Soil quality in the vicinity of palm oil mills in Umuahia, Nigeria

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The study focused on the effect of the palm oil mill effluent (POME) on the physico-chemical parameters of agricultural soil within Umuahia. The soil samples were collected from the areas where the POME was discharged. The following parameters were analyzed: particle size, organic carbon, organic matter, total nitrogen, total phosphorus, available phosphorus, exchangeable cations (Na, K, Ca, Mg), electrical conductivity. Digested samples were also analyzed for heavy metals (Cd, Cr, Ni, Cu) using an atomic absorption spectrophotometer. Results of the physico-chemical analysis showed that the discharge of POME onto the soil causes the degradation of soil physico-chemical properties and increase heavy metal contamination.

Keywords: Physico-chemical, soil, palm oil, effluent, heavy metals

INTRODUCTION

The local palm fruit processing method used in Nigeria to produce palm oil is very long and laborious and large quantities of wastes are produced including oil palm trunk (OPT), oil palm frond (OPF), empty fruit bunches (EFB), palm press fibre (PPF), palm kernel cake (PKC), shells, palm oil mill sludge (POMS), decanter cake and palm oil mill effluent (POME). For every ton of crude palm oil produced, about 5 – 7.5 tonnes of water are used and about 50% of the water results in POME. POME produced by the small scale traditional operators undergoes little or no treatment and is usually discharged into the surrounding environment (Ohimain et al., 2012). Raw POME has an extremely high content of degradable organic matter and is a thick, brownish, colloidal suspension with high amounts of suspended solids, organic matter, oil and grease (Ahmed et al., 2003; Onyia et al., 2001). POME also contains nutrients like carbohydrates, proteins, fatty acids, nitrogen, potassium, magnesium and calcium; heavy metals like chromium, iron, copper and lead (Muhrizal et al., 2006; James et al., 1996). The three basic processes through which soil quality can be degraded are: physical – arising from erosion; chemical – due to nutrient deficiency, heavy metal contamination etc. and biological – resulting from loss of organic matter (NAS, 1993). Heavy metal accumulation is a principal factor in soil quality degradation and reduction of the capacity of the soil to grow healthy plants (Mansur and Jazuli, 2007). When POME is discharged without treatment, it affects the physico-chemical properties of the soil and increases the heavy metal content of the soil (Piccolo and Mgbagwu, 1997). Crop farming areas located where POME is discharged are at the risk of physico-chemical degradation and heavy metal contamination. These heavy metals may also accumulate to high levels in different parts of plants and may also pose health risks to human beings and animals who consume plants or food stuffs grown on such soils. This work investigated the effects of POME discharge on soil quality in Umuahia, Abia state.

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MATERIALS AND METHODS

Study area

The sampling sites were located in Umuahia North, Umuahia South and Ikwuano Local Government Areas of Abia State. Umuahia is the capital of Abia State, Nigeria and is a well-known palm oil processing area. Soil samples were collected from Umuahia, Eziam-Ubakala; Lodu-Ndume, Ibeuku; Umuhe-Umuopara; Ohiya and Ntalakwu-Oboro, Ikwuano.

Sample Collection and Pre-treatment

Samples were collected randomly from the 0 – 20 cm depth at each sampling site with a soil auger. Five sub-samples were collected at each site and mixed thoroughly to give a composite sample. Control sample was also collected from a site that does not experience POME discharge which was located 500 m from the Lodu oil palm mill. Extraneous materials were removed from the samples and they were kept in plastic bags, labeled appropriately and then transported to the lab for analysis. The soil samples were air-dried at room temperature, crushed with porcelain mortar and pestle and sieved with 2 mm sieve. They were then stored in plastic bottles prior to analysis.

Physico-chemical Analysis

Soil pH was determined by inserting the probe of a pre-calibrated digital pH meter (model pH 5 - 25) into a 1:2.5 soil/water suspension (Ano, 1994). Electrical Conductivity (EC) was determined with the 0.1 % sodium metaphosphate method (Agbenin, 1995). Organic carbon was determined by the wet-acid oxidation method (Walkley and Black, 1934). Organic Matter (OM) was determined by oxidation of 1 g of oven-dried sample with 50 % H2O2 solution and ignition in a muffle furnace. Bulk density was determined with the clod method (Blake and Hartge, 1986). Oil and grease was determined by the USEPA method 9071 (USEPA, 1998). Total nitrogen (TN) was analysed using the Kjeldahl method while total phosphorus was determined using the colorimetric method after acid digestion of the sample and extraction of neutralized digest with deionized water (Agbenin, 1995). Available Phosphorus was analysed using the Bray-1 method (Bray and Kurtz, 1945) while total phosphorus was analysed using HNO3 digestion and spectrophotometric method. Particle size analysis was done using the hydrometer method which utilizes 50 % Calgon (sodium hexametaphosphate) as dispersing agent (Bouyoncus, 1951). Total exchangeable bases (K, Na, Ca and Mg) were determined by the ammonium acetate (NH4AOC) extraction method (Jackson, 1958). All analyses were in triplicate.

Preparation of standards

Five standard solutions for each element (Cd, Cr, Ni and Cu) were prepared from a stock solution by serial dilution. In this case, stock solutions with a concentration of 1000 ppm were diluted to obtain standard solutions of low concentration. The absorbance obtained from AAS instrument for each standard of a particular element was used in drawing calibration curves. The concentrations of the metals in each sample were obtained from the calibration curve in mg L^-1 and were converted to mg kg^-1 with the formular:

Metal concentration in soil (mg kg^-1) = [(A x B)/C] D  
A = value from calibration curve in mg/l; B = total volume of extract in ml; C = weight of sample digested in g; D = dilution factor

Sample Digestion and Metal Analysis

Soil samples were digested in triplicate as described by Bamgbose et al. (2000). 5g of sieved sample was placed into a beaker and 10ml of concentrated HNO3 was added. The beaker was covered with watch glass and refluxed for 45 minutes. The watch glass was removed and the content of the beaker evaporated to dryness. 5ml of aqua regia was added and evaporated to dryness after which 10ml of 1 mol dm^-3 HNO3 was added and the suspension filtered through a Whatman no 42 filter paper. The filtrate was diluted to volume with distilled-deionized water in a 50ml volumetric flask and used for metal determinations. Four metals (Cd, Cr, Ni and Cu) were determined in the soil samples with Buck Scientific Flame Atomic Absorption Spectrophotometer (Model, Accusys 211).

Statistical Analysis

Statistical analysis was done using the SPSS (version 15.0) for Windows software package. Mean concentrations and standard deviations were calculated for each parameter. The results were also subjected to analysis of variance (ANOVA) and means were compared using Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Table 1 shows the results of physico-chemical parameters in soil samples. The result shows that silt content was significantly lower (P < 0.05) in the control sample compared to the five oil mill samples. This may be attributed to increased deposition of solids from POME onto the oil mill soils. The mean pH of the soil from the five oil mill samples were significantly lower (P > 0.05) than that of the control sample. When raw POME is discharged, the pH is acidic but seems to gradually increase to alkaline as biodegradation takes place (Hemming, 1997). The mean EC value of the control soil sample was significantly lower (P < 0.05) than the mean values for the oil mill samples. This compares well to the values obtained by Eze et al. (2013) who found higher EC values in soil samples contaminated by POME than in control samples. Electrical conductivity (EC) is a measure of the amount of salts in soil the and it may be inferred that the higher
mean EC value in the oil mill samples means higher deposition of dissolved ions from POME discharge. Bulk density and oil and grease concentration were significantly lower in the control sample compared to oil mill samples. This is in accordance with the conclusions reached by Table 2 shows the mean values of organic carbon (OC), organic matter (OM), available phosphorus (AP), total phosphorus (TP), total nitrogen (TN) and exchangeable bases (Ca, K, Mg and Na).

The mean OC, OM, TP, AV and TN concentration in the oil mill samples were significantly higher (P < 0.05) in the oil mill samples compared to the control sample. This conforms to the findings of Rupanni et al. (2010) who observed significant increase in these parameters in soil amended with POME. This indicates the impact of POME discharge on soil in the vicinity of the oil mills. Available phosphorus concentrations in the five samples were relatively high which infers high organic matter content of POME. Among the oil mill samples, the highest mean TP value of 108.00 ± 22.37 mg kg⁻¹ recorded for the sample from Lodu while the lowest value of 67.76 ± 4.80 mg kg⁻¹ was recorded for the sample from Ohiya. The same profile was recorded for available phosphorus.

Mean Ca, K and Na were significantly higher (P < 0.05) in the oil mill samples compared to control sample. Okwute and Isu (2007) also obtained similar results in a study on the impact of POME on physico-chemical parameters of soil in Anyingba, Nigeria. Mean concentration of Ca was significantly higher (P < 0.05) in the sample from Ohiya when compared to other oil mill samples. However, mean Mg concentration in the sample from Ohiya was similar (P > 0.05) to that of the control sample but significantly lower (P < 0.05) than those of the other oil mill samples. Mean total Heavy metal (Cu, Cd, Ni and Cr) concentrations in the soil samples from the sampling and control sites are shown in Table 3.

Mean total Cu concentrations were significantly higher (P < 0.05) in all soil samples than the mean concentrations of other metals. Mean Cu and Cr

### Table 1. Means (±SD) Values for Particle Size, pH, EC and Bulk Density

<table>
<thead>
<tr>
<th>Sites</th>
<th>Clay (% )</th>
<th>Sand (% )</th>
<th>Silt (% )</th>
<th>pH</th>
<th>EC (µS cm⁻¹)</th>
<th>Bulk Density (g cm⁻³)</th>
<th>Oil and Grease (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohiya</td>
<td>10.52±0.00a</td>
<td>66.50±1.26a</td>
<td>23.00±1.00a</td>
<td>5.80±0.22a</td>
<td>138±29a</td>
<td>1.58±0.05a</td>
<td>10.36±1.49a</td>
</tr>
<tr>
<td>Ubakala</td>
<td>14.66±1.05a</td>
<td>63.94±1.33a</td>
<td>21.40±1.50a</td>
<td>6.20±0.35a</td>
<td>180±17a</td>
<td>1.50±0.11a</td>
<td>12.18±3.08a</td>
</tr>
<tr>
<td>Ikwuan</td>
<td>16.20±0.95a</td>
<td>56.65±0.88b</td>
<td>27.15±0.85c</td>
<td>5.60±0.81c</td>
<td>168±10bc</td>
<td>1.40±0.30b</td>
<td>9.30±0.88bc</td>
</tr>
<tr>
<td>Umuihe</td>
<td>15.39±0.72a</td>
<td>65.97±2.17a</td>
<td>18.64±0.59a</td>
<td>5.70±0.42a</td>
<td>106±30bc</td>
<td>1.45±0.08b</td>
<td>11.29±2.11a</td>
</tr>
<tr>
<td>Lodu</td>
<td>20.77±0.53c</td>
<td>55.83±1.49c</td>
<td>23.40±0.66a</td>
<td>5.60±0.18a</td>
<td>159±11bc</td>
<td>1.39±0.20a</td>
<td>8.30±1.20bc</td>
</tr>
<tr>
<td>Control</td>
<td>12.19±1.50a</td>
<td>75.55±2.55c</td>
<td>12.26±0.33c</td>
<td>7.08±0.20a</td>
<td>85±20bc</td>
<td>1.17±0.07b</td>
<td>3.25±0.95c</td>
</tr>
</tbody>
</table>

EC = electrical conductivity
Means in the same column with different superscripts are significantly different (P < 0.05)

### Table 2. Means (±SD) Values for other Physico-chemical Parameters

<table>
<thead>
<tr>
<th>Sites</th>
<th>OC (%)</th>
<th>OM (%)</th>
<th>TP (mg kg⁻¹)</th>
<th>AP (mg kg⁻¹)</th>
<th>TN (%)</th>
<th>Exchangeable Bases</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca (mg kg⁻¹)</td>
<td>Mg (mg kg⁻¹)</td>
<td>K (mg kg⁻¹)</td>
<td>Na (mg kg⁻¹)</td>
</tr>
<tr>
<td>Ohiya</td>
<td>1.03±0.08</td>
<td>3.50±1.2</td>
<td>19.35±4.2</td>
<td>1.21±0.1</td>
<td>172.10±23.4</td>
<td>2.91±0.9</td>
<td>8.00±1.46</td>
<td>34.80±8.14</td>
<td></td>
</tr>
<tr>
<td>Ubakala</td>
<td>4.03±0.8</td>
<td>7.40±1.7</td>
<td>23.00±2.8</td>
<td>0.72±0.0</td>
<td>140.92±26.7</td>
<td>1.76±0.5</td>
<td>7.40±0.91</td>
<td>27.49±6.91</td>
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</tr>
<tr>
<td>Ikwuan</td>
<td>1.83±0.2</td>
<td>3.02±0.9</td>
<td>44.90±5.0</td>
<td>0.80±0.0</td>
<td>112.85±18.3</td>
<td>3.56±0.9</td>
<td>9.60±1.80</td>
<td>37.72±9.34</td>
<td></td>
</tr>
<tr>
<td>Umuihe</td>
<td>2.63±0.7</td>
<td>5.53±1.0</td>
<td>30.10±9.1</td>
<td>0.96±0.1</td>
<td>124.40±30.0</td>
<td>1.14±0.6</td>
<td>10.40±2.1</td>
<td>43.50±10.2</td>
<td></td>
</tr>
<tr>
<td>Lodu</td>
<td>2.01±0.9</td>
<td>4.70±1.1</td>
<td>46.30±7.8</td>
<td>1.28±0.3</td>
<td>107.61±10.8</td>
<td>2.69±0.8</td>
<td>8.80±2.15</td>
<td>40.08±8.30</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.70±0.0</td>
<td>1.21±0.3</td>
<td>14.31±2.5</td>
<td>0.44±0.0</td>
<td>48.95±5.70</td>
<td>1.10±0.5</td>
<td>5.22±1.07</td>
<td>10.26±2.39</td>
<td></td>
</tr>
</tbody>
</table>

OC = organic carbon, OM = organic matter, TP = total phosphorus, AV = available phosphorus, TN = total nitrogen
Means in the same column with different superscripts are significantly different (P < 0.05)
concentrations were significantly lower (P < 0.05) in control soil samples compared to oil mill samples. However, mean Cd and Ni concentrations in control sample were similar (P > 0.05) to concentrations in Ubakala and Ohia, respectively. POME discharge seems to impact greater Cu and Cr loads on soil samples compared to the other metals determined in this study. The Canadian Quality Guidelines values for soil meant for agricultural use have the following limits for the metals analyzed in this study: Cd 1.4, Cr 64 and Cu 63 mg kg⁻¹ (CCME, 2007). Total Cd, Cr and Cu concentrations in this study were below the guideline limits.

CONCLUSION

This study has shown that the discharge of POME onto the soil causes the degradation of soil physico-chemical properties and increase heavy metal contamination. Thus, while essential products like palm oil are obtained from oil palm milling, the adverse environmental impact of POME discharge should be placed in the proper context. Adequate treatment and proper disposal of POME is advocated.

REFERENCES


Table 3. Mean (±SD) Total Cu, Cd, Ni and Cr concentrations (mg kg⁻¹) in the Soil Samples

<table>
<thead>
<tr>
<th>Sites</th>
<th>Cu</th>
<th>Cd</th>
<th>Ni</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohiya</td>
<td>10.80±1.32a</td>
<td>0.05±0.00a</td>
<td>0.25±0.43a</td>
<td>0.74±0.07a</td>
</tr>
<tr>
<td>Ubakala</td>
<td>13.37±1.74a</td>
<td>0.02±0.00b</td>
<td>0.60±0.10b</td>
<td>0.82±0.11a</td>
</tr>
<tr>
<td>Ikwuano</td>
<td>9.80±2.60a</td>
<td>0.07±0.01a</td>
<td>0.10±0.05c</td>
<td>0.70±0.16a</td>
</tr>
<tr>
<td>Umuahia</td>
<td>21.40±4.59b</td>
<td>0.13±0.05c</td>
<td>0.09±0.02c</td>
<td>1.05±0.29a</td>
</tr>
<tr>
<td>Lodu</td>
<td>10.44±1.88a</td>
<td>0.08±0.01a</td>
<td>0.10±0.03c</td>
<td>1.33±0.63b</td>
</tr>
<tr>
<td>Control</td>
<td>5.82±1.20d</td>
<td>0.01±0.00b</td>
<td>0.31±0.02a</td>
<td>0.42±0.05c</td>
</tr>
</tbody>
</table>

Means in the same column with different superscripts are significantly different (P<0.05)


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