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Preliminary communication

LABORATORY SCALE BIOREMEDIATION OF CRUDE OIL IMPACTED SOIL USING ANIMAL WASTE COMPOST

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Abstract: This study investigated various ways by which the rate of biodegradation of hydrocarbons {ex-situ treatment} can be enhanced in an efficient, cost effective and environmentally friendly manner. To achieve this, bioremediation processes were applied to a crude oil impacted soil. Tests were conducted to evaluate the biodegradation effect of the oil on the soil e.g. effect on density, electrical conductivity, etc. The percentage of organic matter and carbon was evaluated in order to determine the organic carbon interaction with the contaminated soil sample. The effect of contamination on the geotechnical properties of the contaminated soil was also evaluated using compaction test. Two types of compost - sheep waste compost and crude oil (SCRO), and goat waste compost and crude oil (GCRO) - with an application rate of {0g, 350g and 550g} were applied in the treatment. The results showed that all bioremediation agents applied enhanced the natural bioremediation of the contaminated soil and the most preferred results were obtained when treatments were done using SCRO compost. This study revealed that the remediation process was influenced by application period, type of oil, and compost rate.

Keywords: Remediation, Contaminated soil, Soil sample and crude oil, Compost and Crude Oil.

1 INTRODUCTION

Royal Dutch Shell was granted an exploration license in 1956, after discovering the first commercial oil field at Oloibiri, a village in the Niger Delta, and commercial production began in 1958 (NNPC [1]). With a total of about six hundred and six (606) oil fields in the Niger Delta out of which three hundred and sixty (360) are on-shore and two hundred and forty-six (246) offshore (Nwilo and Badejo [2]), oil exploration and production activities have significant environmental consequences that occur.

The search for oil in Nigeria begun in 1937 (Awobajo, [3] Ifeadi, C.N and Nwankwo, J. [4]): with increasing production of crude oil and discovery of major oil reserves, more effort was added to exploit this resource. Operations include oil exploration, oil drilling, oil production, oil transportation, oil processing, and oil storage (Bossert and Bartha, [5], Odeyemi and Ogunseitan, [6]).

Oil spill is a release of petroleum hydrocarbon into the environment as a result of human activities. They are usually mostly caused by accidents involving oil tankers, barges, refineries, pipelines and oil storage facilities. These accidents can be caused by human mistakes or carelessness and sometimes by natural disaster such as earthquakes, deliberate acts by terrorists, militants or vandals. Another major cause of oil spill here is sabotage which involves bunkering by some unpatriotic Nigerians. They damage pipelines in the attempt to steal oil from them.

In twenty years (1976-1996), four thousand six hundred and forty-seven (4,647) incidents resulted in the spill of approximately two million three hundred and sixty-nine thousand four hundred and seventy (2,369,470) barrels of oil into the environment. Of this quantity, an estimated one million eight hundred and twenty thousand four hundred and ten and a half (1,820,410.5) barrels were lost to the environment as reported (Nwilo and Badejo, [2]).

The growth of oil industry alongside population increase with a lack of enforcement of environmental laws has led to substantial damage to Nigeria's environment especially in the Niger Delta area. Oil spillage in petroleum producing communities produces a two sided problem; sterile land and polluted water.

Oil spillage leads to contamination of the natural environment and these petroleum-derived substances especially contribute to the degradation of land around the contaminated area. Changes in some soil properties resulting from contamination of soil with petroleum-derived substances bring about soil changes. Also, oil contamination is known to alter the properties of soil. According to (Head, [7] and Adekunle [8]) oil contamination alters soil moisture condition and can lead to non-homogenous distribution of water in soil due to the hydrophobic nature of oil. Contamination modifies the engineering properties of soil, thereby restricting its further use either as a construction material or as a supporting medium. Due to the scarcity of land, it becomes imperative to reuse the land for infrastructure developmental activities. Remediation has been defined as the management of a contaminant at a site so as to prevent, reduce or mitigate damage to human health, or the environment, which can also lead to quick recovery of the affected lands (Doelman, [9] and Christofi et. al [10]). Physical, biological and chemical processes are employed for remediation. But for the purpose of this study, only biological process of remediation will be discussed.

For bioremediation to be successful, the bioremediation methods depend on having the right microbes in the right place with the right environmental factors for degradation to occur. The right microbes are bacteria or fungi, which have the physiological and metabolic capabilities to degrade the pollutants.

Bioremediation is not a new technology but it has been discovered that among several clean-up techniques available to remove petroleum hydrocarbons from the soil and groundwater, bioremediation processes are gaining ground due to their simplicity, higher efficiency and cost-effectiveness when compared to other technologies. These processes rely on the natural ability of microorganisms to carry out the mineralization of organic chemicals, leading ultimately to the formation of CO_2, H_2O and biomass (Duarte da Cunha and Leite, [11] and Adekunle et al. [12]).

Petroleum hydrocarbons in oil polluted soils create a condition which makes nutrients such as nitrogen and oxygen - essential nutrients for plant growth, unavailable to plants with an increased level of toxic nutrients according to (Samina et al. [13] and Jorgensen, [14]). Hence, oil contamination of the soil makes arable land unsuitable for agriculture as well as for engineering purposes.

Therefore, this study is aimed at determining the feasibility of bioremediation technique using compost technology as a treatment option for a chronically crude – oil contaminated soil. This was done by:

- Assessing the impact of different compost material in cleaning up crude oil contaminated soil.
- Remediating the soil biologically so that the soil's bearing capacity and other properties would be sufficient to withstand a structure instead of using more expensive methods like pile foundation to support the structure.
- Conducting assessment test on remediated soil in term of checking soil pH, soil organic carbon and matter and electrical conductivity.

2 METHODOLOGY

Crude oil impacted soil sample used for this analysis was taken next to the Civil Engineering building, Federal University of Agriculture Abeokuta, Ogun State, Nigeria. The analysis of soil was carried out by the determination of the pH, soil organic carbon and organic matter, percentage moisture content and determination of heavy metals. These analyses were carried out after air drying of the procured sample.

2.1 Experimental Design

Soil samples, mixed as follows, were weighed and set up in plastic pots in the laboratory and labeled:

SCRO = Soil + Crude oil + Compost (in 3 plastic pots)
GCRO = Soil + Crude oil + Compost (in 3 plastic pots)
SCDO = Soil + Crude oil (in 3 plastic pots)

Where: SCRO - sheep waste compost and crude oil, GCRO - goat waste compost and crude oil, SCDO - soil sample and crude oil.

2.2 Remediation of contaminated soil samples

The remediation process began by the addition of the compost to each of the soil samples procured, mixing it thoroughly with a little amount of water to moisten the mixture in other to enhance biodegradation. Each pot was then covered with polythene bag and left for a week. At the end of one week, the pots were opened, temperatures were taken, and samples were equally taken at the four sides of the sample, mixed together for analysis. Then an additional 350g was added to the samples, mixed together, returned to the pots and covered again. After another 7 days, the samples were opened, the temperature was taken and portions were taken for analysis. This procedure continued for another two week with no further addition of compost.

3 RESULTS AND DISCUSSION

3.1 Effects of compost induced remediation on sample pH

The pH for each replicate of the soil sample was taken before and during the process of remediation with SCRO and GCRO compost. The results of the pH value over the remediation period ranged from 6.16 to 6.37 with a means value of 6.31 ± 0.1 before crude oil spill. Immediately after the crude oil spill, the soil pH varied from 5.67 to 6.59 with a mean value of 6.13 ± 0.39. The use of composted waste increased the soil pH from 6.5 to 8.73, a 34.3 % increase. The pH range before remediation was from 6.5 to 8.73 for the sample treated with SCRO compost and varied from 6.63 to 8.22 for sample treated with GCRO compost. The value generally increased for both treatments with that of SCRO and GCRO after the remediation period. Although there was fluctuation in the pH value during the remediation period, there is an increment in pH value and this indicates that the compost reduces the acid content of the contaminated soil, which shows the effectiveness of the method applied to remedy the soil.

Table 1 Mean pH values before and after remediation for each treatment over the remediation period of 0 to 28 days.

S/N	Sample code/Remediation period	pH Before remediation	pH After remediation
1	GCRO/day 7	6.5 ± 0.361	8.45 ± 0.132
2	GCRO/day 14	6.5 ± 0.361	8.73 ± 0.10
3	GCRO/day 21	6.5 ± 0.361	8.41 ± 0.133
4	GCRO/day 28	6.5 ± 0.361	8.51 ± 0.080
5	SCRO/day 7	6.63 ± 0.294	8.06 ± 0.032
6	SCRO/day 14	6.63 ± 0.294	8.20 ± 0.052
7	SCRO/day 21	6.63 ± 0.294	7.96 ± 0.055
8	SCRO/day 28	6.63 ± 0.294	8.22 ± 0.082
9	S+CDO/day 7	6.8 ± 0.1	7.62 ± 0.049
10	S+CDO/day 14	6.8 ± 0.1	7.45 ± 0.380
11	S+CDO/day 21	6.8 ± 0.1	7.49 ± 0.096
12	S+CDO/day 28	6.8 ± 0.1	7.23 ± 0.195

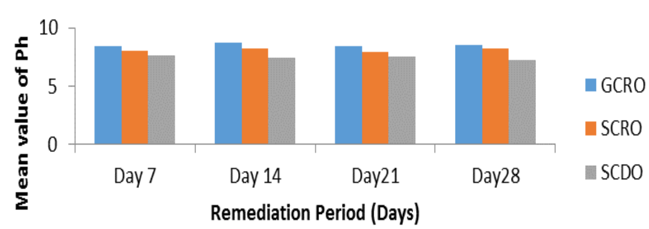

Figure 1 Mean pH Value in samples treated with SCRO and GCRO compost in relation to remediation period.

3.2 Effect of compost induced remediation on the content of zinc, copper and cadmium

The content of heavy metals like zinc (Zn), copper (Cu) and cadmium (Cd) was evaluated at the start and end of the remediation process. The samples treated with SCRO showed a significant reduction in the content of these heavy metals and the same is valid for those treated with GCRO compost. The results are as shown in Fig. 2 in the form of heavy metals over the remediation period. The range at the beginning of remediation was from 85.57 to 294.33 mg/l, 6.24 to 12.36 mg/l and 86.33 to 239 mg/l for zinc, copper and cadmium respectively for the samples treated with SCRO compost and it varied from 136.83 to 210.83 mg/l, 6.24 to 11.68 mg/l and 107.33 to 238.67 mg/l for Zn, Cu and Cd respectively for samples treated with GCRO compost. The value generally decreased for both treatments with that of SCRO having a mean value of 168.29 mg/l, 9.1 mg/l and 199.05 mg/l for Zn, Cu, and Cd respectively and a mean value of 211.95 mg/l, 11.42 mg/l and 174.6 mg/l for Zn, Cu, and Cd respectively for samples treated with GCRO.

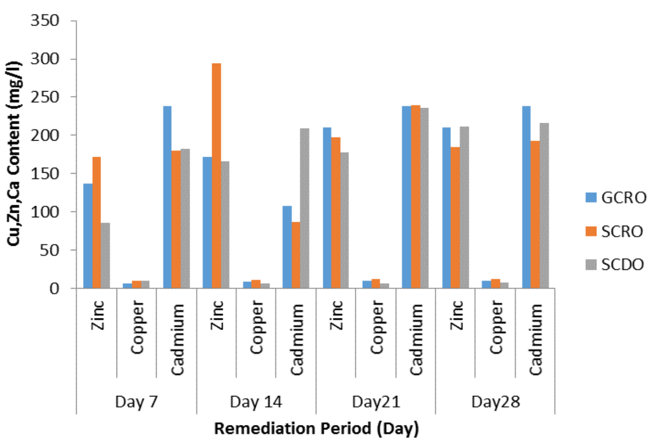

Figure 2 Heavy metals (Cu, Zn, and Ca) content over the remediation period

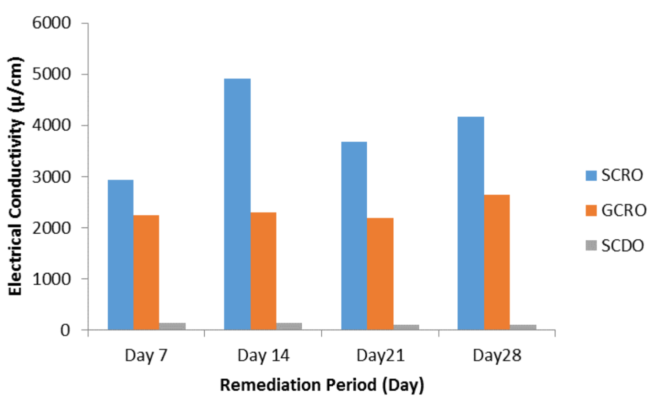

Figure 3 Percentage of electrical conductivity in treated samples in relation to remediation period

3.3 Effect of compost induced remediation on electrical conductivity

The Electrical Conductivity {EC} values for crude oil polluted soils are presented in the appendix. The values before crude oil spill ranged from 153.63 µs/cm to 5231.40 µs/cm, immediately after crude oil spill, the soil EC varied from 98.67 µs/cm to 4916.33 µs/cm.

3.4 Effect of compost induced remediation on sample organic carbon

The percentage of organic carbon of each replicate of the soil sample was calculated before and during the process of remediation with SCRO and GCRO compost. The results are plotted in Fig. 4 in the form of the percentage of organic carbon versus the remediation period. The range before remediation was from 2.7 % to 3.2 % for the samples treated with SCRO compost and varied from 0.52 % to 2.3 % for samples treated with GCRO compost. The value generally increased for both treatments with that of SCRO by 8.45 % and GCRO increase by 12.82 % after the remediation period. The increase in soil percentage organic carbon seen in this write up indicates that the compost increased the organic carbon content of the contaminated soil after treatment. The samples treated with SCRO compost have a lesser percentage increment but with a high efficiency of remediation. This is due to the consistency shown by the compost throughout the remediation process.

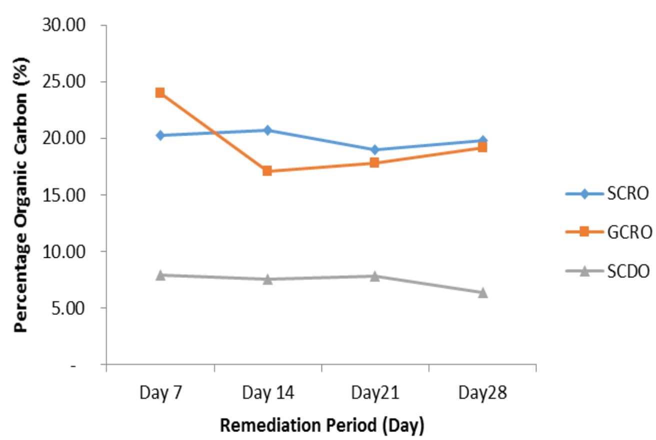

Figure 4 Percentage of organic carbon in treated samples in relation to remediation period.

3.5 Effect of compost induced remediation on sample organic matter

The percentage of organic matter of each replicate of the soil sample was calculated before and during the process of remediation with SCRO and GCRO compost. The results are plotted in Figure 5 in the form of the percentage of organic matter versus the remediation period. The value generally increased for both treatments with that of SCRO increased by 5.67 % and GCRO increased by 18.84 % after the remediation period. The increase in soil percentage organic matter as observed in this write up indicates that the compost increased the organic matter present in the contaminated soil after treatment. The samples treated with SCRO compost have a lesser percentage increment but with a higher efficiency of remediation. This is due to the consistency shown by the compost throughout remediation process.

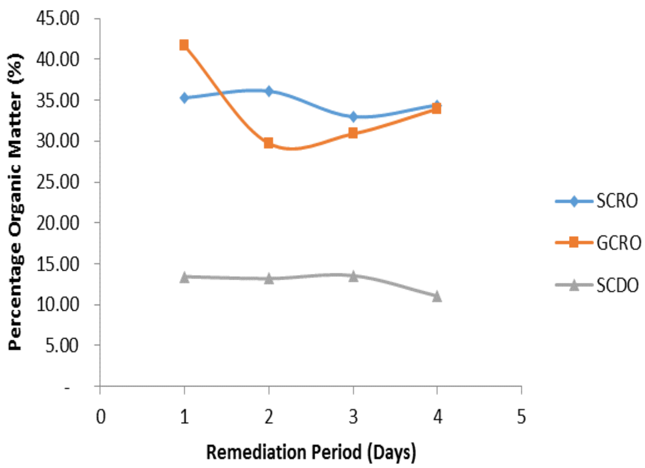

Figure 5 Percentage of organic matter in treated samples in relation to remediation period.

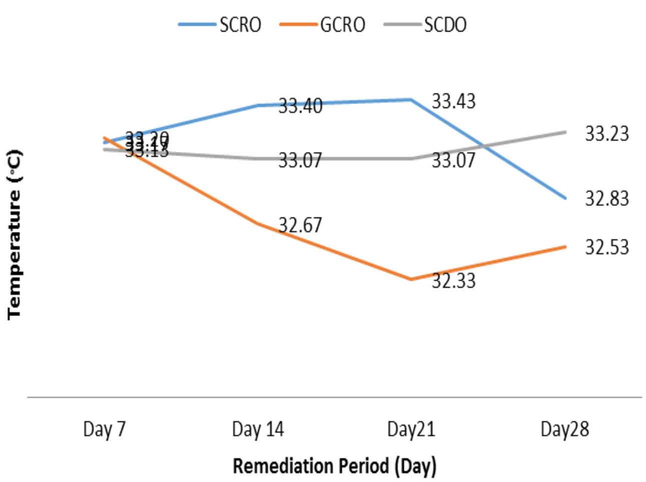

Figure 6 Temperature of treated samples as against the remediation period

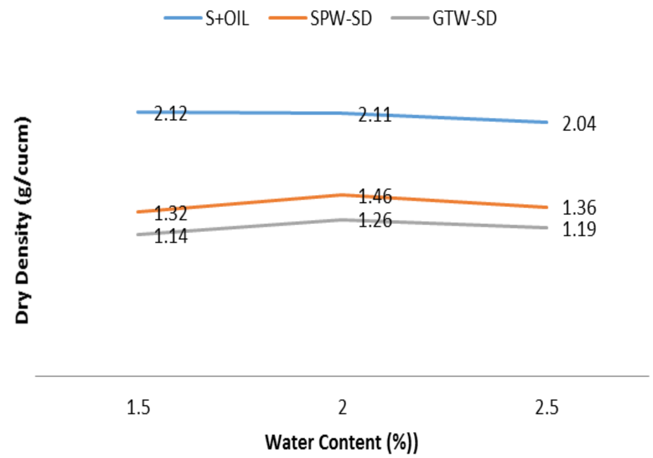

Figure 7 Dry density versus percentage of water content for untreated and treated samples.

3.6 Effect of compost induced remediation on sample compactive efforts

Standard Proctor Compaction Test (ASTM-D698) was carried out on the contaminated soils samples. The results are plotted in Fig. 7 in the form of dry density with increasing water content. They generally show a reduction in dry density with increasing water content before remediation process. After remediation, the samples treated with SCRO compost gave a maximum dry density of 1.46 g/cm^3 and a value of 1.26 g/cm^3 for samples treated with GCRO compost. After remediation, there is a reduction in the maximum dry density with increasing water content and this is depicted in the graph below.

4 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Bioremediation using compost technology to enhance the biodegradation of crude oil contaminated soil showed a satisfactory result. It positively modified soil quality in terms of pH, temperature, percentage organic carbon and matter, the content, electrical conductivity and the heavy metals analyzed. For the pH value, it increases for both treated with SCRO and GCRO. The increase shows that the acidic nature of the contaminated soil has been reduced to the barest minimum. Moreover, as for the heavy metals like zinc, copper and cadmium, it shows a considerable reduction in their contents. This is indicative of the efficiency of the bioremediation methods used and it shows that the content of heavy metals in the soil contaminated is reduced. With this, some of the plants can survive from it. The electrical conductivity of the remediated soil also reduces, which shows the effectiveness of the remediation process. The organic carbon and organic matter increase for the sample treated with both SCRO and GCRO. With this increment in the organic content of the crude oil contaminated soil, it will be rich enough for plant to survive. However, since we know that a soil which has a high organic content is not suitable for engineering purposes, the soil has to be used for farming for a period of time and then later it will be useful for engineering purposes because the farming will reduce the level of organic carbon and matter concentration on the soil. The reduction in optimum moisture is indicative of excess oil in the soil before remediation process. This also indicates the efficiency of the bioremediation method used.

The application of composted organic waste is a good and efficient way of remediating crude oil contamination. It is also environmentally sound and not hazardous to the health.

4.2 Recommendation

Considering the efficiency of the method of bioremediation during the short period of application, it is recommended that further application of the compost technology in bioremediation of crude oil contaminated soil should be conducted for a long period of time so as to achieve increased degradation of total petroleum hydrocarbon and to increase the suitability of the soil for engineering application.

It is also recommended that further studies be conducted in the application of this method of bioremediation to other petroleum products so as to further probe the efficiency and effectiveness of the method in treating oil related spillage.

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