Research Journal of Environmental Toxicology

ISSN 1819-3420

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS Research Journal of Environmental Toxicology

ISSN 1819-3420
DOI: 10.3923/rjet.2018.34.41

Research Article
Impact of Palm Oil Mill Effluent (POME) Contamination on Soil Enzyme Activities and Physicochemical Properties

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Abstract

Background and Objective: Increased milling of oil palm in the South-East area of Nigeria has led to copious production of palm oil mill effluents (POME) whose disposal on agricultural farmlands has brought unforeseen challenges. If this POME is disposed, is it fertile or toxic? What are its constituents and chances of appropriate disposal in water body? In this study, the effect of palm oil mill effluent (POME) on the integrity of soil was investigated. **Materials and Methods:** The samples (POME and soil) were collected from ROCHE-ADAPALM milling site in Ohaji-Egbema LGA, Imo state. Soil samples from the POME dumpsite as well as a non-POME site, both at different depths and were assessed for their enzymatic and physicochemical properties using standard analytical procedures. **Results:** The results of the physicochemical analysis of the POME were obtained in the following range: pH, 5.2-6.3; Dissolved Oxygen (DO), 12.20-12.60 mg L^{-1}; Biochemical oxygen demand (BOD), 120-130 mg L^{-1}; Chemical oxygen demand (COD), 488-504 mg L^{-1}. Findings revealed that the enzyme activities were affected significantly ($p<0.05$) with differing levels of activity at both top and subsoil levels. The carbon (%) and organic matter, total nitrogen and water holding contents across top soils showed a significant increase in their respective values with a significant decrease ($p<0.05$) across subsoils. **Conclusion:** Indiscriminate disposal of POME on land poses a threat to the soil properties, microbes, plants and by extension the ecosystem. For an entirely stable ecosystem waste materials should undergo quality control as to curtail its excesses.

Key words: Palm oil mill effluent (POME), physicochemical properties, ecosystem waste materials, integrity of soil, agriculture farmlands, dehydrogenase, catalase and lipase

Citation: Nwachukwu Justus Nmaduka, Njoku Uzoma Obioma, Agu Chidozie Victor, Okonkwo Christopher Chukwudi and Obidiegwu Chinonye Juliet, 2018. Impact of palm oil mill effluent (POME) contamination on soil enzyme activities and physicochemical properties. Res. J. Environ. Toxicol., 12: 34-41.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Environmental issues are increasingly becoming more important globally. Over the recent years, there has been an increasing concern for environmental risk of industrial activities associated with extraction, hydrocarbons, food processing, transportations and refining[1]. Industries have increased the threat of oil pollution to the environment and concomitant effluent discharged into the natural environment had created major ecological problem throughout the world. Discharge and indiscriminate dumping of palm oil mill effluent (POME) has led to alterations overtime on soil physicochemical characteristics[2]. Palm oil is one of the many vegetable oils widely consumed around the world. Oil palm production in Nigeria has risen[3] from 8.2 in 1990 to 9 million Mt in 2001. Nigeria is currently the 5th world's leading producer of palm oil[4]. The palm oil industry is a major agro based enterprise in Nigeria especially in the southern part of the country where palm oil trees are found both in the wild and plantations[5].

Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. About 43-45% of this is always a mill residue in the form of empty fruit bunches (EFB), shell, fibre and palm oil mill effluent (POME), which will continue to accumulate with increasing production[6]. The production of palm oil requires large volumes of water with concurrent generation of wastewater known as palm oil mill effluent (POME). The POME is a mixture of water, oil and natural sediments (solid particles and fibres), large quantities of which are generated annually during crude palm oil production[7] and is amenable to microbial degradation. It is estimated that for each tonne of crude palm oil (CPO) that is produced, 5-7.5 t of water are required and more than 50% of this water (about 3.5 m^3) ends up as POME[8].

The management of agro industrial effluents such as palm oil mill effluent (POME) has been a major environmental concern in countries producing them. These effluents are land and aquatic pollutants when discharged untreated, due to the presence of high organic load. Also, their phytotoxic properties are serious nuisance when discharged untreated, as they have high levels of organic loads and some organic acids. These effluent streams are normally disposed of in drainage channels or stored in evaporation ponds or worse still discharged in arable lands to possibly avert the cost of treatment[9,10].

This practice is predominant in developing countries where effluent discharge standards are not strictly adhered to. It has been observed that most of the POME produced by the small-scale traditional operators undergoes little or no treatment and is usually discharged into the surrounding environment. There is a dearth of information on these POME sediments. The characterization of these sediments and their effects on the land or water body into which they are dumped are important for future researches due to the fact that these properties have significant effects on the settling process that occurs either under natural gravity or by coagulations[11].

In this research study, palm oil mills wastewater has been used as an oily wastewater for the case study after being characterized for some physicochemical parameters. This research, therefore, aimed at studying the general impact of POME in the effluent dumpsite on soil enzyme activities and some physicochemical properties of soil including pH, cation exchange capacity, water-holding capacity, total organic carbon and total nitrogen of the soil.

MATERIALS AND METHODS

Chemicals and bio-chemicals: All chemicals were purchased from sigma Aldrich Chemical Company, Germany. Other laboratory reagents used were of analytical grade.

Collection of effluents/soil sampling: Fresh and fermented (1 week) palm oil mill effluents (POME) composite samples were collected from ROCHE-ADAPALM oil mill site, a government/private-partnered palm oil milling enterprise in Owerri, Nigeria. Sampling was done three times according to the method described by Okwute and Isu[11] i.e., from an effluent dumpsite, a site about 10 yards away from the effluent dumpsite and a non-effluent dumpsite about 1 km from dumpsite served as the control. Soil samples from each of the three sites were collected at depths of 0-15 and 15-30 cm, respectively. The samples were air-dried and sieved using a 2 mm sieve and then stored in fresh, clean polyethylene bags in the refrigerator at 4°C prior to laboratory analysis so as to maintain the stability of samples without significant alteration in their biological properties. The samples collected are as follows: Sample 1 (Fresh POME), Sample 2 (1 week old POME), Sample 3 (Top soil dumpsite (0-15 cm)), Sample 4 (Sub-soil dumpsite (15-30 cm)), Sample 5 (Control topsoil (0-15 cm)), Sample 6 (Control subsoil (15-30 cm)) and Sample 7 (Topsoil 10 yards away from dumpsite).

Analysis of physico-chemical properties of soil samples: These assays were carried out after the soil samples have been air-dried, after which they were sieved in a 2 mm mesh. After sieving, the samples were leached and the leachate used in the assays.

pH determination: A pH meter made by Hanna instruments was used in determining the pH of the leachate of the samples and the values recorded.

Water holding capacity: Determination of the water holding capacity of the soil samples was done using the method described by Agbenin[12].

Exchangeable cations (Ca, K, Na and Mg): These were determined according to the methods described by Agbenin[12]. A flame photometer (FP 640) was used in this assay.

Cation exchange capacity: This was determined according to the method described by Agbenin[12]. The KCI leachates (second leachates, 50 mL) were put in conical flasks for each soil samples. About 20 mL of formalin solution (20%) was added to each conical flask. About 3 drops of phenolphthalein indicator (colour changes from colourless to light pink) were added and each mixture titrated against 0.1 N NaOH. Titre values were also recorded.

Organic carbon: Percentage carbon and organic matter analysis was done using a modified method of Landis *et al.*[13].

Available phosphorus: Available phosphorus in the soil was determined using the Trough method as described by Landis *et al.*[13].

Total nitrogen: Available phosphorus in the soil was determined using the Trough method as described by Landis *et al.*[13].

Analysis of physico-chemical properties of POME

pH determination: The POME pH was determined by pocket-sized pH meter.

Dissolved oxygen (DO): The DO was determined using the method as described by Ademoroti[14].

Biochemical oxygen demand (BOD): The BOD was determined using the method described by Ademoroti[14] and APHA[15].

Chemical oxygen demand (COD): The COD was determined by titrimetric/dichromate oxidation method as explained in detail in APHA[15].

Total nitrogen: Total nitrogen was carried out using Kjeldahl method as described by Landis *et al.*[13].

Elemental metals (Ca, Mg, Na, K) in POME: The elemental metals of interest include calcium, magnesium, sodium, potassium. These were determined using modified methods described by Agbenin[12]. A flame photometer (FP 640) was used in this assay.

Oil and grease determination: Soxhlet extraction method described by Ademoroti[14] and APHA[15] was used to extract the oil and grease from the POME.

Available phosphorus: Available phosphorus in the effluent samples was determined by Vanado-molybdo-phosphoric acid colorimetric method described by Ademoroti[15]. The effluent sample was prepared by wet digestion method.

Total solids, suspended solids and volatile solid determination: The method used for this analysis was adopted from the method described by Ademoroti[14] and APHA[15]. The principle involved is the evaporation of the liquid at different temperature to get fixed, volatile and suspended solids.

Determination of soil enzyme activities

Soil dehydrogenase activity: Dehydrogenase activity was determined using the method described by Tabatabai[16]. Dehydrogenases convert 2,3,5-triphenyl tetrazolium chloride to formazan. About 1 g of sieved soil was placed in test tubes, mixed with 1 mL of 3% aqueous (w/v) 2,3,5-triphenyl tetrazolium chloride and stirred with a glass rod. After 96 h of incubation (27°C) 10 mL of ethanol was added to each test tube and the suspension was vortexed for 30 sec. The tubes were then incubated for 1 h to allow suspended soil to settle. The resulting supernatant (5 mL) was carefully transferred to clean test tubes and absorbance was subsequently read spectrophotometrically at 485 nm after having zeroed with distilled water. The concentration of formazan was evaluated using extinction coefficient of 15433 Mol cm^{-1}.

Soil catalase activity: Catalase activity was determined using the method described by Landis *et al.*[13]. Catalases decompose hydrogen peroxide, the extent of which is measured by reacting it with excess potassium tetraoxomanganate. Residual $KMnO_4$ is measured spectrophotometrically at 480 nm. About 100 mL of phosphate buffer (0.05N, pH 7.4) was added to 10 g of each soil sample contained in test tubes and the mixture homogenized by shaking. The mixture was filtered using cheesecloth and the filtrate obtained was centrifuged at 7000×g for 5 min. The supernatant obtained was decanted. About 5 mL of the supernatant was introduced

into differently labelled test tubes containing 0.5 mL of 2 m Mol hydrogen peroxide and a blank containing 0.5 mL of distilled water. About 0.5 mL of 6N H_2SO_4 was added to the test tubes one at a time, immediately followed by the addition of 3.5 mL of $KMnO_4$ (0.1 N). The solution was mixed thoroughly and absorbance was subsequently read using a spectrophotometer at 480 nm. Spectrophotometer standard was prepared by adding $KMnO_4$ (3.5 mL) to a mixture of phosphate buffer (2.75 mL) and H_2SO_4 (0.5 mL). The spectrophotometer was then zeroed with distilled water before taking absorbance readings.

Soil lipase activity: Lipase activity was determined using the method described by Sakai *et al.*[17]. Lipase releases lauric acid on incubation with Tween 20 and toluene at 30°C for 18 h under agitation. For each soil sample, a quantity, 1 g was measured in triplicate into three test tubes. To each test tube, 0.2 mL of toluene, 0.6 mL of Tween 20, 1.15 mL of distilled water and 0.2 mL of sodium acetate was added. Each test tube was capped with silicon material and left to incubate at 30°C for 18 h with intermittent shaking. After incubation, 8 mL of ethanol was added and the mixture was swirled for 10 sec. Subsequently, each mixture was centrifuged at 3000×g for 10 min. The supernatants were decanted and to each, 0.375 mL of phenol red indicator (0.02 g L^{-1} in ethanol.) was added. Each of the resulting solutions was titrated with 0.01 M NaOH and the titre value noted.

Statistical analysis: The SPSS software version 17 (SPSS Inc, Chicago) was used to carry out the statistical analysis. A one-way analysis of variance was carried out at $\alpha = 0.05$ and Duncan's multiple range test was used to discern the source of the observed differences.

RESULTS

Results from Table 1 showed significant increases ($p<0.05$) in the pH, elemental metals (K, Ca, Mg, N and P) of soils from the Top effluent site as compared to soils from other sites. Organic matter content and Carbon (C) had highest values in the Top effluent sites. Water holding capacity (WHC) for both 4 and 48 h and the cation exchange capacity (CEC) of soils from top effluent site did not show significant increases as compared to soils from other sites.

Results from Table 2 showed increases in oil and grease, COD, BOD, DO and TSS in aged POME as compared to the fresh POME with values above the USEPA standards for effluent discharge, while differences in elemental metals between fresh and aged POME was not conclusive. Result showed decreases in magnesium, phosphorus and potassium and increases for sodium, calcium and nitrogen for aged POME as compared to fresh POME.

Results from Fig. 1 showed a significant increases ($p<0.05$) in the dehydrogenase activity of the subsoil of POME dumpsite as compared to the control and a significant decrease ($p<0.05$) in the dehydrogenase activity of the top soil of POME dumpsite as compared to the control.

As evident from the Fig. 2, catalase activities of subsoil POME dumpsite was clearly significantly higher ($p<0.05$) compared to soils from other sites. Catalase activities for POME dumpsite topsoil had the lowest catalase activity in the entire groups.

Results from Fig. 3 showed a significant increase ($p<0.05$) in lipase activity of the topsoil dumpsite and a subsequent decrease in lipase activity of the subsoil dumpsite as compared to the control.

Table 1: Physicochemical parameters of soil

Soil description	Topsoil non-effluent site	Subsoil non-effluent site	Topsoil effluent site	Subsoil effluent site	10 yards away from effluent site from effluent site
pH in distilled water	5.400±0.060^{b}	5.200±0.09^{a}	5.900±0.060^{d}	5.500±0.060^{bc}	5.600±0.060^{b}
pH in 0.1N KCl-	5.700±0.060^{b}	4.900±0.060^{a}	6.300±0.060^{d}	6.100±0.060^{d}	5.500±0.060^{ab}
Sodium (Na) (%)	0.007±0.000	0.006±0.017	0.009±0.000	0.010±0.000	0.011±0.000
Potassium (K) (%)	0.009±0.000^{b}	0.018±0.000^{a}	0.031±0.000^{d}	0.013±0.000^{d}	0.004±0.000^{ab}
Calcium (Ca) (%)	0.096±0.001^{b}	0.012±0.000^{a}	0.136±0.001^{d}	0.002±0.000^{d}	0.136±0.001^{b}
Magnesium (Mg) (%)	0.010±0.000^{b}	0.023±0.000^{a}	0.110±0.000^{d}	0.004±0.000^{d}	0.091±0.000^{ab}
Nitrogen (N) (%)	0.224±0.000^{b}	0.168±0.001^{a}	0.243±0.001^{ab}	0.210±0.000^{d}	0.196±0.001^{ab}
Phosphorus (P) (%)	68.080±0.140^{b}	42.900±0.27^{a}	92.330±0.210^{d}	18.650±0.24^{d}	45.700±0.23^{ab}
CEC (meq)	14.400±0.120^{b}	16.800±0.12^{a}	15.600±0.120^{d}	10.400±0.00^{d}	20.800±0.01^{ab}
Carbon (C) (%)	2.490±0.010^{b}	1.080±0.000^{a}	3.730±0.017^{d}	3.110±0.012^{d}	2.490±0.012^{b}
Organic matter (%)	4.290±0.006^{b}	1.860±0.012^{b}	6.440±0.012^{d}	5.360±0.012^{d}	4.290±0.006^{ab}
WHC (4 h) (%)	31.32	31.46	33.85	29.03	34.15
WHC (48 h) (%)	17.77	7.10	21.23	6.34	13.73

Each value is expressed as Mean±SEM (n = 3). Values with different letter(s) as superscripts across the column are considered significant ($p<0.05$). meq: milliequivalent, CEC: Cation exchange capacity, EHC: Water holding capacity

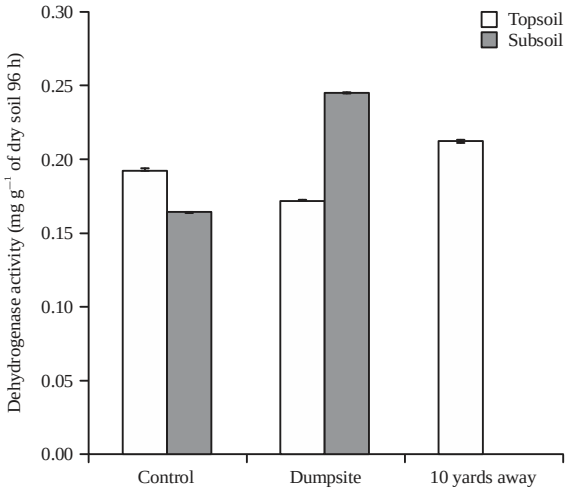

Fig. 1: Effect of POME on soil dehydrogenase activity

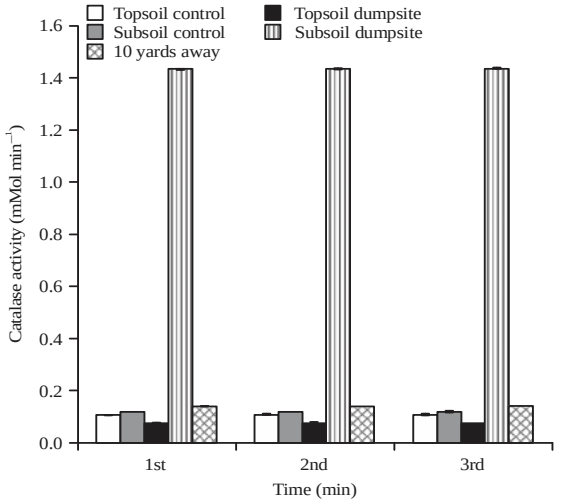

Fig. 2: Effect of POME on soil catalase activity

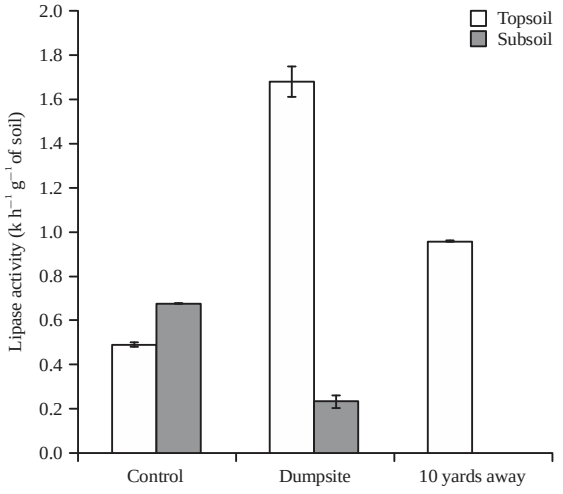

Fig. 3: Effect of POME on soil lipase activity

Table 2: Physicochemical parameters of POME

Parameters	Fresh POME	Aged POME	Standard limit for discharge[19]
pH	4.300±0.088	4.300±.088	5-9
DO (mg L^{-1})	12.200±0.012	12.600±0.006	10
BOD (mg L^{-1})	120.000±1.155	130.000±1.155	100
COD (mg L^{-1})	488.000±0.577	504.000±0.577	150
Oil and grease (mg L^{-1})	284.000±0.577	364.000±1.155	50
TSS (mg L^{-1})	17.750±.0.006	19.340±0.002	20
Total solids (mg L^{-1})	51.900±0.012	49.600±0.006	38
Phosphorus (ppm)	23.000±0.003	20.000±0.116	
Sodium (%)	0.029±0.000	0.029±0.000	
Potassium (%)	0.022±0.000	0.017±0.000	
Calcium (%)	0.060±0.001	0.080±0.001	
Magnesium (%)	0.024±0.001	0.018±0.000	
Nitrogen (%)	0.294±0.003	0.336±0.001	

Each value is expressed as Mean±SEM (n = 3), DO: Dissolved oxygen, BOD: Biochemical oxygen demand), COD: Chemical oxygen demand), TSS: Total suspended solids

DISCUSSION

Anthropogenic activities of man cause the release of effluents into soil and water bodies. Results from depth (topsoil, subsoil), across site (uncontaminated, effluent, 10 yards away from effluent site) samples showed that several chemical and biochemical properties of the investigated soil changed in response to POME contamination. This may be the basis for Okwute and Isu[11] suggesting proper treatment of POME before discharge, while assessing the impact of POME on soil physicochemical parameters. Also, Ohimain *et al.*[18] in a study on the physicochemical properties of palm oil mill effluent suggested that its high level of oil and grease, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand could contribute to environmental pollution and should therefore be recycled. The results from the present investigations carried out substantiate these suggestions.

From the results of the pH studies, the pH of the effluent site was significantly higher ($p<0.05$) than that of the non-POME. It was also observed that the organic matter, carbon (%) and total nitrogen for all the sites were significantly different ($p<0.05$) from each other for all the samples. The carbon (%) and organic matter, total nitrogen and water holding contents across topsoils showed a significant increase in their respective values with a significant decrease ($p<0.05$) across subsoils. The cation exchange capacity (CEC), usually expressed in milliequivalents/100 g of soil, is a measure of the quantity of readily exchangeable cations neutralizing negative charges in the soil. The CEC values observed in this study when considered along with the exchangeable cations (Ca, Mg, Na, K) were found to be significantly higher ($p<0.05$) in the POME when compared with the non-POME soil. The

POME soil was equally observed to be richer in phosphorus than the non-POME soil. In fact, there was a significant difference ($p<0.01$) in phosphorus values of the POME-treated soil over that of non-POME as shown in Table 1.

In the POME samples, a significant increase in dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil and grease, total suspended solids and calcium were observed with aging. These parameters exceeded the USEPA standard limits of discharge and as such suggest that it is not advisable for aged POME to be channelled into water bodies as this could harm aquatic life and other supporting water microbes[19]. The pH and sodium showed no significant difference ($p>0.05$) in both samples, while total solids, phosphorus, magnesium and potassium decreased.

Organic amendment with POME increased the pH of effluent soils. It has been reported that when raw POME is discharged the pH is acidic but tends towards alkalinity as biodegradation takes place[18]. In a similar study by Oviasogie and Aghimien[20], the results showed an overall increase in the CEC of POME soils especially at the area close to the source of the POME and agree with the observation in this investigation. The results showed that the soils are enriched with phosphorus, nitrogen, calcium, magnesium, sodiumm and potassium due to the application of POME. In fact, there was a significant increase ($p<0.01$) in phosphorus values of the POME-treated soil over that of non-POME as shown in Table 1. This agrees with the findings of Wood[21] and Lim [22]. There is good evidence that suggested that phosphorus is the dominant element controlling carbon and nitrogen immobilization.

Soil acidity (pH) is one of the principal factors affecting nutrient availability to plants. Therefore, the availability of plant nutrients in soils is affected by the soil's pH. When the POMEis discharged into the soil, it affects nutrient availability of the nearby plants, because most plants grow and do better within the pH range of 6.5-7.5. The organic matter of a soil is usually determined and reported as a measure of the organic carbon concentration in the soil and it strongly affects the soil fertility by increasing the availability of plant nutrients, improving the soil structure and the water holding capacity and also acting as an accumulation phase for toxic, heavy metals in the soil environment. For this reason, the recycling of organic wastes through their application to the soil can be an important promising practice for agricultural activities[22,23].

The higher organic carbon and increased nitrogen content observed in the POME soil in this study correlate the findings of Amelia *et al.*[24] and Hazelton and Murphy[25]. The higher organic carbon value for the POME soil can be related to the constituents of raw and untreated POME. It is possible that a slow decomposition of organic matter in POME under water-saturated conditions, particularly when mean soil temperatures are low contributed significantly to the higher organic carbon of the POME soil. The high organic matter is also attributable to the presence of different sugars such as arabinose, xylose, glucose, galactose and manose at the concentrations of 6.43, 0.44, 0.22, 0.15 and 0.10% dry weight, respectively[26].

The amendment of soil with POME showed a marked increase in total nitrogen as POME amendment may have provided the needed microbes and $N0_3$-N that stimulated soil organic matter (SOM) degradation[27]. The increase in CEC could be attributed to the increase in the pH dependent charge as well as the addition of organic matter from the effluent as observed by Amelia *et al.*[24]. Mackenzie *et al.*[28] recorded an increase in pH, potassium, calcium, magnesium and organic matter content with the application of POME to soil. The increase in the available phosphorus in the POME soil suggested a possible high absorption in the soil or a possible precipitation of phosphate. This may be due to the gradual biodegradation of POME, which leads to a delayed effect on the soil. Longer days for which POME was fermented provided quality time for microbial build up which ultimately increased residual organic Carbon and Nitrogen[29].

This implies that fresh POME poses less threat to aquatic life than aged POME, thus, less polluting but fermented POME material enhances more soil microbiological activities and thus ultimately increases soil fertility.

Palm oil mill effluent pollution alters soil dehydrogenase activity at the subsoil (15-30 cm) level. The soil dehydrogenase activity of the subsoil effluent site was found to be significantly higher ($p<0.05$) than in the subsoil from uncontaminated site. However, soil dehydrogenase activity was highest in the topsoil (0-15 cm) effluent site compared to the topsoil of both the effluent site and the uncontaminated site (with the uncontaminated site higher than that of the effluent site). At the subsoil level, the dehydrogenase activity in the effluent site is higher than that of the uncontaminated site. The results obtained for catalase activity for micro-organisms from the effluent site showed a decrease in activity in the topsoil effluent site when compared to the uncontaminated site; while soils of 10 yards away from effluent site were higher than those of the uncontaminated site. However, the trend of the lipase activity occurred in reverse, being significantly higher in the topsoil of the effluent site as against that of the uncontaminated site.

The significant decrease in activity of both enzymes (dehydrogenase and catalase) at the topsoil level of the effluent site could be attributed to the constant exposure of the soil micro-organisms to palm oil effluent which could bring about changes in soil conditions as pH, hypoxia and exposed the organisms' dehydrogenase and catalase systems to more work (stress), in the oxidation of organic matter contained in the effluent-polluted soil, bringing about a reduction in their number and activities. These changes make the soil, which was previously fertile before exposure to the effluent pollution, to lose its productive potentials[30].

The increase in soil enzyme activities in the subsoil of the effluent site may be the result of soil physical and chemical changes, so there is a direct expression on microbial biomass and soil enzyme activities since changes in soil dehydrogenase activity indicate the amount of micro-organisms present in the soil; a higher dehydrogenase activity in the effluent site indicates increased amounts of micro-organisms and a corresponding increase in biological activity and respiration rate[31]. Higher organic matter levels support greater microbial activity because of greater supplies of energy and nutrients.

Additionally, high humus content in soils could facilitate incorporation of soils enzymes into the soil matrix, allowing stabilization of higher content of exoenzymes in soils, because humus are important in forming soil enzyme complexes[32]. The addition of organic amendments (POME) and adoption of management practices that increase soil organic matter lead to increased enzyme activity. Plant roots stimulate enzyme activity because of their positive effect on microbial activity and production of exudates rich in substrates acted on by enzymes[33]. The trend in lipase activity (an increase in the effluent site) is explained by the fact that the substrates for the lipase enzymes (triacylglycerols) are found in the oil and grease content of POME and as such, accumulate on the topsoil of the effluent site. The lipase activity is a valuable indicator of oil biodegradation in the soil[34].

While this study espouses the changes in various properties of soil on POME contamination, it is difficult to give a definite action because some soil properties are improved while others deteriorate, but a pre-treatment process before elimination will enable a more nourished soil and ensure detoxification of POME.

CONCLUSION

The data obtained in the course of the project shows that the physicochemical properties of the soil at effluent sites are altered. Hence, it is imperative to pre-treat POME before disposal on the environment. Proper use and safe disposal of POME on the land environment could lead to improved soil fertility; it could also be hazardous to soil micro-organisms. In the absence of pre-treatment facilities, POME could be recycled and reused rather than disposed on the environment so as to forestall its adverse effect on the environment.

SIGNIFICANCE STATEMENT

This study on effluents from palm oil mills is important as it helps environmentalist and industry identify with the adverse effect of indiscriminate dumping of POME on agricultural farmlands and find ways to end the menace. It is of value to researchers as it challenges them to postulate ways in which POME can be treated with the least chances of being deleterious to farmlands and water bodies.

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