Direct Research Journal of Biology and Biotechnology

Vol. 9(5), Pp. 49-55, August 2023
ISSN: 2734-2158
DOI: https://doi.org/10.26765/DRJBB47507368
Article Number: DRJBB47507368

https://directresearchpublisher.org/drjbb

Original paper

Evaluation of Physicochemical Properties of Palm Oil Mill Effluent (POME) Polluted Soil Amended with Organic Wastes

Okwute, Ojonoma L.,[1]* Ijah, Udeme J.J.[2] and Egharevba, Nosa A.[3]

[1]Department of Microbiology, University of Abuja, P.M.B. 117, Gwagwalada-Abuja, Nigeria.
[2]Department of Microbiology, Federal University of Technology, P.M.B. 65,Minna-Niger State, Nigeria.
[3]Department of Agricultural and Bioresources Engineering, Federal University of Technology, P.M.B. 65, Minna-Niger State, Nigeria.Corresponding author email: ojonoma.okwute@uniabuja.edu.ng

Received 6 July 2023; Accepted 17 August 2023; Published 24 August 2023

ABSTRACT: Soil plots polluted with raw palm oil mill effluent (POME) were amended with organic wastes at different concentrations of 5 kg, 10 kg and 15 kg per 4m^2 plot of land. The plots were assessed for physicochemical properties before and after amendment over a period of two (2) months. Physicochemical properties analyzed include pH, moisture content, organic carbon, total nitrogen, mineral assay, available phosphorus, exchangeable cations and heavy metals. There was a significant difference ($P \leq 0.05$) in some soil physicochemical properties which were affected by the application of the raw POME by a decrease in most values. These parameters included pH (6.9-4.0), Nitrogen (0.08-0.05), Phosphorus (21.40-1.82) and effective cation exchange capacity (17.26-7.35) but the values of others improved after the addition of organic wastes. The physicochemical properties with a significant difference in increase included pH (4.0-7.0), organic matter (1.59-3.02), organic carbon (0.92-2.32), moisture (7.03-11.00) and available phosphorus (1.82-15.61). These values buttress the fact that the addition of organic wastes to oil-polluted soil improves soil quality and integrity and ultimately soil fertility for agriculture.

Keywords: Physicochemical properties, palm oil mill effluent (POME), organic wastes

Citation: Okwute, O. L., Ijah, U. J.J., and Egharevba, N. A.(2023). Evaluation of Physicochemical Properties of Palm Oil Mill Effluent (POME) Polluted Soil Amended with Organic Wastes. Direct Res. J. Biol. Biotechnol. Vol. 9(5), Pp. 49-55. https://doi.org/10.26765/DRJBB47507368.

INTRODUCTION

The processing of palm oil is carried out in mills where oil is extracted from the palm fruits. The global market for palm oil has experienced rapid growth in recent decades with current production of palm oil estimated at over 81 million metric tonnes (Murphy *et al*., 2021). In 2021, the palm oil production in Nigeria reached 1.4 million metric tonnes (AgroNigeria, 2022). Apart from palm oil and palm kernel, the processing of oil palm also produces copious amounts of waste commonly referred to as palm oil mill effluent (POME). This is because when palm oil is processed, what ends up as POME can be up to 50% of the liquid waste (Poku, 2002) and discharged onto soil in the environs in a raw state by local mill operators more often than not. The properties of POME make it a major environmental pollution problem in the palm oil industry. These properties are a thick, brownish, slurry of water, oil and solids including suspended solids of about 2 % (Bek-Nielsen *et al*., 1999) and a high amount of biodegradable organic matter (Ahmad *et al.,* 2003). Besides the presence of lipids and volatile compounds, the physicochemical properties of soil have been said to be altered by POME, (Okwute and Isu, 2007a), a significant change in microbial numbers in POME-polluted soil (Okwute and Isu, 2007b; Okwute and Ijah, 2014a; Okwute *et al*., 2017) and a major source of water pollution (Osman *et al*., 2020). Andrews *et al.* (2021) therefore, recommended the use of crop residues and other organic wastes as supplements inorganic fertilizers.

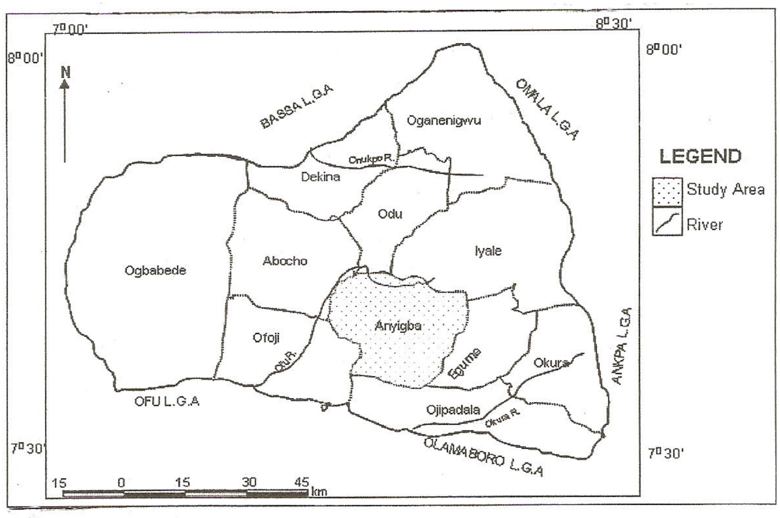

Figure 1: Map of Dekina LGA of Kogi State Showing the Study Area, Anyigba
Source: Geologic Information Systems (GIS) Laboratory, (2006).

This study assessed the effects of POME on physicochemical properties of the soil, amendment of such soil using organic wastes and the resultant growth of maize plants on polluted and amended soils in the field.

MATERIALS AND METHODS

Study area

The study area was Anyigba, a known palm oil producing town (Figure 1). It is a central Igala town in Dekina Local Government in the eastern flank of Kogi State, Nigeria with a total land area of about 5,091 km^2 (Musa, 2009). It lies between latitude 8^{0}43^i North and 9^{0}15^i South and longitude 6^{0}06^i East and 7^{0}54^i West (Musa, 2009). The large number of palm trees in the area makes palm oil production a natural source of income for most families and Igala's most important crop (Agi, 1980). The bulk of palm oil produced in Igalaland comes from individual homesteads all over the area and the industry is a true example of a cottage system of production. The methods employed are traditional ones, the equipment is simple, and the division of labour and processes are closely integrated with the domestic routine of an agricultural economy (Agi, 1980).

Preparation and demarcation of plot

A randomized complete block design, (RCBD) was adopted. The land which was situated in a demarcated and secured area in Faculty of Agriculture, Kogi State University, Anyigba, Nigeria was flat, non-sloping and well drained. It was ploughed, harrowed and mapped out using wooden pegs and twine. They were mapped into 5 main plots (80 m^2, 80 m^2, 80 m^2, 20 m^2, 20 m^2). Three plots (80 m^2 each) representing those for cow dung, chicken droppings and a mixture of the two organic wastes were subdivided into 9 sub-plots, each measuring 2m by 2m (4m^2) and a space of free land of 1m by 2m on each side of each plot to create adequate gaps (alleys) between plots. The remaining two main plots having an area of 20 m^2 each were subdivided into 3 plots of 2m by 2m with a gap (alley) of 1m by 2m in between plots. The two plots served as control 1 (soil alone) and control 2 (soil + POME).

Palm oil mill effluent (POME)

A composite sample of palm oil mill effluent (POME) was collected from a functional oil mill in Anyigba Town, Kogi State, Nigeria. The effluent which is usually contained in a plastic drum was mixed thoroughly and then transferred into clean plastic containersand tightly screwed. It was transported to the laboratory in an ice box. Any time the POME was not in use, it was stored in a refrigerator at 4^0 C.

Organic wastes

The organic wastes used were cow dung and chicken droppings. The deep litter chicken droppings was obtained fresh from a poultry house in Gwagwalada, Abuja-Nigeria while the cow dung was collected fresh from Gwagwalada-Abuja abattoir, Abuja, (Nigeria) in clean unused polythene bags before transportation to the laboratory.The wastes were sun-dried for 48 hours, ground and packed in clean polythene bags. The organic wastes were kept in a refrigerator at 4^0C until required.

Determination of physicochemical properties of Unpolluted Soil and Organic wastes

The physicochemical properties assessed included available phosphorus (Bray and Kurtz, 1945), heavy metals, organic carbon and mineral assay (Black, 1965), exchangeable cations (Sumner and Miller, 1996), moisture content determination and total nitrogen (Agbenin,1995) and pH determination by the potentiometric method as described by Brady and Weil (1999).

Pollution on the field

On each sub-plot of $4m^2$, 12 litres of palm oil mill effluent (POME) was applied evenly using a garden watering can. This was done on all plots except control 1 (soil alone) which was left undisturbed. After the application of POME, soil samples were collected using a hand trowel and thereafter, at 1month interval for duration of two months into properly labeled, clean unused polythene bags for analysis.

Bioremediation of polluted soil in the field

After two weeks of pollution, bioremediation was carried out. Cow dung was applied to each subplot measuring $4m^2$ in the following order, 5kg (3 subplots), 10 kg (3 subplots), and 15kg (3subplots). This was done by spreading the organic wastes evenly on each subplot. The same treatment was given to another set of 9 subplots for chicken droppings and the remaining 3 subplots were for a mixture of the two organic wastes in the same order. No organic waste was applied to two main plots which served as control 1 (soil alone) and control 2 (soil + POME). After application of the wastes, adequate mixing of the wastes with the polluted soil using a shovel was done. Tilling was repeated once in two weeks throughout the period of the field experiment (two months). Soil samples were immediately collected after the application of the organic wastes and at 1 month and 2 months. The soil samples were collected using a hand trowel into properly labeled, clean unused polythene bags for physicochemical analysis.

Statistical analysis

Data generated from the study were analyzed using SPSS (Version 19.0) (SPSS, 2010) computer package. This was achieved using univariate analysis of variance (ANOVA) at the $P \leq 0.05$ confidence limit to analyze the variance in the results obtained from all field studies.

RESULTS AND DISCUSSION

The addition of POME to soil had a clear effect on the pH of the polluted soil as there was a significant difference ($P \leq 0.05$) between the pH of the unpolluted (UPS) and polluted soils (PS) (Okwute and Ijah, 2014b). This is due to the fact that raw POME is said to be acidic (Salihu and Alam, 2012; Fitri *et al*., 2022) resulting from the oxidation of organic acids, lipids, volatile compounds and water-soluble compounds ((Mohammad *et al*., 2021). Therefore, the gradual increase in the pH of the soil after amendment with the organic wastes in the field over the period of 2 months (Tables 1 –3) show that the constituents of the organic wastes might have caused the increase in pH (Sayara *et al*., 2020). This is due to microorganisms in the organic wastes that degrade POME (Okwute and Ijah, 2014a; Okwute *et al*., 2020). POME has been said to have low nitrogen values (less than 0.05 % of total nitrogen) (Ma *et al.,* 2001; Osman *et al*., 2020). However, relatively high amounts of nitrogen were observed in the chicken droppings (0.31 %) and the cow dung (0.15 %) (Okwute and Ijah, 2014b), which confirms earlier reports that these compounds are rich in nitrogen (Lau and Wu, 1987; Pharm-Phu and Asari, 2021). *Pseudomonas aeruginosa* and *Bacillus* sp. which are present in the organic wastes had earlier shown ability to utilize palm oil and POME in laboratory simulated tests (Okwute and Ijah, 2014b). Cow dung had an alkaline pH of 8.64 (Okwute and Ijah, 2014b) and this encourages the activity of microorganisms, particularly bacteria. It is possible that the cow dung neutralized the acidic effect of raw POME in the soil given its alkaline nature.

Chicken droppings have also been said to have a buffering effect on the soil (Ijah and Antai, 2003). There were also significant differences in the pH values of soil treatments across the varying quantities of organic wastes added to the polluted soil (PS). Furthermore, since microorganisms are known to thrive well at pH 5.0 - 8.0 with optimum of near neutral (Nester *et al*., 2009), the addition of cow dung and chicken droppings to such soil may have stimulated the proliferation of microorganisms. The highest pH values recorded from the field soil treatments was 6.0. Paul and Clark (1989) reported that nutrient availability is at a maximum when soil pH is at 6.0 to 6.5.

The high moisture level observed in the polluted soil was probably due to the mulching effect of the applied POME. However, the soil moisture was greatly enhanced with the application of chicken droppings and cow dung as the soil moisture was increased from 7.03 to 11.00 % for chicken droppings (10kg) after 2 months of bioremediation, from 7.03% and 10.99% for cow dung (10%) (Table 3) with $P \leq 0.05$ significant difference. This agrees with the findings of Adeleye *et al.* (2010) and

Table 1: Physicochemical properties of different soil treatments at start of experiment.

		Moist.	Org.M	Org.C	Nit.	Avail. P	Exchangeable Cations (mg/l)					Heavy metals (ppm)			
Soil Treatment	pH	(%)	(%)	(%)	(%)	mg/kg)	Na^+	K^+	Ca^{++}	Mg^{++}	ECEC	Cu	Pb	Fe	Zn
A	5.5	14.94	1.36	0.79	0.04	5.82	1.17	0.98	1.90	1.00	5.05	5.72	1.51	31.73	0.21
B	5.6	19.05	2.64	1.53	0.08	12.19	1.44	1.70	2.60	1.03	6.77	5.73	1.50	31.73	0.21
C	4.6	25.00	2.55	1.48	0.07	15.92	1.54	3.24	3.50	1.21	9.49	5.71	1.49	31.71	0.20
D	5.5	17.44	2.09	1.21	0.06	4.19	1.15	1.68	1.70	0.80	5.33	5.73	1.50	31.73	0.21
E	5.9	14.61	3.91	2.27	0.11	7.67	1.66	2.32	3.90	1.30	9.18	5.72	1.49	31.70	0.20
F	5.5	15.48	1.97	1.14	0.06	6.51	1.00	1.70	2.30	0.92	6.33	5.71	1.45	31.68	0.20
G	5.1	11.95	1.40	0.81	0.04	4.43	1.23	1.16	2.10	1.01	5.50	5.72	1.50	31.71	0.21
H	6.0	17.44	2.03	1.18	0.06	8.58	1.00	2.88	3.40	1.14	8.42	5.70	1.49	31.70	0.19
I	5.8	24.05	1.71	0.99	0.05	0.52	1.75	1.80	3.80	1.25	8.60	5.69	1.43	31.67	0.17
J	4.0	8.60	1.59	0.92	0.06	1.82	0.95	0.58	1.80	0.85	4.18	5.73	1.51	31.74	0.21
K	6.93	7.03	0.98	0.57	0.08	21.40	0.26	3.50	9.70	3.80	17.26	0.20	0.43	22.03	0.05
FEPA Limits	6-9	NA	NA	NA	10.00	NA	NA	NA	75.00	50.00	NA	1.00	0.05	20.00	1.00

Values are means of three replicates ± standard error

A=Cow dung 5 kg, B=Cow dung 10 kg, C=Cow dung 15 kg, D=Chicken droppings 5kg, E=Chicken droppings 10 kg, F=Chicken droppings 15kg, G=Cow dung + Chicken droppings 5kg, H=Cow dung + Chicken droppings 10 kg, I=Cow dung + Chicken droppings 15kg, J=Polluted soil and K=Unpolluted soil, ECEC=Effective cation exchange capacity, Moist.= Moisture, Org. M=Organic matter, Org. C.= Organic Carbon, Nit.= Nitrogen, Avail. P=Available phosphorus FEPA=Federal Environmental Protection Agency, NA=Not Applicable or not stipulated

Haque *et al.* (2021) that the application of organic wastes increases soil moisture content. Similarly, Khaleel *et al.* (1981) and Haque *et al.* (2021) reported that soil water retention capacity due to application of animal manure could cause structural improvement in soil; that is, increase in porosity and the amount of porosity involved in soil water storage.

In addition, the improvement of soil moisture by chicken droppings may be due to the colloidal and hydrophobic nature of the chicken droppings (Mbah and Mbagwu, 2006; Mau *et al*., 2018).

There were significant differences ($P \leq 0.05$) in the soil treatments on the field when compared to each other. This may have been due to the different concentrations of organic wastes used in the study. Treatment of the polluted soil with the chicken droppings and cow dung whose organic matter (76.22 % and 33.72 % respectively) and organic carbon (44.08% and 19.50% respectively) (Table 1) were originally high greatly improved the soil organic matter, organic carbon, texture and structure for field bioremediation (Tables 2 and 3).

This may have been due to the intermittent mixing of the soil for proper aeration and porosity. Organic matter is known to improve the physical properties of soil (Aluko and Oyeleke, 2005; Lal, 2011). Organic matter content is said to affect soil fertility by increasing the availability of plant nutrients, improving the soil structure and water holding capacity, and acts as an accumulation phase for toxic, heavy metals in the soil environment (Farooqi *et al.*, 2020).

Besides, organic matter changes soil physical and chemical properties and releases nutrients for a longer period of time (Asawalam and Onwudike, 2011). Only cow dung at 15 kg and chicken droppings at 10 kg organic matter/carbon values were significant at 0.05 % significance level when compared to those of the polluted soil over the period of the bioremediation (0-2 months).

The nitrogen values when compared across the time of bioremediation (0-2 months) were not significant ($P > 0.05$) in the field (Tables 1 –3). This could be due to the low nitrogen content of the POME (0.03 %) (Table 1). The application of these organic wastes to polluted soil did not lead to a significant increase in nitrogen values for all the soil treatments in the field experiments. This may be due to soil erosion and leaching in the field or denitrification (Narendar *et al.*, 2017; Bashagaluke *et al.*, 2018). The increase in nitrogen to almost original unpolluted soil levels by chicken droppings has been recorded by Okafor *et al.* (2016) and Orprapa *et al.* (2022). However, in this study, nitrogen levels marginally rose to above the original unpolluted soil levels after bioremediation with the organic wastes but was not significant statistically. The rise in the values of available phosphorus in the field was significant for chicken droppings + cow dung (10kg) in the first month of bioremediation (Table 2) and chicken droppings (15kg) (Table 3). This finding seems to agree with the reports of Egobueze *et al.* (2019) and Lanno *et al.* (2021) that organic wastes and compost soil increase available phosphorus in oil polluted soils. It may be the same with POME polluted soil.

The lowest phosphorus level was observed in the polluted soil on the field even after two months of pollution. This indicates that unless the soil is amended, the phosphorus in the soil will not support meaningful agricultural growth and biodegradation process. There was also an increase in cation values in the field observations. This was however, more significant at 15 kg in the field. Increase in cations' values on application of POME to soil and organic wastes to soil have been reported by Baskaran *et al.* (2009). The general decrease in the values of heavy metals in the amended soil in the field shows a direct effect of nutrients in the chicken droppings and cow dung. This observation was also reported by Wyszkowski *and* Kordala, (2022) where the addition of organic wastes to oil-polluted soils significantly ($P < 0.05$) led to the reduction in the levels of zinc, lead, chromium and nickel. In addition, it was

Table 2: Physicochemical properties of different soil treatments at one month of bioremediation.

		Moist.	Org.M	Org.C	Nit	Avail. P	Exchangeable Cations (mg/l)					Heavy metals (ppm)			
Soil Treatment	**pH**	**(%)**	**(%)**	**(%)**	**(%)**	**(mg/kg)**	**Na^+**	**K^+**	**Ca^{++}**	**Mg^{++}**	**ECEC**	**Cu**	**Pb**	**Fe**	**Zn**
A	6.2	12.79	1.93	1.12	0.06	9.24	1.34	2.01	3.05	1.48	7.88	5.32	1.33	31.45	0.21
B	6.3	8.05	1.93	1.12	0.06	10.90	1.20	3.02	3.49	1.62	9.33	5.01	1.21	31.24	0.21
C	6.4	6.59	2.81	1.63	0.08	11.36	1.24	3.40	2.25	1.04	7.93	3.57	0.87	30.98	0.20
D	6.1	24.36	2.29	1.33	0.07	12.96	1.07	1.87	4.01	1.92	8.87	4.78	0.95	31.36	0.20
E	6.0	12.20	1.52	0.88	0.04	8.78	1.14	1.79	3.40	1.77	8.10	3.34	0.76	31.12	0.18
F	6.3	7.95	2.23	1.29	0.07	14.76	1.22	1.92	3.00	1.52	7.66	2.45	0.54	29.89	0.16
G	6.0	12.99	1.70	0.99	0.05	7.45	1.11	1.68	2.55	1.23	6.57	4.25	0.36	30.56	0.19
H	6.1	9.20	2.40	1.39	0.07	17.51	1.21	2.48	3.89	1.81	9.39	3.56	0.22	30.03	0.17
I	6.1	8.05	2.78	1.62	0.08	16.91	1.22	2.39	4.55	2.01	10.17	2.78	0.15	28.18	0.14
J	4.5	10.47	1.47	0.85	0.04	1.64	0.98	1.50	3.45	1.74	7.67	5.73	1.51	31.74	0.21
K	6.93	7.03	0.98	0.57	0.08	21.40	0.26	3.50	9.70	3.80	17.26	0.20	0.43	22.03	0.05
FEPA Limits	6-9	NA	NA	NA	10.00	NA	NA	NA	75.00	50.00	NA	1.00	0.05	20.00	1.00

Values are means of three replicates ± standard error

A=Cow dung 5kg, B=Cow dung 10 kg, C=Cow dung 15kg, D=Chicken droppings 5kg, E=Chicken droppings 10 kg, F=Chicken droppings 15kg, G=Cow dung + Chicken droppings 5kg, H=Cow dung + Chicken droppings 10 kg, I=Cow dung + Chicken droppings 15kg, J=Polluted soil and K=Unpolluted soil, ECEC=Effective cation exchange capacity, Moist.= Moisture, Org. M=Organic matter, Org. C.= Organic Carbon, Nit.= Nitrogen, Avail. P=Available phosphorus FEPA=Federal Environmental Protection Agency, NA=Not Applicable or not stipulated

Table 3: Physicochemical properties of different soil treatments at two months of bioremediation.

		Moist.	Org.M	Org.C	Nit	Avail. P	Exchangeable Cations (mg/l)					Heavy metals (ppm)			
	pH	**(%)**	**(%)**	**(%)**	**(%)**	**(mg/kg)**	**Na^+**	**K^+**	**Ca^{++}**	**Mg^{++}**	**ECEC**	**Cu**	**Pb**	**Fe**	**Zn**
A	7.0	6.40	2.36	2.05	1.01	8.14	0.89	2.81	3.34	0.96	8.00	4.01	0.80	28.45	0.17
B	7.8	10.99	3.28	2.32	1.03	8.65	1.07	2.70	3.46	1.29	8.52	3.34	0.65	27.67	0.14
C	7.7	8.70	2.99	2.16	1.05	10.15	1.15	3.36	3.86	1.40	9.77	2.05	0.47	19.83	0.11
D	7.6	6.38	2.70	1.99	1.08	7.56	0.98	1.92	4.22	1.62	8.74	2.43	0.69	19.90	0.08
E	7.6	11.00	2.83	2.06	1.05	9.98	1.08	2.23	4.04	1.49	8.84	1.32	0.49	17.45	0.05
F	7.0	6.40	2.91	2.11	1.07	15.61	1.11	3.11	4.18	1.63	10.03	0.75	0.33	15.78	0.03
G	7.2	8.70	2.76	2.02	1.05	7.49	1.07	2.05	3.38	1.24	7.74	3.68	0.28	25.47	0.15
H	7.5	8.60	2.83	2.06	1.09	12.04	0.79	3.20	4.11	1.55	9.65	3.23	0.20	20.01	0.13
I	6.8	8.40	3.02	2.17	1.15	10.83	1.01	2.10	3.64	1.72	8.47	2.45	0.15	18.67	0.10
J	7.0	8.90	2.39	1.81	0.04	2.35	0.96	1.55	3.46	1.38	7.35	5.73	1.51	31.74	0.21
K	8.4	7.03	1.98	0.57	0.08	21.40	0.26	3.50	9.70	3.80	17.26	0.20	0.43	22.03	0.05
FEPA Limits	6-9	NA	NA	10.00	NA	NA	NA	NA	75.00	50.00	NA	1.00	0.05	20.00	1.00

Values are means of three replicates ± standard error

A=Cow dung 5kg, B=Cow dung 10 kg, C=Cow dung 15kg, D=Chicken droppings 5kg, E=Chicken droppings 10 kg, F=Chicken droppings 15kg, G=Cow dung + Chicken droppings 5kg, H=Cow dung + Chicken droppings 10 kg, I=Cow dung + Chicken droppings 15kg, J=Polluted soil and K=Unpolluted soil, ECEC=Effective cation exchange capacity, Org. M=Organic matter, Org. C.= Organic Carbon, Nit.= nitrogen, Avail. =Available phosphorus FEPA=Federal Environmental Protection Agency, NA=Not Applicable or not stipulated.

reported by Chokor and Augustine (2017) and Irfan *et al.*, (2021) that the addition of organic waste material corresponded to a reduction in levels of metals uptake by maize plants. The reductions were associated with the capacity of the amendments to immobilize metals in the soil; that is, the transformation of the metals in the potentially available pools into forms in which they are less bioavailable.

Conclusion

Application of chicken droppings (15 kg per $4m^2$ plot of land) and cow dung (15 kg per $4m^2$ plot of land) in the field caused significant improvements in the physicochemical properties of POME polluted soil after 2 months of bioremediation. The physicochemical properties that improved with the amendments and the reduction in acidity of the soil and increase in organic matter enriched the soil for agriculture. Also, the reduction in heavy metals with the application of the organic wastes helped in the bioremediation of the palm oil mill effluent oil-polluted soil. Therefore, the application of organic wastes after pollution of soil by palm oil mill effluent and indeed, other oils does improve the quality of the polluted soil and its bioremediation.

REFERENCES

Adeleye, E.O., Ayeni, L.S. and Ojeniyi, S.O. (2010). Effect of poultry manure on soil physicochemical properties, leaf nutrient contents and yield of yam (Dioscorea rotundata) on alfisol in Southwestern Nigeria. Journal of American Science, 6(10):871-878.

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.

Agi, F.I. (1980). Oil palm improvement in Igalaland In: B. Dawtrey (ed.) Elaeis: A Journal of Igalaland 2 (2): 8-11.

AgroNigeria (2022). Nigeria's palm oil production from 2015-2021 in 1000-metric-tons Retrieved on 13th May, 2022 from https://www.agronigeria.ng.

Ahmad, A., Ismail, S. and Bhatia, S. (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination*, 157, 87-95.

Aluko, O.B. and Oyeleke, D.J. (2005). Influence of organic wastes incorporation on changes in selected soil physical properties and during drying of a Nigerian alfisol. Journal of Applied Science, 5, 257-362.

Andrews, E.M., Kassama, S., Smith, E.E., Brown, P.H. and Khalsa, S.D.S. (2021). A Review of Potassium-rich crop residues used as organic matter amendments in tree crop agroecosystems. Agriculture 11580. https://doi.org/10.3390/agriculture 110707580.

Asawalam, D.O. and Onwudike, S.U. (2011). Complementary use of cow dung and mineral fertilizer: effect on soil properties, growth, nutrient uptake and yield of sweet potato (Ipomeabatatas). Production, Agriculture and Technology, 7 (1), 36-48.

Bashagaluke, J.B., Logah, V., Opoku, A,, Sarkodie-Addo, J. and Quansah, C. (2018). Soil nutrient loss through erosion: Impact of different cropping systems and soil amendments in Ghana. PLoS One 13 (12) e0208250 doi:10.1371/journal.pone.0208250.

Baskaran, L., SankarGanesh, K,, Chidambaram, A.L.A. and Sundaramoorthy, P. (2009). Amelioration of sugar mill effluent polluted soil and its effect on Greengram (Vigna radiate L.) Botany Research International, 2 (2), 131-135.

Bek-Nielsen, C., Singh, G. and Toh, T.S. (1999). Bioremediation of palm oil mill effluent.In: Proceedings of the PORIM International Palm Oil Congress 16th February 1999, Istana Hotel, Kuala Lumpur, Malaysia.

Biotechnology,6 (6): 83-89.

Black, C.A. (ed.) (1965). Methods of Soil Analysis Agronomy Part 2 American Society of Agronomy, Madison, Wisconsin, USA. (9).

Brady, N.C. and Weil, R.R. (1999). Soil colloids, their nature and pre-clinical significance, The Nature and Properties of Soil 12th edition. Prentice-Hall Inc., Upper Saddle River, New Jersey, USA, pp. 338-384.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soils. Soil Science, 59, 39-45.

Chokor, C. and Augustine, M. (2017). The effects of two organic waste amendments on uptake levels of heavy metals by maize plant (Zea mays L.) from contaminated soil. IOSR Journal of Environmental Science, Toxicology and Food Technology 11 (3): 42-44 doi:10.9790/2402-1103024244.

Egobueze, F.E., Ayotamuro, J.M., Iwegbue, C.M.A., Eze, C. and Okparanma, R.N. (2019). Effects of organic amendment on some soil physicochemical characteristics and vegetative properties of Zea mays in wetland soils of the Niger Delta impacted with crude oil. International Journal of Recycling of Organic waste in Agriculture 8: 423-435doi.org/10.1007/s40093-019-00315-6.

Federal Environmental Protection Agency (FEPA) (1991). Effluent Limitation Guidelines for discharge of pollutants in bodies of water in Nigeria. Federal Environmental Protection Agency, Nigeria.

Fitri, H., Adhe, M.R., Medias, I.M.S., Muhammad, R., Dwi, S.K., Rianyza, G., Tuty, E.A., Susila, A. and Tuti, I.S. (2022). Deacidification of palm oil mill effluent using anion exchange resin. Materials Today In: Proceedings of the 2nd International Conference on Chemical Engineering and Applied Sciences 63 (1): 550-554.

Geographic Information Systems (GIS) (2006). Map of Dekina Local Government Area. Department of Geography, Kogi State University, Anyigba, Kogi State, Nigeria.

Haque, A.N.A., Uddin, M.K., Sulaiman, M.F., Amin, A.M., Hossain, M., Zaibon, S. and Mosharaf, M. (2021). Assessing the increase in soil moisture storage capacity and nutrient enhancement of different organic amendments in paddy soil. Agriculture11 (1):44

Ijah, U.J.J. and Antai, S.P. (2003). The potential use of chicken-drop microorganisms for oil spill remediation. The Environmentalist, 23, 89-95.

Irfan, M., Mudassir, M., Khan, M.J., Dawar, K.M., Muhammad, D., Mian, I.A., Ali, W., Fahad, S., Saud, S., Hayat, Z., Nawaz, T., Khan, S.A., Alam, S., Ali, B., Banout, J., Ahmed, S., Muheen, S., Danish, S., Datta, R., Eigorban, A.M. and Dewil, R. (2021). Heavy metals immobilization and improvement in maize (Zea mays L.) growth amended with biochar and compost Science Reports 11: 18416 doi:10.1038/s41598-021-97525-8.

Khaleel, R., Reddy, K.R. and Overcash, M.R. (1981). Changes in soil physical properties due to organic waste applications: A Review. Journal of Environmental Quality, 10, 133-141.

Lal, R. (2011). Organic matter, effects on soil physical properties and processes. In: Encyclopedia of Agrophysics doi:10.1007/978-90-481-3585-1-102.

Lanno, M., Kriipsalu, M., Shanskiy, M., Silm, M. and Kisand, A. (2021). Distribution of phosphorus forms depends on compost source material. Resources 10, 102.

Lau, D.C.W. and Wu, M.M.W. (1987). Manure composting as an option for utilization of management of animal waste. Resource Management, 13, 145-156.

Ma, A.N., Chow, C.S., John, C.K., Ibrahim, A. and Isa, Z. (2001). Palm oil mill effluent – A survey. In: Proceedings of the PORIM Regional Workshop on Palm Oil Mill Technology and Effluent Treatment, Palm Oil Research Institute ofMalaysia (PORIM), Serdang, Malaysia p.233-269.

Mau, V., Arye, G. and Gross, A. (2018). Wetting properties of poultry litter and derived hydrochar PLoS One 13 (10): e0206299 doi:10.137i/journal.pone.0206299

Mbah, C.N. and Mbagwu, J.S.C. (2006). Effects of animal wastes on physicochemical properties of a dystric Leptosol and maize yield in Southern Nigeria. Nigerian Journal of Soil Science, 16, 96-103.

Murphy, D.J., Goggin, K. and Paterson, R.M. (2021). Oil palm in the 2020s and beyond: Challenges and solutions CABI Agriculture and Bioscience 2: 39

Musa, S.D. (2009). Evaluation of Soil and Plant Conditions on a Waste Dumpsite in Anyigba

Narendar, K.M., Ramavtar, G., Prabhat, T. and Prashant, S. (2017). Nutrient losses in soil due to erosion. Journal of Pharmacognosy and Phytochemistry SP 1: 1009-1011.

Nester, E.W., Anderson, D.G., Roberts, E.V. Jnr. and Nester, M.T. (2009). Microbiology: A Human Perspective. 6th Edition, McGraw-Hill Co., New York, 767 pp.

Okafor, U., Orji, M., Nwankwegu, A.S., Anaukwu, C., Onuorah, S., Archibong, E., Obika, I. and Agu, K.C. (2016). Effect of chicken droppings amendment on bioremediation of crude oil-polluted soil. European Journal of Experimental Biology 6 (4): 62-68.

Okwute, L.O., Okpiaifo, S., Giwa, H.J. and Stephen, E. (2017). Comparative Studies on the Biodegradation of Crude oil-polluted soil by Pseudomonas aeruginosa and Alternaria sp. isolated from unpolluted soil. Microbiology Research Journal International 19 (1):1-10.

Okwute, O.L. and Ijah, U.J.J. (2014a). Changes in Microbial Population of Palm Oil Mill Effluent Polluted Soil amended with Chicken droppings and Cow dung. British Biotechnology Journal, 4(3):279-288.

Okwute, O.L. and Ijah, U.J.J. (2014b). Bioremediation of Palm oil mill effluent (POME) polluted soil using microorganisms found in Organic Wastes. International Journal of Biotechnology,3 (3): 32-46.

Okwute, O.L. and Isu, N.R. (2007a). The environmental impact of palm oil mill effluent (POME) on some physicochemical parameters and total aerobic bioload of soil at a dump site in Anyigba, Kogi State, Nigeria. African Journal of Agricultural Research,2 (12), 656-662.

Okwute, O.L. and Isu, N.R. (2007b). 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.

Okwute, O.L., Ijah, U.J.J., Dauda, B.E.N. and Okwute, S.K. (2020). Bioremediation of palm oil mill effluent (POME) polluted soil using organic wastes: GC-MS Monitoring of the volatile organic compounds (VOCS) of POME and Soil. Direct Research Journal of Biology and

Orprapa , T., Preuk, C., Sudathip, S. and Hiroshi, E. (2022). Effect of chicken manure and chemical fertilizer on the yield and qualities of white mugwort at dissimilar harvesting times. PLoS One 17 (4): e0266190 doi: 10.1371/journal.pone.0266190.

Osman, N.A., Ujang, F.A., Roslan, A.M., Ibrahim, M.F. and Hassan, M.A. (2020). The effect of palm oil mill effluent final discharge on the characteristics of Pennisetum purpureum. Scientific Reports 10:6613.

Paul, E.A. and Clark, F.E. (1989). Soil Microbiology and Biochemistry. Academic Press Incorporated San Diego, California, p.265

Pharm-phu, S. and Asari, M. (2021). Study on Nitrogen Recovery from

Nutrient-rich waste by ADCSTR systems 2020. Applying new Technology in Green Buildings (ATIGB) 125-129.
Poku, K. (2002). Small-Scale Palm Oil Processing in Africa. Technology and Engineering Food and Agriculture Organization of the United Nations, Rome, Italy, 59 pp.
Salihu, A. and Alam, M.Z. (2012). Palm oil mill effluent: A waste or a raw material? Journal of Applied Sciences Research 8 (1): 466-473.
Sayara, T., Basheer-Salimia, R., Hawamde, F. and Sanchez, A. (2020). Recycling of organic wastes through composting: Process performance and compost application in Agriculture, Agronomy 10: 1838.
Statistical Package for Social Sciences (SPSS) 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corporation
Sumner, M.E. and Miller, W.P. (1996). Cation exchange capacity and exchange coefficients In: D.L. Sparks (ed.) Methods of Soil Analysis. Part 2: Chemical properties (3rded.). ASA, SSSA. CSSA, Madison, WI.Unpublished Ph.D Thesis, Department of Geography, University of Abuja, Abuja-Nigeria. 222 pp.
Wyszkowski, M. and Kordala, N. (2022). Petrol-contaminated soil following the application ofcompost and mineral materials. Materials 15:5233. https://doi.org/10.3390/ma/5155233.