International Journal of Agriculture System
Vol. 13 Issue 1, June 2025
Nationally Accredited Journal Decree No. 177/E/KPT/2024
P-ISSN: 2337-9782, E-ISSN: 2580-6815. **DOI: 10.20956/ijas.v13i1.3950**

Influence of Palm Oil Mill Effluents on Selected Soil Physicochemical Properties and Soil Enzyme Activities

Robert Ikechukwu Uroko[1*], Chinomso Friday Aaron[2], Mercylyn Ezinne Uche[2], Chinedu Aguwamba[3], Paul Chukwuemaka Nweje-Anyalowu[3]

[1] *Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.*
[2] *Department of Biochemistry, Faculty of Biological and Physical Sciences, Abia State University, Uturu, Nigeria.*
[3] *Biochemistry Unit, Department of Chemical Sciences, Faculty of Sciences, Clifford University, Owerrinta, Abia State, Nigeria.*

[*] *Corresponding author's e-mail: ir.uroko@mouau.edu.ng*

How to Cite: Uroko, R.I., C.F. Aaron, M.E. Uche, C. Aguwamba, P.C. Nweje-Anyalowu. (2025). Influence of Palm Oil Mill Effluents on Selected Soil Physicochemical Properties and Soil Enzyme Activities. *Int. J. Agr. Syst. 12*(1): 41-58.

ABSTRACT

Palm oil mill effluent (POME) is applied on cultivated farmlands at various stages by many farmers in southeastern Nigeria with many reporting that it helps to improve crop yield and productivity despite no availability of data to support their claims. This study was therefore designed to investigate the impact of POME on soil physicochemical parameters and soil enzyme activities in soil samples from POME irrigated farmlands. In this study, top and subsoil samples from control farmland unirrigated with POME, dumpsites and 10 m away from POME dumpsites in six different farmlands irrigated with POME labelled A – F were investigated using standard analytical procedures. The results of physicochemical properties of the soils including nitrogen, phosphorus, organic carbon, organic matter, cation exchange capacity and exchangeable cations indicated significant (P<0.05) in topsoil and sub-soils containing POME when compared with their corresponding control1 soils. The lipase activities of topsoil from dumpsites A-E and subsoil 10m away from dumpsite C indicated a significant increase (P<0.05) relative to the corresponding control soils. The effluents caused a significant (P<0.05) decrease in the dehydrogenase and catalase activities of top-soils and sub-soils from each of the dumpsites and 10m away from respective dumpsites when compared with their respective control soils. The findings of this study revealed that the application of POME on soil increases the contents of soil organic carbon, organic matter, exchangeable cations, and cation exchange capacity interfere with enzyme activities.

Keywords:
Cation exchange capacity; exchangeable cations; organic matters; POME containing soils; soil enzymes.

1. Introduction

There is an increasing scarcity of quality irrigation water for agricultural purposes and the reuse of wastewater such as palm oil mill effluents (POME) for irrigation may be a suitable sustainable option as it could aid plants' uptake of wastewater nutrients (Khurana and Singh, 2012). However, wastewater such as palm oil mill effluents may contain many undesirable pollutants and toxic substances that can inhibit the metabolic processes of soil microbes when applied to soils in excess amounts (Belhaj et al., 2014). It has been reported palm oil mill effluents have higher dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil and grease, heavy metals, total volatile solids (TVS), and total suspended solids (TSS) that could affect soil physicochemical properties if discharged untreated (Uroko and Njoku, 2015). Palm oil mill effluents consist of water-soluble components of palm fruits as well as suspended cellulosic materials such as palm fibre, fat, grease, and oil residues (Uroko and Njiku, 2021). The constituents of untreated POME have been reported by many authors to be a colloidal suspension of 95-96% water, 0.6-0.7% oil, and 4-5% total solids including 2-4% suspended solids and a high concentration of organic nitrogen (Ahmad et al., 2003). However, it also contains significant amounts of plant nutrients which include; nitrogen, potassium, magnesium, and calcium (Muhrizal et al., 2006; Uroko and Njoku, 2015). The untreated POME has a very high content of degradable organic matter, which could be partly attributed to the presence of unrecovered palm oil (Ahmad et al., 2003). Untreated POME contains high amounts of fatty acids, proteins, carbohydrates, and other plant materials, which can alter the carbon and nitrogen ratio in the soil (Okwute and Isu, 2007). Oviasogie and Aghimien, in their work, reported that proper use and safe disposal of POME in the land environment would lead to improved soil fertility and contribute to environmental sustainability (Oviasogie and Aghimien, 2002).

Untreated POME is generally regarded as harmful waste that could have a detrimental impact on the environment if it is discharged in its raw form (Rupani et al., 2010). Although many researchers have treated POME using various methods such as filtration and coagulation, the use of sequence batch reactors is the most cost-effective treatment option for treating wastewater and effluents that have COD content ranging from 1,000 mg/L to 5,000 mg/L as it can achieve COD removal efficiency ranging from 91.2 % to 95.6 % (Vijayaraghavan et al., 2017). Ibrahim et al. (2017) have also reported that residual pollutants in biologically treated palm oil mill effluents could be greatly reduced by steam-activated bio-adsorbent from oil palm biomass which could make the treated POME safe to discharge into the environment. Thus, when POME is treated and levels of pollutants in it are significantly reduced, it could be used as alternative irrigation for agricultural purposes without causing environmental deterioration. Wu et al. (2009) reported that biologically treated POME has been widely used in oil palm plantations for irrigation purposes and can be employed as a liquid fertilizer. The richness of POME in vital elements such as nitrogen, phosphorus, potassium, magnesium, and calcium required for effective plant growth and crop yield makes treated POME plays a vital role in improving soil fertility (Muhrizal et al., 2006). The use of POME has been shown to improve soil productivity and increase the yield of crops as well as contribute to better root health by improving the soil structure.

The activities of soil enzymes have been linked to soil fertility status and contributions of soil microbial population toward soil nutrient enrichment and level of contamination of the soil by environmental pollutants (Dick and Tabatabai, 1992). Catalase activity is relatively stable in healthy soil and gives a good reflection of the organic carbon content in the soil which gives good reflection of the soil fertility index (Shiyin et al., 2004). Proper management of POME has been poorly practiced in Nigeria mostly in the South-East as many palm oil mills dispose of their POME in arable land or dump them in pits that could later drain to surface and ground waters. This study investigated the impact of palm oil mill effluents on soil physicochemical parameters and soil enzyme activities.

2. Materials and Methods

2.1 Collection of the soil samples

For this study, soil samples were sourced from six separate palm oil milling sites having common processing methods. The palm oil milling sites include Amurie (site A), Eziisu (site B), Nnerim (site C), Olori (site D), Umudiokpara (site E), and Obeakpu (site F), respectively and were located in Umuaka, Njaba of Imo State, Nigeria. The soil samples were collected in triplicates from the effluent dump-site, 10 m away from the effluent dump-site and an effluent-free dump-site 1 KM from the dump-site, respectively as described by Okwute and Isu, 2007. The soil I KM from effluent-free dump-site was used as the control in line previous reports of Okwute and Isu, 2007. The soils were collected at depths of 0-15 cm and 15-30 cm from the six dumpsites and 10m away from dumpsites respectively. In this study, the palm oil mill effluent dumpsite in Eziisu shown in Fig. 1 serves as a typical example of palm oil mill effluent dumpsites in Umuaka.

Figure 1. Palm oil mill effluent dumpsite in Eziisu.

2.2 Quantification of soil acidity (pH) and Exchangeable Acidity

The soil pH and exchangeable acidity were evaluated following the methods of Ademoroti (2006).

2.3 Determination of Total Nitrogen Content

Total nitrogen content in soil samples was determined using a modified Kjeldified method as with partial modifications outlined by Ademoroti (2006). Nitrogen is usually found mainly in organic form, and varying amounts of ammonium and other forms but this method only evaluate the amounts of available organic and ammonium forms of nitrogen. However, application of potassium sulphate, concentrated Sulphuric acid and heat converts nitrogen to ammonium sulphate which was quantified.

2.3 Determination of Available Phosphorus Content

Available phosphorus content in the soil samples was determined by the Vando-molybdao-phosphoric acido-metric method as described by Ademoroti (2006). When dilute sulphuric acid is added to the soil, available phosphate is released which in the presence of ammonium molybdate and a few drops of $SnCl_2$ gives blue colouration that absorbs maximally at 490 nm wavelength. The absorbance of the resulting mixture at 490 nm is proportional to the concentration of total available phosphate. The phosphorus content was determined in triplicates.

2.4 Determination of Exchangeable Cations

In this study, exchangeable cations including calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) were quantified according to the method of y IITA (1979) partially modified by Agbenin (1995). The Flame Photometer with the help of its sensor electrode which automatically gave the absorbance readings of sodium or potassium relative to the reference metal which could be either sodium or potassium for the scandalization of the analyzer. The concentration of sodium or potassium can be extrapolated from the standard curve of their respective standards. The principle of calcium determination was based on titration of soil leachate in the presence of 10% potassium hydroxide and deionized water against 0.01 N EDTA with a calcine indicator which gives a light orange colour at the endpoint. Magnesium content was evaluated by titration of soil leachate in the presence of ammonium chloride buffer soil (pH 7.0) against 0.01 N EDTA using erichrome black-T indicator that gives a purple colour at the end.

2.5 Estimation of Cation Exchange Capacity (CEC)

Cation exchange capacity was estimated using methods of IITA (1979) as modified by Agbenin (1995).

2.6 Estimation of Soil Organic Carbon and Organic Matter Contents

Organic carbon and organic matter contents were estimated following the methods outlined by Kalembasa and Jenkinson (1973).

2.7 Assay of the Soil Dehydrogenase Activities

Soil dehydrogenase activity was assayed as outlined the assay procedure described by Tabatabai (1982). The principle of the assay was dependent on the ability of soil dehydrogenase to convert 2, 3, 5-triphenyl tetrazolium chloride to a chromogenic product called formazan with a maximum absorption at 485nm wavelength. The absorbance of formazan produced is directly proportional to the soil dehydrogenase activity. The assay was conducted in triplicates (n = 3).

2.8 Assay of soil catalase activity

The catalase activities in the experimental samples were assayed according to the method described by Rani et al. (2004). The assay is based on the ability of catalase to break down hydrogen peroxide, the extent of which was quantified by reacting it with excess potassium tetraoxomanganate (iv) oxide ($KMnO_4$). Residual $KMnO_4$ was measured spectrophotometrically at 480 nm which was proportional to catalase activity. The soil catalase activity was assayed in triplicates.

2.9 Assay of the soil lipase activities

Soil lipase activity was assayed using the method described by Margesin et al. (2002). Soil lipase releases lauric acid from the soil when incubated with Tween 20 and Toluene at 30℃ for 18 hours under agitation. The amount of lauric acid released or neutralized by sodium hydroxide (NaOH) is proportional to lipase activity. The soil lipase activity was assayed in triplicates.

2.10 Statistical Analysis

Statistical Product and Service Solutions (SPSS) version 22 was used to carry out the statistical analysis. A one-way analysis of variance (ANOVA) was carried out, and Duncan's multiple range test was used to separate the differences determined. Significant differences were observed at $P < 0.05$.

3. **Results and Discussion**

3.1 Effects of POME on soil pH and exchangeable acidity

The results in Table 1 indicated the occurrence of the highest (5.33 meq/100g) and least (3.29 meq/100g) levels of exchangeable acidity in the topsoil from sites B and topsoil obtained 10m away from site A dumpsite, respectively, relative to the soil acidity from other sites considered. In contrast, all the subsoils from various sites investigated exhibited considerably lower exchangeable acidity in comparison with the soil. Also, site B topsoil from dumpsite displayed the least pH in KCl compared to the control soil, however, there was no significant variation observed in its pH in distilled water relative to the control. The levels of pH detected in the various soil samples evaluated in this study indicated that the soils are acidic in nature with soils containing palm oil mill effluents and control soils showing varying levels of acidity. Except for the topsoil 10m away from sites B and F dumpsites respectively which exhibited comparable acidity level with the control, there was rise in the topsoil acidity level in comparison with the pH of the control topsoil in distilled water.

Apart from topsoil 10m away from site D dumpsite and topsoil from site B dumpsite that showed more acidity compared to the control topsoil when their pH was determined in potassium chloride solution (KCl), all other topsoil showed lesser acidity compared to the control. All the subsoil showed lower acidity compared to the control in KCl. Only the subsoil 10m away from sites C and E POME dumpsites showed equal acidity with the control while the rest subsoil 10m away from other dumpsites showed slightly lower acidity compared to the control subsoil when their soil pH was determined in distilled water.

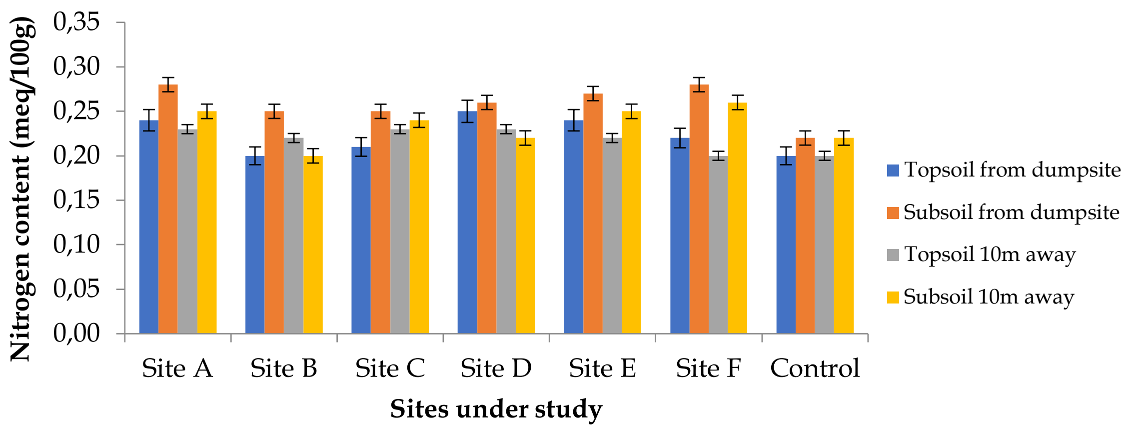
The impact of palm oil mill effluents (POME) on soil physicochemical parameters and soil enzyme activities was investigated. This was to ascertain whether and to what extent the impact of the effluent on soil fertility. The palm oil mill effluents containing soils that have low pH may be attributed to the effect of acidic POME discharged on them in their raw forms. The higher acidity nature of the soil samples may not be attributed to the effects of palm oil mill effluents alone but also previous anthropogenic activities, nature of the soils and possibly due to higher acidic rainfall. Soil samples from various regions of the world associated high levels of acidic rainfall usually possess low pH score making very acidic in nature and may not support the growth of some crops. Most fertile farmlands have their soil pH within 6 – 6.5 which promote nutrient availability and improved crop growth and yield. The growth of acid-loving plants like blueberries, azaleas, and rhododendrons that secrete weak acids into the soil may have also contributed to lowering the soil pH. Thus, in acidic soils, non-acid-loving plants may not grow well, and yields and productivity could be impaired (Joris et al., 2013). The adverse impact of soil acidity on plant growth can be reduced by a lime application which causes, negative charges of the soil exchange complex to be released, and subsequently replaced by Ca^{2+}, $Mg^{2+,}$ and K^{+}, improving the soil fertility and optimizing conditions for crop productivity (Oates and Kamprath, 1983).

Table 1. Soil pH and exchangeable acidity levels of palm oil mill effluents

		Topsoil			Subsoil		
POME Sites	Soil Samples	pH (H_20)	pH (KCl)	Exchangeable Acidity (meq/100g)	pH (H_20)	pH (KCl)	Exchangeable Acidity (meq/100g)
	10m away	5.5	4.9	3.21	5.5	4.5	4.19
Site A	Dumpsite	5.4	4.9	3.29	5.6	4.7	3.61
Site B	10m away	5.6	4.4	4.35	5.4	4.6	4.03
	dumpsite	5.6	4.0	5.33	5.5	4.8	3.45
Site C	10m away	5.2	4.4	4.70	5.3	4.6	4.12
	dumpsite	5.3	4.6	4.12	5.3	4.6	4.12
	10m away	5.2	4.3	4.95	5.7	4.5	4.01
Site D	dumpsite	5.2	4.6	4.21	5.6	4.5	4.10
Site E	10m away	5.4	4.6	4.03	5.6	4.6	3.86
	dumpsite	5.5	4.7	3.70	5.3	4.7	3.87
	10m away	5.6	4.7	3.61	5.7	4.7	3.52
Site F	Dumpsite	5.5	4.6	3.94	5.6	4.6	3.86
Control		5.6	4.4	4.35	5.3	4.3	4.86

3.2 Effects of POME on soil nitrogen contents

There were substantial variations in the nitrogen levels in the soil samples from POME dumpsites in comparison with the nitrogen content in the soil samples 10m outside the dumpsites. Conversely, there was no significant changes observed in the nitrogen concentrations in the dumpsite soil samples and the corresponding control soil sample. Highest amount of nitrogen was observed in POME dumpsite soil samples compared to the amount recorded in the soil samples 10m outside corresponding dumpsites. The subsoil samples 10m outside dumpsites including site A, C, E, and F displayed increased amount of nitrogen level compared to their corresponding topsoil.



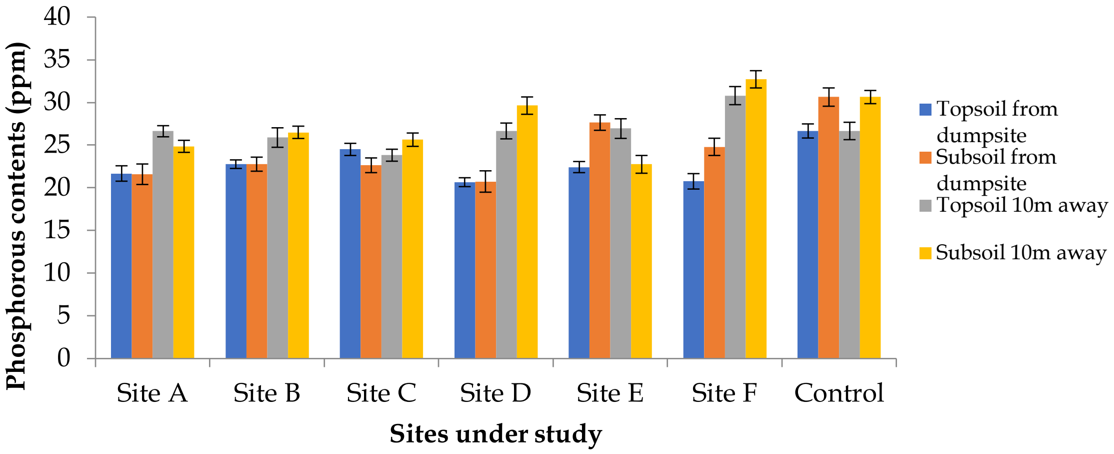
Each bar is expressed as mean ± standard edeviation (n = 3)

Figure 2. Nitrogen contents in soils containing palm oil mill effluents.

The substantial amount of total soil nitrogen in the POME containing soil relative to the soil samples with POME could be associated to the elevated level of nitrogen in POME deposited on the soils (Figure 2). The biodegradable components of the POME when acted upon by microorganisms enrich the soil with nitrogen and thus, improve the soil nutrient content, and fertility potentials. The substantial amount of nitrogen observed in POME containing soils relative to soil samples free of POME is in line with earlier report by Wood (1977), Huan (1987) and Dolmat et al. (1987) respectively that deposition of untreated POME to farmlands increases its total nitrogen content.

3.3. Effects of POME on soil phosphorus contents

The results in Figure 3 indicated marked variations in the phosphorus concentration in the soil samples from POME-dumpsites relative to the phosphorus concentrations measured in the soil samples 10m outside POME-dumpsites and reference soil samples in the study. The phosphorus contents in the topsoil from POME-dumpsites and sub-soils 10m outside POME-dumpsites were significantly ($P < 0.05$) reduced in comparison to the corresponding reference control soil samples. In contrast, the phosphorus contents in the POME-dumpsites E and F were significantly high relative to the phosphorus content in their respective topsoil. The subsoil 10m outside POME-dumpsite F recorded the hight amount of phosphorus content among all the subsoils evaluated whereas, the least concentration of phosphorus was observed in the top and subsoil from POME-dumpsites D compared to all other soil samples evaluated.



Each bar is expressed as mean ± standard deviation (n = 3)

Figure 3. Phosphorus contents in soils containing palm oil mill effluents

The increase in available phosphorus in Soil containing palm oil mill effluents 10m away from POME-dumpsites could be attributed to the washing of POME into the soil by rainfall leading alteration of soil pH which increase phosphorus absorption and retention in the soil. The higher phosphorus content in the POME containing soils is in agreement with the previous findings by Ayodele and Agbola (1981) that lower pH associated with discharge of untreated POME improves phosphorus content in the soil. 1981). Phosphorus is absorbed by plants in the form of $H_2PO_4^-$ at lower pH and HPO_4^{2-} at higher pH (Wood et al., 1979). The phosphorus content in the POME-containing soils were moderately elevated unlike the phosphorus content in the soil sample without POME. This agrees with the findings of Wood; and Huan which respectively showed that high organic matter content in POME contributes to nutrient cycling in soil containing palm oil mill effluents (Wood et al., 1979; Huan, 1987). There is good evidence that suggests that phosphorus is the dominant element controlling carbon and nitrogen immobilization (Paul and Clarke, 1989). The increase in the available phosphorus in the Soil containing palm oil mill effluents suggests a possibly high absorption in the soil or possible precipitation of phosphate (Huan, 1987).

3.4 Effects of POME on soil cation exchange capacity

As shown in Fig. 4, the cation exchange capacity (CEC) in the topsoil and subsoils in all the POME-dumpsites evaluated were significantly (P <0.05) elevated in comparison with the respective control soils. Similarly, there were substantial rise in the CEC of the topsoil from POME-dumpsites and subsoils 10m outside POME-dumpsites in relation to the corresponding control topsoil and subsoil.

The substantial amount of CEC in both the topsoil and subsoils from all the POME-dumpsites relative to the reference soils suggestion that the discharge of untreated POME on farmlands increases its CEC and possibly enhance soil quality and fertility potentials. The elevated CEC in the subsoil from POME-dumpsites are indication that CEC is more prominent in the subsoils than topsoil and thus, suggest that subsoils could be more fertile due to nutrient availability which could promote plant growth and productivity. The elevated CEC in POME-containing soils could be partly linked to the change in pH and degradation of the bioconcstituents of POME deposited on the soils that release various nutrients to the soil on decomposition in line the findings of Oviasogie and Aghimien (2002).

CEC is used to assess the level of negative charges on the surface that could interact with cations such as calcium, potassium, magnesium and sodium and thus the elevated CEC in POME-containing soils suggest that POME-containing soils could effectively maintain a balance of calcium, sodium, magnesium and potassium concentrations in the soils. Soils with balance calcium, sodium, potassium and manesium concentration have been reported to be very fertile and improves crop growth and yield (Sparks, 1995).

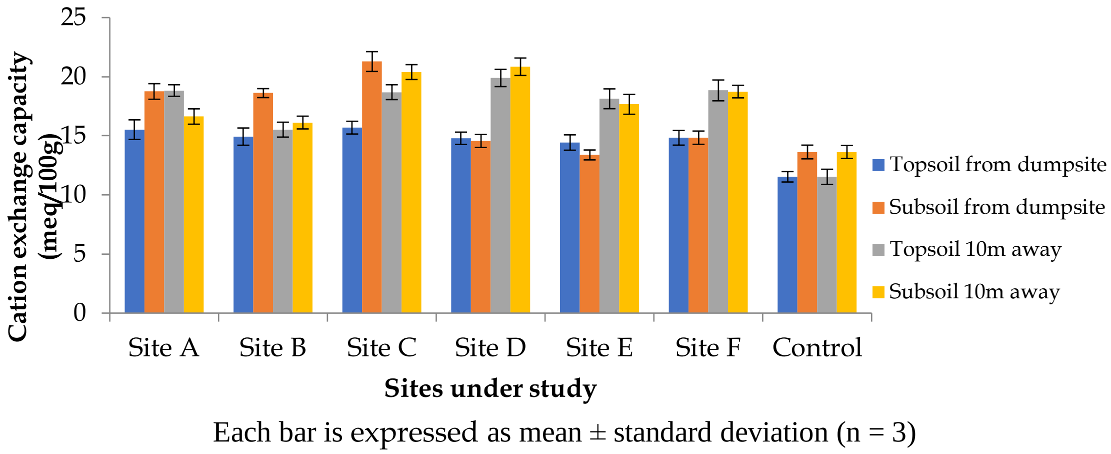
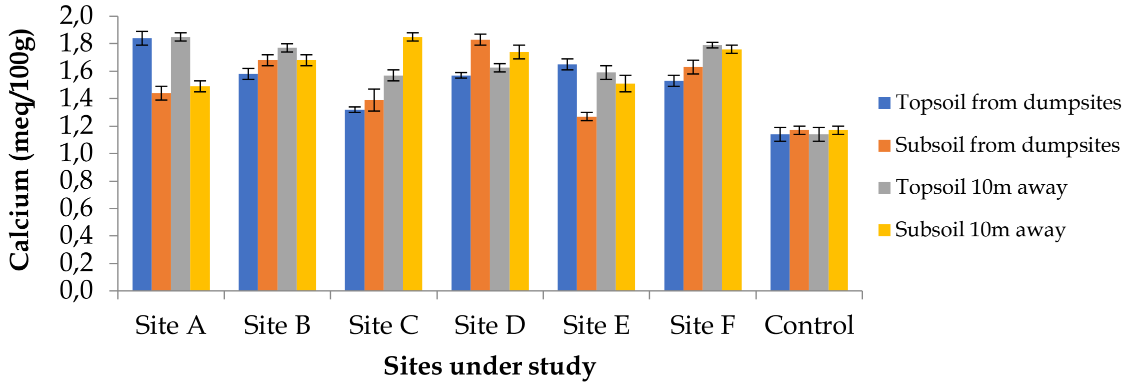


Figure 4. Cation exchange capacity (CEC) in soils containing palm oil mill effluents

3.5 Effects of POME on soil calcium contents

The results in Figure 5 displayed significant (P< 0.05) differences between the calcium concentrations of the soils from POME-dumpsites and soil sample 10m outside the

POME-dumpsites as well as the control soils. The least and highest amount of calcium were observed in the subsoil 10m anf topsoil from POME-dumpsite A compared to the soil samples evaluated. The calcium levels in the subsoils from POME-sites B, C, D, and F were significantly ($P < 0.05$) elevated when compared with calcium levels in their respective topsoil. Conversely, the calcium content in the soil samples from topsoil in POME-dumpsites A and E were significantly raised compared to their corresponding subsoils. The calcium concentrations in the subsoils from POME-dumpsites A, B, E, and F were considerably elevated in relation to the calcium level in the control subsoil.

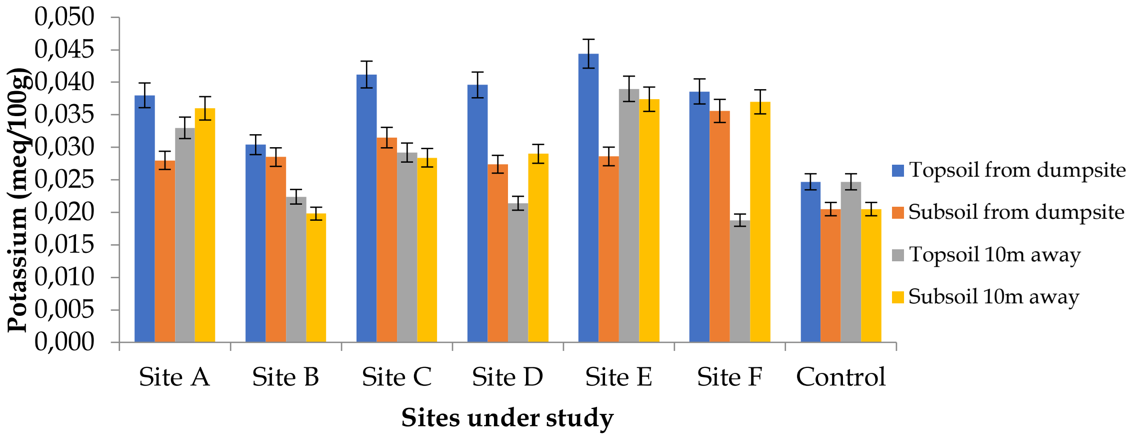


Each bar is expressed as mean ± standard deviation (n

Figure 5. Calcium contents in soils containing palm oil mill effluents

3.6 Effects of POME on soil potassium contents

From the results in Figure 6, considerably increased potassium concentration was observed in all the soil samples evaluated. The concentrations of potassium in the topsoil and subsoil obtained 10m outside the POME-dumpsite B, including topsoil from 10m outside POME-dumpsites D and F indicated no appreciable variations compared to the control topsoil. The was significant potassium enrichment of topsoil from each of the POME-dumpsite compared to their respective subsoil which was similar to the pattern observed in the control topsoil.

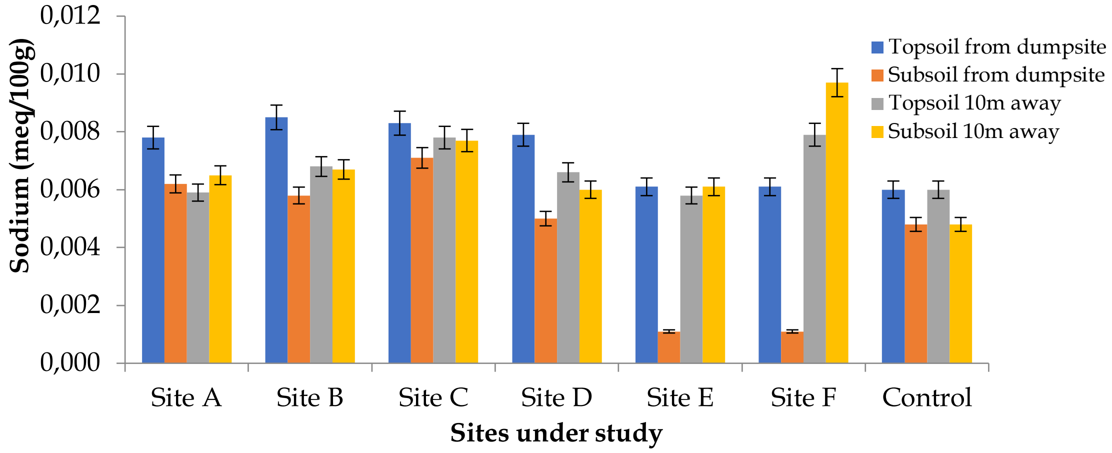


Each bar is expressed as mean ± standard deviation (n = 3)

Figure 6. Potassium contents in soils containing palm oil mill effluents

3.7 Effects of POME on soil sodium contents

The data in Figure 7 indicated a significant (P < 0.05) decline in the sodium concentration in the subsoil from POME-dumpsites E, and D in comparison with the control subsoil. The results indicated that the highest concentrations of sodium occurred in the subsoil 10m outside POME-dumpsite F among all the soil samples evaluated. It was also observed that POME-dumpsites A, B, C, and D showed increased levels of sodium relative to the control topsoil. The topsoil 10m outside POME-dumpsites B, C, and F also exhibited increase sodium content in relation to the control topsoil.



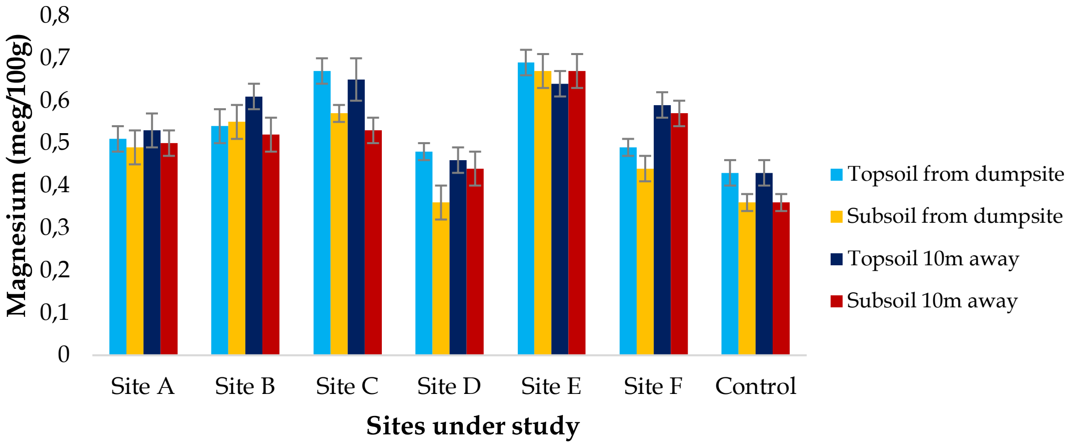
Each bar is expressed as mean ± standard deviation (n = 3)

Figure 7. Sodium contents in soils containing palm oil mill effluents

3.8 Effects of POME on soil magnesium contents

The magnesium concentrations in the subsoil from POME-dumpsite D and subsoil 10m outside POME-dumpsite D were the lowest among the magnesium concentrations assessed from the various soil samples (Figure 8). In contrast, the magnesium concentration observed in the topsoil from POME-dumpsite E and topsoil 10m outside POME-dumpsite E were the highest among all the soil samples evaluated. Also, there was significantly elevated magnesium concentration in the topsoil from POME-dumpsites B, C and E in comparison to the control topsoil. In addition, the magnesium concentrations in the various subsoil 10m outside their corresponding POME-dumpsites were significantly (P < 0.05) elevated relative to the magnesium concentrations in the control subsoil. The findings of the study indicated POME discharge in the farmlands considerably enriched the topsoil and subsoils from POME-dumpsites A, B, C, E, and F with high magnesium content in comparison with the control topsoil and subsoil respectively.

The high levels of calcium, magnesium, and potassium contents in POME-containing soils show the richness of POME-containing soils in nutrients that could improve soil fertility and possibly translate into increased soil productivity. The substantial sodium concentration in topsoil and subsoil from 10m outside POME-dumpsite Fs indicated elevated sodium concentration compared to the sodium concentration in the topsoil and subsoil from its dumpsite possibly due to leaching or erosion that could have washed away sodium to the surroundings of the POME-dumpsite. Sodium ions are rapidly absorbed thereby serving as components of exchangeable cation, which when present in excess could be harmful to plants due its increased ability to negatively alter soil pH, nutrient cycles, and permeability, and soil solution salinity levels. The exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) values in POME-containing soil were considerably elevated relative to the control solils. The finding of the study aligns with the report of Oviasogie and Aghimien (2002) that the discharge of untreated-POME on farmland caused increased exchangeable cations including magnesium content. Our results indicated abundant magnesium, sodium, potassium, and calcium concentrations in POME-containing soils compared to control soil without POME possibly because of the biodegradation of organic matter contained in POME similar to the findings of Lim and P'ng (1983). These findings are in line with the findings of Lim and P'ng (1983) who reported increased exchangeable cation contents in soil samples containing POME.



Each bar is expressed as mean ± standard deviation (n = 3)

Figure 8. Magnesium contents in soils containing palm oil mill effluents

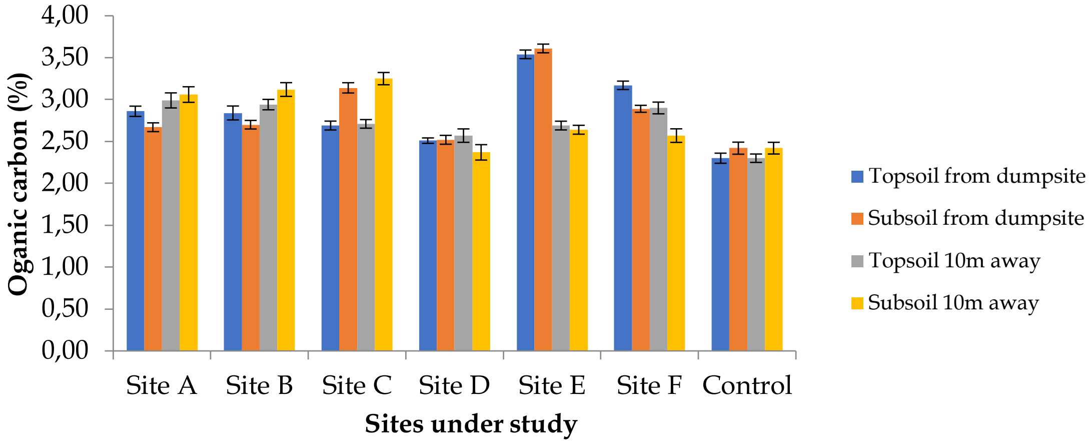
3.9 Effects of POME on soil organic carbon contents

The results in Figure 9 indicated a considerably elevated organic carbon concentrations in each of the soil samples from POME-dumpsites as well as the soil sample 10m outside POME-dumpsites aside soil samples from POME site D that showed organic carbon content relative to the control soils. Significantly ($P < 0.05$) elevated carbon content was observed in the topsoil from POME sites A, B, and respectively in comparison to their corresponding subsoils control the control soil that demonstrated marked rise in the organic carbon concentration relative to the topsoil. The soil samples from POME site E exhibited the high amount of organic carbon among all the soil samples evaluated.

3.10 Effects of POME on soil organic matter contents

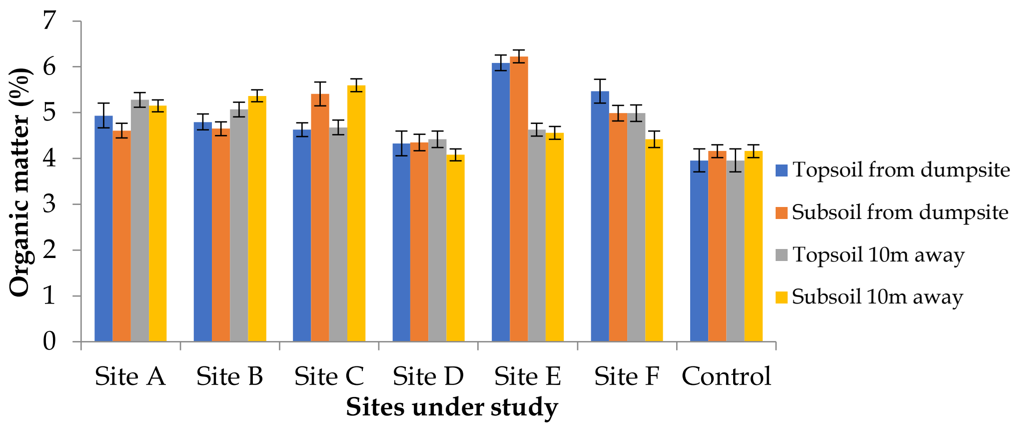
There was marked elevation of organic matter concentrations in both the topsoil and subsoil from each of the POME-dumpsites and 10m outside POME-dumpsites evaluated in relation to their respective control soils (Figure 10). The organic matter concentration in topsoil from POME-site A, B, and E respectively was significantly ($P <0.05$) increased in comparison with their corresponding subsoil contrary to the control soil in which the subsoil demonstrated organic matter concentration relative to the topsoil. Soil samples from POME-dumpsite D and 10m outside POME -dumpsite D exhibited the lowest amount organic carbon among all the soil samples whereas, soils sample from POME-dumpsite E showed the highest organic matter enrichment compared to every other soil sample evaluated.

The substantially elevated organic carbon (OC) and organic matter (OM) in the different soil types from 10m outside each of the POME-dumpsites suggest that most of the organic constituents of POME were gradually washed to the farmlands surrounding the dumpsites possibly by leaching via rainfall and erosion. Similarly, the increased OC and OM concentrations in the topsoil from POME-dumpsites A, B, and F respectively could be associated the bioconstituents in the POME that were consistently discharged in the dumpsites. Increased organic matter concentrations in soils have associated with increased fertility properties via enhanced nutrient availability, soil composition and structure, water holding capacity and detoxification heavy metals in the soil in line the report of (Deiana et al., 1990). The elevated organic carbon concentrations in the soil from POME-dumpsites suggest that POME constituents on decomposition promote release more carbon in addition the organic matter added to the soil which align with the earlier report of Okwute and Isu (2007). The enhanced organic matter and organic carbon concentrations in the soil samples from POME-dumpsites and their surroundings observed in this study are in accordance with the findings of Dolmat et al. (1987), and Shamshuddin et al. (1995) that the discharge of untreated POME on farmlands enhances accumulation of both OC and OM in the soil.



Each bar is expressed as mean ± standard deviation (n = 3)

Figure 9. Organic carbon contents in soils containing palm oil mill effluents

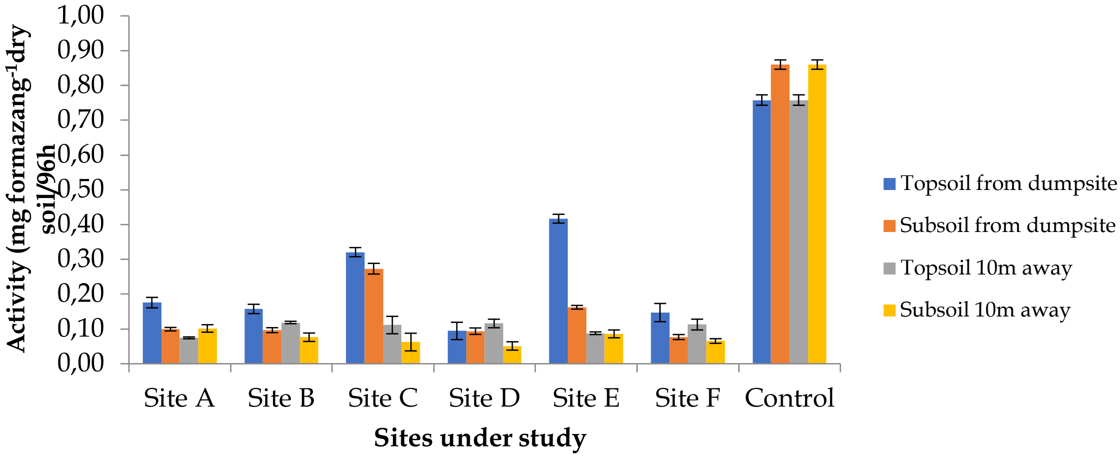


Each bar is expressed as mean ± standard

Figure 10. Organic matter contents in soils containing palm oil mill effluents

3.11 Effects of POME on soil dehydrogenase activities

In Figure 11, the soil dehydrogenase activity in the topsoil and subsoil from each of the POME-dumpsites including 10m outside the dumpsites demonstrated a significant ($P < 0.05$) decline in comparison to the control soil. The decline in the soil microbial activities probably because low oxygen availability to the microbes occasioned by the high oil and grease level in the POME. It was observed that the soil dehydrogenase activities were relative higher in the topsoil compared to their respective subsoil unlike in the control soil.



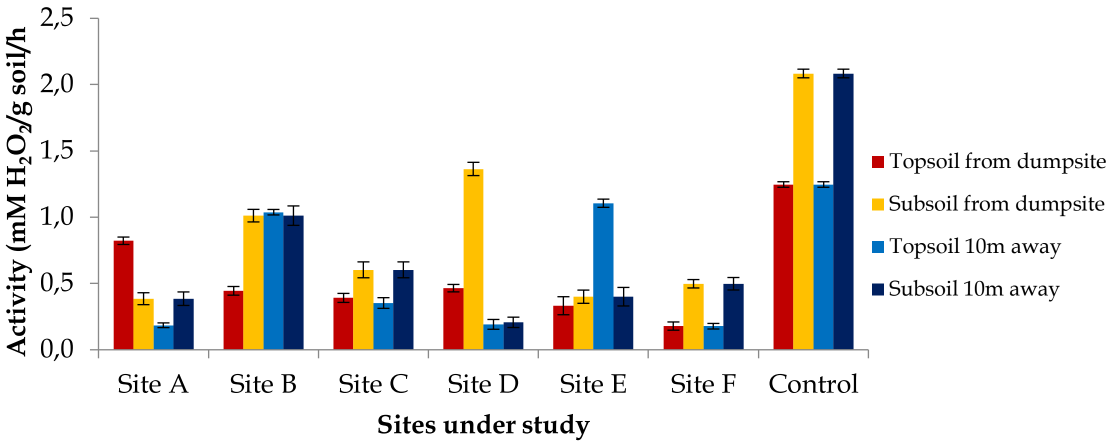
Each bar is expressed as mean ± standard deviation (n

Figure 11. Dehydrogenase activities in soils containing palm oil mill effluents

The significant decrease in soil dehydrogenase activity may be attributed to the chronic exposure of the soil microorganisms to palm oil mill effluent which exposed the organisms' dehydrogenase systems to more acidic POME which could have deactivated some soil enzymes including soil dehydrogenase. The lesser decreases in dehydrogenase activity recorded in the topsoil from POME dumpsites could be probably due to topsoil in dumpsites having improved soil acidity and more viable microorganisms as a result of adaptation to a polluted environment, abundant supply of oxygen, and availability of stabilized enzymes at the topsoil compared to the subsoil. This result agrees with the reports of Garcia-Gil et al. (2000), and Kizilkaya et al. (2004) who worked on the long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass, and the effect of heavy metal contamination on soil microbial biomass and activity respectively. The findings of this study were in accordance with the findings of Uroko and Njoku, 2021.

3.12 Effects of POME on soil catalase activities

The result in Figure 12 indicated significant variations in the catalase activities of the topsoil and subsoil obtained from each of the POME-dumpsites including those from 10m outside the corresponding POME-dumpsites relative to the control soils. There were significantly ($P < 0.05$) elevated catalase activities in the topsoil from POME-dumpsites A, B, C, and D in comparison with the catalase activity of the control soil. The catalase activities in the topsoil from POME-dumpsites E and F respectively showed a significant ($P < 0.05$) decrease in relation to the catalase activity of the control topsoil. There was also, a significant ($P < 0.05$) reduction in the catalase activities in the subsoil from each of the POME-dumpsites and 10m outside in comparison with the catalase activity in the control subsoil. In contrast, there was a significant (P < 0.05) rise in the catalase activity in the topsoil 10m outside POME-dumpsites B, C, and E respectively relative to the control topsoil.



Each bar is expressed as mean ± standard error (n = 3)

Figure 12. Catalase activities in soils containing palm oil mill effluents

The significant changes in the catalase activities in the POME-containing soil samples displayed indicated that prolonged discharge of untreated POME of farmlands affected their soil catalase activity and possibly other soil properties. The alterations in the soil properties including soil pH, depletion of oxygen and increased deposition of heavy metals lead to decline in the soil microbial population and soil microbial activities which could be associated continuous discharge of treated POME on arable land in line with finding of Maila and Cloete (2005). Some of the constituents of POME like heavy metals could have detrimental effects of the soil microbes and soil enzymes activities via denaturation and inactivation thereby causing substantial decline in catalase activity which is in accordance with findings of Moreno et al. (2002). Heavy metals which have been reported to be resented in POME could impair nutrient cycling, microbial community, and catalase activity (Kandeler et al., 2000; Moreno et al., 2002 in the soils and thus reduce soil fertility potentials. The inhibition or impairment of catalase and other soil enzymes activities by the uncontrolled deposition of untreated POME on farmlands, it could affect, crop production, including humans and animal that depend on the farm produce for survival and as such there should be concerted efforts to protect our environment (Adriano et al., 1998; Osuji and Nwoye, 2007).

3.13 Effects of POME on soil lipase activities

It was observed in Figure 13, that there was significantly (P < 0.05) elevated lipase activity in the topsoil from each of the POME-dumpsites in comparison with the control topsoil. In contrast, the subsoil POME-dumpsites A, B, C, E, and F showed significant (P < 0.05) decline in their lipase activity relative to the control subsoil. Topsoil 10m outside POME-dumpsite D exhibited no significant (P > 0.05) variations in lipase activity in relation to the control topsoil. However, there was a significant (P < 0.05) rise in the lipase activity in the subsoil 10m outside POME-dumpsite C in comparison to the control subsoil.

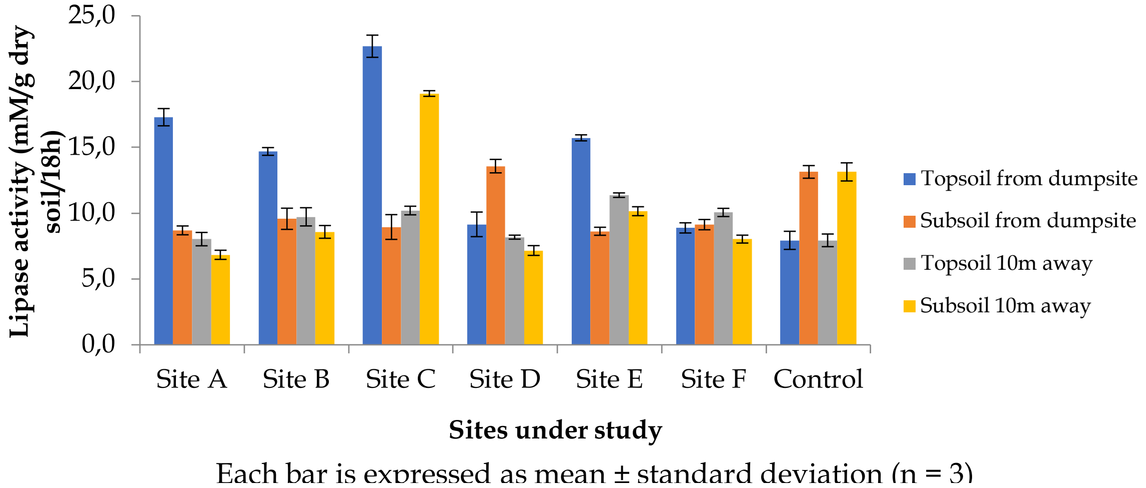


Figure 13. Lipase activities in soils containing palm oil mill effluents

The substantially elevated lipase activity in POME-containing soil suggest that prolong deposition of unprocessed POME in soil samples provided sufficient hydrocarbons as substrates for the soil microbes to metabolize. Availability of lipase substrate for catabolism promote increased lipase due to the sufficient substrate to saturate its active sites leading to enhanced substrate transformation depicted as an increase in lipase activity. The elevated lipase activity could have occurred as result of induction of lipase enzymes and increased translation of mRNA coding for lipase in response to high number of oils and grease, and other hydrocarbons present in the POME deposited on the soil that require lipase assisted degradation. In line with the findings of Margesin et al. (1998) Changes in sol lipase activity have become a viable tool for monitoring the extent of hydrocarbon catabolism and increased soil lipase activity.

4. Conclusion

The findings of this research work show that palm oil mill effluents containing soils were abundantly rich in soil nutrients as they contained high organic carbon, organic matter, exchangeable cations, and cation exchange capacity which could improve soil fertility. However, low soil pH decreased dehydrogenase, and catalase activities observed in POME-containing soils suggest that additional processing of POME was required before discharge on farmlands.

References

Ademoroti, C.M.A. (2006). *Standard Method for Water and Effluents Analysis.* 1st Edition. Foludex Press Limited, Ibadan pp. 3-39.

Adriano, O.C., A. Chopecka, and K.I. Kaplan. (1998). Role of soil chemistry in soil remediation and ecosystem conservation. Soil Science America Special Publication. Madison, Washington D.C p. 361 – 386.

Agbenin, J.O. (1995). Laboratory Manual for Soil and Plant Analysis (Selected Methods and Data Analysis). Faculty of Agriculture/Institute of Agricultural Research, A.B.U. Zaria pp. 7-71.

Ahmad, AL, S. Ismail, and S. Bhatia. (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination,* 157: 87-95. DOI: 10.1016/S0011-9164(03)00387-4.

Ayodele, O.J., and A.A. Agbola. (1981). The relationship between Bray P-1, modified $NaHNO_3$, new Mehlich and NH_4F. HF extractants for Phosphorus in Savanna soils of Western Nigeria. *Soil Society of American Journal,* 45: 462-464 DOI:10.1007/BF01080095.

Belhaj, D., I. Jaabiri, N. Turki, C. Azri, M. Kallel, and H. Ayadi. (2014). Descriptive and multivariable analysis of the water parameters quality of Sfax sewage treatment plant after rehabilitation. *IOSR-JCE,* 16: 81-91. DOI:10.9790/0661-16178191.

Deiana, S., C. Gessa, B. Manunza, R. Rausa, and R. Sebeer. (1990). Analytical and spectroscopic characterization of humic acids extracted from sewage sludge, manure and worm compost. *Journal of Soil Science,* 150(1): 419-426. DOI:10.1097/00010694-199007000-00003.

Dick, W.A., and M.A. Tabatabai (1992). Significance and Potential Uses of Soil Enzymes. In: Blain, F.J. (Ed), Soil Microbial Ecology Application in Agriculture and Environmental Management. Marcel Dekker, New York. Chapter 4 pp. 95-127.

Dolmat, M.T., K.H. Lim, Z.Z. Zakaria, and A.H. Hassan (1987). Recent studies on the effects of land application of palm oil mill effluent on oil palm and the environment. In: Proceedings of International Oil Palm, Palm Oil Conferences (eds.) B. Hj. Abdul Halim, Hassan Chew Poh Soon, B.J. Woond, E. PushParajah 2: 596-604.

Garcia-Gil, J.C., C. Plaza, P. Soler-Rovira, and A. Polo (2000). Long term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. *Soil Biology and Biochemistry,* 32: 1907-1913. DOI:10.1080/00103624.2016.1146749.

Huan, K.L. (1987). Trials on long-term effects of application of POME on soil properties, oil palm nutrition and yields. In: Proceedings of the international oil palm, palm oil conferences (eds.) B. H.J. Abdul Halim, B.J. Hassan Chew Poh Soon, E. Woond. PushParajah industry’s effluent and its environment. *Pakinstan Journal of Science and Industrial Resources,* 45: 10-16.

Ibrahim, I., M.A. Hassan, S. Abd-Aziz, Y. Shirai, Y. Andou, M.R. Othman, A.A.M. Ali, and M.R. Zakaria (2017). Reduction of residual pollutants from biologically treated palm oil mill effluent final discharge by steam activated bioadsorbent from oil palm biomass. *Journal of cleaner production,* 141: 122-127. DOI:10.1016/j.jclepro.2016.09.066.

International Institute for Tropical Agriculture (IITA). 1979. *Selected Methods for Soil and Plant Analysis, Manual Series.* IITA. Ibadan pp. 4-12.

Joris, H.A.W., E.F. Caires, A.F. Bini, D.A. Scharr, and A. Haliski. (2013). Effects of soil acidity and water stress on corn and soybean performance under a no-till system. *Plant Soil,* 365: 409-424.

Kalembasa, S.J., and D.S. Jenkinson. (1973). *Soil Chemical Analysis.* Prentice-Hall Inc., New York pp. 23-25. DOI:10.1007/s11104-012-1413-2.

Kandeler, E., D. Tscherko, K.D. Bruce, M. Stemmer, P.J. Hobbs, and R.D. Bardget. (2000). Structure and function of the soil microbial community in microhabitats of heavy metal polluted soil. *Biology and Fertility of Soils,* 32: 390–400. DOI:10.1007/s003740000268.

Khurana, M.P., and P. Singh. (2012). Waste water use in crop production. A Review. *Resources and Environment,* 2: 116–131. DOI:10.5923/j.re.20120204.01.

Kizilkaya, R., T. Aşkın, B. Bayrakli, and M. Sağlam. (2004). Microbiological characteristics of soils contaminated with heavy metals. *European Journal of Soil Biology,* 40: 95-102. DOI:10.1016/j.ejsobi.2004.10.002.

Lim, C.A., and T.C. P'ng. (1983). Land application of digested POME by sprinkler system. Proceedings of the seminar on land application of oil palm and rubber factory effluent, Serdang.

Maila, M.P., and T.E. Cloete. (2005). The use of biological activities to monitor the removal of fuel contaminants perspectives to monitoring hydrocarbon contamination: A review of *International Biodeterioration and Biodegradation*, 55:1- 8. DOI:10.1016/j.ibiod.2004.10.003.

Margesin, R., A. Zimmerbauer, and F. Schinner. (1999). Soil lipase activity: A useful indicator of oil biodegradation. *Biotechnology Techniques,* 13: 859–863. DOI: 10.1023/A:1008928308695.

Margesin, R., G. Feller, M. Hammerle, U. Stegner, and F. Schinner. (2002). Colorimetric method for determination of lipase activity in soil. *Biotechnology Letters*, 24: 27-33.

Moreno, J.L., C. Garcia, L. Landi, L. Falchini, G. Pietramellara, and P. Nannipieri. (2002). The ecological dose value (Ed_{50}) for assessing cadmium toxicity on dehydrogenase and urease activities of soil. *Soil Biology and Biochemistry,* 33(4-5): 483-495.

Muhrizal, S., J. Shamshuddin, I. Fauziah, and M.A.H. Husni. (2006). Changes in iron-poor acid sulfate soil upon submergence. *Geoderma,* 131: 110-122. DOI:10.1016/j.geoderma.2005.03.006.

Oates, K.M., and E.J. Kamprath. (1983). Soil acidity and liming: Effect of the extracting solution cation and pH on the removal of aluminium from acid soils. *Soil Science Society of America Journal,* 47: 686-689. DOI:10.2136/sssaj1983.03615995004700040016x.

Okwute, O.L., and N.R. Isu. (2007). Impact analysis of palm oil mill effluent on the aerobic bacterial density and ammonium oxidizers in a dumpsite in Anyigba, Kogi State. *African Journal of Biotechnology,* 6(2): 116-119.

Osuji, L.C., and I. Nwoye. (2007). An appraisal of the impact of petroleum hydrocarbons on soil fertility: The Owaza experience. *African Journal of Agricultural Research,* 2(7): 318-324. DOI:10.5897/AJAR.9000036.

Oviasogie, P.O., and A.E. Aghimien. (2002). Macro nutrient status and speciation of Cu, Fe, Zn and Pb in soil containing palm oil mill effluent. *Global Journal of Pure and Applied Science,* 9(1): 71-80. DOI: 10.4314/gjpas.v9i1.15982.

Paul. E.A. and, F.E. Clarke. (1989). Soil Microbiology and Biochemistry. Academic Press Incorporated San Diego, California pp. 11-234.

Rani, P., U.K. Meena, and J. Karthikeyan. (2004). Evaluation of antioxidant properties of berries. *Indian Journal of Clinical Biochemistry,* 19(2): 103-110. DOI:10.1007/BF02894266.

Rupani, P.F., P.S. Rajeev, M.H. Irahim, and N. Esa. (2010). Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice. *World Applied Science Journal,* 11: 70–81.

Shamshuddin, J., I. Jamilah, and J.A. Ogunwale. (1995). Formation of hydroxyl-sulfates from pyrite in coastal acid sulfate soil environments in Malaysia. *Soil Science and Plant Analysis,* 26(17-18): 2769-2782. DOI:10.1080/00103629509369486.

Shiyin, L., N. Lixiao, P. Panying, S. Cheng, and W. Liansheng. (2004). Effects of pesticides and their hydrolysates on catalase activity in soil. *Bulletin of Environmental Contamination and Toxicology,* 72: 600-606. DOI: 10.1007/s00128-004-0286-3.

Sparks, D.L. (1995). *Environmental Soil Chemistry*. Academic Press. San Diego p. 267.

Tabatabai, M.A. (1982). Soil enzymes. In: Methods in soil analysis, part 2, Wisconsin. American Society of Agronomy. *Journal of Soil Science,* 27: 903-947. DOI:10.2134/agronmonogr9.2.2ed.

Uroko, R.I., and O.U. Njoku. (2015). Chemical study of fresh and fermented palm oil mill effluents (POME) as an alternative source of improving soil fertility. *Nigerian Journal of Biochemistry and Molecular Biology,* 29(2): 58-67.

Vijayaraghavan, K., D. Ahmad, and M. Ezani Bin Abdul Aziz. (2017). Aerobic Treatment of Palm Oil Mill Effluent. *Journal of Environmental Management,* 82:24–31. DOI:10.1016/j.jenvman.2005.11.016.

Wood, B.J., K.R. Pilai, and J.A. Rajaratnam. (1979). Palm oil mill effluent disposal on land. *Journal of Agricultural Wastes,* 1: 103-127. DOI:10.1016/0141-4607(79)90046-5.

Wu, TY, A.W. Mohammad, J.M.D. Jahim, and N. Anuar. (2009). Palm oil mill effluent (POME) treatment and bioresourcees recovery using ultrafiltration membrane: Effect of pressure on membrane fouling. *Biochemical Engineering Journal,* 35: 309-317 DOI:10.1016/j.bej.2007.01.029.

Uroko, R.I., and O.U. Njoku. (2021). Ecological and human health risks assessment of heavy metals in vegetables grown in palm oil mill effluents irrigated farmland. *Journal of Applied Research in Water and Wastewater*, 8 (2): 140-149.