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ORIGINAL ARTICLE

INFILTRATION CAPACITY AND PHYSICOCHEMICAL PROPERTIES OF SOIL UNDER PALM OIL MILL EFFLUENT DISPOSAL

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Abstract
The infiltration capacity and physicochemical properties of soil impacted with palm oil mill effluent in Ogale, Rivers State, Nigeria was studied. T-test experiment in randomized complete block design with two factors were employed. Factor A, represented the polluted site, factor B, represented the unpolluted site cultivated with cassava. Results showed that the impact of palm oil mill effluent (POME) significantly affected hydraulic conductivity with value 13.19cm/hr. in the polluted site as against 52.23cm/hr in the unpolluted site. Initial infiltration rate for site A was 17.1cm/hr. while site B was 130.0cm/hr. The result showed that site A had higher bulk density 1.49g/cm^3 and porosity (24.0%) than site B with bulk density1.29g/cm^3 and porosity 12.0% respectively. This study confirms that many soil chemical and physical properties are altered by the impact of POME. Soil properties such as aggregate stability (mm), water holding capacity (%), organic matter (%), total nitrogen (%), Exch. Ca^{2+} (C mol kg^{-1}), Exch. Na^+ , ECEC (C mol kg^{-1}), base saturation (%) and Avail. P (mg kg^{-1}) for site A and B where significantly affected ($p<0.05$) by POME. Conclusively, this work seemingly revealed that direct discharge of POME into the environment may exert undue impact on the infiltration capacity of the soil as well, alter soil structure and other soil properties of the area.

Keywords: Infiltration, Effluent, polluted site, unpolluted site, palm oil.

Introduction
Infiltration is the entry of water from the soil surface into the soil. It is a physical phenomenon and a major process of the hydrological cycle occurring at the soil surface interphase. It is related to the overland flow and ground water and the amount of soil erosion (Ogban et al., 2012). Infiltration is critical because it supports life on land and the planet (Tunner, 2006).
Water measurement in the soil through infiltration is an important indicator for efficient irrigation and drainage system as infiltration studies are useful for determining the most efficient methods of application of irrigation water and runoff studies. Infiltration rate is also a useful index for determining water availability to plant, soil drainability, soil traficability, and soil erosion (Edem, 2007). Water infiltration into the soil is directly related to its structural stability, bulk density and pore shape. Soil water infiltration is controlled by the rate and duration of water application, soil texture, pore configuration, soil structure, and amount of organic residue, slope, vegetation, and surface roughness (Franzluebber, 2002; Green et al. 2003). Oil palm (Elasis guinensis) is the most productive oil producing plant in the world with the production of about 10- 35tones of fresh fruit bunch per hectare of land (Ma et al., 1996). Effluent water is the water discharge from industry which contains soluble materials that are injurious to the environment (Wu et al., 2009). Specifically, palm oil mill effluent (POME) is the sum total of liquid waste which cannot be easily or immediately reprocessed for extraction of useful products and is run down the mill internal drain system to the so-called effluent (sludge) pit. Many researchers have shown that POME in both raw and treated forms contains very high level of nutrients such as N.P.K and Mg (Lim, 1987). In Nigeria palm oil is processed industrially and locally and, in most cases, POME from these mills is discharged directly untreated on nearby agricultural lands or into surface water bodies. Okwute and Isu (2007) noted that POME discharged into agricultural lands, alter soil water holding capacity, organic carbon and total nitrogen. The pollutant level of POME varies with the quality of the raw material and production process used to manufacture the palm oil.

Therefore, this study examined the overall effects of palm oil mill effluent on infiltration capacity of soil of the area and some physical and chemical properties such as texture, porosity, bulk density, water holding capacity, Ksat, pH, organic carbon, total nitrogen of the soil and cation exchange capacity

Materials and Methods

The study was carried out in Ogale, Eleme Local Government Area of Rivers State, Nigeria with Latitude of $4^o 47^o$ and 13^0 N and longitude 7^o7^o and 36^oN. Rivers state is characterized by high rainfall, which decreases from south to north. Total annual rainfall decreases from about 4,700 mm on the coast to about 1,700 mm in extreme north of the state. Temperature is usually high averaging about 28^0C while relative humidity is also high averaging about 95% and decreases slightly in the dry season. (Peters et al. 1989)

Field Methods

This study was summarized using T-test in randomized complete block design. Two factors were considered. Factor A (polluted site) and factor B unpolluted site (control). Each factor represents a treatment and, in each treatment, six infiltration tests was conducted making it twelve infiltration test at a distance of 30m x 30m. The total area for the study was 10,800m^2.The infiltration test was carried out using the double ring infiltrometer and soil sample were collected with soil auger at a depth of 0-30cm for physical and chemical analysis, as well as determination of aggregate sizes stability analysis. Also, core sample was collected close to the infiltration test point using core cylinder for the determination of hydraulic conductivity and calculation of bulk density and porosity

Infiltration Measurement

The double ring infiltrometer with inner ring of 15cm and outer ring of 30cm diameter was used. Infiltration test was carried out at 5m interval in both the polluted and the unpolluted site. Mean infiltration rate was computed for the polluted site (Site A) and also the unpolluted site which was cultivated with cassava (Site B). Infiltration rate was calculated as follows:

$$I = \frac{Q}{AT}$$

Were,

Q - The quantity of water infiltrated

A - The area of soil surface exposed to infiltration (cm^2)

T - Time(s)

Laboratory Methods

The core sample collected where used for the following analysis; saturated hydraulic conductivity which was determined using the constant head permeameter method described by Klute and Dirksen (1982). The water draining through the cylinder over a fixed period of time was collected as.

$$Ksat = \frac{Q}{AT} x \frac{L}{\Delta H}$$

Ksat - Saturated hydraulic conductivity ($cmhr^{-1}$)

Q - The volume of water that flows through a across – sectional area, A (cm^2)

T - Time elapse(s)

L - Length of core (cm)

$\triangle$H - Change in hydraulic heads

Determination of Soil Texture

The disturbed samples (sample gotten with the use of soil auger) were air-dried and passed through 2mm sieve and 50g of soil separate was used to determine particle size distribution by the hydrometer method described by (Gee and Bauder, 1986).

Determination of Bulk Density and Porosity

Bulk density was measured with oven-dried soil core samples by the method of Grossman and Reinsch,(2002)

$$\text{Bulk density} = \frac{mass\ of\ oven-dried\ soil\ (g)}{volume\ of\ bulk\ soil\ (cm3)}$$

$$\text{Total porosity} = \frac{\text{volume of water at saturation (cm3)}}{\text{volume of bulk SOILcm3}}$$

Determination of Aggregate Stability and Water Holding Capacity

The aggregate stability was measured by mean weight diameter of water stable aggregate using the wet-sieving method as described by Kemper and Rosenau (1986). In this method, 50g of 4.75mm dried sieved aggregates was placed in the topmost of a nest of sieves; 2.0, 1.0, 0.5 and 0.3mm. The aggregate was soaked by capillary in distilled water for 15mins and oscillated vertically in water 20 times, the remaining stable aggregates on each sieve was oven-dried at 50^0C for 24 hours and weighed. The percentage of the stable aggregates on each sieve representing water stable aggregates (WSA).

$$\text{WSA} = \frac{MR}{MT} x \frac{100}{1}$$

Where, MR is the mass of resistant aggregates (g) and MT the total mass of wet-sieved soil (g). The mean weight diameter (MWD) of the water stable aggregates was calculated by the following equation (Hillel, 2004):

$$\text{MWD} = \sum_{i-1}^{n} \text{xiwi}$$

Where xi is the mean diameter of each size fraction, and wi is the weight of aggregates in that size range as a fraction of the dry weight of the sample analysed. Water holding capacity of the soil was calculated as:

$$\text{WHC} = \frac{mw - md}{md} \times 100$$

Where

Mw = mass of wet soil

Md = mass of dry soil

Results and Discussion

Effect of Palm Oil Mill Effluent on Infiltration Capacity of Soil

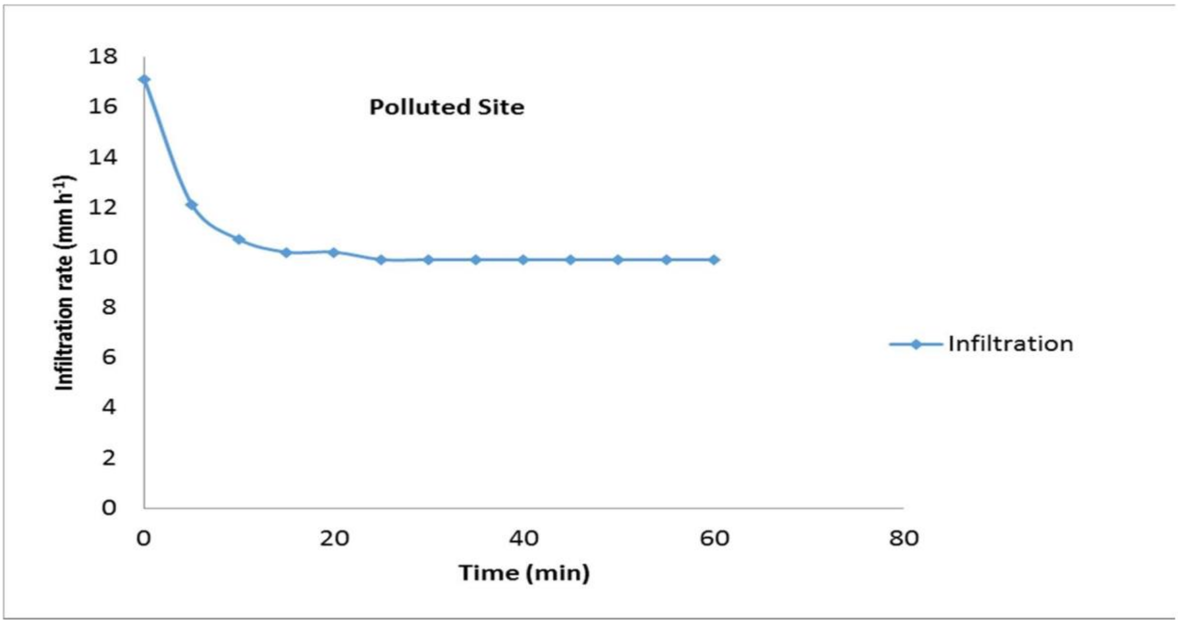

Figure 1: Infiltration Rate of Polluted Site

In figure 1 above, the polluted site had an initial infiltration rate of 17.1cm/hr. and decrease gradually to about 9.9 cm/hr. for 20mins before attaining a steady state for about 40mins. The reason behind the slow rate could be attributed to the sludge from oil palm mill which may have sealed up the soil pore spaces and leads to increase in soil bulk density. The constant deposition of POME into soil over a long period of time can alter soil texture, and its water retention capacity (Eze et al., 2013). The value obtained agreed with Udom (et al, 2020) that reported attainment of steady state infiltration before 1hrs and relatively low initial infiltration rate indicating that the soil is significantly affected by the impact of POME and plant in the area may suffer water stress due to low water transmission

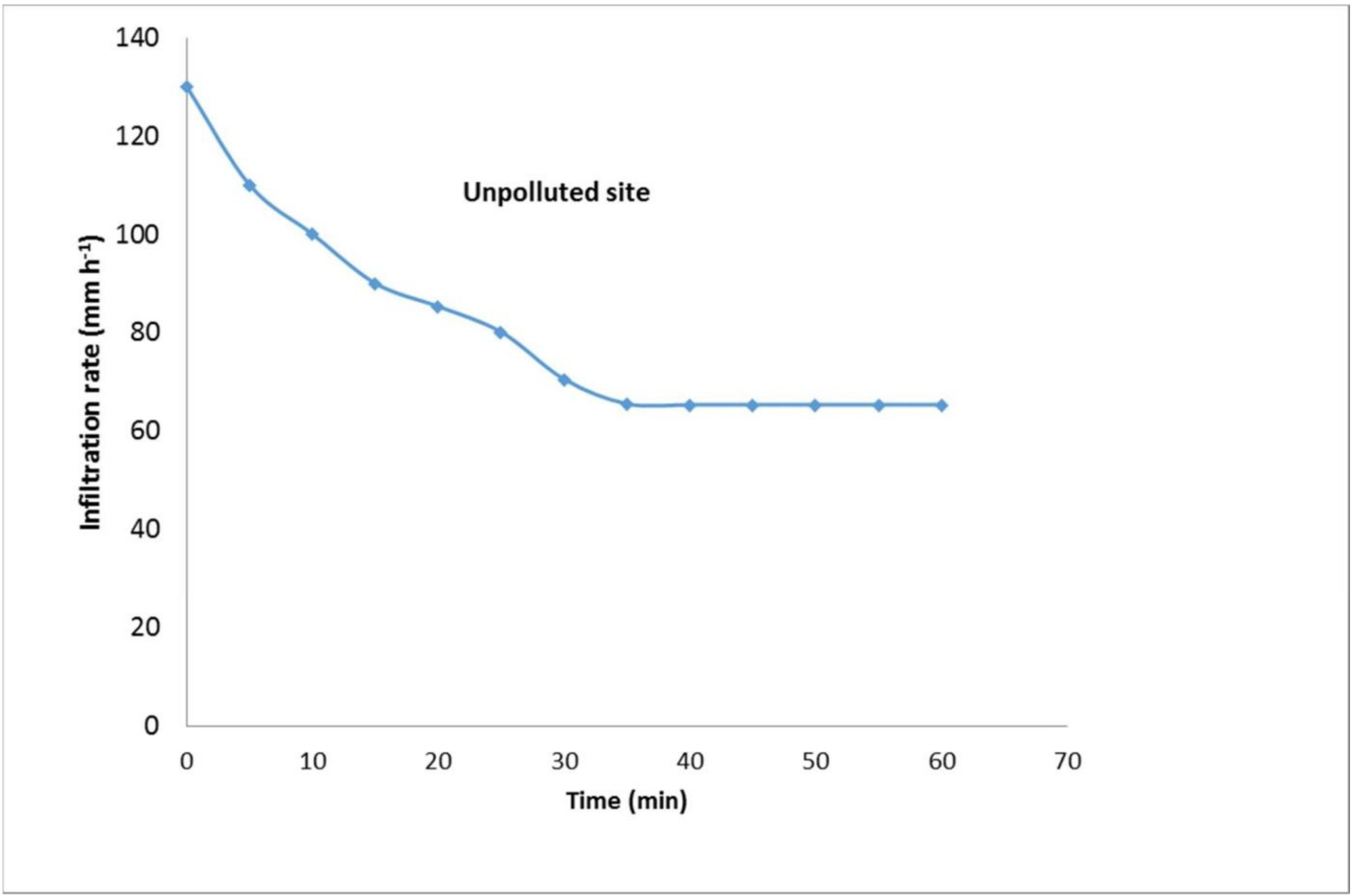

Figure 2: Infiltration Rate of Unpolluted Site

Figure 2 had initial infiltration rates of 130 cm/hr and decrease gradually to about 65.3 cm/hr for about 35mins before attaining a steady state at 25mins. The site had a gradual flow. The quantity of water that infiltrate in the unpolluted site is higher. This could be attributed to a well aggregated pores in the site coupled with drier condition of the soil as compare to the damp nature of the polluted soil. The high initial infiltration rate recorded in the unpolluted/cultivated soil disagree with Udom (et al, 2018) that recorded low initial infiltration rate in a cultivated soil. This may be attributed to the type of crop cultivated and the land preparation measures adopted.

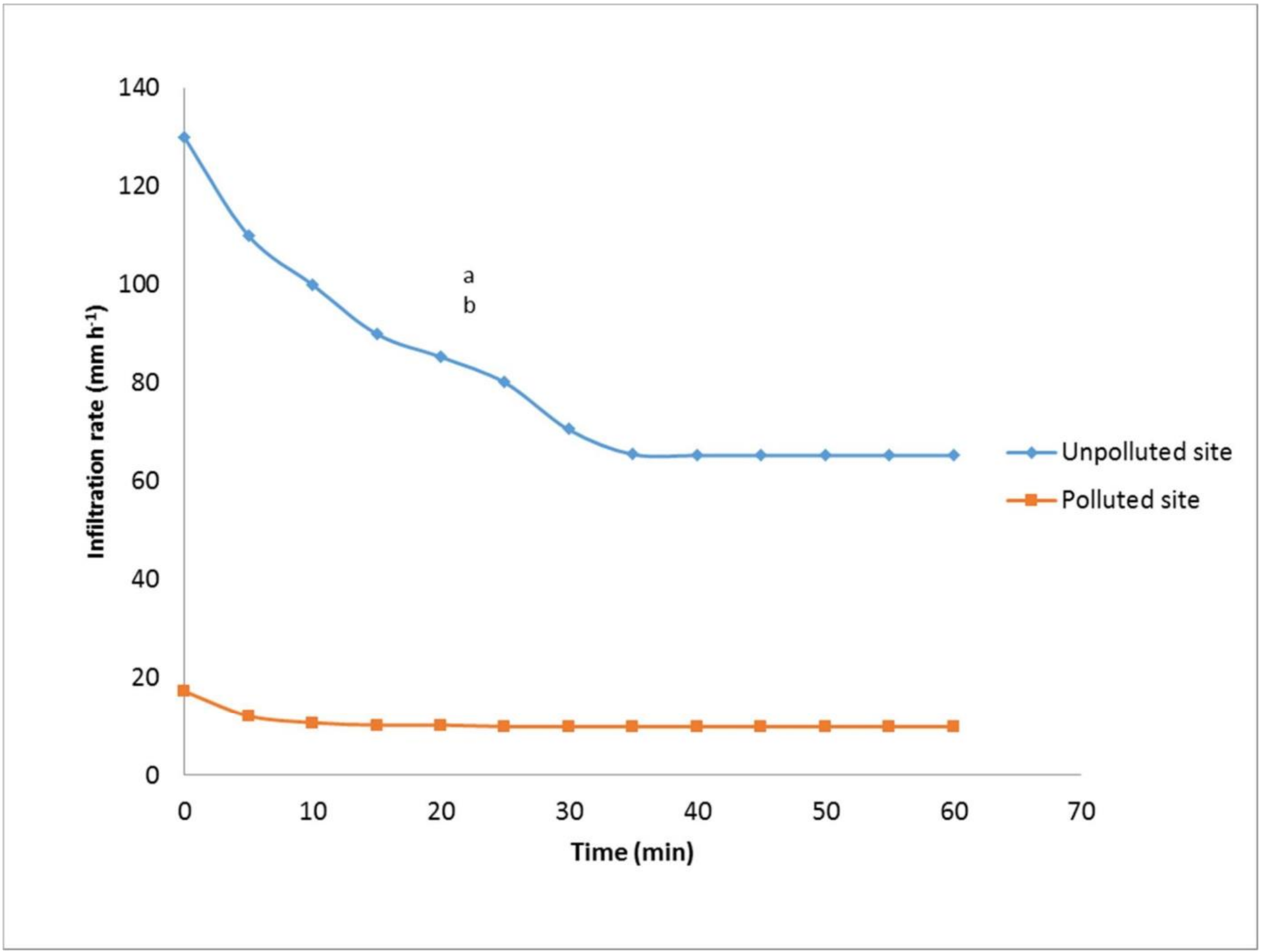

Figure 3: Infiltration Rate of Polluted and Unpolluted Site

The polluted site had an initial infiltration rate of 17.1cm/hr and decrease gradually to about 9.9 cm/hr. for about 20mins before attaining a steady state for about 40mins. While the unpolluted site had initial infiltration rates of 130 cm/hr and decrease gradually to about 65.3 cm/hr for about 35mins before attaining a steady state at 25mins. There was a significant different ($p<0.05$) between the polluted sites and the unpolluted site. The values obtained is in consonant with (Leonard et al., 2004), which reported that infiltration decreases with increase in surface sealing, reduce pore volume and increase in bulk density cause by sludge discharge as a result of biological mat that may be formed.

Effect of Palm Oil Effluent on Soil Physical Properties

Table 1: some physical properties of the polluted and unpolluted soils

Soil properties	Polluted	Unpolluted	t-values
Sand (%)	68.5	69.2	0.037^{ns}
Silt (%)	14.8	15.5	0.41^{ns}
Clay (%)	16.7	15.3	0.45^{ns}
Total porosity (%)	24.0	12.0	3.25**
Bulk density (g cm^{-3})	1.49	1.29	2.17*

Aggregate stability (mm)	1.64	0.89	4.11**
Ksat (cm h^{-1})	13.19	52.23	5.91**
WHC (%)	25.0	21.7	!.69*

Ns: non-significant at p>0.05, *significant at p <0.05, **highly significant, ksat- saturated hydraulic conductivity, whc- water holding capacity.

Table1 shows no significant difference between Soil textural class such as sand (%), silt (%) and clay (%) of polluted and unpolluted sites at (p>0.05). This in contradiction with (Okwute et al., 2007) which reported significant difference between polluted and non-polluted site of about 10yards attributed to high organic matter content in the polluted site which was also recorded in this work, maybe the non-significant difference textural class is due to the difference in research environment. Bulk density (g cm^{-3}) of values 1.49 and 1.29 for polluted and unpolluted respectively is significant at p<0.05. The high bulk density in the POME site is not surprising since the sludge is capable of creating a cast that can cause densification of the soil and restriction of water movement, also the relative increases in the control site is an indicator that cultivation increases the soil bulk density. Aggregate stability measured by the mean wet diameter (MWD) of water stable aggregate 1.64 and 0.89 mm in polluted and control site respectively indicate that POME enhances stable aggregate at (p>0.05). Hydraulic conductivity (Ksat) value of 13.19 and 52.23 for polluted and unpolluted site respectively has significant difference at p<0.01. Ksat for polluted site is very slow but moderate in control site indicating moisture deficits in the POME site. (WHC %) showed a significant difference in (p<0.05) between the polluted and control site with value of 25.0 and 21.7 respectively indicating tendency of polluted site to retain more water than the control site.

Effect of Palm Oil Mill Effluent (POME) on Soil Chemical Properties.

Table 2: Some Chemical Properties of the Polluted and Unpolluted Soils

Soil properties	Polluted	Unpolluted	t-values
pH (H_2O)	6.6	5.2	0.81^{NS}
Organic matter (%)	4.9	3.1	2.38*
Total N (%)	0.44	0.28	2 96*
Exch. Ca^{2+} (C mol kg^{-1})	4.4	3.5	3.11*
Exch. K^{+} (C mol kg^{-1})	0.34	0.19	1.26^{NS}
Exch. Mg^{2+} (C mol kg^{-1})	3.5	2.5	0.94^{NS}
Exch. Na^{+}	0.40	0.19	3.51**
Exch. Acidity (C mol kg^{-1})	1.14	1.72	1.11^{NS}
ECEC (C mol kg^{-1})	9.42	8.05	2.65*
Base saturation (%)	88.01	78.51	4.12**
Avail. P (mg kg^{-1})	36.7	28.7	4.02*

NS- non-significant at p>0.05, *significant at p <0.05, **significant at p <0.01,

Table 2 shows no significant different at p>0.05, for pH (H_2O) of values 6.6 and 5.2 for polluted and unpolluted site respectively. (Hemming, 1977) reported acidity in P^H of soil when raw POME is discharged but later become alkaline as biodegradation take place this may be the reason for the slight increase in the p^H of the polluted site over the control site. Organic matter (%), shows significant at p <0.05 as shown in table 2. The higher organic matter and increased in total nitrogen in this study is in consonance with the findings of Acea and Carballas (1996) which was believed to be related to the constituent of the untreated POME, secondly the high nitrogen and organic matter in the POME site can also be attributed to the slow decomposition of organic matter under damp soil condition and low temperature (Batjes, 1996). The exchangeable calcium (C mol kg^{-1}), exchangeable potassium (C mol kg^{-1}), exchangeable potassium (C mol kg^{-1}) and exchangeable sodium (C mol kg^{-1}) which formed the CEC are all significant at ($p < 0.05$). The relatively high CEC in the POME site agreed with the work of (Oviasogie and Aghimien, 2002) which shows an enrichment in the POME site with calcium, potassium, magnesium and sodium. The increased could be attributed to the increase in p^H dependent charge as well as the addition of organic matter from the effluent as observed by Huan, (1987). ECEC of the soils is significant at ($p < 0.05$). This may be as a result of longtime biodegradation of the effluents. Base saturation (%) with value 88.01 and 78.51 for polluted and control site respectively is significant at ($p < 0.01$) although relatively higher in the polluted site which invariably account for the abundance of nutrients contain in the effluents. Further, Avail. P (mg kg^{-1}) was significant at $p < 0.05$ with POME site relatively higher in phosphorus than the control site which agree with the finding of Wood (1977) and Huan (1987) therefore validated that phosphorus is a dominant element controlling carbon and nitrogen immobilization (Paul and Clarke. 1989).

Conclusion and Recommendation

Important conclusion drawn from this research is that initial infiltration rate in the polluted soil was very low with steady state infiltration obtained within a very short period of time compare to the control site. This may lead to poor moisture availability, barrenness of the environment, wasteland and runoff and erosion if not properly address. Although organic carbon, total nitrogen, potassium and magnesium and phosphorous were observed to be higher in the polluted soil than the control but were not made available due to phosphorus immobilization controlling behaviour on carbon and nitrogen coupled with poor biodegradable nature of POME. It is therefore imperative to avoid direct discharge of POME on agricultural land to prevent altering the physiochemical properties of the soils.

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