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RESEARCH ARTICLE

EFFICIENCY OF BANANA STALK ASH ON BIOREMEDIATION OF CRUDE-OIL CONTAMINATED SOIL

*Kefas, H. M., Lebnebiso, J. S., Luka, Y. and Ndagana, S. F.

Department of Chemical Engineering, Moddibo Adama University of Technology, Yola, Nigeria

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ABSTRACT

Bioremediation of ex-situ crude oil contaminated soil to which Banana Stalk Ash (BSA) was added has been studied in this paper, based on Total Petroleum Hydrocarbon (TPH) content. Four samples each were contaminated with 20g, 40g and 60g respectively of crude oil and 0g, 20g, 40g and 60g of banana stalk ash was added respectively to the four samples to produce twelve samples. Analysis of samples for TPH at two weeks interval after pollution up to the eight week revealed that bioremediation occurs naturally and is more profound within the first two weeks and the percentage reduction in TPH increased with increase in BSA content and level of crude oil contamination, with a maximum of 90.1% TPH reduction obtained after eight weeks. Therefore, Banana stalk ash (BSA) is a good substitute to NPK fertilizer for bioremediation considering its ability to achieve a high percentage reduction in TPH and its low cost.

INTRODUCTION

Increasing legislative and economic pressure to develop strategies for remediation of contaminated land and water, coupled with the fact that utilities for conventional methods of treating contaminated soil suffers from recognizable drawbacks and may involve some level of risk (Donlon and Bauder, 2006), led to bioremediation becoming an attractive remedial solution. Bioremediation is the process of utilizing biological agents (bacteria, fungi, higher plants, algae, and cyanobacteria etc) to remove contaminants from the environment in order to remediate land or water. During the process, microbes utilize chemical contaminants in the soils as an energy source and through oxidation-reduction reactions, metabolize the target contaminant into viable energy for microbes,releasing by-products that are typically in less toxic form than the parent contaminant (Onwurah, 2000; Nester *et al*., 2001; Aguwa, 2007).

Due to its increased usage, as a result of its low cost and availability compared to bio-based products, Petrol derived hydrocarbons are the most frequent environmental soil contaminants. Since the beginning of petroleum exploration in the 19th century and its quick acceptance as energy source to countless inventions, there has been a huge increase in demand and production of petrol derivatives. The production, transport, distribution and utilization of these natural resources certainly offer some risks. The quality of light in earth linked inextricably, to the quality of the environment and therefore, the release of persistent bio-accumulative and toxic chemicals have a detrimental impact on human health and the environment.

Soil contaminated with petroleum products can be defined as any earthen material or artificial fill that has human or natural alteration on its physical, chemical, biological or radiological integrity resulting from the introduction of crude oil, its fraction or derivative thereof, or oil based product (Dhanasekaran *et al*., 2009). These alterations pose a potential threat to public health and the environment therefore, some forms of remediation become imperative. It is well documented that a large number of contaminants can be degraded by microorganism under aerobic and anaerobic condition (Litchfield, 1991; Funk, 1993).

This study incorporates the laboratory experiments on crude oil contaminated soil by testing the effectiveness of bioremediation on crude-oil contaminated soil using banana stalk ash (BSA) as substrate/biostimulate under aerobic condition.

MATERIALS AND METHODS

Materials

Banana stalk Ash (NPK 2.34/49/0.4), Crude oil, Chloroform, Distilled water, Soil sample

Apparatus

Electronic weighing balance (ZL 200630014473.3), Jenway UV-VIS Spectrophotometer (AAS), Sieve (mesh size: 0.3mm), Measuring cylinder, Digital thermometer, Beaker, Conical flask, Spatula, PH meter, Oven (4824213), Stirrer, Plastic bucket, Stove, Sample bottles.

Preparation of Banana Stalk Ash

Banana stalk Ash collected from Jimeta (Yola North L. G. A., Nigeria) was crushed, sieved and dried for ninety minutes in an oven at a temperature of 200^{o}C.

Preparation of Crude Oil Contaminated Soil Samples

Four samples each were contaminated with 20g, 40g and 60g respectively of crude oil. Later, 0g, 20g, 40g and 60g of banana stalk ash was added respectively, to produce twelve

* Corresponding author: **Kefas, H. M**
Department of Chemical Engineering, Moddibo Adama University of Technology, Yola, Nigeria

samples as presented in Table 1. Banana stalk ash was added to a samples as follows: 0g of (BSA) was added to (M,N,O), 20g of the samples was added to (P,Q,R), 40g was added to (S,T,U) and 60g of the sample was added to (V,W,X). Each sample was tilled for one minute every 24 hours and analyzed every two weeks for eight weeks to determine the total petroleum hydrocarbon (TPH). The method was adopted from Onyelucheya *et al*, (2010).

Table 1 Quantity of crude oil contamination and ash in soil sample M to X

Quantity of ash	Quantity of oil		
	20g	40g	60g
0 g	M	N	O
20 g	P	Q	R
40 g	S	T	U
60 g	V	W	X

Twelve sample of 2.0 liter each in a plastic bucket were labeled M to X. 1000g of soil was weighed and added to each of the twelve samples. Crude oil was weighed and added to each of the soil samples as follows: 20g of the sample was added to M,P,S,V 40g was added to N,Q,T,W and 60g was added to O,R,U,X.

The contents of the bucket were properly mixed after the addition of the oil and kept in a room, away from sunlight, rain and direct climatic influence. Ten days after the pollution of the soil samples, the sample were tilled for one minute. Each to allow aeration, the crude oil used was procured from Kaduna refinery, Kaduna, Nigeria, prior to this the physio-chemical analysis of the soil collected such as; soil texture, moisture content , porosity, PH, temperature, particle density and bulk density were carried out.

Table2 Crude oil analysis results

Analysis	Results
Specific gravity at 15/4 ˚C	0.8486
Sulphur (%)wt	0.812
Viscosity at 40 ˚C	3.03
API gravity	35
Base sediments & water (%) vol	Trace

The sample from each buckets were allowed for 2 weeks after pollution each set of soil sample were collected in sample bottles for analysis of total petroleum hydrocarbon (TPH) before addition of the ash.

Table 3 Soil properties

Parameters	Value/Types
Texture	Sandy/loamy
Particle density (g/ml)	2.6
Bulk density (g/ml)	1.4
Porosity (%)	46.5
PH	6.1
Temperature (˚C)	29.9
Moisture content (%)	11

Measurement of Total Petroleum Hydrocarbon (TPH)

3g of each sample was taken into a conical flask and 40 ml of chloroform was measured and added to sample bottles labeled M to X and the sample was tightly closed and shaken vigorously for proper mixing of the content and the sample was allowed to stand for seven hour to enable complete extraction of oil by the chloroform. After 24 hours each of the samples was decanted and a clear liquid was obtained and transferred into a fresh sample bottles and the volume made up to 50 ml using chloroform. The clear liquid was poured gently into the beaker and place on the heating mantle for evaporation at 40^0C. The beaker was weighed after cooking to determine the oil content (Abdulsalam and Omale, 2009). The results obtained were measured in g/kg or ppm the UV- vis spectrophotometer was standardized using chloroform blank with wavelength at 290nm. The total petroleum hydrocarbon is given below.

$$\text{TPH (PPM)} = \frac{\text{weight of oil in sample}}{\text{weight of sample taken}} \times 10^6 \quad 1$$

Table 4 Variation of TPH with Time for sample (g/kg) MPSV

Time (wks)	M	P	S	V
0	18.00	18.10	18.05	18.00
2	8.84	8.00	7.20	5.40
4	7.30	7.00	6.50	5.00
6	6.80	6.20	5.80	4.20
8	5.20	4.80	4.00	3.20

Estimation of Particles Density

50ml of distilled water was added to a clean 100ml capacity graduate cylinder; 40g of oven dried soil was weighed and transferred into the 100ml graduated cylinder. A glass rod was used to stir the contents thoroughly for about 10 minutes and the particles were allowed to settle. The increase in the level of water on adding 40g of the soil was noted as the volume of water dispersed by the soil in ml (Bram *et al*., 1977)Pticle density (g/ml) = $(1- \frac{\text{mass of oven dried soil (g)}}{\text{volume of water dispersed by soil (ml)}})$ 2

Porosity = $(1- \frac{\text{bulk density}}{\text{particle density}}) \times 100\%$ 3

RESULTS AND DISCUSSION

The results obtain from the analysis of crude oil and soil sample prior to contamination and the contaminated soil analysis within eight weeks are presented in Tables 2-8 and Figures 1-6.

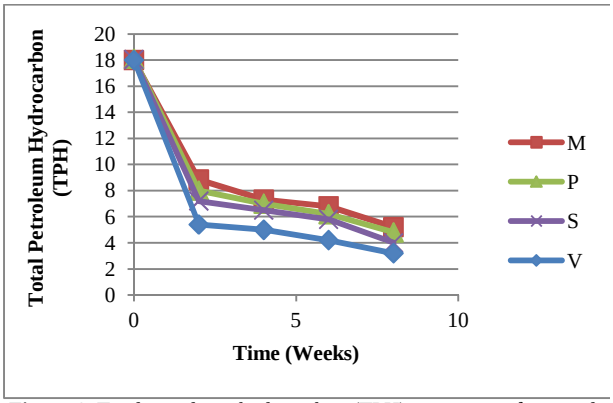

Figure 1: Total petroleum hydrocarbon (TPH) versus time for samples M, P, S and V

The percentage reduction of crude oil content in all the samples were appreciably high when compared with previous work done on similar cases (Abdulsalam and Omale, 2009) notwithstanding the high contamination level of 79 g/kg and the short treatment period of 8 weeks for each sample.

Table 5 Percentage reduction in TPH (%) for MPSV

Time(wks)	M	P	S	V
0	0.00	0.00	0.00	0.00
2	48.20	55.20	56.20	62.00
4	50.60	57.00	60.00	65.00
6	56.00	65.00	68.00	75.00
8	61.20	68.00	72.00	79.10

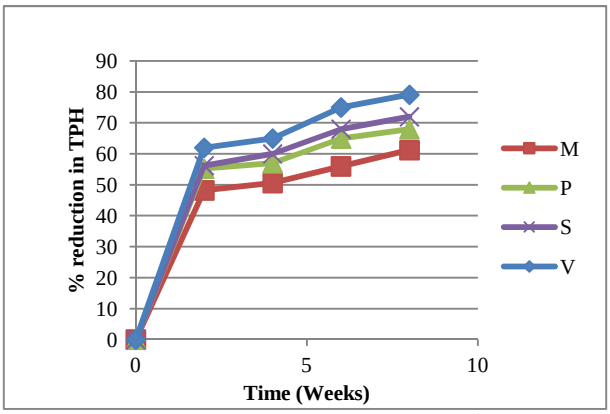

Figure 2: Percentage reduction in (TPH) versus time for samples M, P, S and V

The moisture content of the soil was measured at 11% but was maintained at 25% for a period of 8 weeks and the porosity of the soil sample used was measured at 46.5% giving good room for moisture distribution and oxygen availability by encouraging bacterial growth (perfumo *et al*, 2007).

Table 6 Variation of TPH with Time for sample (g/kg) NQTW

TIME(WKS)	N	Q	T	W
0	30.00	30.00	30.10	30.20
2	8.00	7.60	7.20	7.00
4	7.00	6.50	6.20	6.00
6	6.50	6.20	5.80	5.20
8	5.00	4.60	4.20	4.20

The initial values of total petroleum hydrocarbon (TPH) for samples M, P, S and V are almost equal, because each sample was contaminated with the same amount of crude oil. Each sample showed reduction in TPH, including sample (M) to which Banana stalk ash (BSA) was not added. Most of this reduction in TPH (>50%) occurred within the first two weeks. Samples M and V gave the lowest and the highest rate of TPH reduction respectively within the first two weeks, while the rate of TPH reduction for sample P and S were also equal for the first two weeks. After week four, the rate of TPH reduction was apparently the same for all samples, though slightly higher for samples with low BSA content beyond week six. Sample V gave the highest percentage reduction of (79.1%) and sample M gave the lowest percentage reduction of (61.2%).

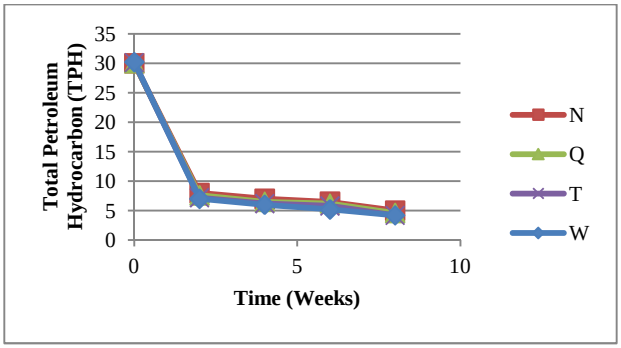

Figure 3 Total petroleum Hydrocarbon (TPH) versus time for samples N, Q, T and W

The initial value of total petroleum hydrocarbon, TPH for samples N, P, T and W are almost equal since each sample was contaminated with crude oil. Each sample showed reduction in TPH including sample N to which BSA was not added. Most of this reduction in TPH (>60%) occurred within two weeks. Sample W and T had the highest rate of TPH reduction within the first two weeks, while sample N had the lowest rate of TPH reduction within the same time period. After week four, the rate of TPH reduction was apparently the same for all samples, though slightly higher for sample with low BSA content beyond week 6. Therefore sample W gave the highest percentage reduction in TPH at (83.10%) where N gave the lowest percentage at (72%)

Table 7 Percentage reduction in TPH (%) for sample NQTW

TIME(WEEKS)	N	Q	T	W
0	0.00	0.00	0.00	0.00
2	60.00	65.00	62.00	70.00
4	65.00	67.20	70.00	72.00
6	68.00	70.00	73.00	78.00
8	72.00	73.00	78.00	83.00

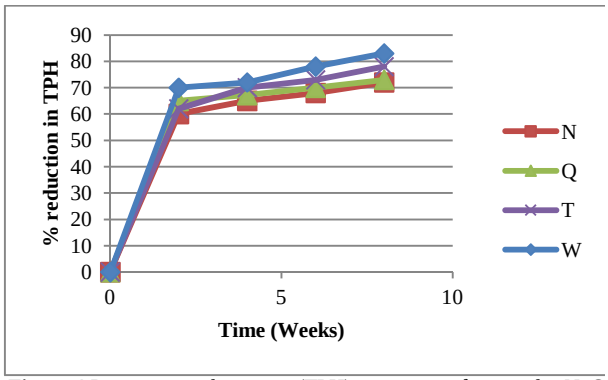

Figure 4 Percentage reduction in (TPH) versus time for samples N, Q, T and W

The initial value of total petroleum hydrocarbon TPH for sample O, R, U and X were almost equal, because each sample was contaminated with the same amount of crude oil. Each sample showed reduction in TPH including sample O to which no banana stalk ash was added. Most of the reduction in TPH (>70%) occurred within the first two weeks.

Table 8 Variation of TPH with Time for sample (g/kg) ORUX

TIME(WEEKS)	O	R	U	X
0	40.00	40.05	40.1	40.25
2	9.00	8.00	7.20	6.00
4	8.00	7.50	6.00	5.20
6	7.30	7.00	6.10	5.00
8	5.20	5.00	4.80	4.00

Therefore, sample O and X has the lowest and highest rates of TPH reduction respectively within the first two weeks while the rate of TPH reduction for sample R and U were almost the same for the first two weeks.

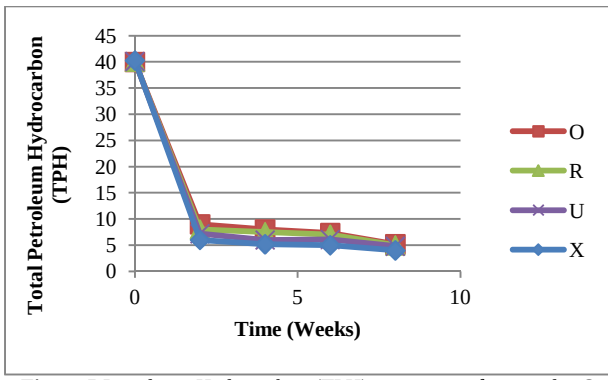

Figure 5 Petroleum Hydrocarbon (TPH) versus time for samples O, R, U and X

Beyond week four, the rate of TPH reduction was apparently the same for all samples, though slightly higher for sample with low BSA content beyond six weeks. Therefore sample X showed the highest percentage reduction in TPH (90.1%) and sample O, the lowest at (75.2%).

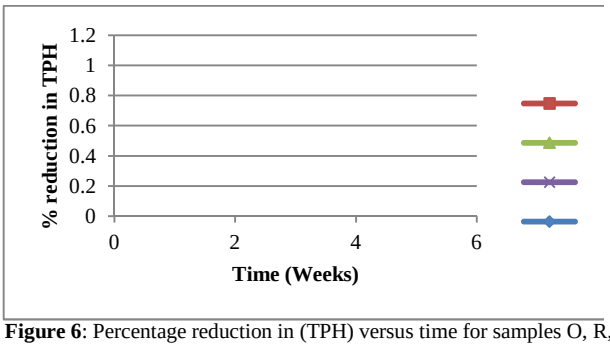

Figure 6: Percentage reduction in (TPH) versus time for samples O, R, U and X

Table 9 Percentage reduction in TPH (%) for sample ORUX

TIME(WEEKS)	O	R	U	X
0	0.00	0.00	0.00	0.00
2	70.00	75.00	78.00	85.00
4	72.20	78.00	80.00	87.50
6	75.00	80.00	85.20	89.00
8	75.20	82.00	85.00	90.10

CONCLUSION

Bioremediation occurs naturally even without addition of nutrient to the soil and this is more profound of higher crude oil contaminations. Addition of nutrients, like banana stalk ash (BSA), in this case increases the rate of bioremediation. The increase is more profound for low crude oil contaminations than it is at high crude oil contaminations.

Thus, the percentage reduction in TPH during bioremediation increased with addition of BSA and decreased in level of soil contamination with crude oil. Therefore, Banana stalk ash is a good substitute to NPK fertilizer for bioremediation considering its ability to achieve up to 85 % and 90.1% within 2 weeks and eight weeks respectively and its low cost, as against fertilizer.

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