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Palm Oil Mill Effluent Disposal and Its Utilization in Agricultural 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.

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ABSTRACT

In the study, soil samples were impacted with 10%, 50% and 100% (v/w) of the palm oil mill effluents. Soil physicochemical properties, soil stress marker enzymes, soil bacteria populations were studied using standard methods. Analysis of the physicochemical properties of the Palm oil mill effluent (POME) showed that POME in the presence of the reference showed the following: pH, conductivity, BOD_5, TDS, TSS, TS at 5.67 $\pm 0.014^a$, 610 ± 0.023^c , 4.87 ± 0.025^b, 372.1 ± 0.015^c , 539.55 ± 0.04^a, 911.6 ± 0.032^b mg/ml, respectively dissolved mineral such as Magnessium (Mg), potassium (K), calcium (Ca) and phosphate (PO_3) were recorded at 9.82 ± 0.05^b , 14.52 ± 0.05^a, 13.23 ± 0.04^c and 8.69 ± 0.01^{bc} mg/ml respectively. Total organic carbon and organic matter contents were recorded at 81.87 ± 0.01^a and 100.7 ± 0.02^c mg/ml respectively. Organismal proliferation increase as the percentage of the POME per gram of the soil increase from 10-50% (v/w) while a downturn in the organismal counts decreases significantly at 100% (v/w). There was a noticeable decrease in the coliform counts/g of the organisms as the incubation days increases from day 0-14. Enzyme activity relatively decreases as the contaminant concentrations increases from 0-100 v/w.

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Lipases activity was seen relatively low in all the soil at low concentrations of the effluents (0-50 v/w). At high concentrations of the effluents, there was a significant increase in the enzyme activity. POME can be utilized as sustainable source of organic agro fertilizer when quantified; however poor incentive by peasant farmers may lead to abysmal utilization of the waste water and its negative impact in the soil with aftermath of low soil fertility and poor agricultural productivity.

Keywords: Impact; POME; physicochemical; stress enzymes; organismal proliferation.

1. INTRODUCTION

Improved agricultural productivity is evident of uncompromised soil in experimented fertility indices; which largely depends in the bioavailability of minerals in the soil for cultivated crops utilization. Local agriculturists within the tropics are in search of cheap organic facilities for improvement of their crop yield after hard peasant cultivation process. However non proper guide on the facility utilizations reversely affect the fertility of the soil and in turn crop yield. The present study brings to the fore an efficient bio-technique of improvement of soil fertility through increasing the concentration of ions ordinarily under chelation due to the presence of certain organic compound(s). "Waste water is one of the crucial sources of pollution in terrestrial and water body" [1]. Industry including those of inorganic and organic bias in utility is of economic importance in terms of their impact on the environment.

"Nowadays, the palm oil business is developing rapidly and transforming into an imperative agriculture-based industry in these two countries. The numbers of palm oil processing factories have increased generally, with a minute strength of 10 plants in 1960 to 1600 operating mills in 2018 in Nigeria. While the palm oil industry has been perceived emphatically for its commitment toward monetary development and quick improvement, it has additionally added to environmental pollution because of the creation of huge amounts of by-products during the process of oil extraction" [2,3-5].

"Palm oil mill effluents are waste accruing from processing of raw palm to finished red oil" (Okwaye et al*.*, 2013), [6]. "At least 44 million tons of POME was produced and are expanding each year in Nigeria, especially as a result of the activity of the legislature to advance the palm oil industry" (Aziz, 2017). "The wastewater from this processing industry and other domestic sources are generally polarize and may contain toxic pollutants. It contains acids, bases, toxic materials, and matter high in biological oxygen demand, color, and low in suspended solids" [1].

The continual increase in the number of these industries in Nigeria has predisposed the surrounding biosystem with various noxious contaminants accruing from the activities of these industries [7]. The enroute path of this danger potential contaminants include the: soil, air, water and the surrounding biotic flora and fauna [8,9].

Compromised implementation of stringent standards and development of management techniques by environmentalist for the disposal of wastes into the environment has necessitated the need for the development of alternative waste treatment process [1].

Exploit by subsistence farmers within the local region in the utilization of this effluent as myth of supplementing nutrients to the soil have been overage; lack of quantification and unseasoned flocculation of the soil have impacted on the fertility of the soil for agricultural activities [10]. The present study looks into the various fertility indices of soil affected by this unguided effluent usages by farmers.

2. MATERIALS AND METHODS

2.1 Materials

Materials including those of equipments, apparatus and reagents utilized during the course of the present study were of products of designated companies (BDh, Bristol, May and Bakers); they were calibrated at each use and in good working condition. The reagents were analytical graded and properly stored.

2.2 Methods

The present study adopted experimental design.

2.3 Sample Collection

Palm oil mill effluents (POME) collection: Palm oil mill effluents were collected from palm fruit milling center located at Awka South, Anambra State, Nigeria. The sampling was conducted by 6.00am as described by Ezenwelu et al. [11]. The collected effluent in clean sample bottles was acclimatized before subjecting to physicochemical analysis.

Determination of physicochemical properties of the effluent: POME collected from the milling ditch after acclimatization was subjected physicochemical analysis as described by ATSDR [12]. Parameters such as: pH, temperature, dissolved oxygen/biochemical oxygen demand counts, total dissolved solids, total solids, total suspended solids, total oxidizable carbon, total organic matter, mineral concentrations, conductivity were evaluated in mg/l.

Contamination of soil samples at different concentrations of POME: Soil sample 50g from an agricultural garden was impacted with 0, 10, 50 and 100% of POME as described by Vallero [13]. The impacted soils were incubated at 30°C for 36 hours.

Assessment of microbial diversities in the POME impacted soil: Organismal proliferation in the soil sample impacted with various concentration of POME was analysed; total coliform and organisms identification was carried out as described by Ezeonu et al.[14].

Assessment of stress marker enzymes in the contaminated soil: Stress marker enzymes responses in the impacted soil with POME analysed include: Catalase, peroxidase, urease and lipase. They were assayed using standard biochemical assay techniques as described by: Haluk et al. [15], Eze et al. [16], Okwaye et al*.* (*2*010); Douglas & Bremner [17], respectively.

3. RESULTS

Fig one below showed a typical discharge site of palm oil mill effluent in a local community within the South East region of Nigeria. The pictorial view shows packed heightened layers of POME submerged on each other after a long period of time. Aesthetically, there were observable awful view of the site, logging of the agricultural soil and possible breeding of pathogenic organisms through cross specie interactions within the environment.

From the Table 1, POME showed significant properties different from the control experiment in the following parameters; pH, conductance, dissolved oxygen, BOD_5 , total solids, suspended solids and dissolved solids, total oxidizable carbon and organic matter contents while certain selected minerals like chloride, Mg/Ca showed alike significant variation at $p<0.05$.

Image 1. An aerial view of lined ditches containing effluents from palm oil milling centre

Table 1. physicochemical properties of POME/reference

Physiochemical Factors	Control	POME Impacted Soil
pH	7.78±0.05[b]	5.67 ±0.014[a]
CONDUCTANCE	423±0.01[b]	610±0.023[c]
Magnesium (Mg) (mg/ml)	12.28±0.04[ab]	9.82±0.05[b]
Dissolved oxygen (mg/ml)	7.21±0.05[b]	6.31±0.03[b]
BOD_5 (mg.ml)	2.10±0.01[a]	4.87±0.025[b]
Potassium (K) (Mg/ml)	8.30±0.02[b]	14.52±0.05[a]
Total dissolved solid content (TDS)	258.03±0.05[a]	372.1±0.015[c]
Total chloride (Cl-) (Mg/ml)	334.8.89±0.034[b]	1151.614±0.05[a]
Phosphate ($P0_3$-) (Mg/ml)	7.23±0.032[ab]	8.69±0.01[bc]
Total suspended solid content (TSS)	396.07±0.02[b]	539.55±0.04[a]
Total solid contents (TS)	654.1±0.04[c]	911.6±0.032[b]
Calcium (Mg/ml)	18.33±0.01[b]	13.23±0.04[c]
Total organic matter content (TOM) (Mg/ml)	24.88±0.04[a]	100.7±0.02[c]
Total organic carbon contents (Mg/ml)	20.33±0.14[b]	81.87±0.01[a]

N=3 SD= standard deviation

3.1 Microbial Analysis

Microbial diversities and their proliferation progressions in the contaminated soil in respect to the control experiment. From the tables, organisms coliform number in the impacted soils increases as the incubation days increase from 0-14 days on the interval of 7 days; however the coliform number were seen slightly high when compared to the reference experiment.

3.2 Stress Enzyme Responses

Stress marker enzyme responses in the impacted soil samples with different concentrations of POME showed enzyme activity relatively decreases as the contaminant concentrations increases from 0-100 v/w. Lipases activity was seen relatively low in all the soil at low concentrations of the effluents (0-50 v/w). At high concentrations of the effluents, there was a significant increase in the enzyme activity. Peroxidase and catalase activity was significant at ambient effluent concentrations but was attenuated at high treatment (100%) of the soil with effluent from petroleum hydrocarbon. Peroxidase showed significant activity in all the sampled soils impacted with POME (0-100 % v/w). It was so seen from the result that enzyme activities assayed were relatively high when compared with the control experiment.

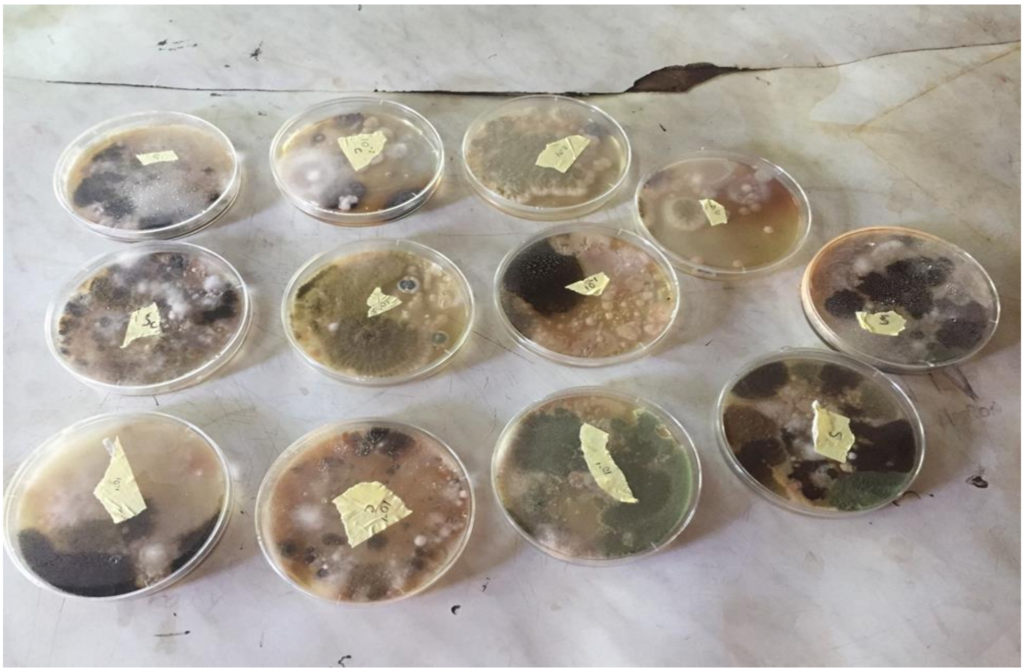

Fig. 1. Soil microbial load from the polluted soil with petroleum hydrocarbons

Table 2. Total coliform counts (CFU/g) of bacteria population

Soil samples	**Control**			**10%**			**50 %**			**100%**		
	Day 0	**Day 7**	**Day 14**	**Day 0**	**Day 7**	**Day 14**	**Day 0**	**Day 7**	**Day 14**	**Day 0**	**Day 7**	**Day 14**
Soil sample I	$2.6 X 10^3$	$1.2 X 10^2$	$2.7 X 10^2$	$7.02 x10^4$	$2.30 x10^4$	$2.7 x10^3$	$4.5 x10^4$	$1.6 X 10^6$	$0.6 x10^3$	$9.1 x10^3$	$1.30 x10^2$	$1.3 x10^1$
Soil sample II	$2.6 X 10^3$	$1.2 X 10^2$	$2.7 X 10^2$	$8.2 x 10^3$	$2.39 x 10^4$	$1.6 x 10^4$	$3.5 x 10^4$	$2.8 x 10^7$	$1.2 x 10^3$	$5.8 x 10^3$	$1.21 x 10^2$	$2.4 x 10^1$
Soil sample III.	$2.6 X 10^3$	$1.2 X 10^2$	$2.7 X 10^2$	$3.5 x10^4$	$3.4 x 10^4$	$4.1 x 10^4$	$1.65x10^5$	$4.2 X 10^6$	$0.4 x 10^4$	$2.21 x 10^4$	$1.02 x 10^2$	$3.9 x 10^1$

CFU/= coliform unit per gram of the soil.

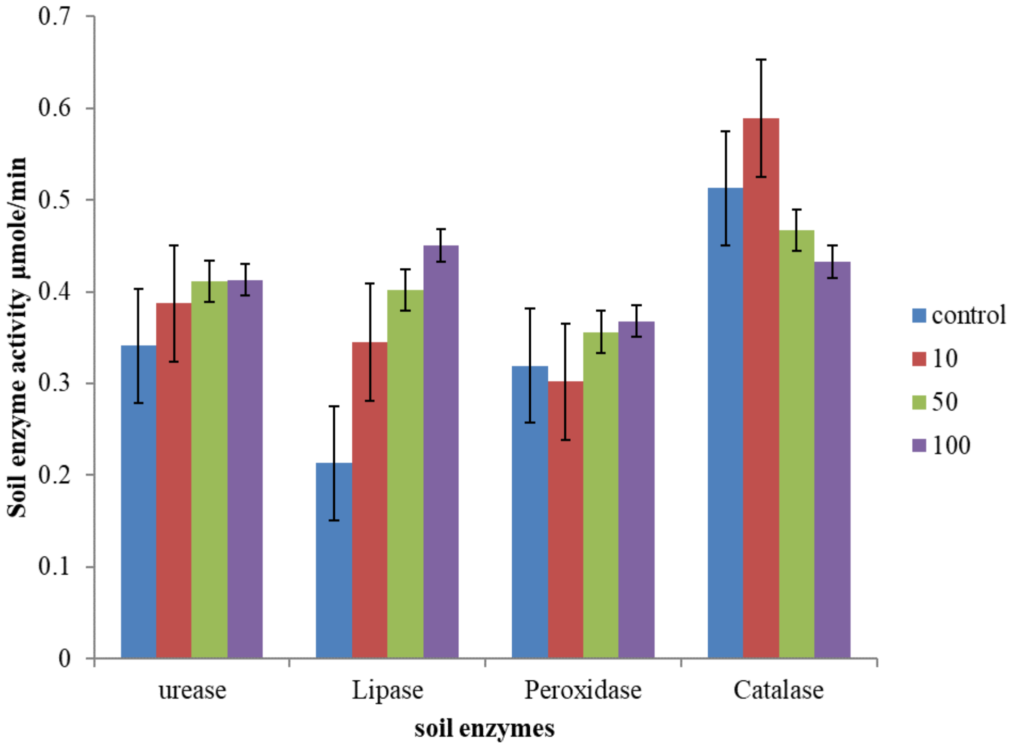

Fig. 2. Soil quality marker enzymes at day 0 of the contamination

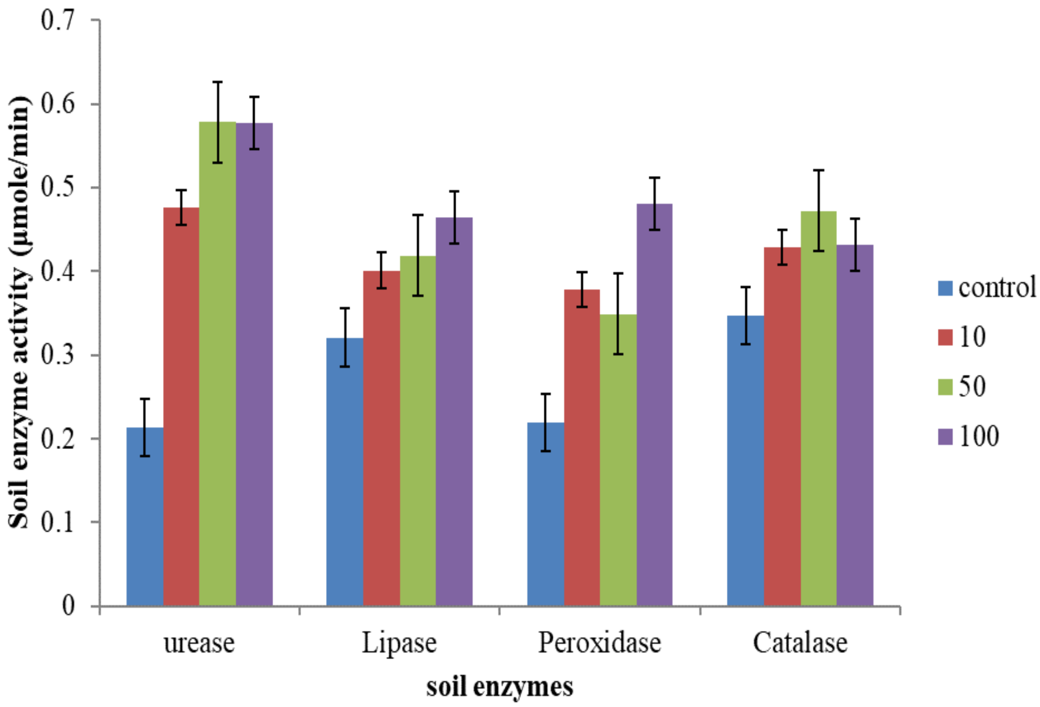

Fig. 3. Soil quality marker enzymes at day 7 of the contamination

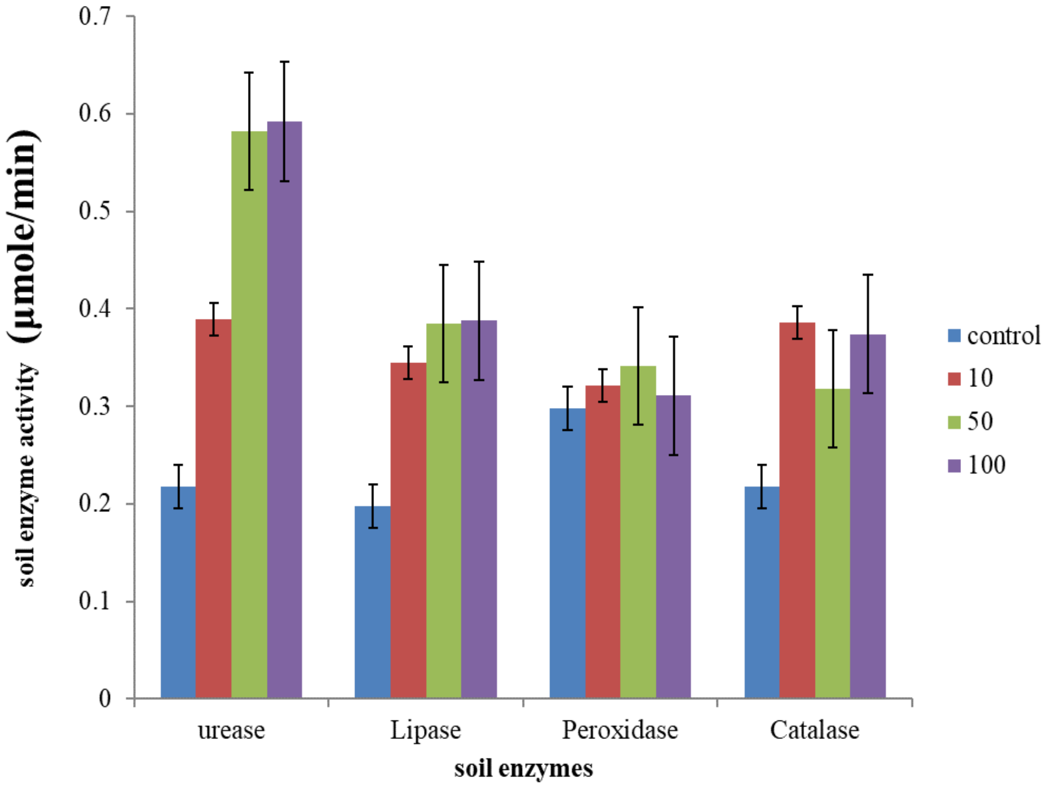

Fig. 4. Soil quality marker enzymes at day 14 of the contamination

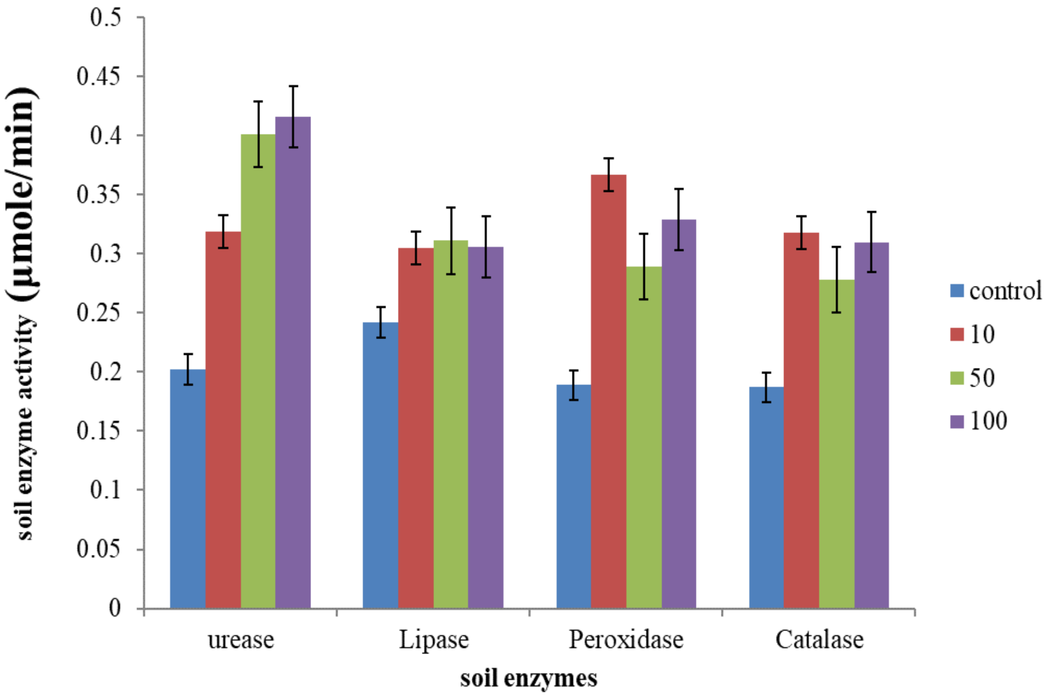

Fig. 5. Soil quality marker enzymes at day 21 of the contamination

4. DISCUSSION

POME accruing from palm oil milling process within various tropical areas in the country has recently attracted the attention of eco-toxicologist and concerned environmentalists for mitigate on the sides effects of these discharges to the soil and surrounding bodies viz: water bodies. Having shown from various literatures the composites of the liquid discharge; the present study through experimental approaches analysed its impact on soils and its selected fertility indices.

Fig one below show the aerial view of an agricultural soil impacted with POME; from the picture, the soil have been receiving the discharged over a prolonged time which have destroyed the structural profile of the soil and evidently on its fertility when analysed. Mosumola and Olatunde (2020) stated that POME increases the textural elasticity of an agricultural soil evidently on its impact in retention of water on the surface of the soil while decreasing its permeability through the soil.

Analysis of the physicochemical properties of the POME showed that POME in the presence of the reference showed the following: pH, conductivity, BOD_5, TDS, TSS, TS at 5.67 ±0.014[a] , 610±0.023[c] , 4.87±0.025[b], 372.1±0.015[c] , 539.55±0.04[a], 911.6±0.032[b] mg/ml, respectively dissolved mineral such as Mg, K, Ca and PO_3 were recorded at 9.82±0.05[b] , 14.52±0.05[a], 13.23±0.04[c] and 8.69±0.01[bc] mg/ml respectively.

Total organic carbon and organic matter contents were recorded at 81.87±0.01[a] and 100.7±0.02[c] mg/ml respectively. The results represented in the table showed significant different when compared reference sample except for some parameters like phosphate. Acidity of the POME when compared with the control (7.78±0.05[b]) can be attributed to insitu free fatty acids (palmitate) present in the yellow effluent which in turn decreases the pH of the effluent by increasing the amount of hydrogen ions $[H^+]$ available for geochemical cycle (Valero, 2010).

Conductivity of the effluent was seen high than the control experiment owing the presence of mineral and other ions in the soil thus increasing their chances of ion exchangeability. The present study correlates with findings of Mosumola and Olatunde (2020) which reported a pH of 4.31 in their study on physicochemical properties of POME and its impact on agricultural soil.

Divalent metals Ca/Mg relatively low in abundance in the POME can be attributed to the chelating effect of the POME to elements especially earth metals, thus diminishing their bioavailability to the soil. It can be recalled that Ca especially as an alkali earth metal is rich in most biological samples; however the high presence of organic matter with its functional species in the POME may facilitate the bounding or sorption of Ca^{2+} and its coeffect ion Mg^{2+} present in the oil effluent.

Significant increase in the BOD_5 counts in the experimented sample suggests the presence of eutrophying organisms in the effluent; this increases the gasp for available oxygen dissolved in the waste water and thus bloom of the organisms. Vallero [8] suggested that waste water with high biodegradable organic matter increases the chances of algal bloom in the aquatic system and thus an increase in their biochemical reactions which shunts of availability of oxygen within the system.

Analysis of solid matter contents (TS, TDS and TSS) of the waste water is seen significantly high when compared with the control experiment. Processing conditions of the palm oil in the milling centre contributes largely to the presence of these solid contents. Shafiqah and Nasir, (2013) findings in their analysis in development of anaerobic membrane base system for remediation of POME stated that raw display of the waste water in most processing center and the nature of the oily fraction of the waste entraps solids substance to which the greater percentage of it dissolves within aided by the oil and less fractions remain insoluble.

Analysis of microbial loading index in the experimented sample showed a significant heterotrophic activity of organisms in the POME impacted soil when compared to the control experiment.

Organismal proliferations increase as the percentage of the POME per gram of the soil increase from 10-50% (v/w) while a downturn in the organismal counts decreases significantly at 100% (v/w). There was a noticeable decrease in the coliform counts/g of the organisms as the incubation days increases from day 0-14. Markou et al. (2016) in their study stated that organisms proliferation in soil samples receiving effluent discharge is significantly high from the lag to the exponential phase of the recipient in the soil, however there will be a noticeable decrease in the proliferation of the organisms as the incubation days increases due to sheer stress of metabolisms and flocculation of nutrients in the soil. This according to Mbachu et al*.* (2016) reported that bacteria strains in most contaminated soil are fastidious in nutritional requirements and may undergo attenuation when the sheer stress increases within the biosystem.

Enzymes are proteins responsible for various biochemical activities within a biota. They catalyse the significant reduction of energy barrier in every reaction pathway so as to attain the reaction complex within shorter time (Anosike, 2002). Analysis of soil marker enzymes: lipase, manganese peroxidase, peroxidase and catalase in all the contaminated soil revealed a significant activity of the enzymes in all the contaminated soil at the concentration quotients. Enzyme activity relatively decreases as the contaminant concentrations increases from 0-100 v/w. Lipases are responsible for hydrolysis of fatty acyl esters in a long chain fatty acids to water and alchohol base while the family of peroxidases (peroxidase, manganese peroxidase and catalase) are house keeping enzymes responsible for dismutation of peroxide and other superoxide to water and release of atmospheric oxygen. Lipases activity was seen relatively low in all the soil at low concentrations of the effluents (0-50 v/w). At high concentrations of the effluents, there was a significant increase in the enzyme activity.

Peroxidase and catalase activity was significant at ambient effluent concentrations but was attenuated at high treatment of the soil with effluent from palm oil waste water. Peroxidase showed significant activity in all the sampled soils. It was so seen from the result that enzyme activities assayed were relatively high when compared with the control experiment. 10-50 % showed marker enzymes with peak activities when compared with enzymes from 100%. Ezenwelu et al*.* [6] reported reversibly to the findings of the present study, they stated an optimum activity of lipase produced from strains of *Aspergillus* from a refuse dump site. They went further to state that lipase a catabolically induced with the presence of oil implicated recalcitrant and can only be attenuated with the oily deposits are of composite heavy metals.

5. CONCLUSION

Palm oil processing is generally a lucrative business within the sub-saharan; nevertheless there are no stringent regulations guiding the operation of processing and milling centers of these agricultural produce. Insinuations by local farmers in the utilizations of the waste water accruing from oil processing as soil organic fertilizers has left soil progressively losing of fertility potentials as there are no indications from experimental analysis of the impact of this waste water. The present study as shown with analysed empirical the effected of differential concentration of POME impacted soil on ecological responsiveness of the soil. There are evidently from the results of the error shift in the utilization of this waste water for improved agricultural productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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