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EFFECT OF PALM OIL MILLING WASTES ON THE PHYSICO-CHEMICAL PROPERTIES OF SOILS IN OKIJA, SOUTHEASTERN NIGERIA

Obi[1], C. I, Onweremadu, [1] E. U. and Obi,[2] J. C.
[1*] Department of Soil Science and Technology, Federal University of Technology, Owerri, Nigeria.
[2] Department of Soil Science, University of Uyo, Nigeria.

ABSTRACT
This research work was carried out to determine the physico-chemical properties of soils as affected by palm oil milling wastes in Okija, Anambra state, Nigeria. Soil samples from an abandoned palm oil mill (site 1), active palm oil mill (site 2) and a fallow land (site 3) were collected from three mini-pits per land unit at 0-20 and 20-40 cm depths. The soil samples were air-dried, sieved with a 2-mm sieve and analyzed for physico-chemical properties. Data collected in a Randomized Complete Block Design (RCBD) were subjected to analysis of variance. ECEC were significantly different ($p<0.05$) in the surface and subsurface soils among the sites. Significant differences also existed among bulk density of the surface soils. Again, significant difference existed in the Ca^{2+} content of the surface and subsurface soils among the sites. The Ca^{2+} content of the soils of abandoned palm oil mill (13.98 $Cmolkg^{-1}$) was about 50% more than that of soils of the other two study sites. Available phosphorous in the study sites was highly variable (CV = 71 %) and the values were significantly different in the surface and subsurface soils among the sites. There were significant differences in the organic matter contents among the surface soils of the study sites and were highly variable (CV= 53%). It is therefore advisable that palm oil mill wastes especially palm oil mill effluent undergoes some form of treatment or decomposition before deposition on the soil.

Keywords: Palm oil milling effluent, soil properties, fertility indices, target soil survey, mini-pits.

INTRODUCTION
Palm oil mill has been seen as an agribusiness that brings a good return on investments. The palm oil industry contributes 83% of the largest pollutant in Malaysia, the situation is probably similar in other palm oil producing countries (Kwon *et al*, 1989) and so raises the need to look at the effect of palm oil wastes (especially the effluent) on the environment in Nigeria. The abundance of oil palm trees (*Elaeis guineensis*) in Okija, southeastern Nigeria is responsible for the large production of palm oil in the area. It is the most important crop for the farmers in the area and most households earn their livelihood on it. The majority of palm oil produced in the area comes from individual households and the industry is a true example of a smallholding. The production line is basically traditional involving rudimentary equipment, division of labour and tasks closely integrated with the domestic routine of a subsistence farming system.

The only palm oil mill in the study area the production line of which involves modern technology was abandoned by the government some 15 years ago. Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. During extraction of crude palm oil from the fresh fruit, about 50% of the water used results in palm oil mill effluent (POME). Each metric ton of fresh fruit bunches at the extraction mill generates approximately 0.22 metric ton of empty bunches and between 800 and 900 litres of effluents and other bye products (Torres *et al*, 1999). It is also estimated that for 1 metric ton of crude palm oil produced, 5-7.5 metric tons of water used ends up as POME (Ahmad *et al*, 2003). Asides the empty fruit bunches (EFB), other solid waste products that result from the milling operation are the palm fibre and palm kernel. These wastes are usually inadvertently disposed on soils of near by palm oil mill without treatment or curing. Generally, homesteads in Okija are dotted with processing

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sites. Thus, while enjoying a most profitable commodity, the adverse environmental impact from the palm oil industry cannot be ignored. This study aimed at determining the effect of palm oil milling wastes, especially the effluent, on the properties of soils of Okija area in Anambra State, Nigeria.

MATERIALS AND METHODS

Description of the Study Area

The **s**tudy was conducted on three sites including; an abandoned (about 15 years of abandonment) palm oil mill (site 1), active palm oil mill (site 2) and a fallow land (site 3) all located in Okija, southeastern Nigeria. Okija is located between latitudes 5°57' and 6°51' N and longitude 3̊ 44' and 4̊ 00' E. The climate of Okija is humid tropical and the annual rainfall ranges from 2300 mm and 2500 mm, while the annual temperature ranges from 25-28°C. The soils parent material is derived from coastal plain sands and alluvial deposits with intercalation of shale.

Soil Sampling and Laboratory Analysis

Reconnaissance survey (1: 200,000) was carried out to identify locations typical of the land use (i.e. milling activity). Three mini-pits (1m×1m×0.5m) were prepared per site to represent sampling points and soil samples were collected at depths of 0-20 and 20-40 cm. The soil samples were air dried, crushed and made to pass through the 2.0 mm mesh sieve. Particle size analysis was performed using the Bouyoucous hydrometer method (Gee and Bauder, 1986). Moisture content was obtained gravimetrically. Exchangeable bases (Ca, Mg, K, and Na) were extracted with 1 N NH_4OAc (pH 7) (Thomas, 1982). Exchangeable calcium and magnesium were determined by ETDA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). The exchangeable acidity (H^+ and Al^{3+}) was determined using 1 N KCl (Mclean, 1982). Effective cation exchange capacity (ECEC) was obtained by the summation of all exchangeable cations. Available phosphorus was determined by the Bray II method (Olsen and Sommers, 1982). Total nitrogen was determined by micro Kjedahl digestion method (Bremner and Mulvaney, 1982). Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724. Soil pH was measured potentiometrically in both water and 1N KCl at the ratio of 1:2.5 soil to water. Bulk density was determined using core method as described by Klute (Klute, 1986).

Statistical Analysis

The soil properties were analyzed using classical statistical methods to obtain descriptive statistics, measure of central tendency and normality of distribution. Analysis of variance was used to compare the soil properties and significantly different means were separated with least significant difference (LSD) at 5% probability level. Correlation was also carried out to find out the way variables relate with each other. All statistical analysis was carried out using SAS Institute software (SAS Institute, 1999).

RESULTS AND DISCUSSION

Data collected in Randomized Complete Block Design (RCBD) were subjected to analysis of variance (Table 2). The mean and median (Table 1) of the soil properties were largely similar with the exception of exchangeable Ca and Mg, total exchangeable bases, C/N ratio, Ca/Mg ratio and clay content dominated by outliers indicating that the soil properties were not actually from the same population showing that the palm oil mill effluent (POME) may have had significant effect on the distribution. Hence the properties which have been partially influenced by the palm oil milling activity were not normally distributed even to the extent of existence of outliers (a rare occurrence in soils). Additionally, exchangeable K, ECEC and total N were not normally distributed as could be seen in Table 1 in as much as they were not dominated by outliers. It has been reported that soil properties are not normally distributed as a result of variability but most times not dominated by outliers (Obi and Ogunkunle, 2009; *Shukla, et al., 2004*) but the contrary is the case in those earlier listed. These are preliminary indicators that apart from the soil properties which were normally distributed, palm oil mill effluent has significantly influenced the characteristics of distribution of these soil properties. The shippiro-wilk was used for evaluation of normality (SAS Institute, 1999). Pr < w greater than 0.01 or 0.05 is considered not significant, hence normally distributed. Again, from Table 1, exchangeable Mg, K, total exchangeable base cations, ECEC, total N, C/N ratio, Ca/Mg ratio, sand, clay, silt/clay ratio and moisture content are all not normally distributed in the entire sites. The differences in their distribution can be attributed to the different land uses to which they are put which include: the active palm oil mill site, the abandoned palm oil mill site and the five year fallow.

Table 1: Descriptive Statistics of the Physico-chemical Properties of Soils of the Study Sites

Variable	CV	SD	SE	Skewness	Kurtosis	Pr < w	Mean	Median	Min.	Max.
pH (H_20)	5.74	0.42	0.10	0.22	- 0.97	0.32^{ns}	7.24	7.24	6.55	7.91
pH (KCl)	3.24	0.21	0.05	0.38	- 0.96	0.43^{ns}	6.35	6.32	6.06	6.73
TEA ($CMolkg^{-1}$)	31.81	0.11	0.03	1.29	2.04	0.04^{ns}	0.35	0.33	0.20	0.65
Ca ($CMolkg^{-1}$)	49.20	4.57	1.08	1.20	0.65	0.01^{ns}	9.29	7.75	4.90	20.40
Mg ($CMolkg^{-1}$)	88.28	0.82	0.19	3.35	12.72	<0.0001	0.93	0.67	0.17	4.00
Na ($CMolkg^{-1}$)	14.35	0.01	0.003	0.24	0.0004	0.08^{ns}	0.08	0.08	0.06	0.10
K ($CMolkg^{-1}$)	35.75	0.03	0.008	- 1.91	3.03	<0.0001	0.09	0.10	0.01	0.12
TEB ($CMolkg^{-1}$)	48.35	5.03	1.18	1.91	0.53	0.008	10.39	8.85	5.52	21.81
ECEC ($CMolkg^{-1}$)	46.68	5.01	1.18	1.20	0.59	0.009	10.73	9.09	5.82	22.16
BS (%)	2.07	1.99	0.47	-0.90	0.08	0.05^{ns}	96.16	96.18	91.84	98.53
Av.P (gkg^{-1})	71.05	18.87	4.45	0.62	-0.40	0.05^{ns}	26.56	26.77	4.90	65.87
TN (%)	103.8	0.04	0.01	0.84	-0.40	0.008	0.04	0.04	0	0.13
OC (%)	53.11	0.47	0.11	0.99	0.54	0.12^{ns}	0.89	0.83	0.32	2.02
OM (%)	53.22	0.81	0.19	1.01	0.50	0.11^{ns}	1.52	1.43	0.55	3.49
CN	95.09	65.90	15.53	0.63	-1.56	0.0003	69.31	23.20	12.70	185.00
Ca/Mg	58.54	7.15	1.68	1.38	1.95	0.002	12.21	9.97	4.00	31.18
Sand (gkg^{-1})	7.82	66.03	15.56	-1.30	0.90	0.002	844.70	866.25	700.40	928.00
Clay (gkg^{-1})	79.36	60.78	14.32	1.18	0.35	0.003	76.58	60.25	20.00	201.60
Silt (gkg^{-1})	36.07	28.44	6.70	-0.19	-0.68	0.76^{ns}	78.83	80.40	24.00	122.00
SCR	99.68	2.02	0.47	1.02	-0.73	0.0002	2.03	8.56	0.44	5.60
BD (gcm^{-3})	18.78	0.24	0.06	-0.44	0.12	0.92^{ns}	1.28	1.30	0.73	1.68
F (%)	18.23	9.32	2.19	0.51	-0.06	0.76^{ns}	51.11	50.56	36.60	72.45
MC (gg^{-1})	40.19	0.12	0.03	1.66	3.51	0.009	0.30	0.26	0.17	0.67

TEA – Total Exchangeable Acidity, Ca- Calcium, Mg- Magnesium, Na- Sodium, K- Potassium, TEB- Total Exchangeable Base, ECEC- Effective Cation Exchange Capacity, BS- Base Saturation, Av.P- Available Phosphorous, TN- Total Nitrogen, OC- Organic Carbon, OM- Organic Matter, CN- Carbon/Nitrogen Ratio, Ca/Mg- Calcium Magnesium Ratio, SCR- Silt Clay Ratio, BD- Bulk Density, f- Porosity, MC- Moisture Content.
ns - not significant at both 1% and 5%

The results shown in Table 2 indicate that there are significant differences ($p \leq 0.05$) among the primary soil particles of the study sites. Among the sites, there are similar trends of decrease downwards in the sand content and increase in silt and clay contents. The sand content was generally high (905 – 713 g kg^{-1}), with low silt (104 – 46 g kg^{-1}) and clay contents (194 – 21.33 g kg^{-1}). This high sand content in all the sites could be attributed to their parent material which is of coastal plain sands mixed with shale (Ofomata, 1975). The sand contents of the active and the abandoned mill are not significantly different from each other while fallow is significantly different from active but not abandoned mill. The effect of colloidal particles that may have affected the clay content may be responsible for this variation as sand content is not expected to vary widely among soils on same parent material apart from land use and management effect. The clay contents, both in the upper layer (0-20 cm) and lower layer (20-40 cm) were highest in soils of the active palm oil mill land use. The colloidal suspension of water and total dissolved solutes in the palm oil mill effluent could be contributory for high clay contents since it includes all fine particles inherent in or introduced to the soil system. This could be a further confirmation of the effect of land use on the characteristics of sample distribution especially of the particle size fractions (psf). As a result, this affected the silt/clay ratio which is an indication of extent of weathering and soil development. The abandoned mill soil has a value approximately five times that of both active and fallow.

The shippiro-wilk test for evaluation of normality (Table 1) showed that bulk density was normally distributed in the entire sites and was not dominated by outliers. Bulk density was found to increase normally downwards in the sites except in the active palm oil mill where the bulk density decreased downwards (Table 2). The effluent was suspected to cause clogging of soil pores and increase in bulk density. Also, Table 2 showed that there was significant difference ($p<0.05$) between the bulk density of the surface soils of the active palm oil mill land use and the other soils.

Table 2: Soil Physico- chemical Properties under various depths and conditions in the study area

	pH		TEA	Ca	Mg	Na	K	TEB	ECEC	BS	Av.P	TN	OC	OM	CN	Ca/Mg	Sand	Clay	Silt	SCR	BD	f	MC
	H_20	KCl	---------------------CMolkg^{-1}----------------------------							%	gkg^{-1}	------------%----------					----------gkg^{-1}----------				gcm^{-3}	%	gg^{-1}
0-20cm																							
Active	7.81	6.53	0.32	7.00	0.89	0.08	0.10	8.07	8.39	96.1	27.79	0.04	0.94	1.61	22.27	6.32	841.3	91.33	67.33	0.74	1.53	39.87	0.19
Abandoned	7.14	6.26	0.38	15.3	1.00	0.07	0.07	16.4	16.87	97.4	57.47	0.11	1.68	2.89	14.50	16.40	874.6	21.33	104.6	4.89	0.92	65.16	0.33
Fallow	6.91	6.21	0.32	8.08	0.81	0.08	0.11	9.08	9.40	96.5	28.33	0.04	0.95	1.64	23.17	10.99	905.8	47.20	46.93	0.98	1.21	54.47	0.26
LSD $_{0.05}$	0.48	0.33	0.17	7.73	0.94	0.03	0.08	8.05	7.92	3.23	13.42	0.02	0.42	0.74	1.30	15.94	36.89	23.15	38.69	1.37	0.39	12.56	0.13
20-40cm																							
Active	7.39	6.39	0.40	5.03	0.39	0.07	0.08	5.58	5.98	93.3	6.17	0.003	0.51	0.88	148.3	16.93	713.8	194.3	92.13	0.48	1.50	43.27	0.22
Abandoned	7.32	6.38	0.42	12.3	1.81	0.08	0.07	14.31	14.63	96.5	33.22	0.043	0.82	1.41	64.50	11.38	871.0	25.33	103.6	4.33	1.24	53.34	0.51
Fallow	6.87	6.33	0.25	7.98	0.70	0.09	0.10	8.87	9.12	97.0	6.41	0.000	0.42	0.72	143.1	11.24	861.5	80.30	58.23	0.73	1.31	50.57	0.31
LSD $_{0.05}$	0.92	0.72	0.28	5.47	2.48	0.02	0.07	7.72	7.77	3.36	17.69	0.070	0.72	1.23	139.5	14.15	19.04	23.51	21.45	2.05	0.31	11.81	0.20
Site1- Abandoned Palm Oil Mill																							
0-20	7.14	6.26	0.38	15.3	1.00	0.08	0.08	16.87	16.87	97.9	57.47	0.11	1.68	2.89	14.50	16.40	874.7	21.33	104.7	4.89	0.92	65.16	0.33
20-40	7.32	6.38	0.42	12.6	1.81	0.08	0.07	14.31	14.63	96.8	33.22	0.04	0.82	1.41	64.50	11.38	871.0	25.33	103.7	2.74	1.24	53.34	0.51
LSD $_{0.05}$	1.11	0.59	0.36	5.04	4.02	0.03	0.24	4.02	4.669	3.35	36.73	0.15	1.51	2.62	202.6	16.74	13.68	13.15	2.48	7.10	0.41	15.48	0.33
Site2- Active Palm Oil Mill																							
0-20	7.81	6.53	0.32	7.00	0.89	0.08	0.10	8.07	8.39	96.1	27.79	0.043	0.94	1.61	22.27	6.32	841.3	91.33	67.33	0.74	1.53	39.87	0.19
20-40	7.39	6.39	0.40	5.03	0.39	0.07	0.08	5.58	5.98	93.3	6.17	0.003	0.51	0.88	148.3	16.93	713.8	194.0	92.13	0.48	1.50	43.27	0.22
LSD $_{0.05}$	0.34	0.50	0.39	1.88	0.82	0.05	0.07	2.739	2.34	7.31	13.80	0.000	0.30	0.52	85.33	34.08	65.54	12.34	62.21	0.55	0.52	11.40	0.00
Site3- Five Year Fallow																							
0-20	6.91	6.21	0.32	8.08	0.81	0.08	0.11	9.08	9.40	96.5	28.33	0.04	0.95	1.64	23.17	10.99	905.9	47.20	46.93	0.98	1.21	54.47	0.26
20-40	6.87	6.33	0.25	7.98	0.70	0.09	0.10	8.87	9.12	97.0	6.41	0.00	0.42	0.72	143.1	11.24	861.5	80.30	58.23	0.73	1.31	50.57	0.31
LSD $_{0.05}$	0.60	0.71	0.14	9.19	0.32	0.01	0.03	8.85	8.83	3.44	3.47	0.01	0.35	0.61	51.47	13.59	54.79	16.93	70.39	1.55	0.19	7.28	0.03

TEA – Total Exchangeable Acidity, Ca- Calcium, Mg- Magnesium, Na- Sodium, K- Potassium, TEB- Total Exchangeable Base, ECEC- Effective Cation Exchange Capacity, BS- Base Saturation, Av.P- Available Phosphorous, TN- Total Nitrogen, OC- Organic Carbon, OM- Organic Matter, CN- Carbon/Nitrogen Ratio, Ca/Mg- Calcium Magnesium Ratio, SCR- Silt Clay Ratio, BD- Bulk Density, f- Porosity, MC- Moisture Content, (LSD, $p \leq 0.05$)- Least Significant Difference tested at 5%

The gravimetric moisture content of the study sites was fairly high which could be due to capillary fringes from the high water table of the soils. The values increased downwards in all the sites (Table 2). There was significant difference between the gravimetric moisture content of the surface and subsurface soils of the active palm oil mill and the soils of the other two land uses. Moderately high pH values were recorded in all the sites with no significant differences (Table 2) which can be adduced to the characteristics of the parent material. The argument is that the dominant mineral in shale is kaolinitic clay and Okija has been known for mining the best clay for molding. The active palm oil mill had the highest pH value among the three sites (Tables 2). The pH value both in water and 1N KCl decreased downwards. It has been reported that when raw POME is discharged, the pH is acidic (Hemming, 1977) but seems to gradually change to alkaline as biodegradation progresses. However, the pH value of the active palm oil mill was found to be slightly higher than the abandoned mill. This could be adduced to the aforementioned parent material with an added effect of the separation processes of the kernel from the shell. During the process, kaolinitic clay is usually dissolved in a pit (plastered with clay) of water for this separation. It could be that the kaolinitic clay water, through seepage and capillary rise has added to the already high pH value derived from the parent material.

The TEA varied moderately in all the sites (CV = 31.81%) (Table 1). There was an increase downwards in the total exchangeable acidity in all the sites (Table 2). Total exchangeable bases were moderate (16 – 5 C $molkg^{-1}$) and varied moderately in all the sites. Significant differences in the TEB existed in the surface and subsurface soils among the sites (Table 2). The value decreased downwards in all the sites. The highest value recorded in the abandoned mill (mean TEB = 15.59 $Cmolkg^{-1}$) could be due to biodegradation of wastes that have taken place in the site. The mean values of the exchangeable Ca^{2+} in the abandoned mill were highest among the site which was 15.33 and 12.36 $Cmolkg^{-1}$ soil for the first and second layers, respectively (Table 2). The major sources of cations are mineral weathering, mineralization of organic matter and soil amendments, particularly lime and fertilizers (Foth, 1990). The results showed a preponderance of Ca^{2+} in the soils with highest values in the abandoned mill. This could be as a result of mineral weathering of the shale parent material of the soils and mineralization of organic matter from the effluents. Results from Table 2 show that percentage base saturation in all the sites were greater than 90%. This could be attributed to the parent material from which the soils are made. The abandoned mill had the highest mean values among the sites with values as 97 % and 96 % for the first and second layers, respectively. The percentage base saturation decreased downwards in all the soils.Table 1 shows that the ECEC varied moderately (CV = 46 %) in all the soils. The abandoned palm oil mill land use had the highest ECEC with 16.87 and 14.63 $Cmolkg^{-1}$ soil for the first and second layers, respectively (Table 2). The ECEC values decreased downwards in all the sites and were significantly different in the surface and subsurface soils (Table 2). The ECEC of 20 $Cmolkg^{-1}$ is suitable for crop production if other factors are favourable (FAO, 1977). Soils around the abandoned mill approached this value with the closest proximity.

Available phosphorous in the study sites was highly variable (CV = 71 %). Also, the values were significantly different in the surface and subsurface soils among the sites (Table 2). Values in the abandoned mill which had the highest available phosphorus were 57.47 and 33.22 g kg^{-1} for the first and second layers respectively. In all the sites, the values decreased downwards. The availability of organic phosphates in the soil is governed essentially by the amount of organic matter in the soil and mineralization rate (Foth, 1990), while availability of inorganic phosphorous is controlled mainly by soil pH which is also invariably controls the amount of soluble iron, aluminum, manganese and calcium. From the results (Table 2), high organic matter content implied high available phosphorous as can be seen in sites 1, 2 and 3. Total N was significantly different only among the surface soils of the study sites (Table 2) and varied highly (CV = 103 %) in the study sites (Table 1). Percentage total N was moderate for abandoned palm oil mill, while it was low for active palm oil mill and fallow and decreased with increasing soil depth in all the sites (Table 2). This could be adduced to the organic matter content of soils in the sites. Soil organic matter typically contains about 5% nitrogen; therefore the distribution of soil nitrogen closely parallels that of soil organic matter (Brady and Weil, 1999). A close examination of the results (Table 2) shows that it agrees with the documentation of Brady and Weil (1999). Higher organic carbon and increased nitrogen content have been observed in palm oil mill sites (active) in similar studies (Okwute and Isu, 2007; Ngan *et al*, 1996) but this could be dependent on the age of the mill which may affect organic matter decomposition and thus nitrogen content through mineralization. Significant difference in the organic matter contents existed only among the surface soils of the study sites (Table 2) and were highly variable (CV = 53 %) in the study sites. The results showed that the abandoned palm oil mill soil has the highest organic carbon and organic matter contents with the mean of the organic matter as 2.89 and 1.41% for the first and second layers respectively. These values decreased with depth in all the sites. This could be as a result of litter accumulation and decomposition, *inter alia*, on the surface of soil. The results have shown that soils of the study sites are of low organic matter content which could be due to climatic conditions of high humidity and warm temperatures. In tropical soils, mineralization is accelerated, so nutrient release is rapid, but residual organic matter accumulation is lower than in cooler soils (Brady and Weil, 1999). The highest value recorded in site 1 also reflected from the results of physical properties analysis-bulk density, porosity and moisture content (Table 2). The greater plant productivity engendered by humidity generally leads to greater additions to the pool of soil organic matter (Brady and Weil, 1999).

CONCLUSION

The data generated in this study revealed that the physico-chemical properties of soils at the active palm oil mill land use were altered by the anthropogenic activities of the milling processes. Exchangeable Ca and Mg, total exchangeable base cations, C/N ratio, Ca/Mg ratio and clay content were dominated by outliers indicating that the soil properties were not actually from the same population showing that the palm oil mill effluent (POME) may have had significant effect on the distribution. The properties which have been partially influenced by the palm oil milling activity were not normally distributed even to the extent of existence of outliers. The ECEC indicated that soils of active palm oil mill were least in soil fertility status compared to the other land uses studied. Only the significant difference in clay content between the active mill and the other two sites is enough to explain reasons for high bulk density in the active site. Colloidal particles from the palm oil mill effluent had been suspected to be responsible for this variation. The upper layers of the abandoned mill site were found to have high organic matter content. From the findings, it is advisable that palm oil mill wastes especially palm oil mill effluent undergoes some form of treatment or decomposition before deposition on the soil. More so, its application as soil amendment has been found very useful where it was properly processed before application. The condition or the inherent physico-chemical properties of a particular soil will determine the best treatment for the palm oil mill effluent and other usable wastes. In some cases it can be very good for making compost for soil amendments.

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