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Physicochemical properties and selected metals in soils of Ohaji-Egbema, Imo State, Nigeria

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ABSTRACT

This study assesses the physiochemical characteristics and heavy metals content of crude oil polluted soils and non-polluted soils from Ohaji/Egbema, Imo State. Soil samples were collected at depths of 0-30 cm at each sampling point and then analyzed using standard analytical methods. Data from the five areas were compared to standards for soils in Nigeria and in World Health Organization (WHO) data banks. The results obtained from the analysis showed an average pH of $(4.88 \pm 0.02$ to $5.02 \pm 0.04)$ for polluted soil and $(6.57 \pm 0.05$ to $6.82 \pm 0.03)$ for non-polluted soil, electrical conductivity $(571 \pm 1.1$ to 592 ± 0.8 µS/cm) for oil polluted soil and $(383 \pm 0.5$ to 415 ± 1.6 µS/cm) for non-polluted samples, moisture content $(5.2 \pm 0.2$ to $9.1 \pm 0.1\%)$ for polluted soil and $(4.5 \pm 0.1$ to $4.7 \pm 0.3\%)$ for non-polluted soil samples. There was no significant difference in temperature and organic matter for both the polluted and non-polluted soil samples. The heavy metals analysis results showed Fe^{3+} (0.615 to 0.989 ppm) for oil-polluted soil samples and (0.0453 to 0.273 ppm) for non-polluted soil samples, Pb^{2+} (0.017 to 0.180 ppm) for oil-polluted soil and (0.008 to 0.010 ppm) for non-polluted soil. The study reveals that areas that are polluted need urgent remediation if the soil is to be used for agricultural purposes.

Keyword: Characterization, Heavy metals, Oil pollution

1. INTRODUCTION

Soil is the mixture of minerals, organic matter, gases, liquids, and the countless organisms that together support life on Earth. Soil is a natural body known as the pedosphere and which performs four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of the atmosphere of Earth; it is a habitat for organisms; all of which, in turn, modify the soil. Soil is considered to be the skin of the earth and interfaces with its lithosphere, hydrosphere, atmosphere, and biosphere. Soil consists of a solid phase (minerals and organic matter) as well as a porous phase that holds gases and water. Accordingly, soils are often treated as a three-state system.

Soil can be seen as solid material on the Earth's surface that results from the interaction of weathering and biological activity on the parent material or underlying hard rock. The study of soils as naturally occurring phenomena is called pedology, which was derived from the Greek word pedon, meaning soil or earth. Pedology takes into account: factors and processes of soil formation, Soil characteristics, and distribution of soil types.

Soil science has two basic branches of study: Edaphology and Pedology. Pedology is focused on the formation, description, morphology and classification of soils in their natural environment, whereas edaphology is concerned with the influence of soils on organisms. In engineering terms, soil is referred to as regolith, or loose rock material that lies above the solid geology. Soil is commonly referred to as earth or dirt, technically the term dirt should be restricted to displaced soil [1].

The inorganic components of soil are principally the products of rocks and minerals. The organic materials are composed of debris from plants and from the decomposition of the many tiny life forms that inhabit the soil. Soils vary widely from place to place. Many factors determine the chemical composition and physical structure of the soil at any given location. Soil actually constitutes a living system, the essential process of photosynthesis, serves as a vital part of the food chain for living things, including humans; without soil there would be no vegetation—no crops for food, no forests, flowers, or grasslands, life on Earth depends on soil.

The objectives of this study are to:

(1) Carry out physiochemical characterization of the soil samples

(2) Record visual characteristics of soil samples

(3) Determine the metal concentration of the soil samples

(4) Compare the result of the oil polluted soil samples with non-polluted soil samples.

This study helps to determine the physiochemical characteristics, visual characteristics, heavy metals determination and cation exchange capacity of crude oil contaminated soil and non contaminated soil collected from Ohaji/Egbema in Imo state, Nigeria.

The scope of study of this project covers studies on the physiochemical characteristics of soil sample which include the pH, electrical conductivity, moisture content, organic matter, texture, temperature, heavy metals, cation exchange capacity and visual characteristics like the soil colour, odour, size gradation, reaction with HCl and evidence of contamination.

2. MATERIALS AND METHOD

2. 1. Chemical and Reagents:

All instruments used in this work were in good working condition and were used according to manufacturer's instructions. Aqua-Regia, Hydrochloric acid (HCl), Nitric acid (HNO$_3$), Ethanol, Sodium hydroxide (NaOH) (0.1 N), Phenolphthalein indicator, and Distilled water.

2. 2. Study area

The study was carried out among five (5) different villages in Ohaji/Egbema local government area in Imo state. Ohaji-Egbema lies in the South/Western part of imo state and shares common boundaries with owerri in the east. It covers an area of approximately 958.010 km^2.

2. 3. Study population

A total of 5 samples were collected from 5 different communities in Ohaji/Egbema community in Imo state. Three of the samples were crude oil contaminated soils (Ugwuagba, Mmahu and Umukanne) while two of the soil samples are non-contaminated (Obirikom and Umuapu). The soil samples were examined in October 2015.

2. 4. Ethical approval

Before the study commenced, approval was obtained from the people taking charge of the oil spill areas and from the owners of different farm lands that are not polluted. Prior to this approval, a letter of recommendation was collected from my project supervisor.

2. 5. Sample collection

All soil samples were collected in Ohaji-Egbema community, Imo state using sterile containers to collect the soil samples from crude oil polluted and non-polluted areas in Ohaji-Egbema. Each sample was labeled appropriately and transported to the chemical laboratory of the Imo state University Owerri, Nigeria, for analysis.

2. 6. Visual Soil Field Classification

This was done using the munsell soil colour chart. Munsell soil colour chart was placed close to the sample and ready the soil colour was determined by visual assessment. The moisture description was determined by collecting some soil samples from the field, and then placed it on a paper. Then it was observed for moist, dry or wet. The size gradation was determined with the use of hand lens. The odour was determined by smelling with the nose. The staining was done with the use of a muslin cloth to check the soil for staining. Diluted hydrochloric acid was added drop-wise to the soil sample and observed for either strong, weak, or no reaction.

2. 7. Physico-Chemical Analysis of Soil

2. 7. 1. Determination of moisture content

10 g of the sample was weighed into a porcelain dish and was placed in a hot air oven at 105 °C. The weight of the sample was checked at 30-minute interval until constant weight. The moisture in the soil was calculated using the formula:

$$\text{Moisture content} = \frac{\text{wet weight} - \text{dry weight}}{\text{Dry weight}}$$

2. 7. 2. Determination of soil texture

100 g of the sample was weighed into the quart bottle and the quart bottle was filled with water up to the neck of the bottle. The bottle was shaken very well and to ensure uniformity on the bottom of the quart bottle. It was allowed to stand overnight and the level of sand, clay and silt was measured.

The formula below is used to calculate the percentage of clay, silt, and sand:

$$\% \, Sand, Clay \, or \, Silt = \frac{V_w}{T.V} \times 100$$

where:
V = volume, w = clay, silt, or sand
T.V = total volume of soil.

2. 7. 3. Determination of soil temperature

This was determined by using the gardener's thermometer. The gardener's thermometer was inserted inside the soil sample and it was allowed to stay for about 5 minutes and the temperature of the soil sample was read.

2. 7. 4. Determination of electrical conductivity

The electrical conductivity was determined by using the HANNA HI8733 electrical conductivity. The electrical conductivity meter was first calibrated using a solution of potassium chloride. 20 g of the sample was weighed into 500 ml beaker and 200 ml of water was added, and it was allowed to stay for about 30 minutes. The electrode was dipped inside the beaker and the reading was obtained from the electrical conductivity screen.

2. 7. 5. Determination of organic matter

This was determined using the muffle furnace. 10 g of the sample was weighed into a porcelain dish and it was placed inside a muffle furnace, keeping the temperature at 420 °C for 2 hours. The Formula below was used to calculate the organic matter content:

$$SOM = \frac{Mo}{M_D} \times \frac{100}{1}$$

where:
SOM = Soil organic matter, Mo is organic matter, M_D is mass of dry soil, M_A is mass of burned soil.

$$Mo = M_D - M_A$$

2. 7. 6. Reaction with hydrochloric acid

10 g of the sample was weighed into a beaker, two drops of diluted hydrochloric acid was dropped on the soil sample in order to check if the soil sample is weak or strong.

2. 7. 7. Determination of the soil pH

This was done by the use of JENWAY 3510 pH meter which is calibrated using buffer 4 and buffer 7. 10 g of the sample was weighed into 250 ml beaker and 100 ml of distilled water was added and stirred for about 30 minutes and it was allowed to stay for 2 hours. The pH electrode was dipped into the beaker and was left for about 5 minutes before taking the reading.

2. 7. 8 Determination of cation exchange capacity/heavy metals

Heavy metal analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer according to the method of APHA 1995 (American Public Health Association) 1g of each sample was digested with aqua-regia for 5days. The extract was centrifuged at 30000 rpm for 15mins and the heavy metal and cations were determined using appropriate calibration curves prepared in the same acid matrix with standard metal solutions for atomic absorption spectrophotometer.

2. 8. Statistical Analysis

The data obtained from the physico-chemical analysis of the soil samples were taken to statistical analysis using mean, standard deviation, and contamination factor. Graphs were also used to show the heavy metal content of the soil samples.

3. RESULTS AND DICUSSION

Tables 1, **2**, **3**, and **Figures 1**, **2**, **3**, presented below, show the visual characteristics, texture content, physiochemical characteristics, cation exchange capacity and heavy metal concentration and contamination factor of the heavy metals of the soil samples. The soil samples collected from Ugwuagba, Mmahu and Umukanne are polluted soil samples, while soil samples from Obosima and Umuapu are non-polluted soil samples.

Table 1. Visual characteristics of soil samples

Location	Ugwuagba	Mmahu	Umukanne	Obosima	Umuapu
Colour	RB	B	RB	RY	RG
Moisture	Moist	Moist	Moist	Wet	Dry
Size deg.	Sand	sand	Sand	Sand	Sand
Odour	HC	HC	HC	Organic	Organic

E. con.	staining	staining	Staining	Staining	P. staining
R.W. HCl	Weak	strong	Weak	Weak	Strong

Key: HC = hydrocarbon, RG = reddish grey, B = black, RB = reddish brown, RY = reddish yellow, E con. = evidence of contamination
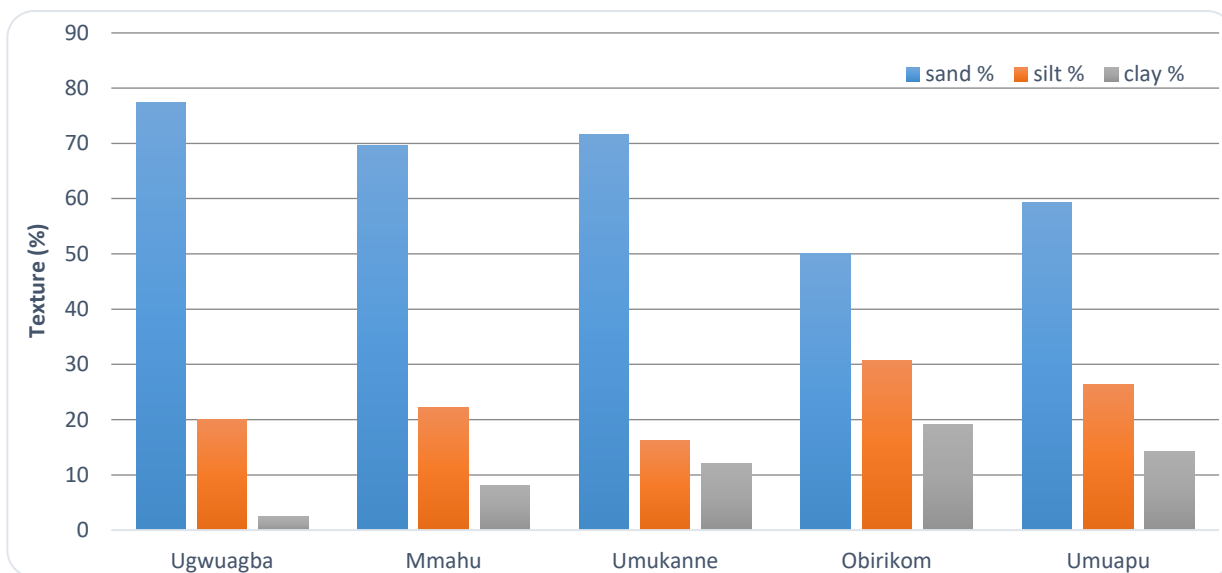
Fig. 1. Bar chart showing the texture classification of the different soil samples.

Table 2. Physiochemical characteristics of the soil samples
(given as mean ± standard deviation for all the soil samples).

| **Location**	Temp. °C	EC µS/cm	MC %	pH	OM %
Ugwuagba	28.08 ± 0.4	592 ± 0.8	5.2 ± 0.2	4.88 ± 0.02	3.61 ± 0.1
Mmahu	28.78± 0.5	634 ± 1.1	9.1 ± 0.1	4.94 ± 0.10	4.77 ± 0.05
Umukanne	28.14± 0.5	571. ± 1.1	7.4 ± 0.2	5.02 ± 0.04	3.35 ± 0.03
Obosima	28.20± 0.3	383 ± 0.5	4.5 ± 0.1	6.82 ± 0.03	3.69 ± 0.02
Umuapu	27.93 ± 0.2	415 ± 1.6	4.7 ± 0.3	6.57 ± 0.05	3.01 ± 0.02

Key: EC = electrical conductivity, MC = moisture content, OM = organic matter, Temp. = temperature

Table 3. Cation exchange capacity and Micro nutrients of the soil samples.

Location	Ca (ppm)	Mg (ppm)	K (ppm)	Na (ppm)	CEC(ppm)
Ugwuagba	0.892	4.557	3.018	0.751	5.5421
Mmahu	1.554	1.864	0.923	0.683	5.0240
Umukanne	1.044	2.654	0.9048	0.741	5.3438
Obosima	3.515	4.765	0.564	0.561	9.405
Umuapu	2.638	1.557	2.040	0.052	6.247
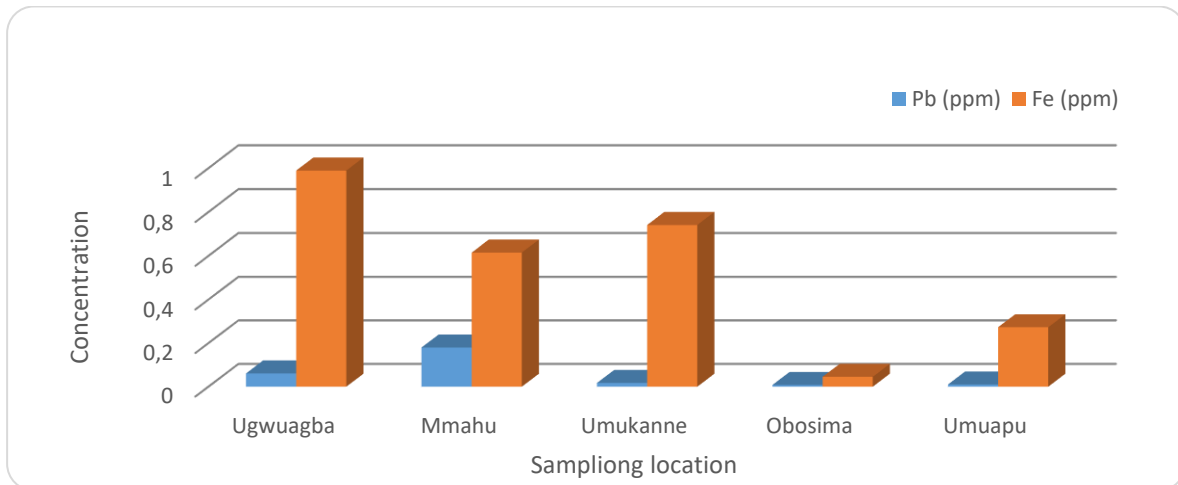
Fig. 2. Bar chart showing Pb and Fe concentrations of the soil samples
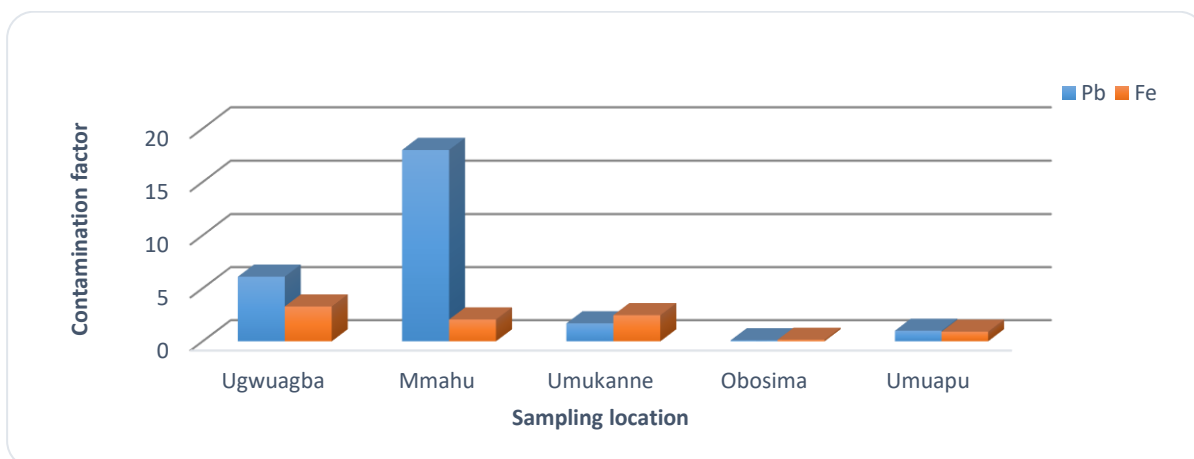
Fig. 3. Bar chart showing contamination factors of all the soil samples.

The contamination factor [7] was calculated following the use of expression:

$$C_F = C_S/C_b$$

where: C_F is the contamination factor, C_s is the measured concentration of the examined metal in the soil, and C_b is the background levels of metals in soil reported by WHO and NESREA as follows: 0.01 ppm and 0.03ppm, for Pb and Fe, respectively.

4. DISCUSSION

4. 1. Visual characteristics

It was found from Table 1 that the soil samples from Ugwuagba, Mmahu and Umukanne have a characteristic odour, similar to that of hydrocarbon, while the samples from Obosima and Umuapu have the odour similar to organic matter. There was no significant difference in the size degradation of the five samples form (Table 1). The evidence of contamination of all the soil samples shows staining, except for Umuapu that has poor staining. The moisture description obtained from Table 1 shows that the soil samples from oil polluted areas (Ugwuagba, Mmahu and Umukanne) have moist description, while those from Obosima have wet description, and Umuapu have dry description. The colours of the different samples are different and this may be due to difference in locations.

4. 2. Physiochemical characteristics

From the data obtained from **Fig. 1**, in Ugwuagba, sand content was 77.5%, silt was 20.1%, and clay was 2.4%. In Mmahu, sand content was 69.7%, silt was 22.2%, and clay was 8.1%. In Umukanne, the sand was 71.7%, silt was 16.2%, and clay was 12.1%. In Obirikom, the sand content was 60.1%, silt was 29.7%, and clay was 10.2%. In Umuapu, the sand content was 59.3%, silt was 26.4%, and the clay was 14.3%. Ugwuagba has the highest sand content (77.5%) and also the lowest clay content (2.4%), so it shows it has the lowest water / hydrocarbon holding and very low nutrient storage capacity. Obirikom has the highest value of silt content (30.7%) which may result in slower hydrocarbon and water intake and higher water holding capacity. Mmahu and Umukanne have almost balanced values of sand and clay with lower amount of silt. Mmahu have balanced sand, silt and clay content. From the result from Table 2, the significantly higher electrical conductivity of Ugwuagba (592 µS/cm), Mmahu (634 µS/cm) and Umukanne (571 µS/cm) could be as a result of high concentration of charged ions (cations and anion) in the polluted soil.

The electrical conductivity of Obosima (383 µS/cm) and Umuapu (415 µS/cm) are relatively lower than those from the oil polluted areas due to loss of anions, metallic ions and carbonic acids. However, the generally low electrical conductivity values of the soils of the study area is an indication of the high degree of leaching of nitrate salt, taking place as a result of high rainfall in Owerri. It was found from Table 3 that the moisture content in the Ugwuagba (5.2%), Mmahu (9.1%), and Umukanne (7.4%) shows that the three oil polluted areas retain more water, especially in Mmahu soil sample, than soil from Ugwuagba and Umukanne. The moisture content of the soil sample from Obosima (4.5%) and Umuapu (4.7%) was relatively low. High moisture content may reduce microbial activities not as a result of the water itself but rather by the indirect hindrance to the movement of air, which would reduce oxygen supply

to plants. The average pH values in samples analyzed show Ugwuagba (4.88), Mmahu (4.94), and Umukanne (5.02), indicating that the soil in these areas are acidic compared to the pH in Obosima which has the average of 6.82, and in Umuapu which has an average of 6.27. pH value between 6.5 and 7.5 is considered optimum for the growth of many plants. The organic matter of Mmahu (4.77%) is relatively similar to other sample's organic matter content and also there was not a high variation in the temperature of the soil samples. The cation exchange capacity obtained from Table 3 shows that Obosima (9.405 ppm) has a higher cation exchange capacity than other samples followed by Umuapu (6.247ppm) that has higher cation exchange capacity more than Ugwuagba (5.5421 ppm), Mmahu (5.0240 ppm), and Umukanne (5.3438 ppm).

4. 3. Heavy metal concentration

The data obtained from Fig. 2, shows that the lead contents in Ugwuagba (0.061 ppm), Mmahu (0.180 ppm), and Umukanne (0.017 ppm) show higher level of contamination in those polluted which recorded Mmahu (0.180 ppm) the highest, higher than Obosima (0.008 ppm) and Umuapu (0.010 ppm) which are lower in contamination. The iron concentration of Ugwuagba (0.989 ppm) shows higher contamination than other soil samples from Mmahu (0.615 ppm), Umukanne (0.741 ppm), Obosima (0.0453 ppm) and Umuapu (0.273 ppm). The contamination factors, both for lead and iron from the oil polluted samples from Ugwuagba (6.1 ppm and 3.29 ppm), Mmahu (1.8ppm and 2.06 ppm) and Umukanne (1.7ppm and 2.47 ppm), are very high especially for Ugwuagba (6.1 ppm). Obosima (0.1ppm and 0.15 ppm) has a moderate contamination while Umuapu (1 ppm and 0.91 ppm) has low contamination. The contamination factor $C_F < 1$ refers to low contamination; $1 \leq CF < 3$ means moderate contamination; $3 \leq CF \leq 6$ indicates considerable contamination, and $CF > 6$ indicates very high contamination, this was compared using the NESREA standard for soil quality [2,3].

5. CONCLUSION

It can be concluded that the test results obtained from the soil analysis of the oil-spilled impacted sites (Ugwuagba, Mmahu and Umukanne) compared to the results of the un-impacted sites (Obosima and Umuapu) show that the pH, electrical conductivity and contamination factor of the heavy metal concentration observed from both the oil spilled locations have provided evidence of severe hydrocarbon contamination of the sites. These conditions generally imply low soil fertility, which in turn implies low agricultural productivity and reduces source of livelihood in the affected areas. There was a significant difference in electrical conductivity values between the impacted and un-impacted sites. However, there was no significant change or difference in values for properties like temperature and organic matter for both, affected and un- affected sites or locations [4-14].

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