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Evaluation of Spatial Variation of Palm Oil Mill Effluents (POME) in Cross River State, Nigeria

Oko, Comfort N., Eni, D. Imoke and Oka, Peter Onen

Abstract— The study examined the spatial variation in palm oil mill effluents (Pome) in Cross River State. The extraction and purification processes of palm oil generate different kinds of wastes known as palm oil effluent (Pome). The impact of Pome on the soil cannot be over emphasized; hence the need for proper treatment measures to reduce its degradational effect when discharged unto the soil. Soil auger was used to obtained surface soil samples of 0-15cm depth from six selected study locations. They samples were air dried at room temperature, ground with wooden roller and sieved through a 2mm mesh before taking it for physico-chemical analysis. The research revealed that the proportion of clay, silt and sand varies greatly between seasons in Cross River State. The values of clay ranged from 2-12%, silt 8-2% and sand 67-90%. Bulk density ranged from 1.14-1.46g/cm^3 and porosity 45-57%. The research further revealed that POME has a very high biochemical oxygen Demand (BOD) and chemical oxygen demand (COD), which is more than what is obtained in the municipal sewage. The high organic matter is due to the presence of different sugars such as Arabinose, Xylose, Galactose, Glucose and Monose. Principal component analysis (PCA) was used to highlight which of the soil properties contributed significantly to the spatial variation across the study locations. The treatment of Pome is incredible, if a friendly and healthy environment devoid of pollution is to be met. The researchers recommends that palm oil mill effluent (Pome) be properly managed and discarded to avoid spillage of effluent onto the soils to reduce clogging of soil pores. Attempts should be made to convert palm oil mill effluent waste into useful products such as feed stock and organic fertilizer.

Keywords: Pome, Palm oil, Porosity, Effluents and Clogging.

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INTRODUCTION

Palm oil is produced from the fruit of the oil palm tree (*Elaeis guinensis*) which is a native tropical plant that grows in the wild form. Edaphic and climatic conditions favouring the growth of oil palm trees include the following, slightly acidic, loamy soils, average annual rainfall of 3550mm and a temperature of 32^{o}C all year round (Ugochukwu *et al*., 1999). Palm oil mills generate many by-products and wastes that have significant impacts on the environment, if not properly treated. Palm oil mill effluent (Pome) is an oily waste water discharged from oil palm processing activities onto soil. It contains various suspended components and soluble materials that are poisonous to the environment.

Palm oil processing discharges large volumes of effluents to the soil which results in soil degradation (Keu, 2005). Soil is said to be degraded when it has lost its productive capacity through the loss of appropriate texture, cation exchange capacity (CEC), water holding capacity and colour. As Pome from the processing of oil palm is released directly to the soil, it automatically alters its physical and chemical properties which cause decrease in nutrient status, compaction, salinization and increased in toxicity of some elements. Some adverse impact of pome on soils includes; increased biological oxygen demand (BOD), chemical oxygen demand (COD), the accumulation of toxic substances, and the clogging of soil pores. The pome from oil processing contains gases such as methane, sulphate, ammonia and halogens with their concentration above the required threshold value (Pfafflin, 1980). Since these compounds are harmful to the environment, it becomes necessary that pomes should be treated before discharged into the environment.

Ahmad (2003), reported that the constituents of raw pome is 95-96% water, 0.6-0.7% oil, 4.5% solid and 2.4% suspended solid. The impact of oil palm production on soil health involves both soil quality and quantity. Soil erosion is the major soil degradation process adversely affecting the soil not only by directly reducing nutrients and organic matter levels but also by affecting soil properties such as infiltration rates directly and indirectly by depleting soil biodiversity and impacting on subsequent plant colonization and composity (Ziergler *et al*., 1996). The most risk prone period for soil erosion during the oil processing activity is the period of new subsequent replanting. Soil loss during the preparation of drains, roads, culverts and bridges in the oil plantations is not so easy to manage.

Chan *et al*. (1980), is of the view that, there is absence of vegetation in oil mill pome soils because of the ability to retain much water which leads to the clogging of soils. This was attributed to the higher organic carbon content present in pome solution, unrecovered oil and cellulose fruit debris. It has been observed that when raw pome is discharged, the pH is acidic but gradually increase in alkaline as biodegradation takes place. Oil palm production has been documented as a cause of substantial and often irreversible damage to the natural environment. Its impact includes deforestation, habitat loss of critically endangered species and a significant increase in greenhouse gas emission.

There is dearth of information relating to the impact of oil palm processing activities on soils in Cross River State. The ecological impact of soil degradation is currently recognized through poor crop yield over the years, and the consequences includes reduced productivity, food crises, damage to basic resource, ecosystem and loss of biodiversity through changes in habitat at both species and genetic levels. The study seeks to determine the spatial variation in pome soils within oil palm Estates in Cross River State.

STUDY AREA

Cross River State is situated within the tropics, sharing common boundaries with Cameroon Republic in the East, Benue State in the North, Abia and Akwa Ibom States in the West. It covers an area of 23,074.425km^2 and it is located between longitude 7^{o}20'E and 7^{o}30'E and latitude 4^{o}20'N and 4^{o}25'N. The Ibad, Okoyong Usang Abasi, Calaro and orient oil mills are located at Akamkpa and Odukpani Local Government Areas of Cross River State. Other palm oil mills are located in Ikom and Boki Local Government Areas and it lies between latitude 5^{o}25'N and 5^{o}50'N and longitude 8^{o}10'E and 8^{o}51'E as shown in figure 1 and 2.

The interplay of the principal climatic elements like wind, rainfall, temperature and relief makes it possible for the division of the state into three climatic regions, namely; coast, middle and northern belt. The climate is determined by the direction of the southwesterly and northeasterly winds. As a result of the movement of these air masses and winds, Cross River State is characterized by two seasons namely; the rainy and dry season. The annual rainfall ranges from 1875mm-4000mm.

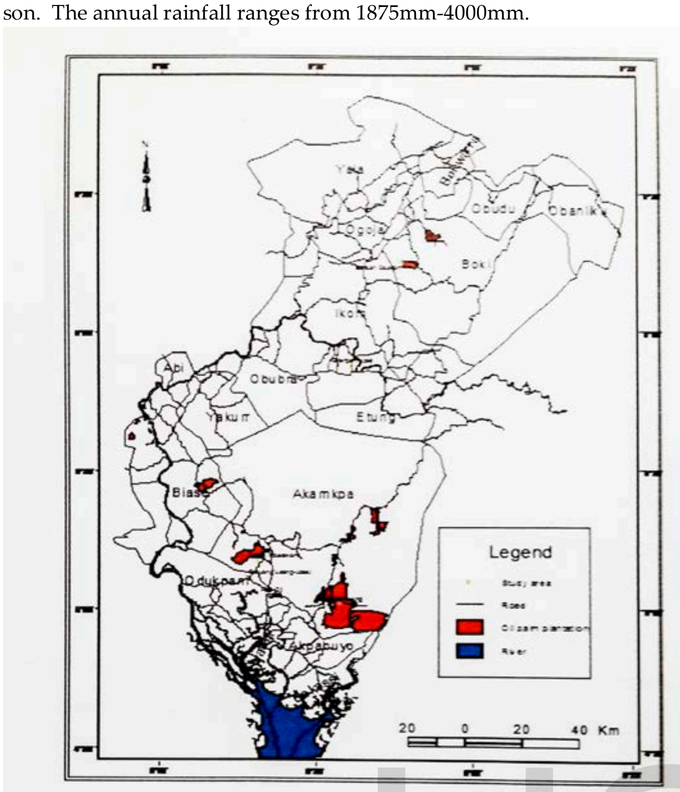

FIGURE *1* Cross River State map showing oil palm plantation

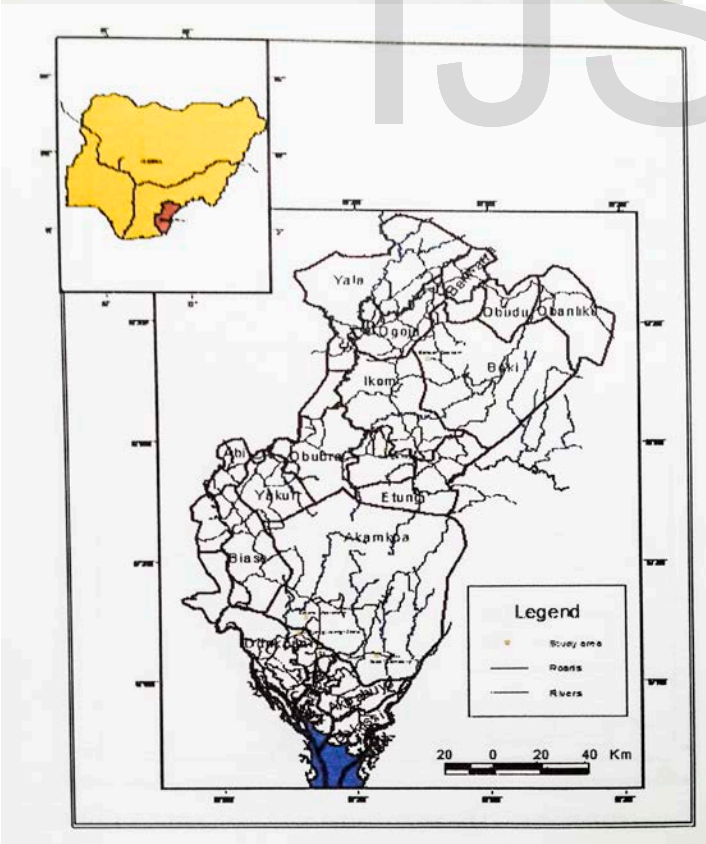

FIGURE *2* Map of Cross River State showing the study area

Owing to its latitudinal location, the Cross River State receives abundant and constant insulation. The angle of the sun's rays is almost vertical over the state throughout the year resulting in high sun intensity. The uninterrupted sunshine results in the high temperature. The rainfall distribution shows that it is characterized by double maxima rainfall which starts from the month of March to October, reaching its climax in the month of July and September. Evaporation is high, due to the average daily maximum temperature of 30^oC and a seasonal variation of 28^o – 31^oC between the hottest month February and the coldest month August.

The study area is made up of sands, which are mostly medium to coarse grained, pebbly moderately sorted with local lenses of fine grained poorly consolidated sand and silty clay. The soil has a high percentage of sand and it is of great socio-economic importance especially for construction purposes. The drainage pattern is dendritic. The vegetation is within the tropical rainforest zone but presently a large portion has been replaced with built-up areas as a result of urban growth which has expanded residential areas, road construction and paved surfaces. The issue of soil degradation has surfaced as an emerging phenomenon, which impacts negatively on the biodiversity and the environmental conditions. Adequate supply of moisture creates an opportunity for luxuriant growth of species which shed their leaves at different periods in the year leaving the forest in an evergreen state.

METHOD OF DATA COLLECTION

The method of study adopted for this research is the physical scientific measurements which involved site selection and data acquisition. The data used for the research were mainly derived from pome soil. Soil auger was used to obtained surface soil samples of 0-15cm depth from six selected study locations of Ibad, Orient, Calaro, Okoyong, Okangha, Nkpansi, Bansam and Osokom in the dry and wet season respectively. The coordinates were samples were taken were properly geo-referenced using the geographic positioning system (GPS).

The collected soil samples were air dried at room temperature, ground with wooden roller and sieved through a 2mm mesh and made ready for the physico-chemical analysis. Particle size distribution was determined by Bouyoucos hydrometer method using sodium hexametaphosphate as a dispersant. Bulk density was determined by collecting undisturbed core samples from the top soil and oven dried at a temperature of 105^oC to a constant weight, as described by Blake (1965). Soil pH was determined in 1:2 soil water suspension ratio using electrode pH meter as outlined by the International Institute of Agriculture (IITA, 1979). Organic carbon was determined by wet combustion method of Walkley-Black as outlined by Nelson and Sommer (1982). Organic matter determination was done by multiplying the value of organic carbon by a factor of 1.724.

Total nitrogen was determined on a sampled sieved through 0.5mm mesh using their micro-kjeldahl method as outlined by Bremner and Mulverney (1982). This involved the digestion of the samples to convert from organic nitrogen to inorganic nitrogen using sulphuric acid. Available phosphorus was extracted by the Bray No. 1 method (Bray and Kurtz, 1945) in solution. The reading was then obtained from the ultraviolet spectrophotometer and the analysed concentration values obtained was multiplied by the total dilution factor (TDF).

Exchangeable acidity, was determined by leaching 5g of soil sample in 100ml of volumetric flask with 1.NICCL solution. The extract was titrated with standard NaOH solution. The leachate was transferred quantitatively to 250ml Erlemmeyer flask and 5 drops of indicator was added and titrated with 0.2 NaOH to a pink end point. The exchange acidity was then calculated in ml/g of soil.

Exchangeable cations were leached from the soil using 1m NHo_4 (pH_7) buffer. Then sodium (Na) and potassium (K) were measured with a flame photometer while calcium (Ca) and magnesium (Mg) were determined by EDITA titrated method. Electrical conductivity (EC) was measured in a 1:1 soil water suspension after the pH measurement was done using a bench or field corning portable conductivity metre with sensitivity of 12 ± 0.5%. The result was expressed in dsm^{-1}.

Finally effective cation exchange capacity was determined by summing up of the exchangeable cations plus exchangeable acidity. ANOVA was used in comparing the spatial variations among pome soils in the study area.

Discussion of Findings

The physical characteristics of the palm oil mill effluent soils (POME) for dry and wet seasons are presented in the table 1 below.

The proportion of clay, silt and sand varies greatly between palm oil mill effluents (pome) soils with little variation between the seasons in Cross River State. The values for clay ranged from 2-12% with mean value at 5% for pome soils in dry and wet season. The values for silt ranged from 8-23% with mean value of 14% for pome soils in dry and wet season. Sand had a value that ranged from 65-90% with mean value of 81% in the both seasons. The bulk density ranged from 1.14-4.17g/cm^3 with a mean value of 1.27g/cm^3 for pome. Porosity ranged from 45-63% with a mean value of 54% in both seasons. The result obtained from this study shows a great variation in the levels of physical properties of soils. This is so because there was a substantial difference in the build-up of physical properties.

TABLE 1

Physical characteristics of POME soils in the study area

Locations	Coordinates	Seasons	Clay (%)	Silt (%)	Sand (%)	Textural class	Textural density (gkm^{-3})	Porosity (%)
A	05°08.238′N 008°21.955E	DS	12.0	21.00	67.00	Sandy loam	1.14	57
B	05°07.847′N 008°19.913E		6.00	9.00	85.00	Loamy sand	1.36	49
C	05°18.063′N 008°34.540E		6.30	21.00	73.00	Sandy loam	4.17	56
D	05°06.882′N 008°34.165E		2.00	11.00	87.00	Sand	1.18	50
E	05°56.721′N 008°36.974E		2.00	11.60	86.00	Sand	1.30	51
F	05°11.421′N 008°37.673E		2.00	8.00	90.00	Sand	1.46	45
A	05°07.847′N 008°21.955E	WS	12.00	23.00	65.00	Sandy loam	0.97	63
B	05°07.947′N 008°19.913E		3.00	10.00	87.00	Sand	1.26	52
C	05°18.063′N 008°34.540E		1.00	14.00	85.00	Loamy sand	1.06	60
D	05°06.882′N 008°34.165E		3.00	12.00	86.00	Loamy sand	1.06	60
E	05°56.721′N 008°36.974E		2.00	13.00	85.00	Loamy sand	1.16	56
F	06°11.421′N 008°37.637E		2.00	9.00	89.00	Sand	1.23	54

Note: A-F represent the study locations, A = Orient (Odukpani); B = Okoyong (Odukpani); C = Calaro (Akamkpa); D = Ibad (Mfamosing); E = Okangha Nkpansi (Ikom); F = Bansan Osokom (Boki).
DS = Dry season; WS = Wet season

There was great change in physical properties due to the fast rate of particle mobility from the parent rock and the influence of land use, erosion and other anthropogenic activities. Physical observation of top soils in the dumpsites across the study area revealed a dark brown colouration and the adhere to each other. This is good evidence in support of the effect that the soil have undergone degradation and it does not allow for free flow of water and air. Vegetations appear to be scanty or bare in some places.

The table revealed that sand in pome soils ranges from 67-90% with mean values of 81%. This high sand content of soils could be a reflection of unconsolidated coastal plain sand and sandstones parent materials of the study area. Such soils lack absorptive properties for basic plant nutrient and water. Furthermore, such soils have weak surface aggregation and vulnerable to erosion hazard. The clay content ranges from 2-12% which corroborated the study by Ogban (1998) which is of the view that, the properties of coastal plain sand and texture is mainly coarse but the percentage of clay varied. The mean bulk densities for pome soils were 1.27g/cm^3. This value is rated as low. Smucker (1985), reported that soil bulk density greater than 1.2g/cm^3 on medium is correlated with diseases of peas. In this study the bulk density is moderately low compared to the 1.60g/cm^3 rating of Arshad (1996). In spite of the low rating of bulk density the soil is suitable for oil palm production because of the varied nature of the soil texture found in the area. Soil characteristics are determined by the type of parent materials, depth, texture, relief and drainage.

TABLE 2
Chemical characteristics of POME soils in the dry and wet seasons

	GPS Coordinates	Months	pH	ECdsm^{-1}	Org.	Tn	C.N/Ratio	Avail.	Ca	Mg	K	Na	Al^{5+}	H^{+}	Bs	ECEC
A	05°08.23′N	Dec.	5.9	0.695	3.69	0.31	12	1.28	5.4	4.4	0.12	0.09	0.32	1.28	86	11.61
	008°21.955E	Jan.	7.2	0.693	3.39	0.29	12	32.37	17.4	7.4	0.20	0.13	0.00	0.00	100	25.13
		Feb.	4.4	0.691	3.65	0.31	12	26.75	7.2	2.2	0.15	0.09	0.28	0.28	74	13.08
B	05°07.847′N	Dec.	5.8	1.060	3.65	0.30	12	83.00	7.4	6.2	0.15	0.10	0.08	1.52	87	15.45
	008°19.913E	Jan.	6.9	1.040	3.63	0.29	12	52.75	19.4	13.4	0.25	0.13	0.20	1.20	96	34.58
		Feb.	5.3	1.020	1.63	0.14	12	19.62	2.4	1.0	0.09	0.06	2.68	1.28	47	7.50
C	05°18.063′N	Dec.	5.9	0.740	2.39	0.21	12	58.82	5.8	5.4	0.14	0.10	0.40	1.04	89	12.88
	008°34.540E	Jan.	5.4	0.720	2.75	0.24	12	12.37	3.4	0.8	0.09	0.06	1.68	0.68	65	6.71
		Feb.	5.0	0.700	1.95	0.16	12	8.25	2.4	0.8	0.08	0.05	1.00	1.58	57	5.89
D	05°06.882′N	Dec.	6.0	0.038	3.65	0.30	12	25.62	5.2	0.5	0.12	0.10	0.40	1.12	80	7.44
	008°34.165E	Jan.	6.5	0.036	3.67	0.32	12	30.75	0.2	8.4	0.11	0.09	0.20	1.40	85	10.40
		Feb.	6.1	0.033	2.61	0.22	12	28.12	8.4	0.2	0.13	0.11	0.12	1.32	86	10.28
E	05°56.721′N	Dec.	8.5	1.360	0.74	0.06	13	25.25	2.2	2.0	0.25	0.12	0.00	0.00	100	3.77
	008°36.974E	Jan.	8.0	1.340	1.46	0.12	13	40.50	2.0	1.4	0.22	0.10	0.00	0.00	100	3.92
		Feb.	5.6	1.320	1.19	0.10	13	33.37	1.4	1.0	0.19	0.09	0.00	0.32	91	3.60
F	06°11.421′N	Dec.	5.9	3.700	0.86	0.07	29	11.00	1.4	2.4	0.14	0.10	0.00	1.68	70	5.72
	008°37.673E	Jan.	6.1	3.660	0.40	0.02	29	41.50	2.0	1.2	9.09	0.11	0.00	0.84	80	4.30
		Feb.	5.8	3.660	0.92	0.08	29	30.25	2.0	2.0	0.15	0.12	0.48	0.48	82	5.25

Note: A-F represent the study locations, A = Orient (Odukpani); B = Okoyong (Odukpani); C = Calaro (Akamkpa); D = Ibad (Mfamosing); E = Okangha Nkpansi (Ikom); F = Bansan Osokom (Boki).

TABLE 3
Summary of seasonal characteristics of POME soils in dry and wet seasons

Parameters	POME soils range				
	Min	Max	Mean	CV	(±SE)
pH	5.40	7.40	6.12	6.12	±0.28
Organic carbon (%)	0.72	3.57	2.34	8.46	±0.48
Total nitrogen (%)	0.10	0.30	0.20	8.66	+0.04
Av.P.(mg/kg)	20.10	60.60	36.65	45.31	±6.49
Exch.Ca (Cmol/kg)	2.00	10.00	5.29	50.6	±1.51
Exch.Mg(Cmol/kg)	1.46	6.87	3.77	54.37	±0.79
Exch.K(Cmol/kg)	0.10	0.66	0.26	54.63	±0.09
Exch.Na(Cmol/kg)	0.10	0.10	0.10	54.75	±0.01
CEC (Meq/100g)	4.10	16.00	9.41	64.14	±2.11
ECEC	3.80	19.20	10.42	74.56	±2.54
A^{+++}	0.00	1.00	0.43	74.99	±0.18
H^{+}	0.10	2.68	1.17	76.16	±0.36
BS(%)	70.00	97.00	81.90	158.06	±3.86
EC(ds/m)	0.36	0.36	1.31	159.37	±0.49
BoD(Cmol/kg)	45.06	57.08	51.07	53.50	± 1.45
COD(Cmol/kg)	37.0	49.8	43.4	47.6	±0.50

Tables 2 and 3 reveals that the pH values ranged from 5.4-7.4 with a mean value of 6.12 for pome soils under investigation. This indicates that pome soils are slightly acidic. The concentrations of organic carbon (OC) and Total Nitrogen (TN) where higher in some sampled points with mean values of 2.34 and 0.20% respectively in both dry and wet season.

Available phosphorous for pome soil ranged from 20.1 to 60.6mg/kg with a mean value of 36.65mg/kg. This high available phosphorous concentration suggests that pome enhances soil fertility. Exchangeable cations in the study area revealed that Ca^{2+} ranged from 2-10cmol/kg with mean value of 5.29cmol/kg. The value for Mg^{2+} ranged from 1.46-6.87Cmol/kg with mean values of 3.77Cmol/kg in dry and wet season. The

value of K^{+} ranged from 0.10-0.66Cmol/kg with a mean value 0.26Cmol/kg. Sodium (Na^{+}) had a value that ranged from 0.10-0.10Cmol/kg. Cations exchange capacity (CEC) ranged from 4.1-16.8Cmol/kg with a mean value of 9.41Cmol/kg. The values of exchangeable acidity (A^{+++}) is lower in pome soils with values that ranged from 0.43-3.29 for both dry and wet seasons respectively. Base saturation ranged from 70-97%. On average, for each ton of fresh fruit bunches(FFB) processed, a standard palm oil mill generate about 1 tonne of liquid waste with biochemical oxygen demand(BOD) 51.07mol/kg chemical oxygen demand(COD) 43.4mol/kg, suspended solids 34mol/kg oil and grease 5mol/kg. Finally it was revealed that electrical conductivity was significantly high in POME soils and its mean value was 1.31. This shows that the soils are non-saline as the values are below 2-3dsm^{-1}.

TABLE 4
Summary results of analysis of variance in POME soil properties across the study location

S/N	Properties	Df	F-ratio	Sig. Value
1	Bulk density	50.3	11.405	<0.001
2	Porosity	5.30	6.142	<0.001
3	pH	5.30	1.802	0.143
4	EC	50.3	8.708	<0.001
5	Org. C	5.30	13.814	<0.001
6	TN	5.30	13.565	<0.001
7	Avail P.	50.3	4.328	0.004
8	Ca	5.30	1.418	0.246
9	Na	5.30	1.174	0.345
10	K	50.3	3.628	0.011
11	Mg	5.30	1.611	0.187
12	BS	5.30	1.346	0.272
13	H	50.3	2.084	0.095
14	A^{+++}	5.30	1.550	0.204
15	ECEC	5.30	3.127	0.022
16	Fe	50.3	8.057	<0.001
17	Pb	5.30	2.650	0.042
18	Ni	5.30	15.163	<0.001
19	Zn	50.3	43.662	<0.001
20	Mn	5.30	20.873	<0.001
21	Cu	5.30	11.274	<0.001
22	Cd	50.3	3.905	0.008
23	Vn	5.30	2.027	0.103
24	THB	5.30	2.910	0.029
25	HUB	50.3	5.559	0.001
16	THF	5.30	4.599	0.003
27	HUF	5.30	0.730	0.607

F-ratio significant at 0.05 level.

The table 4 above presents a summary result for twenty seven (27) properties measured across the study location. The table revealed that eighteen (18) properties out of the (27) twenty seven showed significant variations across the sampling stations. The 18 properties are BD, porosity, EC, organic carbon, TN, available P, K, ECEC, Fe, Pb, Ni, Zn, Mn, Cu, Cd, THB, Hub and THF. This accounts for two-third of the measured variables.

To identify which of the soil properties contributed significantly to the variation across the study locations the principal component analysis (PCA) was used to highlight this as shown in table 4. The data set for PCA were arranged in rows and columns to form a matrix and then transformed into standard scores. Kaiser criterion which stipulates that only components with Eigen values greater than one should be extracted was adopted. The result of the PCA was used to identify soil parameters which contributed significantly to the explanation of soil characteristics.

From table 5 only 8 out of 27 soil parameters have Eigen-values greater than I. The 8 components accounted for 87.1% of the variation in soil properties.

TABLE 5
Eigen-values (variance) associated with the 27 soil parameters total variance explained

Component	Initial Eigen-values		Extraction sums of square loadings		Total	Percentage of variance	Cumulative percent
	Total	Percentage of variance	Cumulative Percentage	Total			
1	5.884	21.793	21.793	5.884	4.729	17.513	17.513
2	5.464	20.238	42.032	5.464	3.529	13.069	30.583
3	3.085	11.427	53.458	3.085	2.879	10.664	41.246

4	2.347	8.692	62.150	2.347	2.847	10.545	51.791
5	2.196	8.133	70.283	2.196	2.772	10.266	62.057
6	1.998	7.401	77.684	1.998	2.654	9.831	71.888
7	1.421	5.265	82.949	1.421	2.346	8.689	80.577
8	1.131	4.188	87.136	1.131	1.771	6.559	87.136
9	.812	3.008	90.144				
10	.508	1.880	92.024				
11	.492	1.823	93.847				
12	.397	1.469	95.317				
13	.276	1.023	96.340				
14	.246	.909	97.249				
15	.201	.745	97.993				
16	.167	.617	98.611				
17	.104	.386	98.997				
18	.082	.303	99.300				
19	.065	.241	99.541				
20	.057	.213	99.753				
21	.027	.099	99.853				
22	.019	.071	99.924				
23	.0.11	.042	99.966				
24	.004	.016	99.982				
25	.003	.011	99.993				
26	.001	.004	99.997				
27	.001	.003	100.000				

Extraction Method: Principal Component Analysis

CONCLUSION

The most environmental damaging by-product of the milling process is palm oil effluent (pone), which is a hot, acidic effluent that contains oil Plant debris, and nutrients. It can be particularly harmful to aquatic communities by causing eutrophication, where excessive algae growth occurs on the water surface.

This research was aimed at investigating the spatial variation of palm oil mill effluent (pome) soils which enhances the soil quality, contrary to expectations from other writers. Pome contains reasonable amounts of essential minerals that are very helpful for plant growth. These essential minerals play crucial roles in maintaining proper physiological processes in plants. Pome has a high amount of organic minerals which could be used as fertilizers. The findings show that a pome soil has significant effect on soil quality status and varies from one location to another.

Finally, the research revealed that discharging pome on soil resulted in the clogging and water logging of the soil which lead to the death of vegetation. It was inferred that based on the substantial increase of nutrient in pome soils that proper use and safe disposal of pome in the land could lead to improved soil fertility. Although pome is organic in nature, atimes it is difficult to decompose, under natural conditions, but micro organisms like earthworm can help digest pome to produce valuable products such as vermicompost which is rich in nutrient and can be used for fertilizer in oil palm plantations. Care should be taken to ensure that pome is treated before discharging them into the environment if not so it may cause serious problem, and degrades the environment.

Attempts should be made to convert palm oil mill effluent waste to useful products such as feed stock and organic fertilizers, thus the need for government to enforce appropriate disposal method for palm estate operators.

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