Efficiency of Municipal Drainage Biosludge Enhanced Bioremediation of Crude Oil Polluted Soil

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Abstract

Crude oil pollution in the environment poses grave ecological threat to the ecosystem and human health. In order to protect the ecosystem and public health, measures are required to remove pollutant from the environment. This study aims at investigating the crude oil polluted soil bioremediation enhancement efficiency of municipal drainage biosludge obtained from the Niger Delta region of Nigeria. Different quantities of dewatered biosludge collected from municipal drainage in the Niger Delta were used to treat microcosm of crude oil polluted soil in pilot scale bioreactors labeled A, B, C, D, E, F, G, H and I. Content of each set up was moisturized and mixed thoroughly at regular intervals. This was to ensure the provision of adequate water for microbes in the systems to thrive and to aerate the soil. The residual total petroleum Hydrocarbon (TPH) and other soil physicochemical properties of the soil were monitor for five months. At the end of the five months, TPH removal efficiency of 59.87%, 62.19%, 65.82%, 67.10%, 68.16%, 69.11%, 69.79% and 1% was recorded in set up A, B, C, D, E, F, G, H and I (control) respectively. Based on the results obtained in the study, it is concluded that municipal drainage biosludge obtained in the Niger Delta is potential supplement for the bioremediation of crude oil polluted soil.

Keywords: *Municipal drainage biosludge, crude oil, bioremediation and efficiency*

1.0 INTRODUCTION

The environment is very critical and important for continuous human existence. It provides the resource base and the conditions for human and other biological life forms to thrive in the biosphere. Nature enhances our wellbeing and freely provides the essentials for our survival (National Environmental Treasure, 2020). The environment sustains life by providing genetic diversity and biodiversity (Veda, 2021). However, human activities are impairing the natural stability and assimilative capacity of the environment by inundating the environment with pollution at an alarming rate.

Oil pollution in soil and water via accidental oil spills and operational leakages or discharges is a major way by which human activities is impairing or stressing the environmental quality. Crude oil also known as petroleum, is one of the natural resources which man exploits for his economic benefits. This precious and valuable liquid is drilled from under the earth or under the sea bed. The revenue derived from crude oil exploitation has in no small measure boosted industrialization throughout the universe as a result of the reliance of many industries on petroleum products for either raw materials or energy supply.

Oil is a very important and versatile substance use in different ways and in different forms for many applications (Jessica, 2023). The global demand for crude oil in 2022 was estimated at 99.57 million barrels per day and it was projected to increase to 101.89 million barrels per day in 2023. This underscores why oil price continues to rise.

Nigeria as a nation has benefited immensely from crude oil. However the nation has got to pay the supreme price by having to bear the negative effect of oil spills most especially in the Niger Delta region. The frequent oil spillage has caused wide spread pollution of the region. Oil spillage has a lot of damaging effects on the environment. It is harmful to the ecosystem. For instance, crude oil pollution kills fishes and birds at a concentration of 4000 parts per million (ppm) (Prasad *et al.,* 1987). Crude oil and its related products can cause birth defects in humans. Benzene being one of the chemical constituents of crude oil is known to cause leukemia in humans (Hussein *et al.*, 2016). The compound is among the most toxic substances to plants and animals when spilled into the environment (Robert, 2002). Concern for the occurrence and distribution of polycyclic aromatic hydrocarbons (PAHs) has also increased in recent times because of their potential harmful effects to the health of human beings (Selina *et al.*, 2005).Polycyclic aromatic hydrocarbon is a constituent of crude oil.

Bioremediation has been described as ecofriendly, efficient and economic environmental pollution remediation technology. Bioremediation can be a viable and effective response to soil contamination with petroleum hydrocarbon and can be positively enhanced by the use of organic waste (Vincenzo, 2016). (Sofia et al., 2022) also reported that the addition of organic materials and suitable food sources aided earthworm subsistence, promoted the decontamination process and improved polluted soil quality.

Various materials such as inorganic and organic fertilizers are commonly used in bioremediation to enhance the natural attenuation of crude oil in the environment. Because of the ability of biological or organic resources to stimulate microbial biodegradation of petroleum hydrocarbon. Many of these organic materials have been studied. Addition of organic materials in contaminated soil improves the abiotic soil conditions, thus enhancing microbial activity in the soil (Mathias, 2016). Literature evidence show that various organic materials such as rice husk, saw dust, cow dung, poultry droppings etc, have proven to be efficient in the stimulation of microbial biodegradation of petroleum hydrocarbon. For instance, (Jude., Tanee and Ngbaraue, 2022) reported that cassava peel waste is an effective biostimulating agent in crude oil biodegradation. The use of rice husk in hydrocarbon polluted soil significantly increased biodegradation rate and resulted in effective AGO cleanup within 2 months period (Amechi *et al*., 2017). Adams., Niyomugabo and Sylvester (2017) also reported that rice husk ultimately removed more petroleum hydrocarbon than chicken manure. Wood ash amendment of Petroleum hydrocarbon polluted resulted to 90.90% reduction of total petroleum hydrocarbon after 90 days of amendment (Akan., Etok and Adegoke, 2013).

However, municipal drainage biosludge has never been used or studied as a potential amendment for crude oil polluted soil bioremediation even though it is rich in microbial nutrient and organic fiber that can improve soil structure and fertility. The aim of this study was to investigate the crude oil pollution bioremediation stimulation efficiency of municipal drainage biosludge.

2.0 MATERIALS AND METHOD

2.1Area of **sample collection**

Samples of crude oil polluted soil were collected from oil spill site around an oil manifold in Ikarama community in Yenagoa Local Government Area of Bayelsa State. Unpolluted soil sample (control sample) was also collected from the same community. While drainage biosludge was collected from concrete drainage in Emeyal 2 community in Ogbia local Government Area of Bayelsa State IKarama is geographically position in 05°09’16” N, 06°27’11 E within Okordia/Zarama Clan in Yenagoa Local Government Area of Bayelsa State. Emeyal 2 is the headquarter of Emeyal Clan in Ogbia Local Government Area of Bayelsa State. The community is also bears the Owuru oil well 15 being operated by SPDC. Emeyal 2 is one of the most developed communities in Ogbia Local Government Area. Ogbia is located in the Southern part of Bayelsa State, lying within 4o93’00" N16º00"E and occupying a land Area of about 695km^2, with a population of about 179,926. The inhabitants of Emeyal 2 community are mostly Fishermen/farmers and business men. The position of the Ikarama is shown in the Bayelsa/Nigeria map as presented Fig 2.1 (Paul *et al.*, 2015).

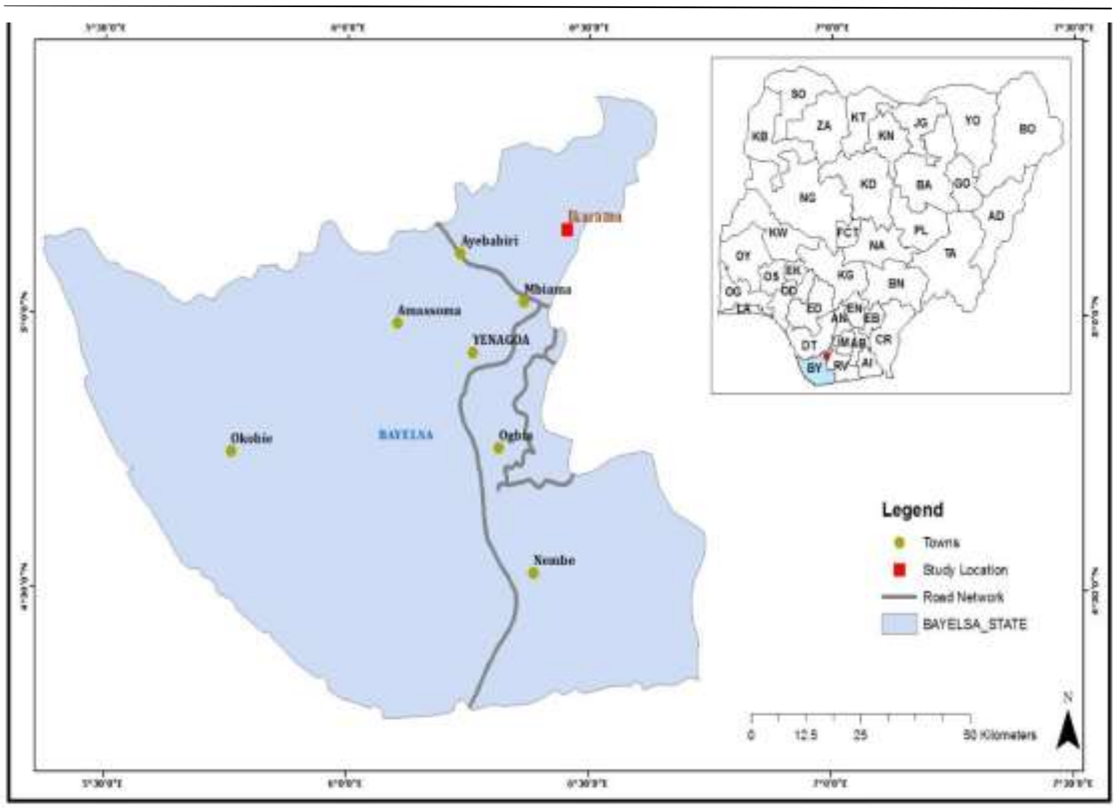


Fig 2.1: Map of Bayelsa State showing location of Ikarama community

Fig, 2.2: Collection of Polluted soil for the study

Fig,2.3: Municipal drainage in Emeyal 2 community

2.3 Experimental design

One kilogram microcosm of the crude oil polluted soil sample was weighed with analytical balance in nine replicates into nine perforated plastic vessels which were labeled A, B, C, D, E, F, G, H and I. The polluted soil sample in vessels A to H were treated with different quantities of dewatered biosludge ie (100, 200, 300, 400, 500, 600, 700 and 800g) respectively. While the soil sample in Vessel I was kept as a control (untreated). Water was periodically added to the content of each set up and thoroughly mixed to ensure good aeration of the soil and distribution of water to every section of the soil since moisture play critical role in the survival and metabolic activities of microorganisms. Analytical sample was collected from each of the experimental set ups monthly for laboratory analysis during the study period of five months. The analyses were conducted following the same procedure conducted for the polluted soil/control soil sample and the biosludge. The experimental setup label and and amount of municipal drainage biosludge added is presented in Table2.1

Table2.1: set up letter and the amount of biosludge treatment.

Experimental Set ups	A	B	C	D	E	F	G	H	I
Amount of biosludge treatment (g)	100	200	300	400	500	600	700	800	0

2.3 Analysis of of the effectiveness of TPH biodegradation in each experimental set up

Following the observed progressive decrease in residual TPH Concentration in the experimental set ups during the study, the percentage bioremediation of Total petroleum Hydrocarbon in experimental set up was evaluated using the equation of (Samuel *et al.,* 2015).

Percentage TPH degradation (Pd) $= \frac{TPHi - TPHt}{TPHi} x\ 100$ (3.10)

Where TPH_i is the initial Total petroleum hydrocarbon concentration in soil samples

TPH_t is the residual Total petroleum hydrocarbon concentration in soil samples at time t

2.4 Analysis of the efficiency of biossludge enhanced bioremediation

The efficiency (% Eff) of the biosludge treatment on the degradation of total petroleum hydrocarbon (TPH) in each treated soil sample was analysed using the Equation of (Samuel, et al, 2015)

$\%\ Eff = \frac{\%\ TPHtr - \%TPHct}{\%TPHtr} x\ 100$ (3.11)

Where

% Eff is percentage efficiency of TPH biodegradation.

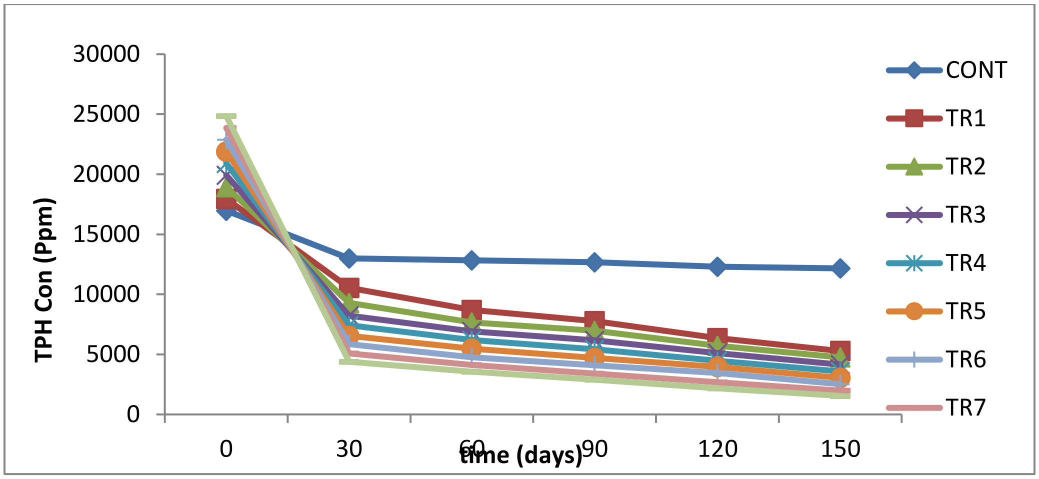
$\%TPH_{tr}$ is percentage of TPH degradation in treated soils

$\%\ TPH_{ct}$ is percentage of TPH degradation in untreated soil.

3.0 RESULT AND DISCUSSION

3.1 Result

The trend of the total petroleum Hydrocarbon degradation in the experimental set ups have been analyzed. The effectiveness as well as biosludge bioremediation enhancement efficiency have also been analyzed. The Total Petroleum Hydrocarbon (TPH) degradation trend in each experimental setup is presented in Fig2. 1



KEY: TR1 = A, TR2= B. TR3= C, TR4= D, TR5 = E, TR6= F, TR7 = G, TR8= H CONT= I

Fig. 3.1: Time series of residual TPH in experimental set ups during the study period

The results of the analysis of the biosludge bioremediation enhancement efficiency in each of the experimental set up from the beginning of the study to the end is presented in Table.3.1

Table3.1: TPH removal efficiency results for the treated soil and control.

Experiments	TPH removal efficiency (%)
A	59.87
B	62.19
C	65.82
D	67.10
E	68.16
F	69.11
G	69.59
H	69.79
I	1

3.2 .1Discussion

The overwhelming acceptance of bioremediation as an environmentally sound and economical treatment technology for hazardous waste is anchored on its effectiveness and efficiency. Heitzer and Sayer (1993) reported that the general acceptance of the technology requires demonstration of its efficacy, reliability and predictability as well as its advantage over conventional treatments. This paper focus on the demonstration of the efficiency of municipal drainage biosludge enhanced bioremediation of crude oil polluted soil. The trend of the biodegradation of total petroleum hydrocarbon in all the experimental set ups is presented in Fig 3.1 While the analysis of the efficiency of the TPH biodegradation in each set up is presented in Table 3,1. The results in Fig3.1 show that initial Total Petroleum Hydrocarbon (TPH) concentration in the set ups was 17955.12ppm in set up (A), 18939.91ppm in (B), 19924.57ppm in (C), 20909.24ppm in (D), 21893.91ppm in (E), 22878.58Ppm in (F), 23862.65 ppm in (G), 24847.91ppm in (H) and 16970.75ppm in control (I). At the end of five period of the study, TPH level was 5280.41ppm in (A), 4749.83 ppm in (B), 4150.14ppmin (C), 3580.38ppm in (D), 3047.35ppm in (E), 2520.49ppm in (F), 1989.87ppm in (G), 1545.80ppm in (H) and 12162.89ppm in control (I). These results represent 70.59% (A), 74.92% (B), 79.17% (C), 82.88% (D), 86.08% (E), 88.98% (F), 91.70% (G), 93.78% (H) and 28.33% in control (I) TPH removal. Set up H which contained the maximum biosludge treatment of 800g recorded the highest TPH removal followed by G. experiment A which contained the least treatment (100g) recorded the least TPH removal among the test experiment at the end of the period of study; while vessel I i.e the control which model natural attenuation recorded the least TPH loss at the end of the study period (months) indicating that the biosludge treatment had effect on the rate of TPH degradation.

3.2.2 Results of analysis of the effectiveness of the bioremediation

The results of the analysis of percentage TPH degradation in the experiment set ups indicate that percentage TPH degradation in the first month (day 30) was 40.24% in (A), 51.00% in (B), 58.77% in (C), 64.54% in (D), 70.06% in(E), 74.45% in (F), 78.69% in (G), 82.32% in (H) and 23.47% in control (I). In the second month (day 60) percentage cummulative degradation was 51.58% in (A), 59.60% in (B), 65.28% in(C), 70.36% in (D), 75.03% in (E), 79.14% in (F), 82.77% in (G), 85.69% in (H) and 24.37% in (I). In the third month (ay 90) percentage cumulative degradation was 56.79% in (A), 63.34% in (B), 69.04% in (C), 74.10% in (D), 78.55% in (E), 82.08% in (F), 85.77% in (G), 88.36% in (H) and in control 25.35% in (I). In the fourth month (day 120) percentage of TPH degradation was 64.59% in (A), 69.74% in (B), 74.41% in (C), 78.58% in (D), 81.92% in (E), 84.95% in (F), 88.73% in (G), 91.23% in (H) and in control (I) it was.27.51% . In the fifth month (day 150) the percentage cumulative TPH degradation was 70.59% in (A), 74.92% in (B), 79.17% in (C), 82.88% in (D), 86.08% in (E), 88.98% in (F), 91.70% in (G), 93.79% in (H) and 28.33)% in control (I). Set up H recorded the highest TPH degradation (93.17%) during the study followed by G While the control (I) which modeled natural attenuation recorded lowest percentage of TPH degradation. The results indicate that percentage TPH degradation in the experimental set ups increased with quantity of biosludge treatment.

3.2.3 Results of analysis of the efficiency of biosludge enhanced bioremediation

The results of the analysis of the efficiency (% E) of the amendment in each experimental set up are shown in Table 3.1. The results indicate that there was TPH removal efficiency of 59.87% in A, 62.19% in B, 64.22% in C, 65.82% in D, 67.10% In E, 68.16% in F, 69.11% in G, 69.79% in H and 1% in I. These results have shown that treatment H with highest mass of biosludge (800g) single treatment has the highest efficiency of TPH removal over the untreated soil, followed by treatment G (700g), while treatment A recorded the lowest percentage treatment efficiency of 59.87% over the untreated soil. (Raphael et al., 2022) reported efficiency of 90% in food waste anaerobic digestate and 86.8% tween 80 surfactant respectively in bioremediation of wetland soil contaminated with crude oil after 49 days. Umeojiakor and Ojiabo, (2019) reported crude oil polluted soil bioremediation enhancement efficiency of 91.08%, 88.62% and 62.61% by Pumpkin leave, wood ash and saw dust respectively after 49 days. (20) reported that organic amendment provides additional Nitrogen and Phosphorus nutrients that stimulate microbial growth that leads to the synthesis of enzymes required to to degrade petroleum hydrocarbon compounds. (21) Also reported that addition of nutrient supplements stimulate the growth of microorganism and biodegradation of polycyclic aromatic hydrocarbon (PAHs) contaminated soil. The efficiency of municipal drainage bioslude enhancement of bioremediation of crude oil polluted soil recorded in this study could be attributed to the availability of microbial nutrient in the biosludge that aided in the stimulation of microbial activities in the amended soil.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Bioremediation is recognized as efficient, economical and environmentally friendly pollution treatment technology. The technology takes advantage of the natural ability of microorganisms such as bacteria and fungi to biodegrade organic pollutant to smaller harmless molecules in polluted environmental medium. The results obtained in this study show that there was significant difference between percentage of TPH degradation in the test set ups and the control set up therefore municipal drainage biosludge obtained in the Niger Delta is a potential supplement for the bioremediation of crude oil polluted soil.

4.2 Recommendations

Based on the results obtained from this research, the following recommendations have been made;

i. Further research on the microbiological characterization of municipal drainage biosludge with molecular techniques recommended.
ii. Further pilot field study using municipal drainage biosludge to enhanced bioremediation of crude oil polluted soil is recommended.

References

Rosenberg E., Lagmann, R., Kushmaro A., Tauba R and Aldler, R (1992).Petroleum bioremediation. A multiphase problem. Bioremediation 3:337-350

Yi, H and Crowley, D.E (2007). Biostimulation of PAH degradation with plants containing high concentrations of Linnileic acid. Environmental Science Technology 4:4382-4388

Umeojiakor C.T and Ojiabo, K.T (2019). Effectiveness of biostimulants amendment with indigebous microbes on bioremediation of crude oil contaminated soil in Niger Delta Region of Nigeria. International Journal of Engineering Research and Technology (IJERT), Vol. 9, Issue 11. DOI:10.17577/IJERTV8IS10077

Raphael Buller Jumbo., Frederick Coulon., Tamazon Cowley., Ikeabiama Azuazu., Emmanuel Atai., Imma Bortone and Ying Jiang (2022). Evaluating different soil amendments as bioremediation strategy for wetland soil contaminated by crude oil. Journal of Sustainability, vol. 14 Issue. 24/10.3390/su142416568

Amechi S. Nwankwo., Chukwudi O. Onwosi., Fidelis Azi., Peter Azumini and Chikodili O. Anaukwu (2017). Use of Rice husk as bulking agent in bioremediation of automobile gas oil impinged agricultural soil. Soil and Sediment Contamination International Journal, 26(1). http://doi.org/10.1080/15320383.2017.1245711

Adams F.V., Niyomugabo and Sylvester O. P(2017). Bioremediation of crude oil contaminated soil using agrc=icultural wastes. Procedia Manufacturing. Volume, 7 Pp 459-464

Hussein, I., Abdel-Shafy, Mon, S.M and Mansur (2016). A review on poly cyclic aromatic hydrocarbon; source, environmental impact, effect on human health and remediation. *Egyptian Journal of Petroleum*. 25(1): 103 – 123.

Jude, K., Tanee F.B.G and Ngbaraue A (2022). Use of cassava peels as biostimulant in Bioremediation of crude oil polluted soil. *Journal of Applied Sciences*. 22(6): 351 – 361

Vincenzo Piemonte (2016). Bioremediation of hydrocarbon contaminated soil using selected organic wasyes. Oil and gas portal. Available at www.oil.gasportal.com/bio

Mathias Kastner and Anja Miltner (2016). Application of composr for effective bioremediation of organic contaminants and pollutants in soil. *App Microbiol Biotechnol*, 100(8):3433 49. Retrieved from https:pubmed.ncbi.nih.gov/2

Sofia Nobili., Caroline Elisabet Masin., Cristina Susana Zalazar and Maia Raquel Lecano (2022).Bioremediation of hydrocarbon contaminated soil using local organic materials and earthworms.Environmetal Pollution, vol, 314, http://doi.org/101016/j.envpol.2022.120169.

National Environmental Treasure, (2020). Important for humans: the basics of ecosystem services. Retrieved on the 15th June, 2023, from www.oursafetynet.org

Jessica Aizarani (2023). Global crude oil demand 2005–2023. Accessed online at www.statista.com/statistic

Veda Shroff (2021). Importance of the environment to human life. Accessed online at www.socialdharal.com/importance

Prasad, M, S, Prasad, P and Sing, D (1987) Some hematological effects of crude oil on fresh water catfish. *Clean soil and Water Journal*, 15. (2): 199- 204

Robert, S (2002) Benzene and leukemia .*Toxicology* 32 (302): 402 – 412.

Selina, M and Banfor, .I.S (2005). Bioremediation of Polycyclic aromatic hydrocarbons ; Current knowledge and future directions. *Journal of chemical Tecnology and biotechnology*, 80 (7): pp. 723 – 736.

Akan, O.D., Etok, C.A and Adegoke, A.A (2013). Bioremediation of crude oil contaminated soil using wood ash. *Journal of pure and Applied Microbiology*. 7(3): 1749 - 1756

Heitzer A and Sayer, G.S (1993). Monitoring the efficiency of bioremediation. *Trends Biotechnol*, 1993. PIMD; 7764180. DOI: 10.1016/0167-7799(93)90156-4