Asian Journal of Environment & Ecology

Volume 22, Issue 4, Page 63-72, 2023; Article no.AJEE.108862
ISSN: 2456-690X

Status of Soil Quality in the Vicinity of Artisanal Refining Sites in Rivers State, Nigeria

M. P. Solomon [a*], I. O. Agbagwa [b] and L. C. Osuji [c]

[a] Institute of Natural Resources, Environment and Sustainable Development, University of Port Harcourt, PMB 5323, Choba, Port Harcourt, Nigeria.
[b] Department of Plant Science and Biotechnology, Faculty of Biological Sciences, University of Port Harcourt, Port Harcourt, Nigeria.
[c] Department of Industrial and Pure Chemistry, Petroleum and Environmental Chemistry Research Group, University of Port Harcourt, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2023/v22i4508

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/108862

Original Research Article

Received: 20/09/2023
Accepted: 25/11/2023
Published: 29/11/2023

ABSTRACT

The environmental quality and sustainability in the Niger Delta region are severely undermined by the increasing practice of artisanal crude oil refining. This study aimed to assess the impact artisanal crude oil refining on soil nutrients stability vis-à-vis plant/vegetal resources of farmlands. Farmlands in Elele-Alimini and Ibaa in Emohua Local Government Area (LGA), Ogbodo in Ikwerre LGA and Umuanyagu (control) in Etche LGA, Rivers State (Nigeria) were sampled in this study. A total of fifty (50) sampling points in both test and control locations, were randomly selected using a standard spatial (grid-based) sampling technique. Soil and plant samples within the farmlands were collected to determine the physicochemical parameters and macronutrient contents. During the dry and wet seasons, mean values of pH, EC and moisture content in test soil were in the ranges 4.60-

**Corresponding author: E-mail: mmefreukut_solomon@uniport.edu.ng;*

4.85 and 4.55-4.79; 66.67-130.0 µS/cm and 31.3-33 µS/cm, and 7.21-11.49 % and 11.71-66 %, respectively. The values of pH, EC and moisture content in the control soil ranged from 4.78-4.84 and 4.81-5.14; 130-152 µS/cm and 31.5-33.0 µS/cm, 11.86-11.88% and 63-66% respectively. Electrical conductivity and pH of soil showed almost a similar trend (Control > Ogbodo > Ibaa > Elele Alimini) for both top and sub-soils and in both seasons. During the dry and wet seasons, mean values of nitrogen (N), phosphorus (P), potassium (K), Total Organic Carbon (TOC) and Soil Organic Matter (SOM) in test soils were in the ranges 0.11-0.17% and 0.11-0.18 %; 0.13-0.23 mg/kg and 0.04-0.06 mg/kg; 22.82-51.87 mg/kg and 14.23-35.60 mg/kg; 1.30-2.00% and 1.36-2.0%, and 2.22-3.45% and 2.24-3.16, respectively. Mean values of N, P, K, TOC and SOM in control soils during the dry and wet seasons were in the ranges 0.12-0.19% and 0.14%; 0.29-0.33 mg/kg and 0.08-0.09 mg/kg; 50.33-52.18 mg/kg and 42.75-50.24 mg/kg; 1.35-2.14 and 1.83-2.08%, and 2.53-3.70% and 2.12-2.85%, respectively. The levels of N, P, K, TOC and SOM in the farmlands were low, and could result in poor crop growth yield.

Keywords: Artisanal crude oil refining; soil; nutrients; farmlands.

1. INTRODUCTION

An artisanal crude oil refinery is a temporary system for the separation of petroleum fractions based on the distillation concept, as used in local gin production. It is relatively cheap to set up and that makes it an easy venture to enter into, so long as there is guarantee of crude [1]. Artisanal crude oil refining is a thriving unlawful and informal business in the Niger Delta, with the value chain encompassing oil theft, transportation, refining, and retailing [2].

Operators of artisanal refineries adopt crude methods to access pipeline and well heads [3]. Also, as stolen crude is ferried in boats to the refining destination it pours into the river and the refining process itself seriously pollutes with fumes and refining residues. Owing to lack of expertise and adoption of crude methods, the operations of artisanal petroleum refining process generate significant wastes that end up being dumped in rivers and creeks and on land, while evaporated low fractions permeate the air [4]. Thus, environmental quality and sustainability in the Niger Delta region are severely undermined by artisanal oil refining activities, particularly from hydrocarbon and soot pollution.

There are well-known hazardous effects of oil-hydrocarbons on vegetation depending on their composition, concentration, environmental factors and on the biological state of the organisms at the time of the contamination. Oil-hydrocarbons can interfere with plant nutrient absorption. [5-8], cause metabolic impairment, leading to accumulation of reactive oxygen species [8,9], inhibit the photosynthesis and transpiration [7,10], and finally lead to the death of plants and the depletion of plant communities. The plants themselves bioaccumulate petroleum contaminants and transfer them to the food chain, which eventually ends up in higher trophic levels with likelihood of human health complication upon consumption [11,12].

Soot, like particles in general, may affect soil and vegetation by both physical and chemical processes. Soot can clog air spaces in soil and reduce the amount of available water [13]. Soot can adhere strongly to soil and accumulate over time. Soot can affect plants by covering leaf and stem surface thereby reducing the amount of light available for photosynthesis [13]. The particulate matter may occlude stomata which could lead to increase in resistance to gas exchange for photosynthesis and respiration, and hinder transpiration [14]. Internal chemical composition and metabolic functions of plant can be altered by inherent chemicals in soot, which could bring about plant stress, growth retardation and possibly death [13,15].

There have been studies of the impact of artisanal refining in the Niger Delta but not much has been done to assess the impact on soil fertility indices. For example, Nwankwoala et al. [16] examined the impacts of artisanal refining activities on soil and water quality in areas of Rivers State's Okrika and Ogu-Bolo Areas, and discovered that the water in the research location is unsafe for drinking and other household uses, with artisanal refining increasing the contamination of aquifer at a very fast rate and rendering the soil quality very poor. Similarly, Yabrade and Tanee [17] reported the impact of the operation on vegetation and soil quality. Asimiea and Omokhua [18] appraised the effects of artisanal refining on plants which they reported caused alteration in the floristic composition of woody plants within and around the area of operation, severe mortality of merchantable trees, and massive destruction of vegetation in the affected areas. Onakpohor et al. [19] in their study of the effect of artisanal petroleum refineries in the Niger Delta focused only on emission into air and established that the activities are sources of significant air pollution, which breached the set limits for CO, NOx, and SO_2. The study by Ogele and Egobueze [20] focused on the negative environmental and social consequences, including the economic gains of the refining process. Gijo et al. [21] assessed the impact of artisanal crude oil refineries on the physicochemical features of the sediments of the Nun River, where they showed that the operations lead to increase in acidity, total organic carbon and total petroleum hydrocarbon. Onwuna et al. [22] examined the impact of artisanal refinery on physicochemical and microbiological properties of soil and water. This study thus seeks to assess the effect of artisanal crude oil refining on macronutrients and fertility indices of soils in parts of Rivers State.

2. MATERIALS AND METHODS

2.1 Study Area Description

Emuoha and Ikwerre are two of the twenty-three (23) Local Government Areas in Rivers State (Fig 1). The study area is on latitude 4°53’N - 4°54’N and longitude 6°52’30’E -7°1’30’E. The topography is a flat terrain; average height of about 11m above sea level. The flat terrain encourages water stagnation after rain episodes and there is no good drainage system to channel runoff to the river. The climate is humid tropical /equatorial zone with mean annual temperature of about 29°C. The temperature ranges from 22°C - 35°C within the rainy and dry seasons respectively. The highest rainfall occurs between the months of July and September and decreases as dry season approaches between December and January with mean annual rainfall of 2500mm. Typically, the region, has a wet equatorial climate with two distinctive seasons known as wet season which is between April and October and dry season which is November and March [23].

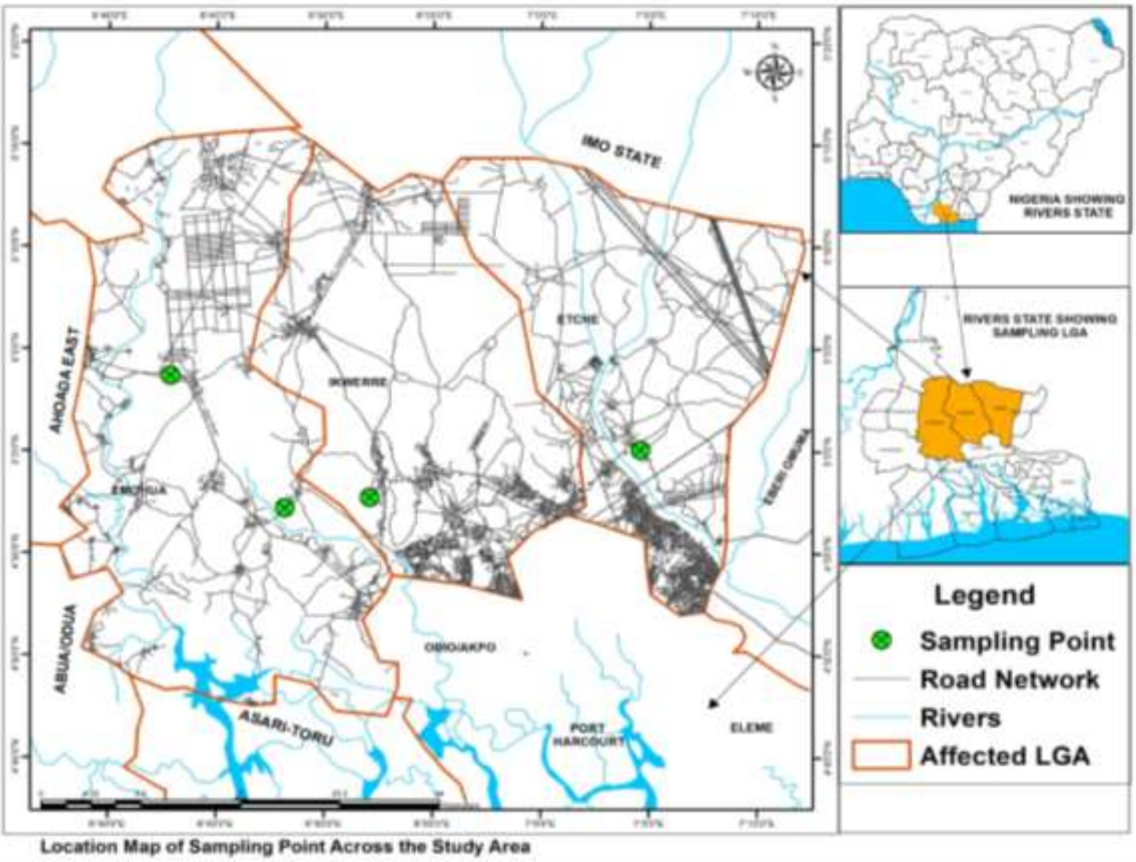

Fig. 1. Map of study area showing sampling sites

This soil is sandy in texture. Some are made of mud combined with decomposed biological materials. There is also mangrove swamp alluvial soil found north of the coastal sediments zone, which is brownish on the surface. There is a third soil group, brown loams and sandy loams, which are found in the delta's fresh water zone [24].

2.2 Sample Design and Collection

Employing the method of Osuji and Nwoye [25] with minor modification, soil samples were collected from farmlands located near artisanal crude oil refining sites in Emuoha and Ikwerre LGA. Fifty (50) soil samples were collected at random from farmlands within 100m x 100m grid plot subdivided into 100 plots. Surface soils (0-15cm) and subsurface soils (15-30cm) were gathered using a conventional steel auger, after removal of litters with a trowel. Ten (10) replicate soil samples were collected at the two depths and placed in well-labeled plastic bags before being transported to the laboratory for analysis. Cassava tuber samples were obtained from the same grid plot as soil samples were collected for the investigation. Control samples were taken from Etche LGA, where there was no presence of crude oil or related activities. Tuber samples were collected from all places by uprooting them using a wooden shovel and knife. Samples were collected and carefully packaged in well-labeled plastic bags before being transported to the laboratory for analysis.

2.3 Analysis of Soil Physicochemical Parameters

Soil parameters including soil pH, electrical conductivity and moisture content were determined according to ASTM methods.

2.4 Determination of Nutrients

Potassium concentration in soil and plant samples was determined by atomic absorption spectrophotometry. Determination of nitrogen (N), phosphorous (P), potassium, Soil Organic Matter (SOM) and Total Organic Carbon (TOC) concentrations was as described by Piper [26].

2.5 Data Analysis

Analysis of data obtained in the study was done using descriptive and inferential statistical methodologies in the SPSS statistics software package. One-way analysis of Variance (ANOVA) and student T-test were used to test for significance difference (p=0.05) in concentrations of physicochemical parameters and macronutrients across sampling locations and seasonal variations.

3. RESULTS

3.1 Physicochemical Properties of Soils

Table 1 shows physicochemical properties of soils with potential hydrocarbon distribution impact at different farm sites in Emohua, Ikwerre and Etche (Control) LGAs during dry and wet seasons. During the Dry season, mean pH in test soil ranged from 4.60-4.85; EC ranged from 66.67-130.0 µS/cm and moisture content ranged from 7.21-11.49 %. The values of pH, EC and moisture content in the control soil ranged from 4.78-4.84, 130-152 µS/cm, 11.86-11.88% respectively. During the Wet season pH in test soil ranged from 4.55-4.79; EC ranged from 31.3-33 µS/cm and moisture content ranged from 11.71-66 %. The values of pH, EC and moisture content in the control soil ranged from 4.81-5.14, 31.5-33.0 µS/cm, 63-66% respectively.

3.2 Fertility Status of Farm Soils During Dry and Wet Seasons

Result of nutrient status in the soil in both seasons, is shown in Table 2. Mean values of N in test soils during the dry season ranged from 0.11-0.17%, P ranged from 0.13-0.23 mg/kg, K 22.82-51.87 mg/kg, TOC ranged from 1.30-2.00% and SOM ranged from 2.22-3.45%. Mean values of N, P, K, TOC and SOM in control soils ranged from 0.12-0.19%, 0.29-0.33 mg/kg, 50.33-52.18 mg/kg, 1.35-2.14 and 2.53-3.70% respectively. Mean values of N in test soils during the wet season ranged from 0.11-0.18 %, P ranged from 0.04-0.06 mg/kg, K ranged from 14.23-35.60 mg/kg, TOC ranged from 1.36-2.0% and SOM ranged from 2.24-3.16%. Means values of N, P, K, TOC and SOM in control soils were 0.14%, 0.08-0.09 mg/kg, 42.75-50.24 mg/kg, 1.83-2.08% and 2.12-2.85% respectively.

4. DISCUSSION

This study set out to determine the fertility indices and macronutrient status of Soils from the vicinity of Artisanal Refining site in Rivers State, Nigeria. All test samples from Elele Alimini, Ibaa and Ogbodo showed soil pH values lower than the Control soil and below

Table 1. Physicochemical properties of soils at different farm sites in Emohua, Ikwerre and Etche (Control) LGAs during dry and wet seasons

Location/Nature of Farm Soil	pH	EC (µS/cm)	Moisture Content (%)
Dry Season (mean value ± SE**)**			
Elele Alimini Top Soil	4.85 ± 0.09 (4.23 – 5.35)	100.9 ± 18.24 (30 – 192)	7.21 ± 0.39 (5.10 – 9.75)
Elele Alimini Sub-Soil	4.63 ± 0.21 (4.42 – 4.83)	101.2 ± 9.92 (49 – 158)	8.53 ± 0.51 (5.96 – 10.90)
Ibaa Top soil	4.60 ± 0.11 (4.44 – 4.80)	66.67± 2.73 (63 – 72)	7.93 ± 0.29 (7.40 – 8.23)
Ibaa Sub-soil	4.70 ± 0.28 (4.40 – 5.26)	130.0 ± 15.23 (45 – 53)	8.81 ± 0.16 (8.54 – 9.09)
Ogbodo Top soil	4.73 ± 0.03 (4.70 – 4.73)	96.5 ± 22.5 (74 – 119)	10.35 ± 0.42 (8.50 – 12.11)
Ogbodo Sub-soil	4.55 ± 0.12 (4.44 – 4.67)	90.0 ± 30.0 (51 – 129)	11.49 ± 0.38 (10.12 – 12.96)
Control Top soil	4.84 ± 0.09 (4.23 – 5.16)	130.0 ± 15.23 (85 – 229)	11.86 ± 1.33 (10.53 – 13.19)
Control Sub-soil	4.78 ± 0.10 (4.43 – 5.60)	152.1 ± 50.22 (36 – 491)	11.88 ± 0.04 (11.84 – 11.91)
Wet Season (mean value ± SE)			
Elele Alimini Top Soil	4.76 ± 0.13 (4.15 – 5.40)	48.7 ± 7.11 (28 – 102)	13.14 ± 0.61 (10.33 – 15.43)
Elele Alimini Sub-Soil	4.79 ± 0.10 (4.32 – 5.36)	44.2 ± 7.25 (27 – 106)	11.71± 0.63 (8.43 – 14.13)
Ibaa Top soil	4.67 ± 0.19 (4.28 – 4.93)	66 ± 12.53 (41 – 80)	33.0 ± 8.0 (25 – 41)
Ibaa Sub-soil	4.74 ± 0.07 (4.66 – 4.88)	63 ± 18.7 (27 – 90)	31.5 ± 0.5 (31 – 32)
Ogbodo Top soil	4.55 ± 0.10 (4.13 – 4.94)	48.3 ± 4.47 (30 – 79)	13.93 ± 0.36 (12.4 – 15.8)
Ogbodo Sub-soil	4.46 ± 0.07 (4.18 – 4.79)	36 ± 4.47 (23 – 54)	15.67 ± 0.32 (14.03 – 16.81)
Control Top soil	5.14 ± 0.21 (4.63 – 6.89)	33.0 ± 8.0 (25 – 41)	66 ± 12.53 (41 – 80)
Control Sub-soil	4.81 ± 0.11 (4.21 – 5.35)	31.5 ± 0.5 (31 – 32)	63 ± 18.7 (27 – 90)
F-value P-value *DPR **WHO	5.143 P = 0.036 5.5 – 6.5	1.788 P > 0.05 300 – 5000	2.837 P > 0.05 13 – 26

**Department of Petroleum Resources EGASPIN acceptable limit*

recommended range of 5.5 to 6.5 as stipulated by Department of Petroleum Resources and World Health Organization. This may be attributed to acid rain which percolates into the soil. Acid rain is a product of direct combination of water vapour with acidic gases such as NO_x (NO and NO_2), SO_x (SO_2 and SO_3) and CO_x (CO and CO_2) which are released into the atmosphere from the refinery(legal/artisanry) as flare gases. This is corroborated by the report of Adewuyi *et al* (2011) who monitored soil pH of oil spill area of Ubeji settlement in Warri metropolis. Soil pH recorded values in acidic range as reported in this study. Study revealed equal percolation of acidic rain in test soils as a result of impact of refinery activities taking place in the area. However, in the control area with little or no impact of artisanal activities, the pH vales were slightly higher (less acidic). The finding in this study was also in agreement with that reported (5.1 ± 0.1) by Osuji and Ezebuiro [27] with similar case of hydrocarbon contamination. Our finding was also in conformity with Odu et al. [28] who reported the mean and the range of pH values below the lower limit of DPR acceptable range of 6.5-7.5. The low pH of the hydrocarbon-impacted soils was attributed to oiling as major hindrance to leaching of basic salts in the study sites [25]. Report also showed that it is possible for oil or refinery effluent to have some direct impact in lowering the pH due to the likely production of organic acids via microbial metabolism pathways. Data revealed higher pH values in wet season in the study area. This is attributed to dilution due to the effect of rainfall. It was, therefore, envisaged that due to strong acidity, many essential soil nutrients/minerals would be lacking. pH of soil determines the fate of many soil pollutants including their breakdown and possible movement through the soil. Therefore, having a pH in the range of 4.09 to 5.26 for the *Test* soil samples affect nutrient availability in soils that are polluted. Solubility of minerals in the soil solution would be hindered in an acidic environment. A strongly acidic soil produces extremely high concentrated manganese and aluminium. They are known to be toxic to many plants, impact nitrogen fixation and hinders decomposition activities. This condition can be ameliorated by addition of lime to provide a buffering capacity to the soil.

Table 2. Fertility status of farm soils during dry and wet seasons

Location of Farm Soil	**Nitrogen (%)**	**Phosphorus (mg/kg)**	**Potassium (mg/kg)**	**TOC (%)**	**SOM (%)**
Dry Season (mean value ± SE)					
Elele Top	0.17 ± 0.01 (0.09 – 0.21)	0.27 ± 0.04 (0.14 – 0.43)	22.82 ± 6.87 [b] (15.95– 29.69)	2.00 ± 0.15 (1.06 – 2.47)	3.45 ± 0.26 (1.83 – 4.26)
Elele Botom	0.13 ± 0.01 (0.08 – 0.17)	0.19 ± 0.02 (0.10 – 0.34)	29.23 ± 8.33 [b] (20.90– 37.56)	1.47 ± 0.11 (0.94 – 1.96)	2.55 ± 0.20 (1.62 – 3.38)
Ibaa Top soil	0.15 ± 0.02 (0.11 – 0.19)	0.13 ± 0.02 (0.11 – 0.14)	44.91 ± 3.86 [b] (39.3 – 52.31)	1.73 ± 0.25 (1.29 – 2.16)	2.98 ± 0.43 (2.22 – 3.72)
Ibaa Sub-soil	0.11 ± 0.02 (0.07 – 0.14)	0.09 ± 0.01 (0.08 – 0.10)	35.60 ± 3.00 [b] (30.32– 40.72)	1.30± 0.24 (0.84 – 1.65)	2.24 ± 0.41 (1.45 – 2.84)
Ogbodo Top	0.12 ± 0.01 (0.11 – 0.13)	0.23 ± 0.03 (0.11 – 0.34)	51.87 ± 8.15 [b] (33.75–118.62)	1.36 ± 0.11 (1.25 – 1.46)	2.34 ± 0.18 (2.16 – 2.52)
Ogbodo Sub-soil	0.13 ± 0.01 (0.09 – 0.18)	0.16 ± 0.02 (0.07 – 0.27)	38.97 ± 1.65 (30.14 – 46.0)	1.47 ± 0.11 (0.98 – 2.04)	2.32 ± 0.30 (2.02 – 2.62)
Control Top	0.19 ± 0.01 (0.14 – 0.23)	0.29 ± 0.06 (0.20 – 0.41)	52.18 ± 5.29 [a] (32.56– 91.56)	2.14 ± 0.09 (1.65 – 2.67)	3.70 ± 0.15 (2.84 – 4.60)
Control Bottom	0.12 ± 0.02 (0.13 – 0.13)	0.33 ± 0.05 (0.24 – 0.38)	50.34 ± 4.47 [a] (30.54– 82.02)	1.35 ± 0.18 (1.17 – 1.52)	2.53 ± 0.19 (1.69 – 3.52)
Wet Season (mean value ± SE)					
Elele Top Soil	0.14 ± 0.02 (0.07 – 0.24)	0.05 ± 0.01 (0.03 – 0.12)	14.23 ± 0.50 (13.73– 14.73)	1.65 ± 0.19 (0.82 – 2.77)	2.82 ± 0.34 (2.49 – 3.16)
Elele Bottom	0.11 ± 0.01 (0.06 – 0.17)	0.06 ± 0.01 (0.03 – 0.12)	17.39 ± 0.58 (16.81– 17.97)	1.23 ± 0.13 (0.66 – 1.99)	2.72 ± 0.34 (2.69 – 2.76)
Ibaa Top	0.18 ± 0.03 (0.12 – 0.21)	0.04 ± 0.00 (0.04 – 0.04)	22.84 ± 1.87 (19.91– 26.32)	1.64 ± 0.20 (1.44 – 1.83)	2.59 ± 0.58 (2.42 – 4.24)
Ibaa Bottom	0.16 ± 0.02 (0.13 – 0.19)	0.04 ± 0.00 (0.03 – 0.04)	35.60 ± 3.00 (30.32– 40.72)	1.58 ± 0.02 (1.56 – 1.60)	3.16 ± 0.39 (2.49 – 3.83)
Ogbodo Top	0.15 ± 0.01 (0.11 – 0.26)	0.05 ± 0.01 (0.03 – 0.09)	30.23 ± 3.89 (14.66– 55.19)	1.59 ± 0.10 (1.21 – 2.18)	2.94 ± 0.28 (2.08 – 5.18)
Ogbodo Sub	0.11 ± 0.01 (0.08 – 0.19)	0.05 ± 0.01 (0.03 – 0.08)	23.82 ± 2.52 (13.64– 41.04)	1.42 ± 0.19 (0.90 – 3.00)	2.24 ± 0.19 (1.55 – 3.77)
Control Top soil	0.14 ± 0.02 (0.13 – 0.16)	0.08 ± 0.03 (0.13 – 0.11)	50.24 ± 19.66 [a] (19.93– 222.21)	2.08 ± 0.34 (1.40 – 2.40)	2.85 ± 0.33 (1.41 – 4.77)
Control Bottom	0.14 ± 0.00 (0.13 – 0.14)	0.09 ± 0.02 (0.04 – 0.12)	42.75 ± 17.02 [a] (19.44 – 194.54)	1.83 ± 1.64 (1.44 – 2.22)	2.12 ± 0.22 (1.14 – 3.43)
F-value	16.090	1.945	7.217	15.621	2.041
P-value	P = 0.007	P > 0.05	P = 0.036	P = 0.008	P > 0.05
**FEPA*	-	*14 – 20*	*50 – 150*	-	-

**FEPA- Federal Environmental Protection Agency acceptable limit*

Soil electrical conductivity defines ability of the soil to conduct electricity and therefore constitutes a totality of ionic concentration in the soil solution may stipulated EC values for arable soils between 200 and 400µS/cm. By implication, a soil is considered fertile and able to support crop growth if it is within this EC range. However, below this range, the soil is considered to be low in nutrients, hence poor fertility. On the other hand, if the soil's EC range is above this range, it is considered sodic (saline). Again, it cannot support crop growth. Therefore, the EC values obtained from the soils under investigation were significantly lower than in the control soils and the stipulated range. This could be traced to the release of petroleum products from the activities of artisanal refining being responsible for low EC values based on the fact that most organic compounds including crude oil is not a good conductor of electricity [29]. More so, direct dehydrogenation via anaerobic metabolism of hydrocarbon is capable of causing anoxic biodegradation. This process may be catalysed in the presence of an electron acceptor such as nitrate ion. The EC values were in conformity with the report of Osuji and Ozioma [30]. Onojake and Osuji [29] reported a significantly larger values of EC from their study at an oil spill site at ebocha-8 oil field, probably because there was an established case of oil spillage in this case. Data in this study showed that the electrical conductivity values in the test locations were not statistically ($p > 0.05$) different, indicating similar impact of artisanal activities. However, the Control sample had higher values of EC, probably a normal soil with absence of refining impacts. Seasonally, values of EC in dry season were higher than wet season for both test and Control samples and the difference was not statistically ($p > 0.05$) different. This was opposed to the report of Ezekiel et al. [31]. The reason for lower values of EC in wet season can be attributed to leaching effect where most ions in soil could have been depleted or washed away. The range of electrical conductivity values (31.5 to 152.1µS/cm) of this study is lower than that reported by Onojake and Osuji [29] (280 to 400 µS/cm) in an oil spill site and Braide et al. (2004) (100 to 230 µS/cm) [32].

Obviously, the values obtained for moisture content during wet season was higher compared to dry season. The increase in the level of moisture in the surface and sub-surface soils can be attributed to intense rainfall and flooding occurring in the wet season [29]. One-way ANOVA conducted showed that there was no statistically ($p > 0.05$) difference between the values of moisture contents in the Test as well as the Control Samples. Data obtained in this study was in conformity with the report of Onojake and Osuji [29]. The report of Goebel et al. [33] indicated that high moisture content may be directly linked to the problem of wettability and soil aeration, which could hinder the nutrient status of the impacted soil. The report of Ozumba and Amajor [34] showed that saturated pore spaces of soils create no more space for gaseous concentration gradient in the soil, hence, hindering oxygen from diffusing to the plant roots from the atmosphere. There would be a change in redox potential in the root zone once the plants roots are starved of oxygen. The higher moisture content of 66.0 ±12.53% and 63.0 ± 18.7% in the Control Top and subsurface soils during wet season can be attributed to the effect of recent flooding in most states of the Niger Delta region which took place in 2022. However, high moisture contents in the test locations can be attributed to both flooding effect and insufficient aeration of the soil due to the displacement of air in the soils thereby causing water logging and reduced rate of evaporation. The hydrophobic hydrocarbons could also pose partial coating of the Top soil thus reducing the water-holding capacity of the impacted soil [35]. Furthermore, influence of hydrocarbon on the soil and causes breakdown of soil structure and soil particle dispersion thus reducing water percolation and retention. The activity of microorganism in the soil is also affected by high moisture content as movement of water and circulation of oxygen into the soil is restricted by hydrocarbon contamination [35].

There are basically three key macro-nutrients (Nitrogen, Phosphorus and Potassium) essentially required for optimal crop growth. These elements were relatively low in this study when compared with soil agricultural standards. The macronutrients concentration in both the study and Control areas are inherently low compared to acceptable ranges of 15,000, 2,000 and 10,000 mg/kg for N, P, and K respectively [25] recommended for agricultural soils. This is in conformity with the report of Onyejekwe et al. [36]. Nutrients are usually available for plants use in the soil in different forms. Most nitrogen are present in the soil in organic form as part of organic matter, while it can be taken up only in mineral forms (ammonium and nitrate). The organic nitrogen is thus mineralized into mineral forms before plant roots can take it up. Phosphorus in the soil is also present in organic matter, but often mainly in chemical forms, which differ in solubility and plant availability. Potassium on the other hand, is mainly present in the soil solution and adsorbed to soil particles - clay and organic matter and then desorb into between the surface of soil particles and the soil solution. The crop roots take up the available nutrients from the top layer of the soil. Irrespective of the differences in plant root systems, many plants (shallow and rooted) take up their nutrients from the top soil [37]. Hence, there is a difference in nutrients' mobility in soils. Nitrogen and potassium are readily soluble in water and become very mobile in soil, while P is rather immobile in soil. Consequently, the supply of NPK to crops from both test and Control soils during dry and wet seasons in this study was grossly inadequate as values fell below the range obtained by Ebe et al. [38], who worked on soils proximate to artisanal refining plants in southern Nigeria. The values of NPK reported in this study was also in agreement with that reported by Otaiku et al [39], which studied macronutrients with no significant difference with site of study.

The ranges of total organic matter (TOM) of the test samples and Control were 1.45 to 4.26% and 1.41 to 4.77% for dry season and 1.41. to 4.77% and 1.55 to 5.18% in the wet season respectively. The data indicated that TOM values were lower in the test soil samples than the Control. Data in this study was in conformity with that obtained by Saravanakumar et al. (2008) (2.56%) from the mangroves of Kachchh-Gujarat; Sawant et al. [40] (0.30%) from Tapti River Maharashtra, India and Akporido and Asagba [41] (4.9 ± 1.0%) from Benin river close to a lubricating oil producing factory. TOM values in the dry season were higher compared to those in wet season. Again, this may be attributable to dilution effect occasioned by rainfall and flooding which might have been responsible for leaching out of the organic matter particles during wet season thus reducing the concertation of the organic matter components. Spatially speaking, the difference in level of organic matter with respect to location of test samples and the control as well, was statistically ($p < 0.05$) significant. This may be attributable to decomposition of organic matter taking place at various test locations in the study area. This is in conformity with the findings of Abowei and Sikoki [42]. The activities within the test locations in the study area and the references (Control) are not similar hence the higher values in the later. Total Organic Carbon (TOC) is defined by the amount of organic carbon contained within soil as a result of the decomposition of plant and animal matter, living and dead microorganisms, roots from plants and soil biota [36]. Our finding showed a similar trend with TOM. The ranges of TOC in this study were in conformity with that of Wegwu et al. [43]. (TOC of 1.38 – 3.27% for the impacted soil).

5. CONCLUSION

Macronutrients in the impacted and control soils vary in both wet and dry seasons. Amount of potassium in impacted soil was significantly lower than the control. The supply of P and K to crops from both test and control soils during dry and wet seasons in this study was grossly inadequate, as values fell below acceptable limit.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Onwuna DB, Stanley HO, Abu GO, Immanuel OM. Air quality at artisanal crude oil Refinery Sites in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria. Asian Journal of Advanced Research and Reports. 2022;16(12):74-83.
2. Eze CO. The Niger Delta Amnesty: Evaluation of a Policy Failure. Doctoral dissertation, Walden University; 2009.
3. Howard AG, Zhu M, Chen B, Kalenichenko D, Wang W, Weyand T, Adam H. Mobilenets: Efficient convolutional neural networks for mobile vision applications. arXiv preprint arXiv; 2017;1704:04861.
4. Obenade M, Amangabara GT. Perspective: The Environmental Implications of Oil Theft and Artisanal Refining in the Niger Delta Region. Asian Review of Environmental and Earth Sciences. 2014;1(2):25-29.
5. Alkorta I, Garbisu C. Phytoremediation of organic contaminants in soils. Bioresour Technol. 2001;79:273–276. DOI:10.1016/0960-8524(01)00016-5
6. Andrews SS, Karlen DL, Cambardella CA. The soil management assessment framework: A quantitative soil quality evaluation method. Soil Science Society of America Journal. 2004;68(6) 1945-1962.
7. Rahbar FG, Kiarostami K, Shirdam R. Effects of petroleum hydrocarbons on growth, photosynthetic pigments and

carbohydrate levels of sunflower. J Food Agric Environ. 2012; 10:773–776.
8. Shukry W, Al-Hawas G, Al-Moaikal R, El-Bendary M. Effect of petroleum crude oil on mineral nutrient elements, soil properties and bacterial biomass of the rhizosphere of jojoba. Br J Environ Clim Change. 2013;3:103–118.
9. Achuba FI. The effect of sublethal concentrations of crude oil on the growth and metabolism of Cowpea (Vigna unguiculata) seedlings. Environmentalist. 2006;26:17–20.
10. Lin Q, Mendelssohn IA, Suidan MT, Lee K, Venosa AD. The dose-response relationship between No. 2 fuel oil and the growth of the salt marsh grass, Spartina alterniflora. Mar Pollut Bull. 2002;44:897–902.
11. Park IS, Park JW. Determination of a risk management primer at petroleum-contaminated sites: developing new human health risk assessment strategy. J Hazard Mater. 2011;185:1374–1380.
DOI: 10.1016/j.jhazmat.2010.10.058
12. Oyedeji AA, Adebiyi AO, Omotoyinbo MA, Ogunkunle CO. Effect of crude oil-contaminated soil on germination and growth performance of Abelmoschus esculentus L. Moench—A widely cultivated vegetable crop in Nigeria. American Journal of Plant Sciences. 2012;3:1451-1454
13. Swami A. Impact of automobile induced air pollution on road side vegetation: A review. Essence Int. J. Env. Rehab. Conserv. 2018;9(1):101-116.
14. Pourkhabbaz A, Rastin N, Polle A. Influence of Environmental pollution on leaf properties of urban plane trees, Platanus orientalis L. Bulletin of Environmental Contamination and Toxicology. Springer Verlag. Bull Environ Contam Toxicol. 2010;85:251–255.
15. Pradeep G. Air pollution and plants. Retrieved 23rd May 2023.
Available:http://pollutionplant.blogspot/2008/02.
16. Nwankwoala HO, Harry MT, Amangabara GT, and Warmate T. Impacts of artisanal refining activities on soil and water quality in parts of Okrika and Ogu-Bolo areas of rivers state, Nigeria. Journal of Scientific Achievements. 2017;2(9):13-19.
17. Yabrade M,Tanee FBG. Research Article Assessing the impact of artisanal petroleum refining on vegetation and soil quality: A case study of Warri South West Salt Wetland of Delta State, Nigeria; 2016.
18. Asimiea A, Omokhua G. Environmental impact of illegal refineries on the vegetation of the Niger Delta, Nigeria. Journal of Agriculture and Social Research (JASR). 2013;13(2):121-126.
19. Onakpohor A, Fakinle BS, Sonibare JA, Oke MA, Akeredolu FA. Investigation of air emissions from artisanal petroleum refineries in the Niger-Delta Nigeria. Heliyon. 2020;6(11):e05608.
20. Ogele EP, Egobueze A. The artisanal refining and socioeconomic development in Rivers State, Nigeria, 2007-2017. International Journal of Research and Innovation in Social Science. 2020; 16-25.
21. Gijo AH, Hart AI, Seiyaboh EI. The impact of makeshift oil refining activities on the physico-chemical parameters of the interstitial water of the Nun River Estuary, Niger Delta, Nigeria. Biotechnol Res. 2016;2(4):193–203
22. Onwuna DB, Stanley HO, Abu GO, Immanuel OM. Impact of artisanal crude oil refinery on physicochemical and microbiological properties of soil and water in Igia-Ama, Tombia Kingdom, Rivers State, Nigeria. Asian Journal of Environment and Ecology. 2022;19(3):56-67.
DOI: 10.9734/ajee/2022/v19i3412
23. Adejuwon JO. Rainfall seasonality in the Niger Delta belt, Nigeria. Journal of Geography and Regional Planning. 2012;5(2):51-67.
24. Nigeria: Physical Settings-Rivers State. Retrieved 23rd May 2023.
Available:http://www.onlinenigeria.com/links/Riversstateadv.asp?blurb=362
25. Osuji LC, Nwoye I. An appraisal of the impact of petroleum hydrocarbons on soil fertility: the Owaza experience. African Journal of Agricultural Research. 2007;2(7):318-324.
26. Piper CS. Determination of nitrogen, potassium and trace elements. In: Soil and Plant Analysis, Srishti Book distributors, Daryaganj, New Delhi. 2010;197-350.
27. Osuji LC, Ezebuiro PE. Hydrocarbon contamination of a typical mangrove floor in Niger Delta, Nigeria. International Journal of Environmental Science and Technology. 2006;3:313-320.
28. Odu CTI, Esuruoso ON, Oguwale JA. Environmental study of Nigeria Agip Oil

Company Operational Areas. Nigeria Agip Oil Company Ltd Lagos; 1985.

29. Onojake MC, Osuji LC. Assessment of the physico-chemical properties of hydrocarbon contaminated soil. Arch. Appl. Sci. Res. 2012;4(1):48-58.
30. Osuji LC, Ozioma A. Environmental degradation of polluting aromatic and aliphatic hydrocarbons: a case study. Chemistry and Biodiversity. 2007;4(3):424-430.
31. Ezekiel CN, Anokwuru CP, Fari A, Olorunfemi MF, Fadairo O, Ekeh HA, Ajoku K, Gbuzue N, Akinsanmi F. Microbiological quality and proximate composition of peanut cake (Kulikuli) in Nigerian markets. Academia Arena. 2011;3(4):103-111.
32. Braide SA, Izonfuo WA, Adiukwu PU, Chindah AC, Obunwo CC. Water quality of Miniweja stream, a swamp forest stream receiving non-point source waste discharges in eastern Niger Delta, Nigeria. Scientia Africana. 2004;3(1): 1–8.
33. Goebel MO, Bachmann J, Woche SK, Fischer WR. Soil wettability, aggregate stability, and the decomposition of soil organic matter. Geoderma. 2005;128(1-2):80-93.
34. Ozumba MB, Amajor LC. Evolutionary relationships in some benthic foraminifera of the middle to late miocene, Niger Delta. Nigeria Association of Petroleum Explorationists. 1999;14:157-167.
35. Osuji LC, Idung ID, Ojinnaka CM. Preliminary Investigation on Mgbede-20 Oil-Polluted Site in Niger Delta, Nigeria. Chemistry and biodiversity. 2006;3(5):568-577.
36. Onyejekwe IM, Osuji LC, Nwaichi EO. Accumulation of Heavy Metal in the Seeds of Zea mays L. from Crude Oil Impacted Soils in Kom-Kom, Rivers State, Nigeria. Journal of Scientific Research and Reports. 2019;25(3):287-300.
37. Marriet N, Buyinza M. Effect of inorganic NPK fertilizer on tea (Camellia sinensis) production in Ruhaija village, Burere Subcounty, Buhweju District, Uganda. Effect of inorganic NPK fertilizer on tea (*Camellia sinensis*) production in Ruhaija village, Burere Subcounty, Buhweju District, Uganda. International Journal of Life Science Research. 2022;03(02):159–168. DOIhttps://doi.org/10.53771/ijlsra.2022.3.2.0139
38. Ebe Y, Onoda M, Nishimura T, Yorimitsu H. Iridium-Catalyzed Regio-and Enantioselective Hydroarylation of Alkenyl Ethers by Olefin Isomerization. Angewandte Chemie. 2017;129(20): 5699-5703.
39. Otaiku AA. Effects of oil spillage on soils nutrients of selected communities in Ogoniland, south-eastern Niger Delta, Rivers State, Nigeria. International Journal of Ecology and Ecosolution. 2019;6(3):23-36.
40. Sawant AD, Raut DG, Darvatkar NB, Salunkhe, MM. Recent developments of task-specific ionic liquids in organic synthesis. Green Chemistry Letters and Reviews. 2011;4(1):41-54.
41. Akporido SO, Asagba SO. Quality characteristics of soil close to the Benin River in the vicinity of a lubricating oil producing factory, Koko, Nigeria. International Journal of Soil Science. 2013; 8(1):1-16.
42. Abowei, JF, Sikoki FD. Water pollution management and control Port Harcourt; 2005.
43. Wegwu MO, Uwakwe AA, Enyi CN. Post-Impact Assessment of Crude Oil well clusters. Petroleum Research. 2011;7(2): 275-285.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/108862