Asian Journal of Advances in Research

4(1): 1296-1302, 2021

ASSESSMENT OF HEAVY METAL BIODEGRADATION POTENTIALS OF PALM BUNCH ASH IN DIESEL OIL POLLUTED SOIL

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Received: 14 September 2021
Accepted: 17 November 2021
Published: 23 November 2021

Original Research Article

ABSTRACT

Diesel oil pollution is a major challenge in most developing countries like Nigeria. This study was carried out to ascertain the possibility of remediating diesel oil polluted soils using palm bunch ash. Samples of garden soil with no history of diesel oil pollution were spiked with 100mL of Bonny Light diesel oil and left for two weeks to simulate a condition of major spill before adding different weights of palm bunch ash (0, P+NOPBA, 50g, 150g, 250g and 350g). 1g from each treatment was collected monthly and subjected to laboratory analysis using standard analytical methods for soil selected heavy metals contents using AAS. Preliminary results revealed alteration of chemical properties of soils, elevated heavy metals levels two weeks after spiking indicating that the soil sample had undergone slight alteration. There was a dose dependent decrease in heavy metal content of the diesel oil polluted soils with time. Mean concentration of Zinc ranged from 95.7mg/kg to 7.45mg/kg; 9590.5 to 99.83 in Fe; 3.5mg/kg 1.4mg/kg Cu; 1.45mg/kg to 0.06mg/kg Cd and 10.90mg/kg to 0.05mg/kg in Pb. Overall, net reduction in heavy metals was very low in soil left under natural attenuation (polluted untreated soil) than treated soils. This study has revealed a marked degradation of the heavy metal content of soil which indicated that palm bunch ash could be used for remediation of diesel oil polluted soil. It is recommended that palm bunch ash be replaced with conventional fertilizer in restoration of crude contaminated soil.

Keywords: Diesel oil; palm bunch ash; biodegradation; polluted; soil.

1. INTRODUCTION

Environmental pollution emanating from diesel oil spillage is an issue of global concern. The soil is the habitat for a myriad of organisms in the ecosystem; therefore, its contamination could lead to alteration of the ecosystem integrity and services they render to humans. Soil is an indispensable key component of natural ecosystem [1]. It is a primary recipient by design or accident of a myriad of waste products and chemicals used in modern society [2]. Pollution caused by petroleum and its derivatives is the most prevalent problem in the environment. Since commercial exploration of petroleum started in Nigeria in 1958 [3], petroleum has continuously grown to be mainstay of the Nigerian economy. However, the exploration of petroleum has led to the pollution of land and water ways [4]. The increasing use of diesel oil in diesel engines of cars, industrial trucks and generators has led to an increased demand

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for diesel oil [4] and this has resulted in accidental spillage of diesel oil along Nigerian high ways, and in turn pollution of agricultural lands [5]. Diesel oil is one of the major products of crude oil and it constitutes a major source of pollution to the environment [6] Diesel oil can enter into the environment through leakage from storage containers, refueling of vehicles, wrecks of oil tankers and through improper disposal by auto mechanics when cleaning diesel tankers [3]. The addition of inorganic or organic nitrogen-rich nutrients (biostimulation) is an effective approach to enhance the bioremediation process [7-8]. Positive effects of nitrogen amendment using nitrogenous fertilizer on microbial activity and/or petroleum hydrocarbon degradation have been widely demonstrated [9].

One of the agro-wastes commonly generated in Nigeria is the Oil Palm Bunch Refuse. Nigeria is still the world’s third largest producer and clearly the largest producer in Africa [10]. The oil palm waste, which has been estimated from this industry at about seven million metric tonnes annually, is yet to be harnessed for the production of organic manures and agricultural development generally [11]. Soils in the Niger Delta region are usually acidic due to soil pollution like oil spillage and deficient in essential plant nutrients due to frequent rain fall associated with erosion and leaching [2]. Contamination of soil with diesel oil and its effect on the soil environment and human health require highly efficient and cost effective means of restoration or treatment [3]. Several methods including the use of chemical fertilizers to augment for mineral element limitations during soil biodegradation has been conflicting in terms of its effectiveness and cost. In developing countries like Nigeria, fertilizers are not sufficient for agriculture, let alone for cleaning oil spills. The need to search for cheaper, locally available and environmentally friendly options like OPBA for enhancing petroleum hydrocarbon degradation is very important [12]. More so, the involvement of microorganisms in the degradation of petroleum hydrocarbons in the environment has been established as an economic, efficient, versatile, and environmentally friendly treatment method. There are no adequate literatures on the potential use of this un-exploited product (OPBA) as biostimulating agent for soil biodegradation [13].

Bioremediation may be regarded as a clean-up technology that uses naturally occurring micro-organisms to degrade hazardous substances into less toxic or non-toxic compounds [14]. It is the optimization of natural biodegradation in which microorganisms chemically alter and break down organic molecules into other substances such as carbon dioxide, fatty acids, and water in order to obtain energy and nutrients [15]. Bioaugmentation and biostimulation are two approaches to bioremediation geared toward enhancing and speeding up the process [16-17]. Bioaugmentation involves the addition of external microbial population (endogenous or exogenous) to the polluted site [6].

2. MATERIALS AND METHODS

2.1 Study Area

The study area was a fallowed plot of land (100 x 50 m) in Ohii, Owerri West Area of Imo State located at latitude 5.3866° N, and longitude 6.9916° E. There is no history of crude oil pollution in the area.

2.2 Sample Collection and Processing

Sandy-loamy top soil was collected within 0-15cm depth from the study site after the removal of plant debris and exposed surface according to MCPA method as described by [9]. Sample preparation followed the method of [11] with slight modifications. Samples of soil (1kg) with no history of diesel oil pollution were transferred into sterile plastic buckets with the aid of a standard potting garden trowel and spiked with 100mL of diesel oil and left for two weeks to simulate a condition of major spill before adding different weights of palm bunch ash. The soil in the pot was incubated with the following treatment combinations:

- Six treatments (Baseline soil (uncontaminated),
- Crude oil soil (contaminated) without oil palm bunch (OPB) ash,
- Treatment 1 (diesel oil + 50g OPB ash),
- Treatment 2 (diesel oil + 100g OPB ash),
- Treatment 3 (diesel oil + 150g OPB ash) and
- Treatment 4 (diesel oil + 200g OPB ash).

The experiment was monitored for six months during which samples were collected monthly and analyzed for selected heavy metals such as Pb, Cu, Zn and Cd. This was done to monitor the rate of degradation of the heavy metals in the various treatments.

3. RESULTS AND DISCUSSION

Figs. 1-5 represents the concentrations of heavy metals across the six months on contaminated and uncontaminated soil samples. There was a significant difference ($p<0.05$) in the zinc concentration of the soils treated with OPB ash as treatment moved from month 1-6 when compared with both baseline and

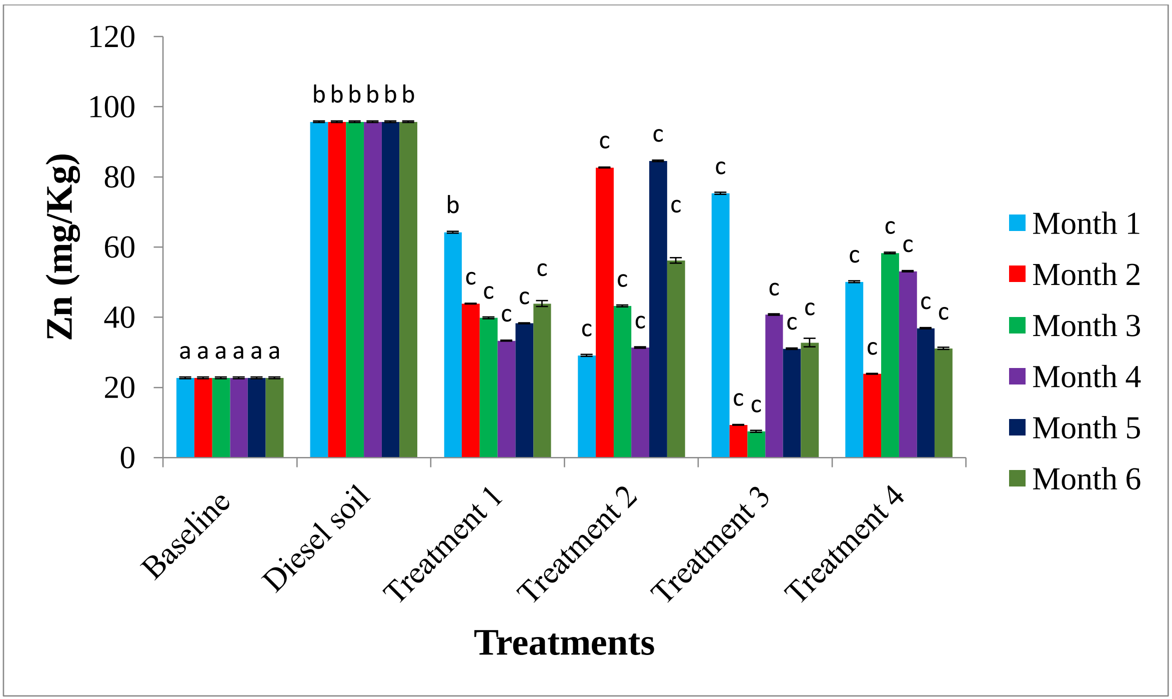

Fig. 1. Concentrations of Zinc heavy metal across the months on contaminated and uncontaminated soil samples

Bars are mean ± S.D; n = 3

Bars bearing different superscript letters show significant difference (P<0.05) when compared with baseline and diesel soil.

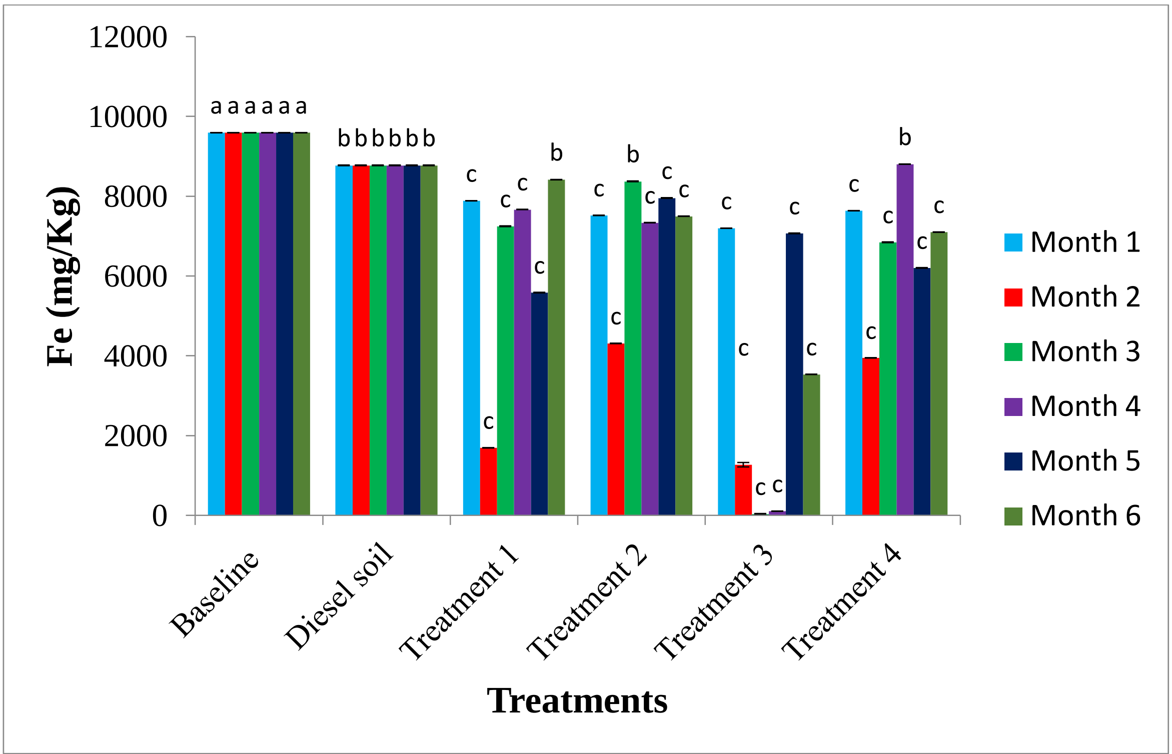

Fig. 2. Concentrations of iron heavy metal across the months on contaminated and uncontaminated soil samples

Bars are mean±S.D; n = 3

Bars bearing different superscript letters show significant difference (P<0.05) when compared with baseline and diesel soil.

There was a progressive decrease in heavy metal content of soil with increased treatment levels at various periods of sampling. The highest reduction rate was observed in 250g and 350g compared with other treatment levels; the lowest reduction rate was noticed in polluted untreated soils left under natural attenuation. Results showed that the unpolluted soil had low values of heavy metals throughout the investigation. The reduction of heavy metals from month 1 to month 6 in polluted untreated soil was slow in comparison with other treatment levels. This slow reduction observed could be attributed to natural attenuation which hindered indigenous microorganisms to use available nutrients as both carbon and nitrogen sources to degrade hydrocarbon compounds. Results of polluted soil without PBA showed increase in heavy metal value on month 1 compared to the value obtained for the unpolluted soil, followed by minimal reduction from month 2 to month 6 of the experiment. The reason for high concentrations of heavy metals observed on month 1 is due to pollution of soil with diesel oil in such a quantity as to simulate natural pollution. A marked reduction observed during the first two months of treatment with PBA could be due to the ability of microorganisms to use the PBA as both carbon and nitrogen sources to degrade the hydrocarbon compounds in the crude oil. [20] has reported that amendment of 100g contaminated soil with 30g organic nutrient led to loss of 40% TPH. [21-25] also reported a similar trend in crude oil polluted soils. There was significant reduction in metal values throughout the investigation. A study by [26-31] documented significant reduction in Arsenic content of soils treated with different weights of palm bunch ash. From this, it could be deducted that the use of PBA effectively stimulated organisms into utilization of diesel oil. All the polluted soil treated with different weights (that is, 50g to 350g) of PBA followed the same trend with that of polluted soil treated with 50g PBA. There was decrease in heavy metal values throughout the experiment for all the soils with different weights of PBA in dose dependent manner. This corroborates the work of [32-37] who made similar observation in crude oil polluted soil. From the observation, PS + 50g PBA showed the lowest percentage reduction in heavy metals while the maximum reduction was observed in 350g treatment level. [21], [38-40] had reported that the quantity of manure is important for bioremediation (in supplying nutrient). Indicating that 350g weights of PBA could be an optimum treatment recipe for diesel oil degradation.

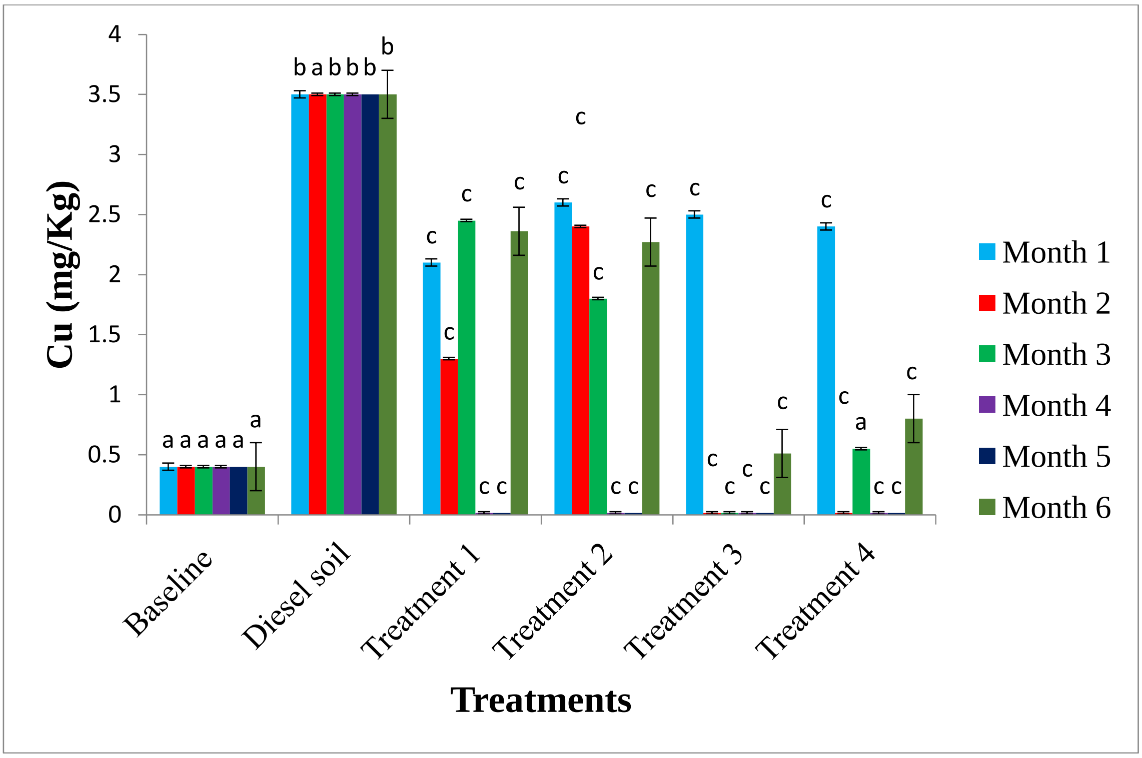

Fig. 3. Concentrations of copper heavy metal across the months on contaminated and uncontaminated soil samples

Bars are mean±S.D; n = 3

Bars bearing different superscript letters show significant difference (P<0.05) when compared with baseline and diesel soil.

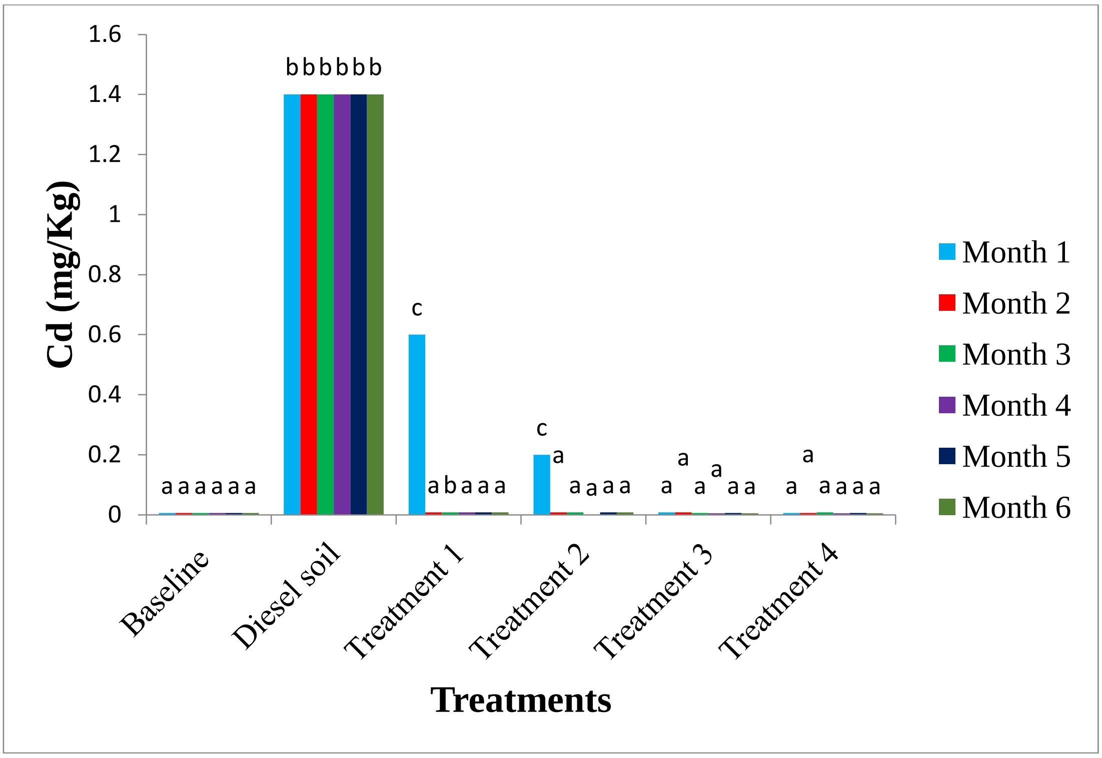

Fig. 4. Concentrations of cadmium heavy metal across the months on contaminated and uncontaminated soil samples

Bars are mean±S.D; n = 3

Bars bearing different superscript letters show significant difference (P<0.05) when compared with baseline and diesel soil.

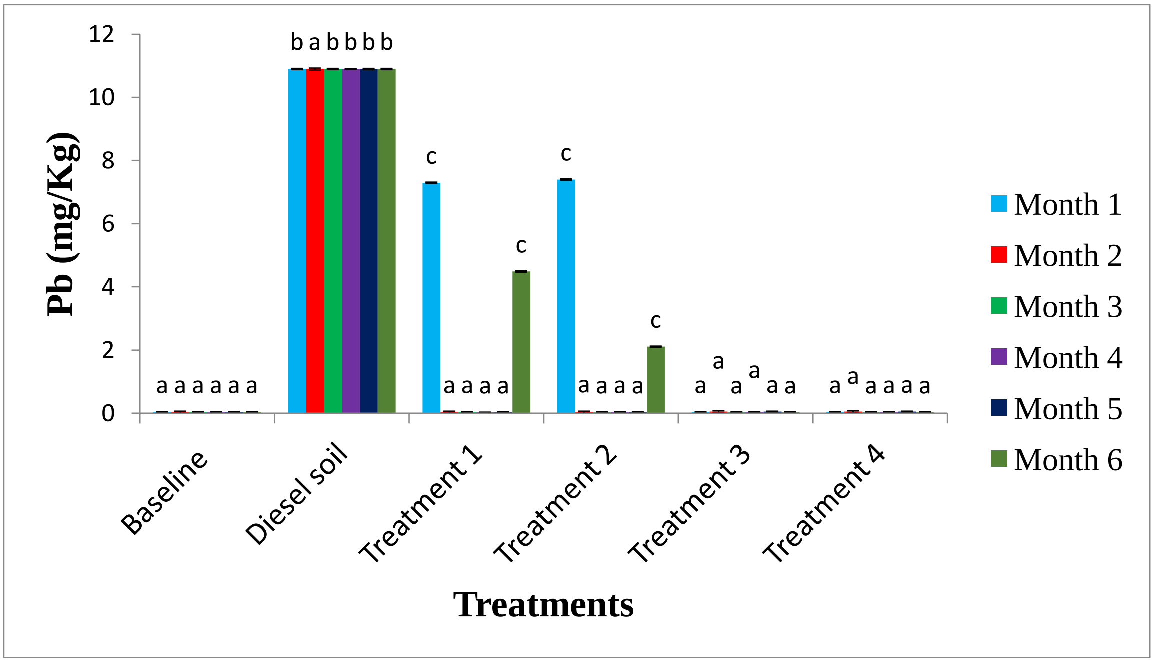

Fig. 5. Concentrations of lead heavy metal across the months on contaminated and uncontaminated soil samples

Bars are mean±S.D; n = 3

Bars bearing different superscript letters show significant difference (P<0.05) when compared with baseline and diesel soil.

4. CONCLUSION

The treatment of diesel oil contaminated soil with palm bunch ash revealed that after two weeks of treatment, chemical properties of soil was adversely affected. Addition of different weights of palm bunch ash aided in the complete disappearance of the heavy metals six months after exposure. This shows that palm bunch ash which has been confirmed to possess rich concentration of nutrients and potassium ions species can contribute to bioremediation of diesel oil polluted soil. This study has also revealed a marked degradation of the hydrocarbons which maybe through the activities of microorganisms or through emulsification. There is need for further studies on this subject so as to elucidate the actual mechanism of degradation that took place in this study. Palm bunch ash could be used in bioremediation of diesel oil polluted soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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