. Due to this fact, Jetty has attracted a large population of non-citizens and indigenes cohabiting together to make a living. Jetty is located in Okrika a town in Port Harcourt, Rivers State, now headquarters of present day Okrika Local Government Area of Rivers State. The town is situated on a small island just south of Port Harcourt, the state capital, making it a merger of the much larger city. It is surrounded at the south by Bonny River, it is 35 miles upstream from the Bight of Biafra. The town can be reached by vessels of a draft of 29 feet or less. The emission of gases like sulfur dioxide, nitrogen oxide, carbon monoxide, carbon dioxide, and other hydrocarbons generated by diesel engines of ships burning high sulfur content fuel oil into the air is characteristics of this area and has been classified by Environmental Protection Agency (EPA) as carcinogenic. EPA recognizes that these emissions from marine diesel engines contribute to the depletion of the ozone layer, climate change and as well has adverse health effects associated with ambient concentrations of particulate matter and visibility, haze, acid deposition.

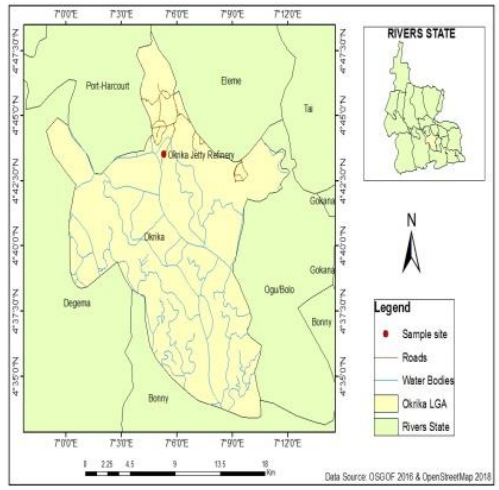

Figure 1: Map of Jetty community in Okrika LGA Rivers State

Collection of Soil Samples

Random sampling was used in obtaining soil samples at the jetty mangrove site.

Mangrove soil samples were collected from 3 different sampling points (Upstream, mid-stream and downstream). The sample was collected using a clean plastic container. The different sampling points were homogenized to form a true representative of the mangrove soil. The soil was properly and clearly labeled. The mangrove soil was taken to the laboratory for the phytoremediation process.

a. Collection of Plant Samples

Random samplings were used in obtaining parts (leaves, branch, stem and roots) of Mangrove plant samples at the jetty mangrove site.

Aquatic plant samples growing in water environment were collected from three samples points (A, B, C) and were properly labeled and taken to the laboratory for proper identification.

b. Preservation of Samples

All samples for physical and chemical analysis were preserved at low temperature as soon as possible after collection.

c. Sample Pre-treatment

The soil samples were stored in plastic bottles with screw caps or an air tight polythene bags prior to the experiment. The Mangrove parts was oven dried to constant weight for 72 hours at 60°C before being homogenized with plastic mortar and pestle prior to the experiment except those selected for pre-test in the laboratory. The homogenized samples were stored in plastic bags.

d. Determination of Hydrocarbon Content

EPA Method 418 (EPA 1999c) will be used to determine the hydrocarbon content of soil samples. Alkanes (paraffins), Naphthenes Aromatics, Asphaltics, n-Hexane, 110-Pentane, 109-Benzene, Toluene 108-Xylenes (o-, m-, p-isomers) and others was estimated.

e. Assessing the Toxicological Load of Soil Sample (TLSB)

Heavy metals such as: Cadmium, Lead and Zinc was estimated. These heavy metals were determined using AAS- Atomic Absorption Spectrometry method.

f. Statistical Analysis

The SPSS version 23 software was used for the statistical analysis of results. Results were represented as mean and standard error mean of variance (M ±SEM). Data collected were subjected to Analysis of Variance (ANOVA) and the significant difference was established at 95% level of confidence where values at $p < 0.05$ points were considered to be statistically different.

RESULTS

a. Total Hydrocarbon content (THC) of mangrove soil treated with various mangrove swamp plant parts

The initial THC contents of root, stem, leaf and branch estimated over two and four months showed a steady decrease of THC contents all through the contaminated soils that were phytoremediated with various mangrove plant parts. There was an enhanced degradation due to the presence of both plant parts and microorganisms feasting on them, when compared to the results of the sixth month, there was a significant ($p<0.05$) rise in the values of THC of groups phytoremediated with branch and stem. Groups remediated with root had a slight rise while the group treated with leaf showed a decrease in values of THC. The differences in the decrease in the THC content between root and leaf treated groups were not significant after six months, as the THC were mainly degraded in the first two months. The average overall results obtained have shown that both root and leaf could efficiently reduce the level of crude oil concentration in soils.

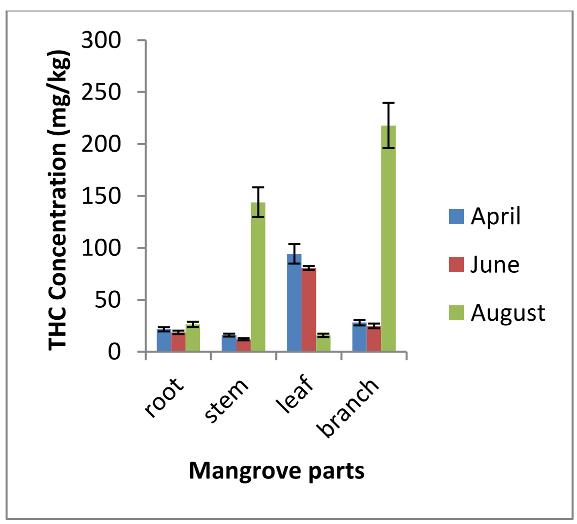

Figure 2: THC concentration of soils treated with mangrove parts after six months ($P< 0.05$)

b. Zinc concentration of soils treated with mangrove parts after six months

The mean level of the heavy metal contamination in soil samples phytoremediated with various mangrove plant parts are presented in Figures 3 - 5. Zn was the most accumulated metal in all the soil samples with stem having the (0.158mg/kg) highest concentration and root (0.022mg/kg) the lowest. The result showed values lower than the FMENV recommended limit (0.05mg/l) in soil.

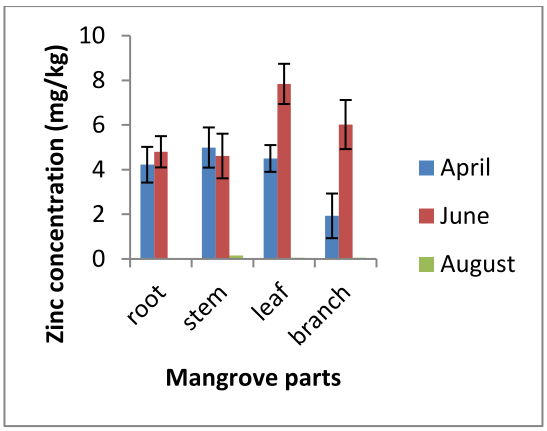

Figure 3: Zinc concentration of soils treated with mangrove parts after six months (P< 0.05)

c. Cadmium Concentration of Soils Treated with Mangrove Parts After Six Months

Cadmium (Cd) was the least accumulated metal in the soil samples with six month treatment showing the highest concentration value of 0.002mg/kg. Cd was below detection limit (<0.001) in all the phytoremediated soils in the second and fourth month of treatment. The results obtained were within the FMENV recommended limit (0.001mg/l) in soil. Cadmium in trace amount is an essential element. It interferes with iron metabolism.

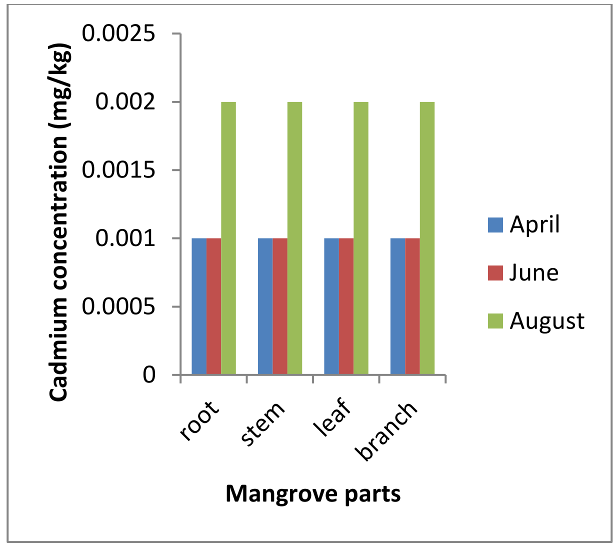

Figure 4: Cadmium concentration of soils treated with mangrove parts after six months (P>0.05)

d. Lead Concentration of Soils Treated With Mangrove Parts After Six Months

The concentration of Pb was below detection level < 0.001mg/kg in all the soil samples in the second and fourth month except in the sixth month which gave the values of 0.456 for both root and stem and 0.239 for both leaf and branch respectively. Lead is a well-known toxicant and has deleterious effect even at low concentration.

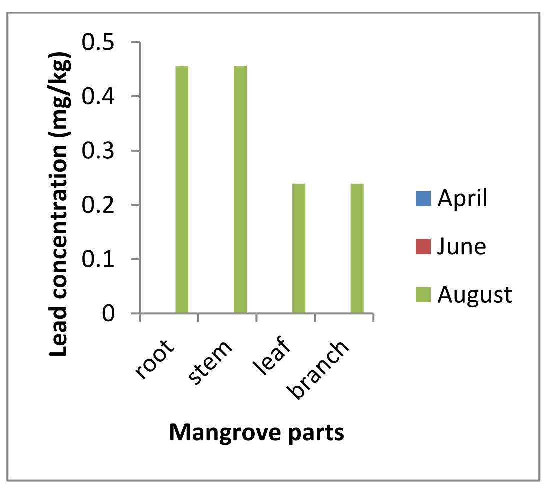

Figure 5: Lead concentration of soils treated with mangrove parts after six months (P< 0.05)

Discussion

Oil spills contribute to degradation and destruction of the mangrove forests and endangered species are increasingly threatened by the activities of the oil companies. The mangrove forests of the Niger Delta are important ecological resources as they provide essential ecosystem services including soil stability, medicines, healthy fisheries, wood for fuel and shelter, tannins and dyes, and critical wildlife habitats. Hence, the preservation of the mangrove becomes essential. Phytoremediation, a strategy that uses plants to degrade, stabilize, and/or remove soil contaminants, has been under investigated (Flowers and Colmer, 2015). This method was explored in this study to ascertain its efficiency in removing crude oil and heavy metal contaminations from contaminated soil samples from oil contaminated site in Jetty (Okrika city) in Rivers State. The crude oil concentration of Jetty was relatively high due to high level of industrial activities going on in the area leading to heavy oil spills which has wiped off most ecological flora that were initially present in this region (Eze and Okpokwasili, 2010). At the moment, only few mangrove plants are seen surviving in the oil sites. Over the years, plants such as Mango, Guava, cassava peels, pineapples have been use ex situ to phytoremediate crude oil contaminated soils and are found to be very effective (Agbim, 1985; Jidere&Akamigbo, 2009; Agbor, *et al.*, 2018; Obire, *et al.*, 2008). If plants such as the aforementioned with low tolerance and survival rate could record such a tremendous effect, then using mangrove plants are anticipated to yield a far more reaching effects when used ex situ for phytoremediation. Hence, this study made use of the leaf, stem, root and branch of the mangrove plant to phytoremediate contaminated soils obtained from the same mangrove oil contaminated site.

Result of the experiment showed that Bioavailability of crude oil components were initially high in the course of the experiment due to the low contents of clay, silt, and soil organic matter in the soil. But as microbial activities proceeded with time, the plant parts added were degraded to add up to the existing organic matters. Increases in microbial load with time were also observed all through the groups thereby enhancing further degradation of crude oil components into less toxic organic compounds with time. However, the degradation rate or the phytoremediation rates of each mangrove plant parts defers from each other. This could be because of the initial uptake of phytotoxic compounds and the attendant adaptation of the plants in the crude oil contaminated soils. The mean reduction in hydrocarbon concentration showed a steady decrease of THC contents all through the contaminated soils that were phytoremediated with various mangrove plant parts. There was an enhanced degradation due to the presence of both plant parts and microorganisms feasting on them.The differences in the decrease in the THC content between root and leaf treated groups were not significant after six months, as the THC were mainly degraded in the first two months. The average overall results obtained have shown that both root and leaf could efficiently reduce the level of crude oil concentration in soils. This agrees with results obtained with some other similar plants like the forage alfalfa (*Medicago sativa*) and Faba Beans (*Ixia faba*) (Iltse *et al*., 1998; Radwan *et al*., 1998) which tolerated and reduced between 2-10% (w/w) Petroleum hydrocarbon contamination in soil.

The concentration of Zn observed in this study is comparable to levels reported by other authors (Vinas, *et al.*, 2005; Hwang, *et al.*, 2001). Hwang, *et al.*, 2001, reported Zn mean concentration in soil samples between the ranges (0.022 – 7.84mg/kg). Zinc was found in all the soils and the pattern of phytoremediation follows the order: root > leaf > branch > stem; root having the highest phytoremediation effect and stem with the least. The values in this study are below the FMENV recommended limit (0.05mg/l) in soil. Zinc contamination has effect on the hepatic distribution of other trace metals in when taken by mammals in the food chain. This is because heavy metals such as Zn, Mn and Cu which are essential elements exhibit similar atomic structures and could therefore, compete for the same site (Dreher, 2003).

Cadmium (Cd) was the least accumulated metal in the soil samples with six month treatment showing the highest concentration value of 0.002mg/kg. Cd was below detection limit (<0.001) in all the phytoremediated soils in the second and fourth month of treatment. The results obtained were within the FMENV recommended limit (0.001mg/l) in soil. Cadmium in trace amount is an essential element. It interferes with iron metabolism.

The concentration of Pb was below detection level < 0.001mg/kg in all the soil samples in the second and fourth month except in the sixth month which gave the values of 0.456 for both root and stem and 0.239 for both leaf and branch respectively. Lead is a well-known toxicant and has deleterious effect even at low concentration.

Conclusion

Bioremediation of heavy metals and hydrocarbons can be achieved through the activities of plant ground parts, plant ground parts, bacteria and other microflora in the soil. Addition of nutrients helps in the enhancement of biodegradation of hydrocarbons and reduction of heavy metal ion concentration on crude oil polluted soil due to stimulation of native microorganisms. This research has discovered heavy metals absorbent potentials and the enhancement of hydrocarbon degradation by various mangrove plant parts on ex situ oil polluted soil. Hence, the root of mangrove plant showed higher phytoremediation potentials than any other parts followed by the leaves and branch while with the stem having the least effect.

Contribution to Knowledge

This research is the first of its kind to explore the various parts of mangrove plant parts in ex situ phytoremediation of contaminated soils. This research also evaluates comparatively the effects of these plant parts taking into cognizance the time needed to adsorb and biodegrade the heavy metals and hydrocarbon constituents of a measured soil sample. This study provides a guideline for evaluation of an improvement on the subject matter.

Recommendation

In general, any chemical handled at construction sites may pollute the soil. However, the higher risk come from those chemicals that are resistant to degradation and has high bio accumulation in living organisms. Hence, heavy metals and hydrocarbon should be characterized and preferential attention should be given to those that will constitute the largest environmental hazard. Government should also state policies that will checkmate the handling and safety of some of these chemicals. Effort also should be made by governments and oil exploration companies in utilization of the available methods and strategies available so far in remediating crude oil contaminated sites especially in the Niger Delta region as their effects on the ecosystem can be deleterious.

REFERENCES

Adamchuk, V. I., Hummel, J. W., Morgan, M. T., Upadhyaya, S. K. (2004). Soil sensors for precision agriculture. Computer and Electronics in Agriculture, 44, 71–91.

Adeleye, A. O., R. O. D. Shelle, & A. E. Akinnigbagbe. (2011). Pollutant Dynamics and Distribution in Sediments North of Lagos Lagoon Ecosystem. Nature and Science 9 (5): 13-16.

Agbim, N. N. (1985). Potentials of cassava peels as soil amendments: field evaluation. Journal of Environmental Quality, 14, 411-415.

Agbor, R. B., Antai, S. P., & Nkanang, A. J. (2018). Microbial degradation of total petroleum hydrocarbon in crude oil polluted soil ameliorated with agro-wastes. Global Journal of Earth and Environmental Science, volume 3, pp1-7.

Anderson TA, Guthrie EA, Walton BT. (2012) Bioremediation in the rhizosphere: plant roots and associated microbes clean contaminated soil. Environ SciTechnol 27:2630–2636.

Anyanwu, D.I. and F.B.G. Tanee (2008). Tolerance of cassava (var. TMS 30572) to different concentrations of post-planting crude oil pollution. Niger. J. Bot., 21: 203-207.

Chindah, A. C., S. A. Braide, and O. C Sibeudu. (2000). Distribution of Hydrocarbon and Heavy Metal in Sediments and Crustacean (shrimps- Paneausnotialia) from Bonny/New Calabar River estuary Niger Delta, Nigeria. African Journal of Environmental Management 9:1-17.

Dreher T. (2003). Evaluation of graphical and multivariate methods for classification of water chemistry data, Hydrogeology Journal, 11, 605–606.

Eze, V. C. & Okpokwasili, G. C. (2010). Microbial and other related changes in a Niger Delta River Sediment receiving Industrial effluents. Continuous Journal of Microbiology. 4, 15-21.

Flowers, T. J.; Colmer, T. D. (2015)."Plant salt tolerance: adaptations in halophytes" (PDF). Annals of Botany. 115 (3): 327−33

Guerin, T.F. (2000) The differential removal of aged PAHs from soil during bioremediation. Environ. Sci. Poll. Res. 7, 19–26

Hwang, E., Namkoog, W., & Park, J. (2001). Recycling of remediated soil for effective composting of diesel contaminated soil. Compost Science and Utilization, 4(3)143 – 149.

Hwang, E., Namkoog, W., & Park, J. (2001). Recycling of remediated soil for effective composting of diesel contaminated soil. Compost Science and Utilization, 4(3)143 – 149.

Jidere, C. M., & Akamigbo, F. O. R. (2009). Hydrocarbon degradation in poultry droppings and cassava peels amended typic paleustults in southeastern Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension, 8(1), 24-31.

Legborsi, S. P. 2007. The Adverse Impacts of Oil Pollution on the Environment and Wellbeing of a Local Indigenous Community: The Experience of the Ogoni People of Nigeria. Khabarovsk: UNDESA Khabarovsk,

Margesin, R. and Schinner, F. (2001) Bioremediation (natural attenuation and biostimulation) of diesel-oil-contaminated soil in an alpine glacier skiing area. Appl. Environ. Microbiol. 67, 3127–3133

Mishra, S. et al. (2001) Evaluation of inoculum addition to stimulate in situ bioremediation of oily-sludge-contaminated soil. Appl. Environ. Microbiol. 67, 1675–1681

Nwilo, C.P. and Badejo, T.O., (2005b). Oil Spill Problems and Management in the Niger Delta. International Oil Spill Conference, Miami, Florida, USA.

Obire, O., Anyanwu, E. C., and Okigbo, R. N. (2008). Saprophytic and crude oil degrading fungi from cow dung and poultry droppings as bioremediating agents. Journal of Agricultural Technology, 4(2), 81-89.

Ohkawa H, Imaishi H, Shiota N, Yamada T, Inui H. (1 999). Cytochrome P450s and other xenobiotic metabolizing enzymes in plants. In: Pesticide Chemistry and Bioscience: the Food-Environment Challenge, Special Publication 233 (Brooks GT, Roberts TR, eds). Cambridge, UK:The Royal Society of Chemistry, 259–264.

Organization of the Petroleum Exporting Countries (2019) “Nigeria facts and figures” Annual Statistical Bulletin 2019

Pezeshki, S.R., M.W. Hester, Q. Lin and J.A. Nyman, (2000). The effects of oil spill and clean-up on dominant US Gulf coast marsh macrophytes: A review. Environ. Pollut., 108: 129-139.

Sabate, J. et al. (1999). Isolation and characterization of a 2-methylphenanthrene utilizing bacterium: identification of ring cleavage metabolites. Appl. Microbiol. Biotechnol. 52, 704–712

Samuel O. Akporido and Percy C. Onianwa, (2015). Heavy Metals and Total Petroleum Hydrocarbon Concentrations in Surface Water of Esi River, Western Niger Delta. Research Journal of Environmental Sciences, 9: 88-100.

Schnoor JL, Licht LA, McCutcheon SC, Wolfe NL, Carriera LH. (2017) Phytoremediation of organic and nutrient contaminants. Environ SciTechnol 29:31 8A–323A.

SPDC: Shell Petroleum Development Company, (2013). People and the Environment.Annual Report.

Stegeman, J.J. et al. (2001) Cytochrome P450 1A expression in mid water fishes: potential effects of chemical contaminants in remote oceanic zones. Environ. Sci. Technol. 35, 54–62

Sugai, S.F. (1997) Environmental influences on the microbial degradation of Exxon Valdez oil on the shorelines of Prince William Sound, Alaska. Environ. Sci. Technol. 31, 1564–1572

Tanee, F.B.G. and D.I. Anyanwu, (2007). Comparative studies of the growth and yield of two cassava lines (TMS 30572 and TMS 30555) in a crude oil polluted habitat. Scientia Afr., 6: 81-84.

Tanee, F.B.G. and P.D.S. Kinako, (2008). Comparative studies of biostimulation and phytoremediation in the mitigation of crude oil toxicity in tropical soil. J. Applied Sci. Environ. Manag., 12: 143-147.

Thompson PL, Ramer LA, Schoor JL. (1998). Uptake and transformation of TNT by hybrid poplar trees. Environ SciTechnol 32:975–980.

Vinas, V., Grifoll, M., Sabate, J., &Solanas, A. M. (2005).Biodegradation of crude oil by three microbial consortia of different origins and metaboiliccapabilities. Journal of Industrial Microbiology and Biotechnology, 28, 252-260.

Xu, J.G. and R.L. Johnson, (1997). Nitrogen dynamics in soils with different hydrocarbon contents planted to barley and field pea. Can. J. Soil Sci., 77: 453-458.

Cite This Article: Amadi, C.S. and Igono, S.A. (2023). **Environmental soil phytoremediation using mangrove parts for crude oil and heavy metal remediation in selected sites in Rivers State, Nigeria**. IJBRA (2), 16-25.