Journal of Environment, Earth Sciences and Ecology
Vol.04, No.03;July –September-2022
p –ISSN (7304–490X);
ISSN (2202–3011

INNOVATIVE USE OF MUNICIPAL DRAINAGE BIOSLUDGE FOR SUSTAINABLE CRUDE OIL POLLUTION BIOREMEDIATION

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Abstract: Crude oil pollution is a common and rampant phenomenon in Nigeria especially in the Niger Delta region of the country. Bioremediation has been adjudged the most efficient, economical and environmentally friendly method of crude spill remediation. The aim of this study is to investigate the use of municipal drainage biosludge as a supplement for the enhancement of crude oil polluted soil bioremediation. One kilogram of impacted soil was collected in nine replicates into perforated plastic vessels labeled (A –I). The impacted soil samples in vessels A – H were treated with 100g, 200g, 300g,, 400g, 500g, 600g, 700g and 800g of characterized municipal drainage biosludge respectively. The soil in vessel I was not treated (Control). The soil in each vessel was sprinkled with water and thoroughly mixed every four days. Change in Total petroleum hydrocarbon (TPH) in each vessel was monitored for a period of five months. At the end of the study, crude oil reduction of 70.59%, 74.92%, 79.17%, 82.88%, 86.08%, 88.98%, 91.70%, 93.78 and 28.33% was observed in vessels A -- H and I respectively from an initial average concentration of 16,970.57mg/Kg. The results obtained in the study indicate that the municipal drainage biosludge collected from the Niger Delta enhanced the bioremediation of crude oil polluted soil. Hence it is concluded that municipal drainage biosludge from some part of the Niger Delta is a potential supplement for the bioremediation of crude oil polluted soil.

Keywords: crude oil, pollution, biosludge, bioremediation and supplement.

1.1Introduction

The problem of solid waste management is of a global dimension. The problem continues to increase and get more complex as human activities become more dynamic and sophisticated. Solid waste could be defined as non-liquid, non-gaseous waste generated from anthropogenic activities, considered as useless materials which could be in the form of refuse, garbage and sludge (Leton and Omotosho, 2004., Babayemi and Dauda, 2009).

Sludge is one kind of solid waste that modern society has got to deal with. Sludge waste is generated from a variety of human activities which include sludge from refinery furnace, industrial storage tank sludge, water treatment plant sludge, sewage sludge, agricultural product processing sludge and sludge from municipal drainage. Sludge could be chemically based or biological based. Chemical sludge is formed as product of chemical activity in a system. Example is precipitation sludge produce during phosphate removal process in water treatment. Biological sludge is produced by the microbial decomposition of organic matter in waste water. Biological sludge is otherwise called biosludge

Municipal drainage biosludge is a slushy mass of muddy material produce in municipal drainage by the degradation of organic materials in the drainage by microorganisms such as fungi and bacteria. In many Nigerian towns and cities, biosludge in municipal drainage is a serious environmental Problem. This slurry mass occurs in the drainage as microorganisms digest organic materials directly dump or carried into the drainage by storm water during heavy rainfall. The environmental effects of municipal drainage biosludge include slowing down of water flow in the drainage which usually results to area flooding. Currently in Nigeria, there is no particular method or strategy that has been adopted or developed for the management of municipal drainage biosludge. In some other countries, biosludge is been strategically managed and put into beneficial use. For instance, in New South Wales biosludge is applied on agricultural land as well as reprocessed through composting for horticultural purpose. If biosludge is not converted to beneficial use, it will otherwise be disposed on landfills which can then lead to emission of greenhouse (Sydney waters, 2012). The advantage of the land application of biosludge is that it makes room for the sustainable use of the nutrient content and soil amendment properties of these residual materials (Lee *et al.*, 2006). In Taiwan, biosludge is used for the generation of power ((Wen-Tien, 2012). Also in Finland, a paper mill uses the biosludges generated from the treatment of its paper mill waste water to generate power for the company's factory (Suomen, 2014). It has also been shown by (Qin et al., 2012) that biosolids from biosludge can be combined in different proportion with other materials to make materials for reclaiming swampy land and land polluted with metals and urban Brownfield sites Biosolid is also applied in the capping of abandon landfill in Australia and New Zealand and other European countries (www.biosolids/comau/what.ax.biosolid). It is also applied as additive in road construction.It is also reported that about 50 percent of the energy in biosludge can be retrieved as liquid oil that can be stored and transported (Lee *et al.*, 2006). The ash generated from the incineration of biosludge is also been used as construction material in the production of interlocking stones with minimal environmental risk (Lee *et al.*, 2006).

In Nigeria, the approach of raking out biosludge from the drainage and leaving it on the street side is not environmentally sustainable. Sustainable development entails clean and wholesome environment. The Brundtland Commission defined sustainable development as the "ability to make development meets the needs of the present without compromising the ability of future generations to meet their own needs" (Robert, *et al*, 2005). Leaving municipal drainage biosludge on road and street sides as obtainable in Nigeria is against the principle of sustainable development.

Crude oil pollution is another environmental factor that is a threat to sustainable development of any nation. Crude oil pollution has negative consequences on the ecosystem and public health. (Iheoma., Adekunle., Neo and Temitope, 2013). Bioremediation has been described as a feasible, eco-friendly, economical and effective crude oil spill remediation technology (Macaulay, 2014). It has been argued that bioremediation is cheaper and more environmental friendly when compared to other remediation technology (Mansi *et al*., 2017). Bioremediation make use of the ability of bacteria and fungi to biodegrade organic compound to cleanup hydrocarbon pollution (Mansi *et al*., 2018). A report by (Greetha *et al*., 2013) indicated that bioremediation offers a very feasible alternative for the decontamination of oil spills. Several bioremediation researches have been conducted and significant impressive results have been obtained. Outside Africa (Wu *et al*., 2007: Bofan *et al*., 2019 and Chao *et al*., 2020) all reported impressive research results on bioremediation. In Nigeria (Ayotamuno *et al*., 2006: Emmanuel *et al*., 2007.: Iheoma, 2011 and Chioma *et al*., 2012) also reported impressive results indicating that bioremediation is a potential remediation technique for cleaning polluted environment. The aim of

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this study is to investigate the enhancement of bioremediation of crude polluted soil, using municipal drainage biosludge from the Niger Delta as stimulant..

2.0 MATERIALS AND METHOD

2.1 Area 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. 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. The community is a host to the Okordia-Rumuekpe Trunk line own by Shell Multinational oil Company (SPDC) in Bayelsa State. While Emeyal II is situated in Ogbia Local Government Area. Ogbia is located in the Southern part of Bayelsa State, lying within 4o93'00" N16º00"E. Fig2.1 is map of Bayelsa State in set showing the position of Ogbia and Ikarama.

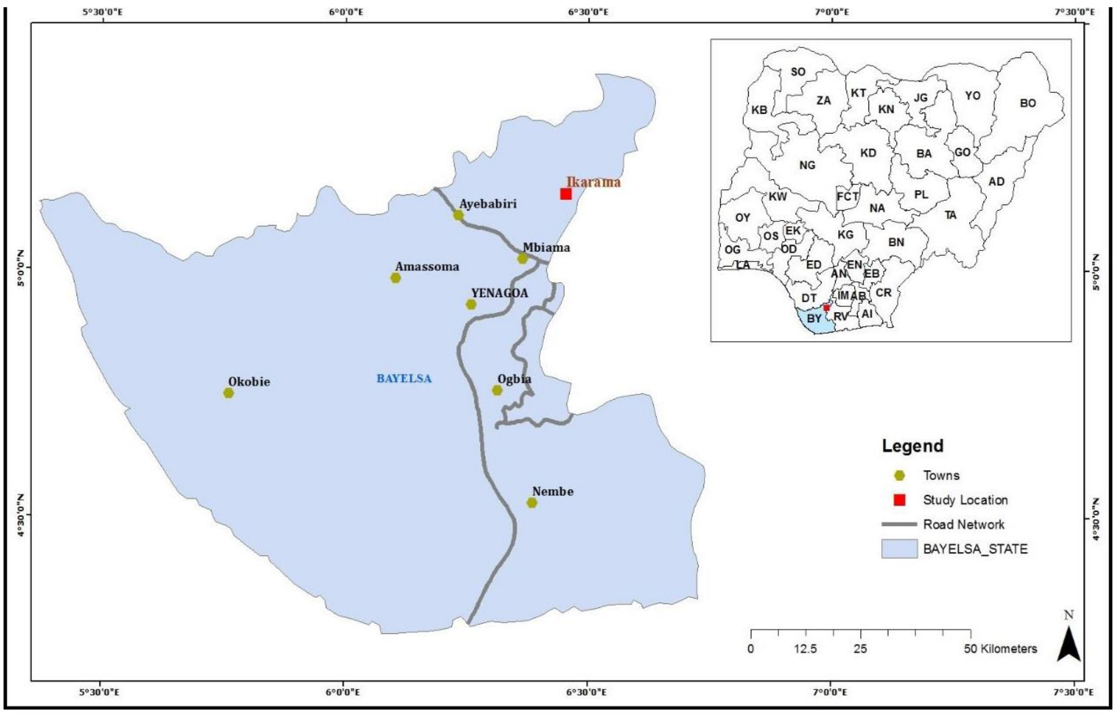

Figure 2.1: Map of Bayelsa State showing location of Ikarama community and Ogbia (**Source:** Paul *et al.*, 2015)[11]

2.2 Materials and method

The study involved field visit for survey, sample collection and laboratory experimental investigation. The soil samples were collected at a depth of 0 to 20cm from three different sampling points on crude oil spill area while a control sample was collected from unpolluted area within the study area. The soil was excavated with spade and collected in black recyclable polythene bags.

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Representative composite soil samples were collected in plastic bottles wrapped with black polythene bag and put in a cooler stuffed with ice block and transported along with the dewatered biosludge to analytical laboratory for pre experiment assessment.

The municipal drainage bio sludge was collected from concrete drainage in Emeyal II in Ogbia Local Government Area. The site for soil sample collection is presented in Fig2.2. While Fig2.3a and 2.3b show the municipal drainage where the biosludge was collected and the collected biosludge respectively.

Fig 2.2: the site of polluted soil sample collection at Ikarama.

Fig 2.3a shows the site of municipal drainage

Fig 2.3b: Sample of biosludge collected
biosludge sample collection in Emeyal II
for the study.

The soil and biosludge collected were analysed for their physicochemical and microbiological properties using standard analytical method. Total petroleum hydrocarbon (TPH) was analysed with Flame ionization detector chromatography (Agilent 6890N Model). While microbiological characterisation was done by microscopic/morphological and biochemical methods as recommended by the United States Environmental protection Agency (USEPA, 2006) and further confirmed by biochemical test.

Hydrocarbon degrading bacteria in the samples were isolated, identified and enumerated by serial dilution pour plate count method of Pepper and Gerba (2004), Benson (2002). Hydrocarbon degrading Fungi were isolated and identified using the guide provided by Pepper and Gerber, (2005); Elis *et al.*, (2007); Bartnet and Hunter, (1972) and Benson, (2002).

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 i.e. (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 sprinkled on 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 up 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 for the study is shown in Fig 2.4.

Fig 2.4.The experimental setup for the study showing treated soil samples in perforated plastic containers.

Analysis 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 of Total petroleum Hydrocarbon biodegraded in each experimental set up was evaluated using the equation of (Samuel *et al.*, 2015).

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

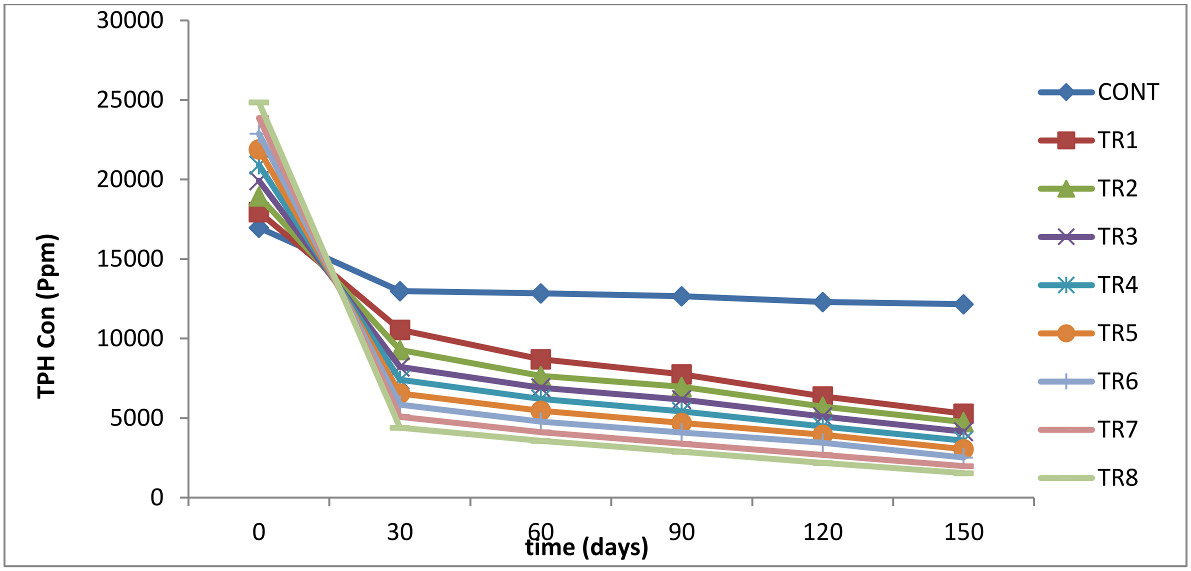
Where TPH_i is the initial Total petroleum hydrocarbon concentration in soil samples

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

3.0 RESULTS AND DISCUSSIONS

3.1 Results

In order to assess the viability and progress of bioremediation process in the study, determination of microbial populations in the polluted soil, unpolluted soil and biosludge was carried out and the results of the microbial enumeration indicated that the mean population of total heterotrophic bacteria was $1.8x10^7$cfu/g, in the polluted soil, $1.7x10^6$cfu/g in the control soil and $7.1.x10^6$cfu/g in the biosludge. Total hydrocarbon degrading bacteria population was $7.3x10^6$ cfu/g in the polluted soil, $1.2x10^5$cfu/g, in control soil and $7.1x10^6$cfu/g in the biosludge. Total Fungi population was $3.5x10^5$cfu in the polluted soil, $1.9x10^5$cfu/g, in the control soil and $2.9x10^5$ cfu/g in the biosludge; while total hydrocarbon degrading Fungi population was $2.9x10^5$cfu/g in the polluted soil, $2.8x10^4$cfu/g in control and $6.2x10^4$cfu/g in the biosludge. The total hydrocarbon degrading bacteria and Fungi population in the polluted soil and biosludge was more than 10^3 cfu/g hence enough to start TPH biodegradation according to the study of Forsyth (Forsyth *et al.*, 1995). Fig 3.1 shows the results of the trend of petroleum hydrocarbon degradation in the various treatment containers during the study period.



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

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

Among the 17 Poly aromatic hydrocarbons (PAHs) compounds listed by United States Environmental Protection Agency (USEPA) as chemical of concerned 15 were detected in the polluted soil and biosludge. The results of this study also showed that PAHs concentration reduced from initial level of 5448.52ppm to 4992.93ppm representing 8.36% PAHs removal in the control. PAHs concentration reduced from 5803.38ppm to 1722.84ppm (70.78% reduction) in ecperiment A at the end of the study period. Setups (treatment options) B, C, D, E, F, G and H recorded 77.77%, 82.70%, 87.01%, 90.57%, 93.22%, 94.91% and 96.65% reduction in PAHs concentration respectively. This is a significant achievement when compared with Providenti *et al.* (1993) which achieved 97and 82% reduction of two and three ring PAHs respectively after 119 days in an *ex situ* bioremediation of creosote polluted soil by addition of fertilizer complemented with tilling and aeration and the work of Lee *et al.* (2001) which reported 90% removal of PAHs in 17days using acetone and ethanol pretreatment before bioremediation and the same percentage was achieved in 35 days without pretreatment. Chang *et al* (2002) also reported a significant reduction of PAHs concentration within 90 days in a laboratory scale anaerobic bioremediation of spiked PAHs. In a bioremediation study conducted by Ambrosoli *et al.* (2005), it was reported that approximately 30 – 60% of PAHs concentration removal was achieved in a denitrifying condition with consortium of microorganisms isolated from contaminated soil. Iheoma *et al.*(2013) researched on bioremediation of crude oil polluted soil in the Niger Delta and reported 100% reduction of Five PAHs identified in the polluted soil using CNB bioremediation product in two times application. This percentage of PAHs degradation was achieved in 157 days.

Total petroleum hydrocarbon (TPH) concentration was also monitored throughout the study and the results are shown in Figure 3.1. The results showed general decrease in TPH in all the test set ups and the control set up (I). In the control set up (I), TPH decreased from an initial concentration of 16970.57ppm to 12162.89ppm representing 28.33% TPH removal in five months (150 days). Treatment option A achieved 70.57% TPH removal, option B achieved 74.92% TPH removal , C achieved 79.17% TPH removal, D achieved 82.88% TPH removal , E achieved 86.08% removal , F achieved 88.98% removal, G achieved 91.6% removal while set up H achieved 93.22% TPH removal during the study. .Gut-Jin *et al*, (2008), reported that addition of organic compost and liquid swine manure for removal of soil Total Petroleum Hydrocarbon showed an efficiency of 84.4% and 92.2%, inorganic nutrient addition only achieved efficiency of 80.2% TPH removal. While addition of chemical oxidant to the residual TPH in biological treated process was able to upscale the TPH removal efficiency to 98%. The work of Laura *et al*, (2011), indicated that 81% and 51% TPH removal was achieved in contaminated sediment after 43days with a combination of anaerobic and aerobic process in one experiment then aerobic process only in another respectively.. The study of Samuel and Oladipupo (2012). Showed that a combination of NPK fertilizer, Tween and Pig manure at concentrations of 4.22g, 80, 10.69mg/l and 47.76g respectively was able to achieved 68.47% and 52.33%, of TPH and Cr(VI) removal respectively after 42 days of bioremediation process. Rupshikha and Sures (2018), reported that rhamnolipid biosurfactant from *Pseudomonas aeruginosa* at concentration of 1.5g/L achieved 86.1% and 80.5% TPH removal efficiency in two soil samples containing 6800ppm and 8500ppm of Total Petroleum Hydrocarbon (TPH).

The results of this study are positively comparable with other studies of Iheoma *et al.* (2013) which recorded 99% TPH degradation with two times application of CNB bioremediation product. Adams *et al.* (2014) which reported 85% TPH removal in bioremediation project using Poultry litter as treatment and Jorgensen *et al.* (2000), which implemented bioremediation of petroleum hydrocarbon contaminated soil using composting biopiles and recorded 70% TPH degradation. The difference in TPH degradation between the control and the test samples recorded in this study is attributed to the influence of the biosludge treatment on crude oil biodegradation rate

4.1 CONCLUSION

Bioremediation is an environmental friendly, cost effective petroleum hydrocarbon pollution remediation technique. Bioremediation can take place naturally in hydrocarbon polluted environmental media, but at slow rate. In order to enhance the rate of natural attenuation of petroleum hydrocarbon pollution materials that can boost the growth of hydrocarbon degrading microorganisms in polluted environmental media are usually added in order to enhanced the rate of microbial degradation of the organic pollutant (Bio-stimulation). In Nigeria, various natural organic materials such as poultry droppings, rice husk, saw dust and cow dung have been studied and in use as bioremediation stimulant or supplement. Biosludge from municipal drainage has not been used. The results obtained in this study revealed that municipal drainage biosludge obtained in the Niger Delta is a potential supplement for the enhancement of petroleum hydrocarbon pollution bioremediation. A minimum biosludge treatment of 100g per kilogram of polluted soil achieved 70.579% TPH removal, 800g per kilogram of polluted soil achieved 93.22% of TPH removal. While 28.67% of TPH removal was achieved in the control set up with in five months period. Statistical analysis of variance ($p < 0.05$) also showed that there was significant difference between percentage of TPH degradation in the test soil samples and the control. Hence, the researchers therefore draw the conclusion that municipal drainage biosludge obtained from the Niger Delta is a potential supplement for enhancing 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.

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