BIOREMEDIATION OF SOIL POLLUTED BY SPENT OIL USING COMPOST TECHNOLOGY.

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ABSTRACT

This study evaluates the impact of the compost technology in bioremediation of the crude oil polluted soils in a53-day screen house experiment. The aim of this work was to evaluate the composting technology in the treatment of soils contaminated with weathered hydrocarbons and drilling cuttings commonly placed in repositories under specific regional condition. Oil contaminated soil was collected from Ibadan and worked on. There were two different composts used for the study, they are Poultry Manure and Goat dung with three replicates each. The control was also studied using three replicates to know the impact of the compost on the contaminated soil. Effects of the technology on soil pH, Total Petroleum Hydrocarbon (TPH) and Electrical Conductivity (EC) were investigated. Soil Temperature profiles were taken on daily basis for each system and chemical analyses were conducted using standard procedures. TPH was determined using standard extraction procedures and qualified by UV – Visible Spectroscope at 510nm. The resulted compost technology increased soil pH and EC. The composting technology to remediate contaminated -soils consists in the addition of organic material and periodic aeration so that the biodegradation of hazardous organic pollutants and organic matter is favored in a simultaneous process.

1. INTRODUCTION

The consequence of the recent rapid growth and increasing complexity of the chemical industries is the increase in toxic waste generation. Fortunately, regulatory agencies have been paying more attention to complications resulting from contamination of our environment. Therefore, these companies are becoming more aware of the political, social, environmental and regulatory burdens of preventing escape of effluents into the environment. The occurrence of major incidents of environmental pollutions and the subsequent awareness resulting from such incidents has emphasized the potential for imminent and long term disasters in the public's conscience.

Microorganisms such as bacteria can be altered to yield enzymes that break down toxic industrial waste components, so also new pathways can be considered for the biodegradation of various wastes (Kulshreshtha *et. al*., 2010). Petroleum is one of the most significant energy resources and a raw material of the chemical industry. Our world depends on oil and its use as fuel has contributed intensively to economic development. As much as petrochemical plants and oil refineries are beneficial to society, they produce large quantities of hazardous waste. Oil spills during exploration, transportation, and refining, have caused serious environmental problems around the world according to Zhang, *et. al.,* (2011); Souza, *et. al.,* (2014); and Marchant, *et. al.,* (2012). The Department of Petroleum Resources estimated 1.89 million barrels (approximately 220,000m³) of petroleum were spilled into the Niger Delta between 1976 and 1996 in 4,835 incidents. A total of 2,300m³ per annum was also estimated as the quantity of petroleum spilled into the environment with an average of 300 individual spills annually (Adekunle *et. al.,* 2010).

Bioremediation is a natural process that uses microorganism to transform harmful substances into non-toxic carbon dioxide, water and fatty acids. Bioremediation of hydrocarbon-contaminated soil therefore exploits the ability of micro-organisms to detoxify organic contamination. This process has been established as an efficient, economic, versatile, and environmentally sound treatment.

A study was conducted using two species of plant (Hibiscus cannabinus and Vetiveria zizanioides) to clean up the spill at Ogbogu town an area located in the niger delta region of Nigeria which is one of the largest oil producing communities according to Limson, (2007). A study was also conducted at Egbema in Imo state to determine the microfloral communities present at the site of an oil spill, and to determine the feasibility of bioremediation as a treatment option for a chronically Spent – oil – polluted soil (Okereke *et. al.,* 2007). The objective of our study was to determine the efficiencies of natural attenuation and the feasibility of bioremediation as a treatment option for a chronically spent -oil-polluted soil.

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2. MATERIAL AND METHODS

Laboratory Procedures

Soil Sample Collection and Pre-treatment

Soil contaminated with crude oil was collected from a site in Orogun area in Ibadan. The soil was taken to the screen house. The soil samples were spread on a well-placed glass mat to air dry it. After the sample had been dried, the soil was sieved with 2mm sieve to separate the gravel and the sand and also remove foreign bodies like leaves, nylon etc. The soil was further air dried and then weighed appropriately and put in the plastic pots. Table 1 shows the labeling of the sample used.

Table 1: Treatments applied in the study

S/N	SAMPLE	SAMPLE CODE
1	GOAT MANURE + SAWDUST 1	GTW + SD 1
2	GOAT MANURE + SAWDUST 2	GTW + SD 2
3	GOAT MANURE + SAWDUST 3	GTW + SD 3
4	SOIL + OIL 1	S + OIL 1
5	SOIL + OIL 2	S + OIL 2
6	SOIL + OIL 3	S + OIL 3
7	POULTRY MANURE + SAWDUST 1	PW + SD 1
8	POULTRY MANURE + SAWDUST 2	PW + SD 2
9	POULTRY MANURE + SAWDUST 3	PW + SD 3

Table 2: Statistical Values of Composted Materials with Contaminated Soil.

	Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std Error	Std Dev Statistic	Skewness Statistic	Std Error
GTW_SD_Day7_OC	3	3.15	4.03	3.5900	0.25403	.44000	.000	1.225
GTW_SD_Day14_OC	3	3.71	3.99	3.8967	.09333	.16166	-1.732	1.225
GTW_SD_Day21_OC	3	3.79	4.03	3.9367	.07424	.12858	-1.545	1.225
GTW_SD_Day28_OC	3	2.27	4.11	3.4833	.60678	1.05097	-1.729	1.225
GTW_SD_Day7_OM	3	5.43	6.95	6.1900	.43879	.76000	.000	1.225
GTW_SD_Day14_OM	3	6.40	6.88	6.7200	.16000	.27713	-1.732	1.225
GTW_SD_Day21_OM	3	6.53	6.95	6.7867	.12991	.22502	-1.545	1.225
GTW_SD_Day28_OM	3	3.91	7.09	6.0067	1.04853	1.81610	-1.729	1.225
S-oil_Day7_OC	3	.48	1.96	1.2133	.42729	.74009	.081	1.225
S-oil_Day14_OC	3	2.00	2.55	2.2200	.16803	.29103	1.458	1.225
S-oil_Day21_OC	3	1.08	2.07	1.4233	.32354	.58039	1.722	1.225
S-oil_Day28_OC	3	.40	.84	.5467	.14667	.25403	1.732	1.225
S-oil_Day7_OM	3	.33	3.37	1.9200	.88038	1.52483	-.410	1.225
S-oil_Day14_OM	3	3.45	4.40	3.8300	.29023	.50269	1.458	1.225
S-oil_Day21_OM	3	1.86	3.58	2.4567	.56203	.97346	1.722	1.225
S-oil_Day28_OM	3	.69	1.45	.9433	.25333	.43879	1.722	1.225
PW_SD_Day7_OC	3	3.79	3.87	3.8300	.02309	.04000	.000	1.225
PW_SD_Day14_OC	3	3.27	4.07	3.6967	.23247	.40266	-.586	1.225
PW_SD_Day21_OC	3	4.03	4.07	4.0433	.01333	.02309	1.732	1.225
PW_SD_Day28_OC	3	1.44	4.07	3.1133	.83953	1.45411	-1.679	1.225
PW_SD_Day7_OM	3	6.53	6.67	6.6000	.04041	.07000	.000	1.225
PW_SD_Day14_OM	3	5.64	7.02	6.3767	.40110	.69472	-.584	1.225
PW_SD_Day21_OM	3	6.95	7.02	6.9733	.02333	.04041	1.732	1.225
PW_SD_Day28_OM	3	2.48	7.02	5.3667	1.44842	2.50873	-1.678	1.225
Valid N (likewise)	3							

Preparation of the Compost Used

Two animal manures were collected from Federal university of Agriculture, Abeokuta, Ogun State (FUNAAB) farm; namely Goat dung and Poultry manure each of these wastes was mixed with sawdust at the ratio of 1: 2. Each of the Goat and Poultry waste mixture was poured into 150L drum with a cover to provide the necessary temperature and moisture condition for optimum performance of the bacteria for composting.

The Composts and the ambient daily temperature values were being monitored on daily basis until the temperatures of the Composts became relatively equal to that of the ambient to signify maturity of the composts which had taken a total of 52 days. During this monitoring stage, the compost was repeatedly turned to ensure homogeneity. 750grams of matured compost was then mixed with the contaminated soil. This was further observed for another 31 days, monitoring the temperature and ambient taken every seven days and turning of the compost. After the whole system had been thoroughly turned, the sample in each system was taken, appropriately labeled and taken to the laboratory for analysis to determine the pH, TPH (Total Petroleum Hydrocarbon), Total Organic Carbon Content, Total Organic Matter Content, Electrical Conductivity, Heavy Metal Analysis, Liquid Limit and Compaction test at the laboratories in the Departments of Civil Engineering, Soil Science, Environmental Management and Toxicology. The heavy metal and TPH were sent to International Institute of Tropical Agriculture (IITA) Soil Laboratory in Ibadan for analysis. ROTAS soil lab in Ibadan and IITA were used for the analysis.

Effect of Compost Induced Remediation on Sample pH

The pH value of each replicate of the soil sample was taken before and during the process of remediation with PW-SD and GTW-SD compost. The results are plotted in Figure 1 in the form of the pH value versus the remediation period. The range before remediation was from 6.1 to 6.8 for the sample treated with PW-SD compost and varied from 6.4 to 6.8 for samples treated with GTW-SD compost. The value generally increased for both treatments with that of PW-SD ranging from 7.0 to 7.47 and GTW-SD ranging from 7.13 to 7.50 after the remediation period. The increase in soil pH value observed in this write up indicates that the compost reduces the acid content of the contaminated soil which shows the effectiveness of the method applied to remedy the soil.

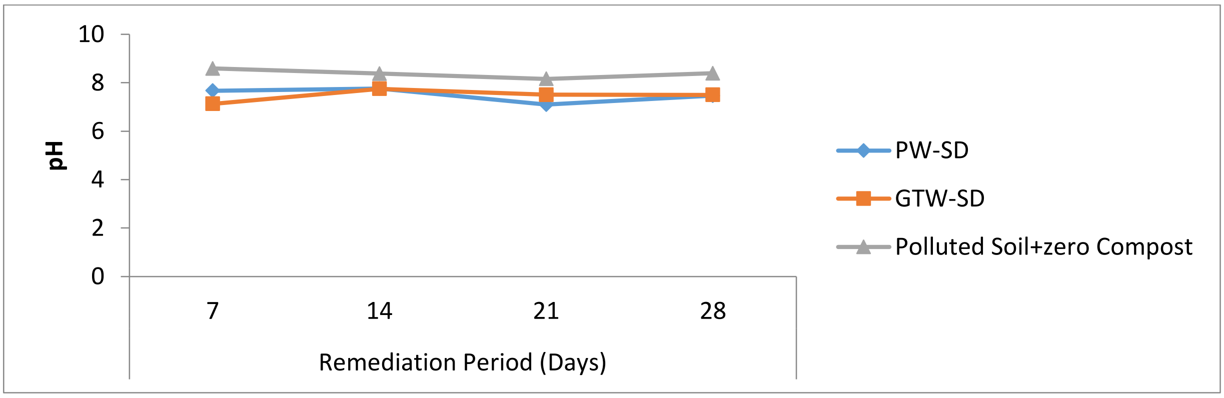

Figure 1: Effect of PW-SD and GTW-SD compost on pH values in oil polluted soil in relation to remediation period.

Effect of Compost Induced Remediation on Soil Organic Carbon

The percentage organic carbon of each replicate of the soil sample was calculated before and during the process of remediation with PW-SD and GTW-SD compost. The results are presented in Figure 2. The range of Organic carbon before remediation was from 2.7% to 3.2% for samples treated with PW-SD compost and varied from 0.52% to 2.3% for samples treated with GTW-SD compost. After the remediation period, values generally increased for both treatments with that of PW-SD ranging from 3.95% to 4.0% and GTW-SD ranging from 3.47% to 3.95%. The overall effect of the applied compost technology showed a total increase of 24.81% and 64.75% in the soil organic carbon for samples treated with PW-SD compost and GTW-SD compost respectively, indicating that the compost increased the organic carbon content of the contaminated soil after treatment.

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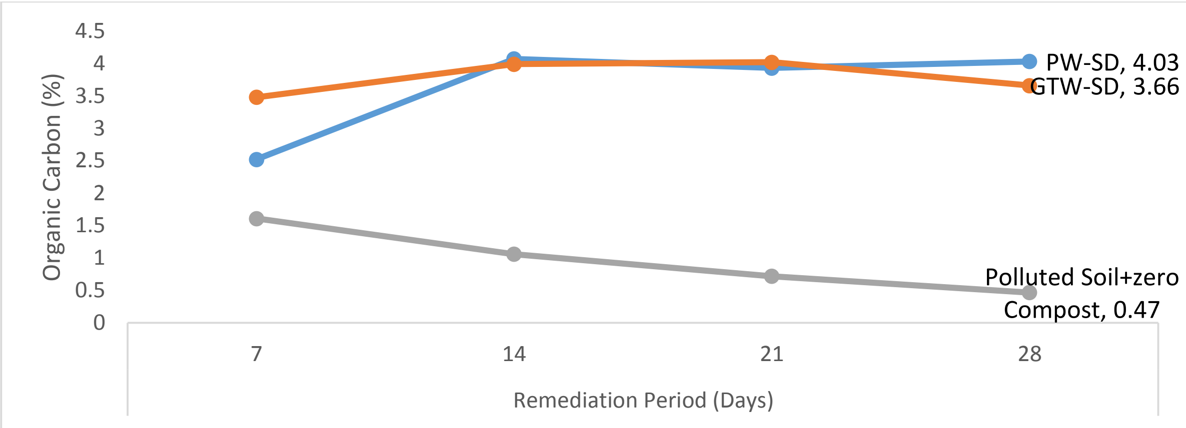

Figure 2: Organic Carbon content of oil polluted soil after Remediation.

Effect of Compost Induced Remediation on Temperature of oil polluted soil.

The ambient temperature and temperature of the PW-SD and GTW-SD compost was monitored throughout the preparation period. The value of the temperature reading is presented in Table 2 and the variation is shown in Figure 4.

The temperature reading of each replicate of the soil sample was taken before and during the process of remediation with both compost types. The results are plotted in Figure 4 in the form of temperature versus the remediation period. The range before remediation was from 31^{0}C to 33^{0}C for the samples treated with PW-SD compost and varied from 30^{0}C to 33^{0}C for samples treated with GTW-SD compost. The value generally increased for both treatments with that of PW-SD ranging from 30.5^{0}C to 31^{0}C and GTW-SD ranging from 31^{0}C to 32^{0}C after the remediation period. The effect of the applied compost technology accessed gave a value of 7.01% and -1.07% for samples treated with PW-SD compost and GTW-SD compost respectively. This implies that the compost did not have any significant effect on the temperature.

Effect of Compost Induced Remediation on Sample Total Petroleum Hydrocarbon

The total petroleum hydrocarbon value of each soil sample was taken before and during the process of remediation with PW-SD and GTW-SD compost. The results are shown in Figure 5. The range at the start of remediation was from 45160 to 4464 mg/kg the samples treated with PW-SD compost and varied from 42470 to 9115 mg/kg for samples treated with GTW-SD compost.

The effect of the applied compost technology showed a percentage degradation of 44.64% and 91.15% for samples treated with PW-SD compost and GTW-SD compost respectively. The TPH degradation was successful since there was significant reduction in TPH population during the bioremediation process.

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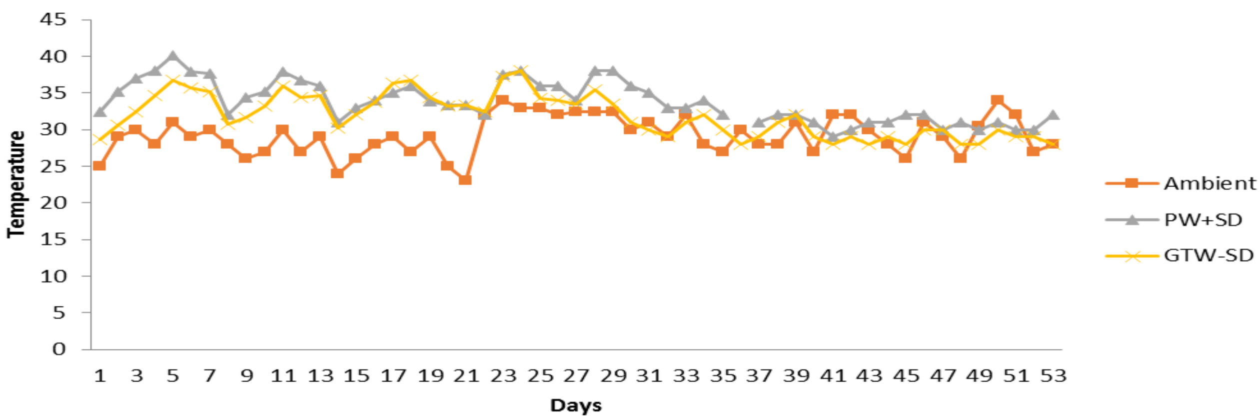

Figure. 3 Effect of Temperature on maturity period of Compost

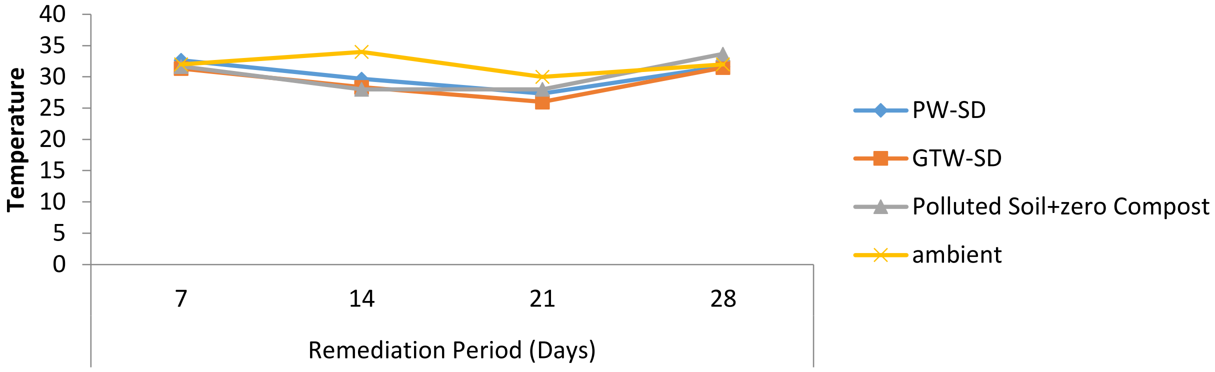

Figure. 4 Effect of Temperature on remediation period of Compost

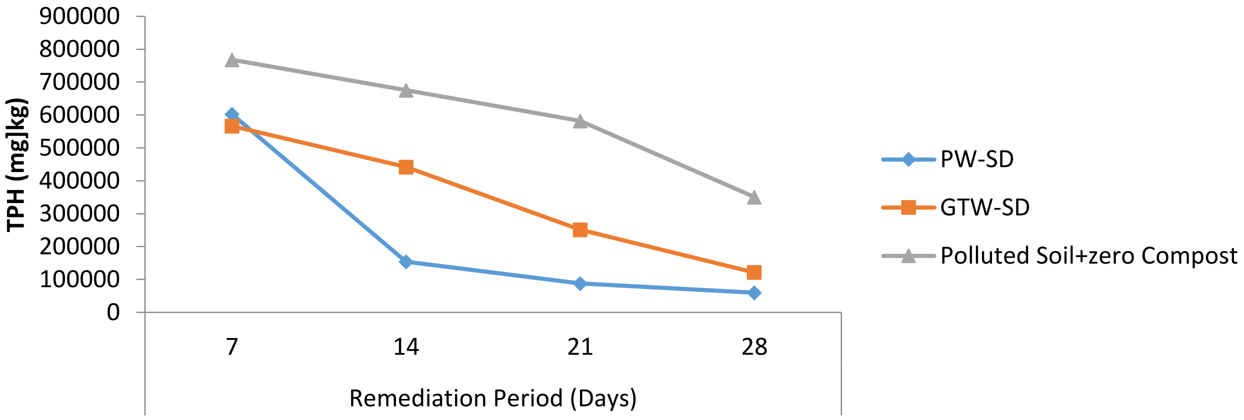

Figure 5: Total petroleum hydrocarbon reduction in samples treated with PW-SD and GTW-SD compost in relation to remediation period.

Table 3: Relationship between Dry Density and Moisture Content Before and After Remediation Process

S/N	% Water Added	% Moisture Content	Dry Density (g/cm^3)	
			Before Remediation	**After Remediation**
1	0	13.87	1.91	3.4
2	1.33	2.145	2.12	6.2
3	2.00	3.185	2.11	10.5
4	2.5	6.37	2.04	14.9

Effect of Compost Induced Remediation on Sample Compactive Effort

Standard Proctor Compaction Tests (ASTM-D698, Method A) were carried out on the contaminated soil samples. There was a general reduction in maximum dry density with increasing water content before remediation process.

3. DISCUSSION

The pH value helps to determine the degree of acidity or alkalinity of the soil (Adekunle *et al.,* 2010 and Kulshreshtha *et al.,* 2010) The increase in soil pH noticed during the experiment could be attributed to the release of alkaline to the system by the compost Adekunle 2005. Electrical conductivity is a measure of total dissolved ions (cations and anions) in the soil solution. The subsequent result after the sample from each of the system reveals that there was increase in the soil electrical conductivity. This result suggests that the applied compost enhanced ions in soils solution. Soil moisture content is a soil fertility factor. Moist soil allows the bacteria and agricultural enhanced organisms like earthworm to perform and multiply rapidly. Hence, moist soil helps in productivity than dry soil.

The reduction of the total hydrocarbon of the soil by the compost applied revealed that compost is a good agent for degradation of hydrocarbons in soils. This could have been due to the mechanism of microbial stimulation to increase indigenous soil microbial organism (Adekunle et al., 2010). The temperature profile in soils treated with compost which exceeded that in the polluted soils without any treatment is evidence that thermophilic microbes which are known to be better hydrocarbon degraders were present in the composted treated soils unlike the untreated soils where mesophilic microbes could have been present.

The applied compost irrespective of the rate ameliorated the toxicities of either crude oil or spent engine oil to seed germination and plant height (Barker and Bryson 2002 and Adekunle et al., 2010). This was due to the fact that compost, being decomposed organic matter is characterized by nutrient such as nitrogen, phosphorus and potassium (Adekunle et al., 2010), known to facilitate degradation of petroleum hydrocarbons in soil. Moreover, compost substrates stimulate the growth of micro-organism. The soil temperature profile (peak values) indicated the presence of thermophilic microbes being found in the range. (Adekunle and Adekunle, 2006 and Adekunle et al., 2010). Thermophilic microbes constitute largely of bacteria which are reported as the dominant microbial agent of decomposition especially in static conditions as was the case in this study.

Organic manures enhanced bioremediation of crude oil polluted sandy – loamy soil. However, the extent of this depends on the source of the organic manure. It was observed that poultry manure effectively remediate crude oil used in this study. This was evidence by the improvement in the soil physical and chemical properties and improved growth characteristics of maize after application of poultry manure.

4. Recommendations

Further study should be encouraged to be carried out to ensure the determination of other various compost materials that could be used.

It is also important to note that the experiment will be better carried out during the dry season to hasten the process and ensure that quite general result is being gotten as bacteria had been known to function best at warm and damp places.

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