Bioremediation of soils and sludges in Port Harcourt, Nigeria – Research Summary

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Abstract

This work summarises the findings of selected bioremediation studies on petroleum contaminated soils and sludges in Port Harcourt, Nigeria. It highlights the abstracts of published works on different biological remediation techniques including biostimulation, composting and phytoremediation deployed for decontamination of soils and sludges. The studies show the utility and applicability of the different techniques in providing solutions to the problem of petroleum contamination, which is common in the study area. The relevance of agro-technical methods such as tillage, watering and fertilizer application, and the utility of a combination of the bioremediation techniques in accelerating hydrocarbon degradation are also highlighted.

Key words: Bioremediation; Biostimulation; Composting; Phytoremediation.
Summary of selected bioremediation studies

The following paragraphs provide the abstracts of published bioremediation works1–7 dealing with biostimulation, bioaugmentation, composting and phytoremediation from the study area in chronological order.

“A combination of treatments, consisting of the application of fertilizers and oxygen exposure, was evaluated in situ during a period of six weeks. Conditions of a major spill were simulated by sprinkling crude-oil on experimental cells containing agricultural soil. The remedial treatments were then applied and the soil characteristics analyzed after set periods. Soil physicochemical parameters, such as moisture content, pH value, electrical conductivity as well as organic-carbon and total-nitrogen contents, showed distinct variations with time. The total heterotrophic-bacteria (THB) count in all the treatment cells increased with time. The control cell, O (which was not treated) indicated no signs of remediation within the study period. The hydrocarbon losses (50–95%) experienced in the five other treatment-cells revealed the effectiveness in degrading the hydrocarbon contaminant. The results of this study indicate that the application of increased concentrations of nutrients (by the application of fertilizers) lead to greater rates of biodegradation of petroleum-polluted agricultural soils”1.

“A combination of field cells was used in experiments involving biostimulation with agricultural fertilizers to evaluate the bioremediation of a crude oil polluted agricultural soil at different levels of soil water. Petroleum pollution of an agricultural soil was simulated on the field by pouring crude oil on the cells from perforated cans. Remediation options involving the introduction of mineral fertilizers and periodic application of different amounts of water to the
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Contaminated soils were then utilized for treatment. Laboratory analysis of soil characteristics showed an increase in the total heterotrophic bacterial (THB) counts and a corresponding reduction in soil organic carbon and total hydrocarbon content (THC) at the end of the six-week remediation period. The percentage of THC reduction ranged from 44% to 90% in the five treatment cells. The control site, which received no treatment, revealed no significant hydrocarbon loss (3%) within the study period. The results of the total heterotrophic bacterial (THB) counts revealed that petroleum-degrading bacteria responded to variations in soil water level during their metabolic activity; this corroborated with the correlation analysis between percent of THC reduction and time across the treatment cells, which indicated significance at 5% probability level thus highlighting the position that different soil moisture levels induces marked differences in biodegradation rates as remediation period increases. This implies that the level of water in the soil is a major factor that affect biodegradation rate and hence attention has to be given to the control of the moisture level in the soil to optimum, in order to achieve an accelerated biological clean up of petroleum polluted agricultural soils in Port Harcourt, Nigeria.

“Two types of plants, *Zea mays* (corn) and *Pennisetum purpureum* (elephant grass) were compared in field studies to evaluate their potential in degrading petroleum hydrocarbons in contaminated agricultural soils. Previous studies have shown that certain plants together with their associated microorganisms could increase the removal of petroleum hydrocarbons from contaminated soils. Consequently, field plots comprising a control and five treatment plots, whose treatment options entailed the use of corn, elephant grass and corn plus elephant grass, were utilized in the research design. The experimental methodology involved the simulation of
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conditions of a major spill through the sprinkling of crude oil on the plots, after which the plants were introduced to the plots. The Z. mays seeds were first grown in nurseries before they were transferred to the plots, while mature already grown P. purpureum stands were transplanted on the experimental plots. Fertilizer application followed thereafter. Relevant soil physicochemical parameters and bacterial counts were analyzed and monitored during the study period. The results of the analyses revealed average hydrocarbon losses of 77.5% (Z. mays) and 83% (P. purpureum) within the first two weeks, these values decreased to 67.5% and 55% after the six-week remediation period for corn and elephant grass respectively. On the other hand, the corn plus elephant grass treatment showed hydrocarbon losses of 62% and 74% for the two and six-week period respectively. These values differed greatly from those obtained in the control plot. It is evident from the percentage hydrocarbon losses recorded in this study that over a wide range of field conditions, corn degrades the contaminant better than elephant grass and the combination of both plants yields the best alternative in the phytoremediation of a petroleum-hydrocarbon-contaminated agricultural soil. The findings of this research further highlighted the position that with ample time at the disposal of stakeholders, remediation of petroleum-hydrocarbon-polluted agricultural soil using corn and elephant grass treatments yields a cost-effective and successful approach. What is necessary for a remarkable remediation to be achieved is the creation of favorable conditions within the soil environment, like adequate nutrient supplementation and oxygen availability, for the proper development of soil microbes and plant utilization of the contaminant for their metabolism”3.

“A combination of field cells involving a control and five treatment cells were evaluated under field conditions in the bioremediation of a petroleum-hydrocarbon polluted agricultural soil over
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a six-week period. Previous works have indicated that crude oil contamination of soils depletes oxygen reserves in the soils and slows down its diffusion rate to the deeper layers. Hence, this hypothesis was tested in the study by the treatments employed. The treatment option used was the application of mineral fertilizer, and different rates of oxygen exposure through various levels of soil tillage. In the experiments described in this paper, conditions of a major spill were simulated by sprinkling crude oil on the cells using perforated cans. The treatment applications were then resorted to and relevant soil physicochemical characteristics monitored at intervals. The results of the study showed an enormous increase in total heterotrophic bacterial (THB) counts in all the treatment cells. The percentage reduction in total hydrocarbon content (88% to 99%) experienced in the cells that received treatment were significantly different from the control. These results highlight the view that the availability of large amounts of oxygen in the soil profile induces an accelerated biodegradation of petroleum hydrocarbons in a polluted agricultural soil and implies that regular tillage of contaminated soils in the presence of nutrients could achieve the decontamination of such soils.4

“A combination of experimental cells consisting of some agro-technical methods aimed at accelerating the biodegradation of petroleum contaminated soils were evaluated in order to ascertain the relevance of these methods and the relative attention due necessary soil environmental parameters. The methods of treatment involved the variation of tilling, watering and nutrient application, plus biopile and phytoremediation treatments. In the experiments described, petroleum contamination of soils was simulated under field conditions, the remedial treatments were then utilized for clean up. Analysis of soil parameters after a six-week study
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period showed an increase in total heterotrophic bacteria (THB) counts across all the treatments, with THB counts increasing with increment in soil nutrient level and initial concentration of the contaminant. The total hydrocarbon content (THC) analysis, based on a performance index introduced in this study, indicated that on the average, the variation of nutrient application, tilling and watering facilitated the attenuation of THC at the rate of 429.4 mg/kg day, 653.2 mg/kg day, and 327.5 mg/kg day respectively. While the combined effect of various levels of nutrients, tiling and watering performed at the rate of 558.7 mg/kg day, biopile and phytoremediation treatments recorded 427.9 mg/kg day and 489.3 mg/kg day respectively. These results imply that though nutrient application, watering and other factors affect the biodegradation process, frequent tilling for maximum oxygen exposure is the most important factor that affects the biodegradation of petroleum-hydrocarbons in tropical soils”.

“Composting and phytoremediation using elephant grass (Penninsetum purpureum) were compared in experiments aimed at investigating the potential of both techniques in the treatment of petroleum sludge. The compost consisted of poultry manure and sawdust. N-P-K fertilizer was used for biostimulation of indigenous microbes. It also served to enhance the growth of the elephant grass. The sludge was mixed with agricultural soil and both techniques were then utilized for treatment. The total hydrocarbon content (THC) of the sludge-soil mixture before treatment was 64,494 mg/kg. After an 84-day treatment period, the composting treatment recorded 47% reduction in THC, the phytoremediation treatment showed 69% THC reduction, while the combination of composting and phytoremediation had 29% THC reduction. Microbial numbers corroborated the THC reduction observed. The results of the study show considerable
promise for the deployment of elephant grass in phytoremediation treatment of petroleum sludge.6.

**Salient findings and Conclusions**

The findings of these studies show the utility of the different bioremediation techniques in decontamination of soils and sludges, as well as the relevance of agro-technical methods such as tillage, watering and fertiliser application in accelerating hydrocarbon biodegradation. The priority of tillage for oxygen exposure, which leads to better microbial activity, has been identified. The importance of elephant grass, which is ubiquitous in the Niger delta region of Nigeria for phytoremediation of hydrocarbon-impacted soils and sludges is highlighted. The utility of a combination of the bioremediation techniques in accelerating hydrocarbon degradation, which is an area of on-going research, is also highlighted. Detailed information on these techniques can be found in the references listed here. The idea of combining techniques contributed to the impetus for the author’s interest in biodegradation in cementitious systems, in research combining bioremediation and stabilisation/solidification (S/S) technologies7,8,9,10. The insights from the above-mentioned S/S studies were also useful in investigations on concrete for liquefied natural gas (LNG) storage11.

**References**


