Investigation of Palm Oil Mill Effluent Pollution Impact on Ground Water Quality and Agricultural Soils

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Abstract - A field study was carried out to investigate palm oil mill effluent pollution impact on ground water quality and agricultural soils. Two water samples were collected, one from the downstream and upstream locations away from the effluent discharge using 1 litre capacity container. Soil samples from the palm oil effluent dumpsite as well as a non-palm oil mill effluent soil were collected. Temperature, pH, electrical conductivity, salinity, total hardness, turbidity, sulphate, COD, BOD5, total dissolved solids, total suspended solids, dissolved oxygen, total alkalinity and percentage saturation for water samples were determined. pH, water holding capacity, total organic carbon, total organic matter, total nitrogen, available phosphorus, exchangeable cations: potassium, Na, Ca, Mg and cation exchange capacity for soil. Data obtained from the study were subjected to statistical analyses of variance (ANOVA). Significant variations exist in most of the physico-chemical variables among the sampled parameters. Data for water samples were also compared with IS: 10500 (1992) and Nigerian Standard for Drinking Water Quality (NSDWQ). Most of these parameters indicated pollution but were below the IS: 10500 (1992) and (NSDWQ) limits for consumption. The pH ranged from 4.6 to 4.7 indicating toxic pollution, electrical conductivity, total hardness, turbidity, sulpahte, COD, BOD5, total dissolved solid, total suspended solids, dissolved oxygen, total alkalinity, % saturation were all significant difference from each other. Soil pH, electric conductivity, organic carbon, total nitrogen, available P, organic matter, Ca and exchangeable acidity were also all significant difference from each other. It is concluded that a drastic move towards quality and environmental conservation through sustainable development and cleaner technology approach within manufacturing industries in Nigeria is implemented.

Keywords: Palm oil effluent, water quality, agricultural soil.

1.0 Introduction

Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. During the extraction process, about 50% of the water results in palm oil mill effluents. It is estimated that for every 1 tonne of crude palm oil produced, 5.0-7.5 tonnes of water end up as palm oil mill effluent ([1], [2], [3], [4]). Raw palm oil mill effluent consisting of complex vegetative matter is thick, brownish colloidal mixture of water, oil and fine suspended solids. It is hot (80 - 90) and possess a very high Biochemical Oxygen Demand which is non-toxic as no chemicals are added to the extraction process [5, 6], and also acidic with a pH of around 4.5 as it contains organic acids in complex forms that are suitable to be used as carbon source [7]. These brownish and colloidal suspension of palm oil mill effluent contain high concentration of organic matter, high amounts of total solids (40,000mg/L), oil and grease (4,000 mg/L), chemical oxygen demand (51,000 mg/L) and biological oxygen demand (25,000 mg/L) (http://www.mpob.gov.my/2012). The constituent of raw palm oil mill effluent have been reported to be a colloidal suspension originating from mixture of sterilizer condensate, separator sludge and hydro cyclone wastewater in a ratio of 9:15:1 respectively [8]. However, it contains appreciable amounts of plants nutrients such as nitrogen, potassium, magnesium and Calcium [9, 10]. Toxic metals such as lead, can also be found in palm oil mill effluent [9], but their concentrations are usually below sub-lethal levels (> 17.5μg/g) [11]. Other heavy metals present in palm oil mill effluent are cadmium, copper, chromium and iron. The raw or partially treated palm oil mill effluent has an extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil [2].

Untreated palm oil mill effluent contains high amounts of fatty acids, proteins, carbohydrates and other plant materials ([12], [13]), which has the tendency of altering environmental parameters particularly BOD, DO, C/N ratio and COD level [3]. This highly polluting palm oil mill effluent can cause pollution of waterways due to oxygen depletion, land use and other related effects ([14], [15], [3], [2], [5], [16]). Discharged palm oil mill effluent on aquatic ecosystem turns the water brown, smelly and slimy [15], which may kill fishes and other aquatic organisms and deny the human inhabitant of such region assess to good water for domestic uses [17]. Thus, while enjoying a most profitable commodity, palm oil, the adverse environmental impact from the palm oil industry cannot be ignored. Large and medium scale mills produce copious volumes of palm oil mill effluent from the processing lines, (sterilizers, clarifying centrifuges and hydrocyclones). However, small-scale processors generate minimal effluents because majority of the wastewater are reused.

In Nigeria's palm oil industry, most of the palm oil mill effluent produced by small scale traditional operators undergo little or no treatment and are usually discharged in the surrounding environment. This palm oil mill effluent could foul streams, rivers or surrounding land [3], either as point or non-point source of pollution. River water consequently turns brown, smelly and slimy. Often fish and other aquatic organisms get killed and local people are denied the availability of local water sources for domestic uses and fishing [18]. The aim of this study was to investigate palm oil mill effluent pollution impact on quality of receiving surface water and agricultural soils in Abak UsungIdim, Abak Local Government area of Akwa Ibom State, Nigeria.

2.0 Materials and Method

2.1 Study Area

The study area is Ekaidem Multipurpose Cooperative Mill, Abak Usun Idem, is located in Abak Local Government Area, Akwa Ibom State, Nigeria. It is located within the fresh water swamp forest between longitude 4 5' 0'' and 5 3' 0'' East and latitude 7 4' 5'' and 8 0' 0'' North. Rainfall ranges from 2000-3000 mm per annum, temperature are generally high all year round ranging between 26 ℃ – 28 ℃.

2.2 Samples and Sampling Techniques

Reconnaissance of the vegetation, soil, water quality, and sources of contamination was carried out. Two water samples were collected (5meters) upstream which serve as a control and (5 meters) downstream from the point of contamination of the river. The water samples (grab samples) were collected at the surface with 1 litre capacity containers rinsed several times with the water to be collected. The samples were filled slowly into the containers to prevent turbulence and exclude bubbles and sealed. Composite soil samples were collected at a depth of 15cm from the palm oil mill effluent dump sites and from a non-effluent soil about 200 metres away which served as control. The samples were transferred to a tray for homogenizing before storing in sample bags. Each sample was labeled immediately after collection and taken to laboratory for chemical analysis.

2.3 Water Samples Analyses

The water samples were preserved in the refrigerator until analyses were conducted. Total alkalinity and hardness were determined by titrimetric method. Conductivity and salinity of the water was determined using conductivity meter. Total suspended solid was determined by filtration and dried at $103 \pm 2^{\circ}C$. Total dissolved solid was determined by electrical conductivity measurement. Temperature was determined using mercury filled Celsius thermometer. Oxidation-Reduction potential and pH was determined by potentiometric measurement according to method No.4500HB. BOD was determined by a five-day dissolved oxygen measurement according to method No. 5210. Chemical oxygen demand was determined by closed reflux titrimetric method according to method No. 5220C. Sulphate was determined by turbidimetric method according to method No. 4500E. Dissolved oxygen was determined by membrane electrode method according to method No. 4500-OG.Turbidity was determined by Nephelometric method according to method No. 2130B. All analyses were carried out according to [19].

2.4 Determination of Soil Properties

Analytical methods used for soil samples were adopted depending on the parameters of interest. The collected soil samples were air-dried for five (5) days to halt all microbial activities in the soil. The air-dried samples were sieved using a 2mm sieve mesh size to remove debris and stones. The air-dried and sieved samples were then used to analyze for soil pH, water holding capacity, total organic carbon, total organic matter, total nitrogen, available phosphorus, exchangeable cations: K, Na, Ca, Mg and cation exchange capacity. Soil pH was measured out by the potentiometric method as described by [20]. A glass electrode Testronic digital pH meter (Model 511) was used for the measurement. Water holding capacity was carried out by the Core method described by [21]. Organic carbon measurement was carried out by the method of [22]. Soil organic carbon was determined by the Wakley and Black procedure according to [24]; soil organic matter was estimated as organic carbon multiplied by 2.724. Total nitrogen assay was carried out by the Kjeldahl method as described by [24]. Available phosphorus was determined by the method described by ([25], [26]).

Exchangeable cations determination was carried out with about 100 ml of concentrated ammonium acetate added to a 10gram measurement of air-dried soil and shaken for 30mins. The preparation was then filtered and taken to the flame analyzer for reading. Calcium, Sodium and Potassium were read on the flame photometer. Readings for Magnesium was obtained from further titration with sodium EDTA as flame photometers cannot be used. Cation exchange capacity was determined by the summation of the cubic centimeter (cm^3) values of the exchangeable cations of each sample determined above.

For available Phosphorus Determination, 2g of air-dried soil was weighed and dispensed in 20 ml of (0.025N HC1 + 0.03N NH4F) solution, shaken for 5 minutes and then filtered. After filtration, 3ml of the preparation was put into test tube, 3 ml of (0.87N HC1, 0.38N ammonium molybdate, 0.05% H_3BO_3) solution and 5 drops of (2.5g of 1-amino 2- tetraoxosulphsate (vi) acid, 5.0g NA_2SO_3, 146g $Na_2S_2O_5$) solution were sequentially added to the preparation. A colorimeter (at wave length of 660 nm) was then used to take readings.

Exchangeable Acidity Determination: 5g of air dried soil was weighed into 250ml of conical flask and about 50ml of Potassium Chloride was added. The preparation was stirred for 1 hr and then filtered. Another 50ml of KCl was added and shaken for 1 hr and was also filtered into 100ml volumetric flask to mark up to 1M KCl using a pipette, about 50ml of the filtered preparation was dispensed into a 250ml conical flask. Using phenolphthalein indicator, the preparation was titrated with 0.01M NaOH into a pinkish end point. One or two drops of 0.01MHCI was added to the pinkish end point to bring it back to colourless, then 10ml of NaF was added to regenerate the faded colour, titration was done again with HCl until it was colourless, titration was done again with 0.01M HCl until it was colourless. The first value was a combination of Aluminum and hydrogen but the second value is hydrogen; the second value was subtracted from the first.

3.0 Results and Discussions

Parameters with the IS: 10500 (1992) and the Nigerian Standard for Drinking water quality (NSDWQ) is presented in Table 1.

3.1 Water Analyses: The results of analysis of variance (ANOVA) and comparison of the sample.

Table 1: Analysis of variance (ANOVA) and Comparison of Chemical Constituent of Water Samples at the Two Experimental Sites (Upstream and Downstream) with IS: 10500 (1992) and NSDWQ Standard.

Samples	**Mean±SD**	
	Downstream	**Upstream**
TEMP	28.40±0.20	28±0.21
p H	4.62±0.05	4.74±0.07
EC	248.67±3.5*	14.63±0.10*
Salinity	0.01±0E-7*	0.00±0E-7*
T. Hardness	685.67±26.6	6.78±0.69*
Turbidity	9.54±0.4*	2.01±0.08*
Sulphate	3.48±0.51*	0.02±0.00*
COD	13.95±1.0*	7.85±0.32*
BOD5	8.84±0.88*	4.68±0.49*
TDS	121.47±1.1*	7.55±0.54*
TSS	1019.00±4.6*	8861.00±8.19*
DO	2.72±0.30*	4.40±0.08*
T. Alkalinity	264.30±12.9*	50.10±0.08*
% Saturation	5.65±0.32*	41.80±0.66*
Samples	**NSDWQ 2007**	**IS:10500 (1992)**
TEMP	NS	NS
p H	6.5 - 8.5	6.5 - 8.5
EC	1000	500
Salinity	-	-
T. Hardness	150	-
Turbidity	-	-
Sulphate	100	200
COD	-	-
BOD5	-	-
TDS	500	500
TSS		
DO	NS	NS
T. Alkalinity		200
% Saturation		

Nigerian Standard for Drinking water quality (NSDWQ);
Values are Means and Standard Deviation of Triplicate
Values with Asterisk (∗) Significant difference (p = 0.05)
Downstream Contaminated Site, Upstream Control Site.

The temperature of water samples (upstream and downstream) was insignificantly different from each other. High water temperature leads to low dissolved oxygen of the water. The pH of the waters studied was strongly acidic, and the other of increase is control higher than the site. They were insignificantly different from each other (P = 0.05). This result is close to the findings of [27], who reported the pH range of Palm oil mill effluent to be between 4 - 5. The value of pH recorded in this study is however lower i.e. more acidic than the ([28], [29]) guideline value (pH 6.5 - 8.5) for drinking water standard. The acidic nature of the water samples may be as a result of organic acids found in fresh fruit. The dissolved oxygen (DO) recorded a lower value at the downstream while a higher value was recorded at the upstream (control), being significantly different (P0.05) from each other. The relatively low DO recorded at the downstream may be due to the high temperature and duration of bright sunlight, which influenced the percentage of soluble gases (O_2 and CO_2) in the effluent [30]. DO is an important parameter in palm oil mill effluent quality assessment and reflects the physical and biological processes prevailing in the palm oil mill effluent, it indicates the degree of pollution in water bodies [31]. The total alkalinity, COD, BOD5, TDS and TSS were all generally higher at downstream than the upstream. They were all significantly different from each other. This result also agrees with the general perspective on the water bodies which are naturally mineralized, probably due to the influence of the underlying rock. However, further study may be required on the composition of the rocks to understand the role of such influence. The electrical conductivity, total hardness, turbidity, sulphate and percentage saturation were also all generally higher at the downstream than the upstream (control), and they were significantly different from each other. The electrical conductivity, turbidity and sulphate were within world health organization (WHO) standard for drinking water quality.

3.2 Soil Analyses

Table 2: shows Chemical Properties Constituent of Soils at the Two Experimental Sites (Site A and Control B).

Table 2: Chemical Properties Constituent of Soils (0 to 15cm) at the Two Experimental Sites (Site A and Control B).

SAMPLES	Mean±SD	
	Contaminated Site A	**Control Site B**
p H	9.27±0.1	6.98±0.09
EC	900.00±35.4*	100.00±35.4*
Organic Carbon	38.22±0.1*	8.74±0.1*
T. Nitrogen	2.96±0.1*	8.64±0.07*
Available Phosphorus	224.97±0.1*	95.27±0.1*
Organic Matter	65.89±0.1*	14.90±0.1*
Ca	2.50±0.1*	1.17±0E-7*
K	0.38±0.9*	1.71±0.1*
Mg	0.21±0.1*	0.14±0.1*
Exch. Acid	0.25±0.0*	1.50±0.1*
CEC	3.42±0.1*	3.73±0.14*
WHO (%)	40.26±3.5*	46.13±3.5*

Values are Means and Standard Deviation of Triplicate.
Values with Asterisk (∗) Significant different (p = 0.05).

pH is extremely important on the decomposition of mineral rock into essential elements that plants can use. The pH of non-effluent dumpsite was acidic while that of effluent dumpsite was alkaline, and it was significantly different (P = 0.05) from each other. [32] reported that when raw palm oil mill effluent is discharged the pH is acidic but seems to gradually increase to alkaline as biodegradation takes place. Soil pH is said to increase with increasing soil depth [33]. The sample was taken at the depth of 0-15cm of the soil, which contained already degrading palm oil mill effluent and the dumping of palm oil mill effluent was irregular, which may have been responsible for the pH of 9.27. The non palm oil mill effluent soil studied in this research was at variance with this norm but reasons for this could not be easily ascertained apart from nature. The organic carbon and total nitrogen contents of the effluent and non effluent soil samples showed a significance difference (P = 0.05). The higher organic carbon value for the palm oil mill effluent dumpsite can be related to the constituents of raw and untreated palm oil mill effluent.

It is possible that a slow decomposition of organic matter in palm oil mill effluent under water-saturated conditions, particularly when mean soil temperatures are low [34] contributed significantly to the higher organic carbon of the palm oil mill effluent soil.

The organic matter of a soil is usually determined and reported as a measure of the organic carbon concentration in the soil as reported by [23]. Organic matter content strongly affects the soil fertility by increasing the availability of plant nutrients, improving the soil structure and the water holding capacity and also acting as an accumulation phase for toxic, heavy metals in the soil environment [35]. For this reason, the recycling of organic wastes through their application to the soil can be an important promising practice for agricultural activities. The organic matter content recorded at the palm oil mill effluent dumpsite was higher than the control site. Organic matter may form natural chelates aiding in maintaining iron in a soluble form. High organic matter contents provides more available boron to plants, but decrease copper availability due to strong bonding of copper to organic matter and may tie up manganese into unavailable organic complexes.

The mean exchangeable cations considered alongside with cation exchange capacity were higher at the palm oil mill effluent dumpsite than the control site except cation exchange capacity which recorded a lower value at control site. They were all generally insignificantly different from one other. The results showed enrichment of the soils in phosphorus, nitrogen, calcium, magnesium, sodium and potassium due to the application of palm oil mill effluent. [36] also recorded increase in pH, potassium, calcium, magnesium and organic matter content with the application of palm oil mill effluent to soil. The palm oil mill effluent soil was observed to be richer in phosphorus than the non palm oil mill effluent soil. In fact, there was a significant different ($P < 0.05$) in phosphorus values of the palm oil mill effluent dumpsite over that of non palm oil mill effluent site. There is good evidence that suggests that phosphorus is the dominant element controlling carbon and nitrogen immobilization [38]. The increase in the available phosphorus in the palm oil mill effluent soil suggested a possibly high absorption in the soil or a possible precipitation of phosphate [38]. This may be due to the gradual biodegradation of palm oil mill effluent, which leads to a delayed effect on the soil. Electrical conductivity recorded the higher value at site while the control site recorded a lower value. The electrical conductivity of the effluent dumpsite was significantly different ($P<0.05$) from the non effluent dumpsite. An increase in EC may be due to the high amount of soluble salts present in palm oil mill effluent and to the presence of NO_3-N and P in soil. The water holding capacity was higher at the control site than the dumpsite and they were insignificance from each other. The reason for this was not far-fetched when comparing the site to the control site (non palm oil mill effluent).

The palm oil mill effluent site was observed to be bare without vegetation whiles the non-palm oil mill effluent site was grown with weeds. Due to the oil-palm effluent discharge noticeable in dump site the color of the soil was dark brown, damp and odiferous while that of the non-palm oil mill effluent site was observed to be brown, dry and free of odour. The palm oil mill effluent site was also covered with debris from the processing mill while that of the non-palm oil mill effluent site is filled with debris from leaves as it is for typical natural environments.

4.0 Conclusions

Results from this study revealed that the physico-chemical properties of soil at the palm oil mill effluent dump site were altered. Since palm oil mill effluent has been shown to be alkaline in nature, it is advisable that it undergoes some form of treatment or decomposition before being discharged into soil environment taking into cognizance the physico-chemical properties of the soil in that particular environment so as to avoid the initial harsh effects of palm oil mill effluent on soil. The state of the soil in that environment will determine the best treatment for the effluent to be dumped on it. It is concluded that proper use and safe disposal of POME in the land environment could lead to improved soil fertility. Environmental pollution considerations in small-scale palm oil milling need better attention as this industrial segment assumes greater importance.

5.0 List of Symbols & Abbreviations

COD: Chemical Oxygen Demand
BOD5: Biochemical Oxygen Demand
K: Potassium
Na: Sodium
Ca: Calcium
Mg: Magnesium
NSDWQ: Nigeria Standard for Drinking Water Quality
TDS: Total Dissolved Solids
TSS: Total Suspended Solid
DO: Dissolved Solid
EC: Electric Conductivity

6.0 *References*

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