ASEAN Journal for Science and Engineering in Materials

Journal homepage: https://ejournal.bumipublikasinusantara.id/index.php/ajsem

Physicochemical Properties of Soil Ecosystem Polluted With Spent Engine Oil

Maximus M. Ebulue [1,*], *C.S. Ebulue* [2]

[1]Department of Biotechnology, Federal University of Technology, Owerri Imo State, Nigeria
[2]Department of Soil Science, University of Benin, Edo State, Nigeria
*Correspondence: E-mail: ebuluemm801f@yahoo.com

ABSTRACTS

Assessment of the possible impact of spent engine oil on the soil ecosystem is imperative for the determination of environmental acceptability. This study investigated this impact *ex-situ* using standard laboratory tools to determine the following parameters: pH, temperature, moisture content, and total petroleum hydrocarbon (TPH). The experiment demonstrated that at 1.0 – 3.5% contamination over time across days-zero to -28, spent engine oil upset the physicochemical equilibrium of the soil. A significantly reduced ($p<0.05$) pH in the range of 7.1 ± 0.00 to 6.2 ± 0.00 meant that the soil was acidic with a significant ($p<0.05$) increase in temperature from 33 ± 0.00 to 35.5 ± 0.03°C at increased concentrations overtime. The moisture content increased significantly ($p<0.05$) from 3.5 ± 0.00 to 19.31 ± 0.01% following the significant increase ($p<0.05$) in total petroleum hydrocarbon (TPH) from 0.002 ± 0.00 to 0.084 ± 0.00. This presupposed a hydrocarbon polluted soil ecosystem with oxygen deprivation; a demonstration of disturbed ecological equilibrium.

ARTICLE INFO

Article History:
Submitted/Received 17 Feb 2022
First revised 03 Mar 2022
Accepted 26 Mar 2022
First available online 28 Mar 2022
Publication date 01 Sep 2022

Keyword:
Moisture,
pH,
Temperature,
Total petroleum hydrocarbon.

1. INTRODUCTION

Petroleum products which are widely spread in the natural environment contribute to soil degradation during spillage. Contamination of the existing and potential agricultural lands is the major problem associated with the processing, distribution, usage, and disposal of crude, refined, and spent petroleum products. Such contaminants are the limiting factors to soil fertility and hence crop productivity. They are toxic to soil organisms and plants (Delille and Pelletier, 2002; Wyszkowska *et al*., 2002) and can contribute to soil toxicity, hypoxic conditions, deterioration, and degradation (Sztompka, 1999). Soil biological activities are vital for the restoration of soil ecosystem contaminated with hydrocarbon from spent engine oil; by bio-transforming toxic petroleum products into harmless compounds.

Spent engine oil, a brown-to-black mineral-based crankcase oil produced when new mineral-based crankcase oil is subjected to high temperature and high mechanical strain. It is a mixture of several different chemicals (Wang *et al*., 2000), aliphatic and, aromatic hydrocarbons, lubricative additives, decomposition products, and heavy metals. Spent engine oil is a common environmental toxicant not found in the natural environment (Dominguez-Rosado and Pichtel, 2004). Its contamination on the existing and potential agricultural lands arises when the motor engine oil is changed and disposed into gutters, water drains, open vacant plots and farmlands, a common practice of motor and generator mechanics (Odjegba and Sadiq, 2002) or from the exhaust system during engine use and engine leakage (Anoliefo and Edegbai, 2000; Osubor and Anoliefo, 2003).

Although the pollutant is biodegradable, it creates an unsatisfactory condition for life in the soil because it disturbs the ecosystem balance, and it can bio-accumulate in food chains where it will disrupt biochemical and or physiological activities of many organisms (Onwurah *et al*., 2007) due to poor aeration, it causes on the soil, immobilization of soil nutrients and lowering of soil pH (Achuba and Peretiemo-Clarke, 2008). This is mainly due to the destructive influence of the oil on the soil structure and soil air, with the loss of soil mineral nutrients due to leaching and erosion (Palese *et al*., 2003).

One way of detecting whether an area is contaminated or polluted with spent engine oil is by estimating the total hydrocarbon content of the oil-impacted soil. Records of hydrocarbons taken seasonally enhance our ability to ascertain the extent of contamination, especially by comparing with data from pristine areas or available baseline data from regulatory bodies. Empirical records of the hydrocarbon content are therefore of great monitoring importance for effective management of an ecosystem impacted with spent engine oil.

However, even though the adverse effect of spent engine oil spillage on soil biota is concentration and time-dependent, periodic monitoring and analyses of typical and potential pollutants is essential for effective management of the hydrocarbon-impacted soil. It is for these reasons therefore that we set out to empirically quantify the hydrocarbon content and physicochemical characteristics of spent engine oil spillage on the soil ecosystem.

2. MATERIALS AND METHODS

2.1. Materials

Soil sample dug about 15cm dept from Botanical Garden of the Department of Plant Science and Biotechnology, Federal University of Technology, Owerri, Imo State, and spent engine oil was obtained from the Mechanic Village in Owerri Imo State, Nigeria.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

2.2. Experimental Design

This study was designed for a-thirty-five-day investigation: Day-zero, Day-14, Day-28 and Day-35; within which the effect of time and various concentrations of spent engine oil on the aforementioned objectives were determined.

2.3. Experimental Soil

The uncontaminated soil from the Botanical Garden of Federal University of Technology, Owerri, Imo State, Nigeria was sieved with cheesecloth to remove tiny stones and other particulate matters.

2.4. Determination of pH

Into small beakers, 1 – 7 was introduced 10g of the sieved soil sample; and into the first beaker, 0.1g of spent engine oil corresponding to 1.0% concentration (w/w) was added and mixed thoroughly. This procedure was repeated at increasing concentrations of 1.5, 2.0, 2.5, 3.0, and 3.5 % over time in all the beakers except the 7th beaker, the control. The mixture was allowed to stand for 10 min before determining the pH with a pH meter.

2.5. Determination of Temperature

Into test tubes labeled 1 – 7 were introduced 10g soils contaminated with different percent concentrations of spent crankcase oil: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5% w/w (oil-soil mixture); and into the 7th tube, the control, 20ml of distilled water was added to 10g soil and mixed thoroughly by hand. The temperature of each sample in the tube was determined in ^{o}C with a thermometer.

2.6. Determination of Moisture Content

Into six Petri dishes were introduced soils contaminated with different percent concentrations of spent engine oil 1.0, 1.5, 2.0, 2.5, 3.0, 3.5% w/w (oil-soil mixture); but into the 7th dish the control, 10g of soil only was added. All the dishes, including the control, were flooded with 10ml of water over time. The weight of the flooded soil was determined. After 24-hour oven drying at 80°C, the percentage of water evaporated was calculated.

2.7. Determination of Total Petroleum Hydrocarbon (TPH)

Total petroleum hydrocarbon content was determined gravimetrically by the method of Osuji and Nwoye (2007), to provide an estimate of the available total hydrocarbon with time. In this procedure, 20ml toluene was added into six test tubes containing different percent concentrations of spent engine oil 1.0, 1.5, 2.0, 2.5, 3.0, 3.5% w/w(oil-soil mixture); and into the 7th tube, the control, 20ml toluene was introduced into 10g of soil. After shaking for 30min, the liquid phase of the extract was measured spectrophotometrically at 420nm. The TPH in the soil was estimated concerning the standard curve derived from fresh spent oil diluted with toluene using the equation $y = 1.094x$; where y = absorbance and x = concentration.

2.8. Statistical Analysis

The results were expressed as mean ± standard error mean (SEM). All results were compared concerning the control. Comparisons between the concentrations and control were made by using Statistical Package for Social Sciences (SPSS) version 20 and Analysis of Variance (ANOVA). Differences at ($P < 0.05$) were considered significant.

3. RESULTS

3.1. Soil Analysis

The physical analysis of the soil revealed a mixture of sandy, clay, and loam soil. Textural characteristics of the soil indicated: sand (80%), clay (4%), silt (2%), as well as tiny stones and other particulates (14%).

3.2. Effect of spent engine oil on soil pH

The pH of the oiled soil is shown in **Table 1**. Relative to the control, there was a progressive reduction in pH which was significant ($p<0.05$) as the concentration of the spent engine oil and its duration of contact increased. Thus, the soil was acidic. The acidity increased from day zero up to day 14^{th} and 28^{th}, and it declined thereafter. Results are expressed as mean ± SEM of seven determinations. This means superscript with the same letter in a row differs significantly ($p<0.05$).

Table 1. pH of the soil polluted with spent engine oil.

%Concentration	pH condition			
	D-0	D-14	D-28	D-35
0.00	7.1±0.00	7.1±0.00	7.1±0.00	7.1±0.00
1.00	7.1±0.00	7.0±0.00	6.8 ± 0.03	6.9 ± 0.00
1.50	7.0±0.03	6.9 ± 0.03	6.7 ± 0.03	6.9 ± 0.03
2.00	6.9 ± 0.00	6.8 ± 0.03	6.6 ± 0.03	6.9 ± 0.00
2.50	6.9 ± 0.00	6.8 ± 0.03	6.5 ± 0.03	6.8 ± 0.03
3.00	6.7 ± 0.03	6.6 ± 0.03	6.4 ± 0.03	6.8 ± 0.05
3.50	6.6 ± 0.03	6.5 ± 0.05	6.2 ± 0.00	6.8 ± 0.03

3.3. The Temperature of the Soil Polluted with Spent Engine Oil

There was a significant ($p<0.05$) increase in the temperature of the soil. Relative to the control, the soil temperature increased in a concentration and time-dependent manner up to day-28 and declined thereafter on day-35 as shown in **Table 2**.

Table 2. Temperature of the soil polluted with spent engine oil.

%Concentration	Temperature (°C)			
	D-0	D-14	D-28	D-35
0.00	33.0 ±0.00	33.0 ±0.00	33.0 ±0.00	33.0 ±0.00
1.00	33.0 ±0.00	33.2 ±0.03	33.5 ±0.03	33.0 ±0.00
1.50	33.0 ±0.00	33.2 ±0.03	33.8 ±0.03	33.0 ±0.00
2.00	33.0 ±0.00	33.2 ±0.03	34.0 ±0.03	33.0 ±0.00
2.50	33.0 ±0.00	33.5 ±0.03	35.0 ±0.33	33.0 ±0.33
3.00	33.0 ±0.00	34.0 ±0.33	35.0 ±0.33	33.5 ±0.03
3.50	33.2 ±0.00	34.0 ±0.06	35.5 ±0.03	33.5±0.06

3.4. The moisture content of the oil-impacted soil

The oiled soil was characterized by high moisture content. Relative to the control, at each concentration of the contamination, there was a significant increase ($p<0.05$) in moisture content which declined over time as shown in **Table 3**.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

Table 3. Moisture content of the oil-impacted soil.

%Concentration	Temperature (°C)			
	D-0	D-14	D-28	D-35
0.00	3.5±0.00	2.81±0.00	2.00±0.00	0.50±0.00
1.00	6.34±0.00	5.98±0.00	4.52±0.01	3.25±0.00
1.50	8.83±0.00	8.01±0.00	7.87±0.00	4.99±0.00
2.00	11.62±0.00	10.55± 0.01	9.8±0.03	6.31±0.00
2.50	15.24±0.00	14.16±0.01	13.45±0.00	11.02±0.01
3.00	19.25±0.0	17.80±0.01	15.91±0.01	13.64±0.00
3.50	24.24±0.00	21.00±0.01	19.31±0.01	17.80±0.01

3.5. Total petroleum hydrocarbon (TPH) of the oil-polluted soil

Following the insult, there was a synergistic increase in total petroleum hydrocarbon (TPH). Relative to the control, at each concentration of the contamination, there was a significant ($p<0.05$) increase in TPH which declined over time as presented in **Table 4**.

Table 4. Total petroleum hydrocarbon (TPH) of the oil-polluted soil.

%Concentration	TPPH			
	D-0	D-14	D-28	D-35
0.00	0.002±0.00	0.000±0.00	0.000±0.00	0.000±0.00
1.00	0.027±0.00	0.023±0.03	0.015±0.03	0.010±0.00
1.50	0.037±0.00	0.033±0.03	0.019±0.03	0.014±0.03
2.00	0.053±0.00	0.040±0.03	0.035±0.03	0.024±0.03
2.50	0.071±0.00	0.056±0.03	0.048±0.03	0.026±0.03
3.00	0.092±0.00	0.080±0.03	0.064±0.03	0.028±0.03
3.50	0.126±0.00	0.092±0.03	0.084±0.00	0.037±0.03

4. DISCUSSION

Contamination of the natural environment with petroleum-derived compounds poses an extremely serious problem; and in this study, spent engine oil has been shown to have adverse effects on the soil ecosystem. It adversely affected the physicochemical status of the soil which included; destruction of the soil texture, alteration of soil hydrogen ion concentration (pH), alteration in the water holding capacity, and temperature. Above all, spent engine oil altered the entire soil biochemistry. These findings are in tandem with the work of Okolo *et al*. (2005), Jidere and Akamigbo (2009), Ebere *et al*. (2011).

From the investigation, the positive correlation between the pH of the soil and the amount of spent engine oil added may be an implication that spent oil pollution led to a reduction in soil pH. Spent engine oil caused a reduction in soil pH in a concentration and time-dependent manner. This could be attributable to the microbial metabolism of the hydrocarbon present in the oil, which consequently gave rise to the production of organic acids. This is replete with the report of, Osuji and Nwoye (2007), Osam *et al*. (2013). This increase in acidity would likely affect plant growth, microbial succession, and metabolism. Soil pH governs the rate and extent of microbial metabolism of the added petroleum hydrocarbons.

The rise in temperature of the oil-impacted soil in this study relative to the control as a result of various biochemical reactions taking place in the affected soil. Akubugwo *et al*. (2007) reported a similar increase in temperature where the degradation of the mangrove of

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

the soil ecosystem exposed to oil spillage, and the blackness of the oil attracts the intensity of sunlight thereby contributing to a rise in temperature.

In this study, the high moisture content recorded at increased concentrations of contaminations over time during the experiment could be unhealthy for microbial activity. The excess moisture found in the oil-saturated soil which is attributable to the formation of oil scum on the soil surface is undesirable because it creates hypoxic conditions. The oil film prevents aeration and water infiltration into the subsoil layers. Lack of water and oxygen could be detrimental to life in the soil (microbial community) as it creates oxygen tension, hinders gaseous diffusion, and reduces the amount of oxygen available for aerobic microbial respiration. This probably aided the persistence of oil and moisture on the surface. The result of the physicochemical properties of the affected soil agrees with what Osuji and Onojake (2004), Osam *et al*. (2013) reported for oil spills on soils in Niger Delta. They reported low permeability value for hydrocarbon-contaminated soils than in uncontaminated areas.

The intense infusion of degradable hydrocarbon witnessed in this work following exposure of the soil ecosystem to spent engine oil would have likely stimulated aerobic and anaerobic microbial metabolism; and so, as oxygen became limiting, utilization of alternate electron acceptors produced an increased reducing environment. The consequence is a reduction in pH. This report is in harmony with the findings of Osuji and Opiah (2007). A high level of hydrocarbon causes oxygen deprivation and reduction in gaseous diffusion by the surface film of oil, and these usually have far-reaching implications on the flora and fauna and reduced microbial population in the affected soil and hence, soil fertility (Osuji *et al*., 2004).

Aside from the soil fertility problems that are usually associated with the contamination of the soil with spent engine oil such spillage may also be accompanied by many other features such as leaf loss or complete defoliation of the trees from either root or leaf. Thus, it has been known for some time that oils have herbicidal properties and this is prejudicial to our farmlands. High hydrocarbon content in soils has been known to affect soil physicochemical properties, which in turn affect the agricultural potentials of such soils (Ezebuiro, 2004). In other words, there could be reduced productivity over time following the impaired state of soil fertility emanating from the hydrocarbon impact from spent engine oil.

4. CONCLUSION

From the results, it would be concluded that spent engine oil contamination adversely altered the soil properties. Its effect is a function of one and several variables. A disturbed ecological equilibrium as the acidity was increased is prejudicial to our farmlands. The supposed bactericidal effect it would have on the microbial population would be correlated to its herbicidal properties on plants. All these effects have profound importance on the biological status of the soil as they altered the entire soil biochemistry.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

6. REFERENCES

Achuba, F.I. and Peretiemo-Clarke, B.O. (2008). Effect of spent engine oil on soil catalase and dehydrogenase activities. *International Agrophysics*, *22*, 1-4.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951

Akubugwo, E.I., Chinyere, G.C., Ogbuji, G.C. and Nwabia, N.G. (2007). Studies on soil and Rivers in three communities affected by refined oil spillage in Isiukwuato Local Government Area, Abia State, Nigeria. *Biotechnology and Allied Sciences*, *2*, 66-71.

Anoliefo, G.O. and Edegbai, B.O. (2000). Effect of spent engine oil as an oil contaminant on the growth of two eggplant species; *Solanum melongena L*. and *S. incanum*. *Journal of Agricultural Forestry Fisheries*, *1*, 21-25.

Delille, D. and Pelletier, E. (2002). Natural attenuation of diesel-oil contamination in a subantarctic soil (Crozed. Island). *Polar Biology*, *25*, 682–687.

Dominguez-Rosado, R.E. and Pichtel, J. (2004). Phytoremediation of soil contaminated with used motor oil. *Environmental Engineering Science*, *2*, 157-168.

Ebere, J.U., Wokoma, E.C. and Wokocha, C.C. (2011). Enhanced remediation of a hydrocarbon polluted soil. *Research Journal of Environmental and Earth Sciences*, *3*(2), 70-74.

Ezebuiro, P.E. (2004). A review of the effect of oil pollution in West African Environment. *Journal of Environmental Science and Technology*, *3*, 313-320.

Jidere, C.M. and Akanmigbo, F.O.R. (2009). Hydrocarbon degradation in poultry droppings and cassava peels-amended. Typic paleustults in South Eastern Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension*, *8*(1), 24-30.

Odjegba, V.J. and Sadiq, A.O. 2002.Effect of spent engine oil onthe growth parameters, chlorophyll and protein levels of*Amaranthus hybridus* L. *The Environmentalist*, *22*, 23-28.

Osuji, L. C., and Nwoye, I. (2007). An appraisal of the impact of petroleum hydrocarbons on soil fertility: the Owaza experience. *African Journal of Agricultural Research*, *2*(7), 318-324.

Okolo, J.C., Amadi, E.N. and Odu, C.T.I. (2005). Effects of soil treatments containing poultry manure on crude oil degradation in sandy loam soil. *Applied Ecology in Environmental. Research*, 3 (1), 47-53.

Onwurah, I.N.E., Ogugua, V.N., Onyike, N.B., Ochonogor, A.E. and Otitoju, O. F. (2007). Crude oil spills in the environment, effects and some innovative clean-up biotechnologies.*International Journal of Environmental Research*, 1,307-320.

Osam, M.U., Wegwu, M.O. and Ayalogu, E.O. (2013). Soil pH, moisture content and some macro non-metallic elements in crude oil contaminated soils remediated by some wild-type legumes. *International Journal of Engineering Science Invention*, 2, 54-59.

Osubor, C.C. and Anoliefo, G.O. (2003).Inhibitory effect of spent lubrication oil on the growth and respiratory function of *Arachis hypogea* L. *Benin Science Dig*, 1,73-79.

Osuji, L.C. and Opiah, U.C. (2007). Hydrocarbon contamination of a terrestrial ecosystem: the case of Oshire-2 oil spill in Niger Delta, Nigeria. *Springer Science+ Business Media*, 27, 337-340.

Osuji, L.C., Adesiyan, S.O. and Obute, G.C. (2004). Post impact assessment of oil pollution Agbada-west plain of Niger Delta: Field reconnaissance and total extractable hydrocarbon content. *Chemistry and Biodiversity*, *1*, 1569-1578.

Osuji, L.C. and Onojake, C.M. (2004). Trace heavy metals associated with crude oil: A case study of Ebocha-8 oil spill-polluted site in Niger Delta, Nigeria. *Chemistry and Biodiversity*, *1*, 1708-1715.

Osuji, L.C. and Nwoye, I. (2007).An appraisal of the impact of petroleum hydrocarbons on soil fertility: the Owaza experience. *African Journal of Agricultural Resources*, *2*(7), 318- 324.

Palese, A.M., Giovannini, G., Luches, S., Dumonte, S. and Perucei, P. (2003). Effect of fire on soil carbon, nitrogen and microbial Biomass. *Agronomite*, *24,* 47–53.

Sztompka, E. (1999). Biodegradation of engine oil in soil. *Acta Microbiology Polish*, *489*, 185–196.

Wang, X.P. and Bartha, R. (1990). Effects of bioremediation on residues, activity and toxicity in soil contaminated by fuel spills. *Soil Biological Biochemistry*, *22*, 501-505.

Wang, J., Jia, C.R., Wong, C.K. and Wong, P.K., 2000.Characterization of polycyclic aromatic hydrocarbon created in lubricating oils. *Water Air Soil Pollution*, *120*, 381-396.

Wyszkowska, J., Kucharski, J. and Wałdowska, E. (2002). The influence of diesel oil contamination on microorganisms and oat growth. *Rost Vancouver*, *48*, 51-55.

DOI:
p- ISSN 2828-920X e- ISSN 2828-9951