The Use of Oil Palm Bunch Ash for Amelioration of Crude Oil Polluted Soils

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Abstract
The use of Oil Palm bunch ash for the amelioration of Crude Oil polluted soil was investigated at six amendment levels (10g, 20g, 30g, 40g, 50g and 60g) per 2kg soil. A further investigation of the cumulative effect of oil palm bunch ash at the above amendment levels were carried out. Experimental soils were subjected to Laboratory analysis using standard analytical methods for soil pH, organic carbon, organic matter, total nitrogen, available phosphorus and total hydrocarbon content. Soil chemical property analysis indicated increase in soil p^H value for soils amended with oil palm bunch ash over time thus reducing soil acidity for enhanced degradation. Soil organic carbon and organic matter increased with levels of amendment material over time. Soil total Nitrogen was generally deficient in soils. However, there was improvement at the end of experimentation. Soil available phosphorus increased with amendment levels and was subsequently depleted in soils over time. At the end of experimentation, there was improvement in soil available phosphorus. Soil carbon, Nitrogen (C/N) ratio was observed to narrow down overtime in soils amended with oil palm bunch ash. Soil total hydrocarbon analysis indicated a significant reduction in amended soils at 20g, 30g and 40g/2kg amendment levels with 28.99% to 30% reduction of total petroleum hydrocarbon content for residual treated soils while cumulative treatment indicated optimum significant reductions at 40g/2kg with 29.34% reduction of TPH content. The finding of the work shows that Oil palm bunch ash amendment at the rate of 20g to 40g/2kg soil is the optimum treatment for
remediation while cumulative application would favour the six levels of amendment with 40g/2kg as optimum.
Keywords: Bioremediation, Biostimulation, Cumulative treatment, Residual treatment.

1 Introduction

One of the greatest challenges of our time is to find ways and means of applying our Science and Technology to the problem of environmental degradation. Apart from being a major stimulant to world economy, crude oil exploration and exploitation have equally imposed some negative impact due to the adverse ecological effects of oil spillage in oil producing communities

This study shows the use of oil palm bunch ash as amendment supplement for the amelioration of crude oil polluted soils. In this study two ex-situ experiments were conducted to

(a) Test the effectiveness of oil palm bunch ash applied at 10g, 20g, 30g, 40g, 50g and 60g per 2kg soil to ameliorate crude oil polluted soils.

(b)Test the residual effect of oil palm bunch ash applied at the above rates on the amelioration of crude oil polluted soils.

(c) Study the cumulative effect of oil palm bunch ash applied at the above rates on the amelioration of crude oil polluted soils.

(d) To monitor the status of total hydrocarbon content in soils amended with oil palm bunch ash at the rates in (a) above.

Petroleum hydrocarbons (PHCs) that enter the soil may be adsorbed on the surface of mineral and organic soil constituents, fixed within the soil pores and fissures, found in mobile form or may form a continuous cover on the soil surface (Trofimov and Rozanova, 2003). In forest soils, studies have shown that heavier fractions of PHC were retained in the eluvia horizons that contained the larger pores, while the higher fractions of PHC were retained in the alluvial horizon that contained the fine
water retention pores (Suleimanov *et al*. 2005).

TPHC polluted soils have been shown to influence water holding capacity and moisture content of soils due to the hydrophobic nature of PHCs. Studies have shown that soils polluted with PHCs are characterized by low water holding capacity, moisture content and hydraulic conductivity when compared with unpolluted soil (Trofimov and Rozanova, 2003; Suleimanov *et al*. 2005; Nwaoguikpe, 2011). Robertson et al (2007) stated that soils polluted with PHCs were different from unpolluted soils due to changes in their biological and physicochemical properties. Soils polluted with PHC was observed to show an initial reduction in soil microorganism, especially soils that have not been previously polluted. This reduction however is followed by a rapid increase in the number of microorganism that are capable of degrading the contaminants (Gramss *et al*. 1998; Seghers *et al*. 2003). Hofman *et al*. (2004) however, observed that though the number of soil microorganism increased in PHC polluted soils, species richness often decrease overtime. Similarly, Toogood, *et al* 1977 observed that the addition of oil to soils increased the microbial population several fold and this in turn increased the organic matter content of the soil.

The effect of oil on soil nutrient status is reported to be related to the energy and carbon obtained by soil microbes from decomposition of the oil (McGill, 1976). According to McGill, (1976) and Odu, (1981), most of the nutrients are tied up in the cells and tissues of microbes that use these nutrients for growth and development. Simpson – Lewis *et al.* (1983) also reported that the inorganic nutrients such as Nitrogen and phosphorus were temporarily converted to microbial biomas. However, nutrients become available when properly recycled following good oil decomposition (Odu, 1981).

The limitation of Nitrogen in oil polluted soils has been demonstrated by Bossert and Barther 1984; Obire and Nwaubete (2002). Zuofa *et al.* (1987) reported increase in organic matter content, pH and total Nitrogen concentration following crude oil application. Akpoveta *et al.* (2011) recorded a reduction of soil phosphorus on a PHC polluted soil. This reduction was attributed to the activities of soil microbes which made them immobile or unavailable (Atlas and Barther 1972). Reductions in soil pH together with increase in soil organic carbon and organic matter in crude oil polluted soils have also been recorded (Marinescu *et al.* 2011; Isirimah *et al.* 1989).

Available evidence suggests that hydrocarbon degradation at contaminated sites proceed naturally (Odu, 1981; Zuofa *et al.* 1985). The quest for effective amelioration of contaminated soils has led to the development of a wide range of cleanup techniques. The recovery of polluted soils on its own without any artificial aid is said to be remediation through natural attenuation. Monitored natural attenuation (MNA) is very effective in soils with high native microbial population (Sarkar *et al*, 2005). Amelioration of polluted soils can be achieved through the process of bio-stimulation (Peressutti *et al*. 2003; Bento et al, 2004; Sarkar *et al*. 2005) which works on the principle that microorganism responsible for degrading pollutants already exists in the soil. The process is enhanced when conditions that promote their activities are made available. This could be achieved through the addition of nutrients in form of organic manure or other organic materials or through the alteration of soil pH, moisture or aeration status. The study by Amadi and UeBari (1992) indicated that the rehabilitation of polluted soils can be achieved through the help of soil microbes, good tillage technique and some amendment with organic fertilizers such as poultry manure, yeast extract and peptone water.

2. Methodology

Soil sample for the experiment was obtained from an oil spill site of Well 31 (PPMC Asset) in BOMU OIL FIELD of the SHELL PETROLEUM DEVELOPMENT COMPANY, NIGERIA LIMITED in Gokana Local Government Area (OGONI) Rivers State.

Surface soil (0 – 20cm) of the polluted site and that of unpolluted adjoining site were collected and bulked to form composite representative samples respectively. The samples were transported to the green house of the Biological Science Department of Rivers State University of Science and Technology, Port Harcourt for experimentation.

The experiment was conducted in two phases. Experiment I and Experiment II. The first experiment (experiment I) was a completely randomized block design (CDR) with six replications treated at 10g, 20g, 30g, 40g, 50g and 60g of oil palm bunch ash per 2kg soil, with a control plot of unpolluted soils without amendments. At the end of experiment I, the original completely randomized block design was transformed into a split block design. This was achieved by splitting the original treatment into two equal halves, with three replications each. One of the halves representing the residual treatment was not subjected to further treatment, while the other half received additional treatments as in the original (experiment 1), serving as the cumulative treatment. Oil palm bunch ash was applied by incorporating appropriate quantities into the soil and properly mixed to ensure even distribution within the soil. All treatments were transferred into planting bags, perforated evenly and incubated. All treatments were watered at three days intervals with 40ml of tap water which was properly worked into the soil. The treatments were spread on polyethylene and aerated monthly by continuous mixing and watering for a duration of three days before re-transferring them into their respective planting bags. Monthly representative samples were collected from the respective treatments and control, labeled and transferred to the Laboratory for soil chemical properties analysis.

All soil chemical parameters were analyzed at the Agricultural Laboratory in the Department of Soil/Crop Science and Forestry, and the Institute of Pollution Studies (I.P.S) Laboratory of the Rivers State University of Science and Technology Port Harcourt. Pre-experimental and experimental soil samples were analyzed. Soil samples for analysis were air-dried, sieved through 2mm aperture sieve and stored in polyethylene bags with labels. Soil and amendment material were analyzed using various methods as indicated below: Soil pH and amendment material were determined by means of the MK20 model of pH meter. Organic carbon and organic matter were determined using the wet combustion method of Walkley and Black (1934). Total Nitrogen was analyzed using the semi micro-Kjeldahl method, an alternative method for Macro-Kjehdahl (Bremner 1965). Available phosphorus was determined by the Bray and Kutz P1 method (1945). Soil total hydrocarbon was determined with spectronic 20 spectrophotometer at 420nm after extraction with 10ml of toluene.

3. Results

The result of pre-experimental soil and oil palm bunch ash initial chemical properties is presented in table 3.1

Table 3.1: Soil and Oil Palm Burch ash initial chemical properties.

	pH	%N	%OC	%OM	P	C/N Ratio	Total Hydrocarbon (ppm)
Polluted soil	5.50	0.01	2.59	4.46	8.40	2597:1	20291.96
Unpolluted soil	4.50	0.2	0.71	1.23	29.47	356:1	132.00
Oil Palm Burch ash	10.00	0.02	0.66	1.14	42.8	42.8	Nil

The above result indicated acidity for both polluted and unpolluted soils. The amendment material (oil palm bunch ash) shows high alkalinity. Soil total Nitrogen shows low concentration in polluted than unpolluted soils. The polluted soil sample indicated a high organic carbon and organic matter content as companied to the unpolluted soil with low organic carbon and organic matter. Soil available phosphorus is observed to be low in concentration for polluted soil sample as against the high level observed in unpolluted sample.

Soil chemical properties also indicate a very wide C/N ratio margin for polluted soil sample against a narrow margin for unpolluted soil.

Soil total hydrocarbon content indicates a very high level of pollution when compared with soils from un-impacted site. Soils from un-impacted sites however indicate some form of total hydrocarbon pollution which may be attributed to overland flow during rain fall.

The result of the effect of palm bunch ash on soil pH is presented in table 3.2.

Table 3.2: Effect of Palm Bunch Ash (Recovery Material) on Soil pH.

Treatment	Experiment I		Experiment II			
	Main Effect		Residual Effect		Cumulative Effect	
	1month	2months	3months	8months	3months	8months
Control	4.30	4.20	4.00	5.70	4.00	5.70
10g	(51) 6.50	(29) 5.40	(25) 5.00	(14) 6.50	(48) 5.90	(15) 6.57
20g	(63) 7.00	(48) 6.20	(50) 6.00	(15) 5.90	(63) 6.50	(12) 6.40
30g	(67) 7.20	(57) 6.60	(39) 5.57	(12) 6.40	(83) 7.30	(10) 6.77
40g	(77) 7.60	(62) 6.80	(46) 5.83	(17) 5.80	(98) 7.90	(9) 6.20
50g	(65) 7.10	(74) 7.30	(48) 5.90	(12) 6.40	(75) 7.00	(15) 6.53
60g	(74) 7.50	(76) 7.40	(83) 7.30	(14) 6.50	(117) 8.70	(26) 7.20
ANOVA						
F value rows	29977.66	76264.0654	4.790814	45.117647	6.225572	72.932331
F value col	1.43911	1.3271028	5.36495	4.291177	1.141518	1.263158
F*critical row	2.420520	2.420520	2.996117	2.996117	2.996117	2.996117
F*critical col	2.533558	2.533558	3.885290	3.885290	3.885290	3.885290

*p = 0.05. The values in parenthesis are percentage increase in soil pH

Statistical analysis shows that variability between treatment levels were significant at 0.05 probability.

From the above result, comparing the control of experiment I main effect with treatment, amendment materials resulted in soil pH moving from acidity to alkalinity as could be shown from percentage increases. The observed alkalinity in amended soils was further observed to have re-adjusted slightly with amendment levels at two months post treatment. Residual experiment shows a slight acidic status at month 3 and 8 post-treatment for respective treatment levels, while the control indicated a slight drop in acidity. The cumulative treatment experiment indicated an increase in soil alkalinity with increase in amendment rate. However, at 8 months post amendment, soil pH indicated slight acidic status against the control.

In summary, there is observable decrease in soil pH with passage of time at all amendment levels.

The result of the effect of oil palm bunch ash (recovery material) on soil organic matter is presented in table 3.3

Table 3.3: Effect of Palm Bunch Ash (recovery material) on Soil Organic Matter (%OM).

Treatment	Experiment I Main Effect		Experiment II			
			Residual Effect		Cumulative Effect	
	1month	2months	3months	8months	3months	8months
CONTROL	0.90	1.10	2.79	1.90	2.79	1.90
10g	(318)3.77	(445)5.99	(175) 7.66	(84) 3.50	(172) 7.60	(62) 3.07
20g	(382)4.34	(464)6.20	(165) 7.40	(89) 3.59	(147) 6.88	(100) 3.80
30g	(373)4.26	(425)5.78	(166) 7.41	(73) 3.29	(132) 6.48	(89) 3.60
40g	(392)4.43	(461)6.17	(154)7.110	(79) 3.40	(90) 5.29	(93) 3.67
50g	(375)4.28	(431)584	(178) 7.76	(125) 4.27	(184) 7.93	(142) 4.60
60g	(382)4.34	(447)6.02	(170) 7.53	(88) 3.57	(176) 7.71	(110) 4.00
ANOVA						
F value rows	37230.650	206222.01	2288.183	143.46059	00079.71	243.73214
F value col	0.368231	0.535545	0.651584	0.5944506	1.0	0.375
F*critical row	2.420520	2.420520	2.996117	2.996117	2.996117	2.996117
F*critical col	2.533558	2.533558	3.885290	3.885290	3.885290	3.885290

*p = 0.05. The values in parenthesis are percent increase in organic matter.

From the above result, main effect indicated a general increase in soil organic matter with time irrespective of treatment levels against the control as shown from the percentage increases. The residual effect indicated a high level of organic matter at 3 months post treatment against the control, but at 8 months post-treatment, organic matter was generally observed to have adversely reduced at all levels of amendment. These observations were similarly observed at month 3 and 8 of the cumulative treatment experiment.

The analysis of variance for the above result indicated that the variability between treatment levels were significant at 0.05 probability, which validate the above observations.

The result of the effect of oil palm bunch ash on soil organic carbon is presented in table 3.4.

Table 3.4: Effect of Oil Palm bunch ash (recovery material) on soil percent organic carbon (%OC).

Treatment	Experiment I Main Effect		Experiment II			
			Residual Effect		Cumulative Effect	
	1month	2months	3months	8months	3months	8months
CONTROL	0.52	0.64	1.62	1.10	1.62	1.10
10g	(231) 2.19	(498) 4.47	(174) 4.44	(82) 2.00	(172) 4.41	(82) 2.00
20g	(385) 2.52	(463) 3.60	(165) 4.29	(103) 2.23	(146) 3.99	(100) 2.20
30g	(375) 2.47	(423) 3.35	(165) 4.30	(76) 1.94	(132) 3.76	(91) 2.10
40g	(394) 2.57	(459) 3.58	(154) 4.12	(82) 2.00	(90) 3.08	(100) 2.20
50g	(377) 2.48	(429) 3.39	(181) 4.56	(74) 1.91	(184) 4.60	(136) 2.60
60g	(385) 2.52	(445) 3.49	(169) 4.36	(131) 2.54	(176) 4.47	(106) 2.27
ANOVA						
F value rows	59013.582	64586.571	29564.217	23.49373	248.78587	130.0
F value col	0.756346	0.3	0.391304	0.490121	0.7542297	0.66667
F*critical row	2.420520	2.420520	2.996117	2.996117	2.996117	2.996117
F*critical col	2.533558	2.533558	3.885290	3.885290	3.885290	3.885290

*p = 0.05. The values in parenthesis are percent increase in soil organic carbon.

The above result indicate an increase in soil organic carbon due to treatment of palm bunch ash in the respective amended soils for the first two months of experimentation against the control. The increase in soil organic carbon was also observed in the residual effect at 3 months post treatment. However, at 8 months post treatment (residual experiment), the level of percent organic carbon had greatly reduced at the respective amendment levels.

Similarly, the cumulative experiment indicated high organic carbon content in respective treatment levels at 3 months post treatment. At 8 months post treatment organic carbon was observed to have generally reduced in the respective amended soils.

The analysis of variance for the above result indicated that the variability between amendment levels were significant at 0.05 probability which validate the observations obtained from the results.

The results of the effect of oil palm bunch ash (recovery material on soil percent total Nitrogen is presented in table 3.5.

Table 3.5: Effect of Palm bunch ash (recovery material) on Soil Percent Total Nitrogen

Treatment	Experiment I Main Effect		Experiment II Residual Effect		Experiment III Cumulative Effect	
	1month	2months	3months	8months	3months	8months
Control	0.02	0.02	0.02	0.13	0.02	0.13
10g	(0) 0.02	(0) 0.02	(300) 0.08	(31) 0.17	(450) 0.11	(-15) 0.11
20g	(0) 0.02	(0) 0.02	(500) 0.12	(38) 0.18	(450) 0.11	(54) 0.20
30g	(0) 0.02	(0) 0.02	(400) 0.10	(54) 0.20	(550) 0.13	(69) 0.22
40g	(0) 0.02	(50) 0.03	(350) 0.09	(69) 0.22	(550) 0.13	(46) 0.19
50g	(0) 0.02	(50) 0.03	(400) 0.10	(31) 0.17	(400) 0.10	(0) 0.13
60g	(50) 0.03	(50) 0.03	(300) 0.08	(38) 0.18	(440) 0.10	(31) 0.17
ANOVA						
F value rows	7.055503	10.101010	22.39285	31.39623	43.024390	41.714286
F value col	0.736595	0.186868	0.75	0.73585	0.146341	0.782608
F*critical row	2.420520	2.420520	2.996117	2.996117	2.996117	2.996117
F*critical col	2.533558	2.533558	3.885290	3.885290	3.885290	3.885290

*p = 0.05 values in parenthesis are percent increase in soil total Nitrogen.

From the above result soil total Nitrogen was observed to be generally deficient in amended soils and the control at one month and two months post treatment. However, at higher levels of treatment there were slight improvements over the control. At three and eight months post treatments, soil total Nitrogen generally improved irrespective of treatment levels against the control. Similarly commutative treatment experiment followed same trend.

This result indicates a positive effect of oil palm bunch ash on soil percent total Nitrogen.

The analysis of variance for the above result indicated that variability between treatment levels were significant at 0.05 probability. These analyses validate the observations from the result.

The result of the effect of oil palm bunch ash on soil available phosphorus is presented in table 3.6.

Table 3.6: Effect of palm bunch ash (recovery material) on soil available phosphorus (ppm).

Treatment	Experiment I Main Effect		Experiment II			
			Residual Effect		Cumulative Effect	
	1 Month	2 Months	3 Months	8 Months	3 Months	8 Months
Control	29.42	28.78	22.10	31.22	22.10	31.22
10g	(-71) 8.2	(-83) 4.91	(-82) 2.80	(-78) 7.02	(-68) 7.01	(-67) 10.35
20g	(-72) 8.43	(-75) 7.09	(-76) 5.26	(-64) 11.21	(-73) 5.96	(-55) 14.02
30g	(-64) 10.53	(-83) 4.91	(-84) 3.50	(-69) 9.77	(-11) 19.64	(-55) 14.20
40g	(-60) 11.92	(-76) 7.01	(-73) 5.96	(-55) 14.01	(-27) 16.14	(-16) 26.31
50g	(-33) 19.64	(-71) 8.4	(-52) 10.52	(-35) 20.18	(-43) 12.63	(-2) 30.36
60g	(-52) 14.03	(-85) 11.98	(-52) 10.52	(-33) 20.95	(-17) 25.96	(-48) 16.14
ANOVA						
F Value rows	26187.84.61	35613.9601	597310.979	529.5299	670671.645	14.85243
F Value col	0.1913358	1.0349715	0.255319	0.567021	1.0654206	1.065808
F* Critical row	2.420520	2.420520	2.996117	2.996117	2.996117	2.996117
F* Critical col	2.533558	2.533558	3.885290	3.885290	3.885290	3.885290

P = 0.05 All values in parenthesis are percent increase in soil available phosphorus.

The above result shows an improvement in soil available phosphorus at one month post treatment due to amendment material. This increase in phosphorus was observed to be depleted at months two and three post treatment. However, at eight months post treatment, there was subsequent improvement in soil available phosphorus along treatment levels. The above trend was also observed for the cumulative treatments. The analyses of variance shows variability between treatment levels and replications which was significant at 0.05 probability level and consequently validate the observations.

The C/N ratio obtained from the result of Organic Carbon and Nitrogen in experimental soils are presented in table 3.7.

Table 3.7: Organic Carbon and Nitrogen ($^C/_N$) ratio

Treatment	Experiment I		Experiment II			
	Main Effect		Residual Effect		Cumulative Effect	
	1 Month	2 Months	3 Months	8 Months	3 Months	8 Months
Control	26.1	64.1	81.1	9.1	16.1	9.1
10g	110:1	224:1	56:1	12:1	40:1	18:1
20g	126:1	180:1	36:1	12.1	36:1	11:1
30g	124:1	168:1	43:1	10:1	29:1	10:1
40g	129:1	119:1	46:1	9:1	26:1	12:1
50g	124:1	113:1	46:1	11:1	46:1	21:1
60g	126:1	116:1	55:1	14:1	41:1	13:1

The above computed C/N ratio from Organic Carbon and Nitrogen analysis (table 3.4 and 3.5) shows a narrow down trend for main effect, residual and cumulative experiments with time along treatment levels.
The results of soil, total hydrocarbon content of post treated soils are presented in table 3.8.

Table 3.8: Total Hydrocarbon content (ppm) of soils treated with oil palm bunch ash.

Treatment	Experiment II				
	Residual Effect		Cumulative Effect		
	2 Months	3 Months	8 Months	3 Months	8 Months
Control	130.05	118.38	118.38	118.38	118.38
10g	19545.23	17772	17284	15730	14883
20g	19217.34	15578	14409	15782	14901
30g	18708.95	15598	14343	15680	14612
40g	17784.39	15299	14205	15489	14339
50g	18434.24	16586	15222	16267	14461
60g	19027.47	16809	15432	16708	14748
ANOVA					
F Value rows	8719.619	9819.166	723690.8	15038.83	2964589.8
F Value col	0.88328	2.73856	1.6238	0.837098	2.47901
F* Critical row	2.420520	2.996117	2.996117	2.996117	2.996117
F* Critical col	2.533558	3.885290	3.885290	3.885290	3.885290

P = 0.05

From the above data, soil total hydrocarbon content was observed to have significantly reduced along treatment levels with time for both residual and cumulative experiment.

The analysis of variance for the above results indicated that the variability between treatment level is significant at 0.05 probability.

The percentage reduction of total hydrocarbon content of post treated soils, compared to pre-experimental soil total hydrocarbon content analysis (20291.96 ppm) table 3.1 is presented below in table 3.9 and 3.10.

Table 3.9: Soil total hydrocarbon content (THC) percent reduction for eight months (residual experiment) post-treatment.

Treatment	THC (ppm)	Percent Reduction
10g	17284	14.83
20g	14409	28.99
30g	14343	29.32
40g	14205	30.00
50g	15222	24.99
60g	15432	23.95

Table 3.10: Soil total hydrocarbon content (THC) percent reduction for eight months (cumulative experiment) post-treated soils.

Treatment	THC (ppm)	Percent Reduction
10g	14883	26.66
20g	14901	26.57
30g	14612	27.99
40g	14339	29.34
50g	14461	28.74
60g	14748	27.32

From the above data, the residual treatment shows an optimum total hydrocarbon content reduction for 20g, 30g and 40g treatment levels, while cumulative treatment shows a significant reduction along treatment levels, with optimum at 40g and 50g treatment levels.

4. Discussion

The result of soil initial chemical properties of field samples indicated an increase in soil pH for polluted sites over the unpolluted control sites. Similarly, organic carbon and organic matter content shows increases at sites polluted with petroleum hydrocarbon, when compared with soil samples from unpolluted sites (Table 3.1). The above observations could be attributed to the high level of petroleum hydrocarbon (20291.96ppm) observed in soil samples from polluted sites, against the low concentration observed at unpolluted sites. Similar observation was reported by Zuofa *et al.* (1987) who noted an increase in organic matter content, pH and total Nitrogen concentration in soils following crude oil application. The observed low concentration of Nitrogen and phosphorus in polluted soils (Table 3.1) also conforms with earlier studies by Obire and Nwaubete (2002) and Akpoveta *et al*. (2011) who reported a reduction in soil Nitrogen and phosphorus in petroleum hydrocarbon polluted soils.Isirimah *et al.* (1989) in their work reported that soil pH increased with increase in crude oil pollution rate. They interpreted the increase to be the consequence of high hydrocarbon compounds in crude oil. Soil pH was measured in this study and the data obtained indicated that oil palm bunch amendment increased soil pH (Table 3.2), which subsequently readjusted to lower values with time. In support of Isirimah *et al*. (1989) it would be deduced that the observed reduction in soil pH is an indication of hydrocarbon reduction in the soil. Organic matter in crude oil polluted soil had been shown to increase the microbial population several fold and this in turn increased the organic matter content in the soil (Toogood, 1977; Zuofa *et al*, 1987). Similarly, Hofman et al (2004) observed that though the number of soil microorganism increased in petroleum hydrocarbon polluted soils, species richness often decrease over time. From the data obtained in this study (Table 3.3), organic matter was observed to have increased in soils amended with oil palm bunch ash with time. These increases in organic matter could be attributed to the growth of

more microorganisms in soil amended with oil palm bunch ash, which in turn increased soil organic matter. Subsequent observation in eight (8) months post residual treatment and eight (8) months post cumulative treatments indicated greater level of reduction in soil organic matter. This reduction is thus attributed to the decline in microbial population in support of Hofman *et al*. (2004) who observed that though the number of soil microorganism increased in petroleum hydrocarbon polluted soils, species richness often decrease overtime. Similarly, the above observations are in agreement with an earlier findings by Toogood (1977) and Zuofa *et al*. (1987). Soil organic carbon data (Table 3.4) followed similar tread as observed in organic matter above. The increase and decline in organic carbon is deduced to be a function of the increase and decline in microbial population in the soil as earlier observed by Toogood (1977), Isirimah *et al*. (1989) and Hofman *et al*. (2004).

Available literature has indicated nitrogen and phosphorus as a limiting factor in crude oil degradation. The limitation of nitrogen and phosphorus in crude oil polluted soil had been demonstrated by Bossert and Barther (1984). This work has further confirmed the limitation of nitrogen in the degradation of crude oil polluted soils as observed in months one and two post-treatment analysis (Table 3.5) where nitrogen was observed to be limited.

Nitrogen however improved at three and eight months post treatment. Similarly, soils cumulatively treated with oil palm bunch ash equally indicated improvement in soil nitrogen with time. The initial limitation of soil nitrogen might be due to its incorporation in the cell and tissue of microbes that use the nutrient for growth and development. Nitrogen was later released to the soil at the decline of microorganism, in accordance to the finding of McGill (1976) and Odu (1981) who stated that nutrients were tied up in cells and tissues of microbes that use these nutrients for growth and development. Odu, (1981) observed that these nutrients however became available when properly recycled following good oil decomposition. Similarly, Zuofa *et al.* (1989) observed the released of nitrogen to soil at the decline of soil microorganism which encouraged plant growth.

Treatment of soils with oil palm bunch ash shows increases in soil available phosphorus with treatment levels (table 3.6). Treatments also followed the same trend as soil nitrogen above.

The result of soil carbon and Nitrogen (C/N) ratio (table 3.7) shows a narrowing down of C/N ration in soils amended with oil palm bunch ash with time. This observation conforms to the work of Amadi and UeBari (1992); Bossert and Bartha (1984) who reported that C/N ratio may have narrowed as a consequence of amendment of soils with poultry manure and decomposition, and that mineralization with a narrow C/N ratio and availability of essential nutrient to soil microbes enhanced degradation.

The use of oil palm bunch ash as soil amendment supplement for the amelioration of crude oil polluted soil is an effective technique for enhancement of bioremediation of soils contaminated with total petroleum hydrocarbon. In this study TPH degradation was successful since results indicated significant reduction (tables 3.7 and 3.8). The depletion of soil available phosphorus and Nitrogen (table 3.5 and 3.6) is an indication of utility of these nutrients by indigenous hydrocarbon-utilizing microorganism to enhance their potential for degradation of total petroleum hydrocarbon.

The reduction in soil total hydrocarbon favoured soils amended with oil palm bunch ash with optimum at 20g, 30g and 40g/2kg soil with 28.99%, 29.32% and 30.00% reduction respectively for the residual experiment at eight months post-treatment. Contrary to the above trend, cumulative treatment did not in clear terms indicate optimization as all treatment levels portrayed similar trend of significant reduction. These observations further show that cumulative treatment greatly enhanced degradation and the process was ongoing at the end of experimentation. However, 40g cumulative treatment is observed as optimum.

5. Conclusion/Recommendation

Treatment of crude oil polluted soils with oil palm bunch ash enhanced the biostimulation of indigenous petroleum degrading microorganism in soils which subsequently led to significant biodegradation of soil total petroleum hydrocarbon (TPH) content. In this study, oil palm bunch ash treatment increases soil pH values with increase in treatment levels, thus reducing soil acidity for enhanced degradation. Treatment generally increased soil organic matter with amendment levels for residual and cumulative experiments, an indication of indigenous microbial population growth in soils. However, with the passage of time and significant degradation, soil organic matter reduced along treatment levels, an indication of decline in microbial population resulting to mineralization of soils.

The limitation of phosphorus in crude oil polluted soil was enhanced in this study upon treatment with oil palm bunch ash. Soil available phosphorus generally increased with increase in amendment levels. The study further reveals a decline in available phosphorus at the respective treatment levels for the residual and cumulative experiments. This decline is attributed to utilization of available phosphorus by soil microbes for growth and development. Furthermore, at eight months post-treatment available phosphorus significantly improved in soils. This improvement is attributed to the decline of soil microbes which resulted to mineralization of soils.

Amendment material did not enhance Nitrogen. However, the study shows an improvement of soil Nitrogen at the end of experimentation due to significant bioremediation and mineralization. Soil carbon to Nitrogen (C/N) ratio at the end of experimentation shows a narrowing trend for all treatments. The use of oil palm bunch ash for amelioration of crude oil polluted soil enhanced a significant percentage reduction of total hydrocarbon content of soils, with optimum ranging from 20g/2kg soil to 40g/2kg soil treatment (28.99% to 30% reduction of TPH), while cumulative treatment favours 40g/2kg soil (29.34% reduction of TPH). Finally, the study discovered that treatment of crude oil polluted soils with oil palm bunch ash will enhance biostimulation of indigenous microorganisms for effective biodegradation of total petroleum hydrocarbon content of soils. As the study have shown, the application of oil palm bunch ash to crude oil polluted soils will lead to biostimulation of soil indigenous hydrocarbon degrading microorganisms and subsequently enhance the restoration of soils.

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