Original Research Article

Determination of the Physicochemical Parameters and Pollution Indices in Soils of Obodo Community in Delta State, Nigeria

ABSTRACT

Oil and gas activities are one of the environmental concerns in the crude oil-rich areas of the Niger Delta. This study aimed to determine the physicochemical status and some pollution indices in thesoils of the Obodo community in Delta State to ascertain if there is an anthropogenic influence on the soil quality. Soil samples were collected from 14 sampling stations and 2 control stations during the wet and dry seasons from two soil depths (topsoil, 0 - 15cm) and (subsoil, 15-30cm) according to standard methods and procedures. The study results revealed elevated concentrations of total hydrocarbon content, polyaromatic hydrocarbon, total petroleum hydrocarbon, and sulphate. The high concentration observed in this study indicates anthropogenic influence that may be due to oil spillage, emission from vehicle exhaust, incomplete combustion of coal and the use of inorganic fertilizer. The results of the index of geo-accumulation and contamination factor showed that the levels of heavy metals were thatthoseof unpolluted soil except for thecadmium concentration observed in the topsoil of the study area, which showed moderate pollution during the wet season. The low pH values and a higher percentage of sand in the soil infer that the low heavy metals concentration observed in this study may be due to cations leaching down the aquifer which this requires further studies to examine the groundwater quality.

Keywords: *Heavy metal, crude oil, Obodo community, pollution indices.*

1. INTRODUCTION

Obodo is an oil-producing community in the Niger Delta sub-region of Nigeria. The main livelihood of inhabitants in the community includes fishing, farming, and trade. Oil spillage, agricultural waste, industrial effluent, and gas flaring are among the top anthropogenic sources that release a large volume of pollutants into the environment in the Niger Delta (Nnaji and Egwu, 2020). Crude oil is a complex mixture that contains heavy metals and hydrocarbons; released into the environment due to oil spillage. Oil spillage is often caused by pipeline sabotage, equipment failure, andoraccident (Osuji and Samuel, 2005). Heavy metals have received global attention because of their toxicity and persistence in the environment. Potentially toxic metals include copper, cadmium, lead, chromium, mercury, nickel, arsenic, and zinc; and among these potential metallic pollutants, lead and cadmium isarethe most lethal (Vineethkumar et al., 2020). Lead affects the reproductive, urinary, and nervous systems, while cadmium causes obstructive lung and renal dysfunction (Ibrahim, 2004). Polycyclic aromatic hydrocarbons are a group of micropollutants that are resistant to environmental degradation because of their hydrophobic nature; some PAHs are carcinogenic and mutagenic (Pashin and Bakhitova, 1979; Gan et al., 2009).

Soil is a biogeochemical material that consists of a complex mixture of organic and inorganic solids, water, air, microorganisms, and plant roots (Hinrich et al., 2001; Gary et al., 2005). Soil pollutants can be from natural or anthropogenic sources; however, anthropogenic sources lead to a higher concentration of these pollutants in the soil (Ibrahim, 2004). Soil contamination occurs when toxic wastes are deposited on-site or on land in high quantities above normal or acceptable limits (Gary et al., 2005). Pollutants may vaporize unchanged chemically or beadsorbed by organic matter in the soil or clay particles, decomposed by aerobic and anaerobic microorganisms, washed into water bodies during surface runoff, andorabsorbed by plant roots or soil animals (Ray and Nyle, 2017). The pollutants adsorbed by plant roots and soil animals bioaccumulate in their body tissues which are then passed on in the food chain in the magnified form to higher tropic levels. Petroleum products, industrial solvents, pesticides, and herbicides are some common pollutants spilled on the soil because of human negligence or by accident.

Soil quality is the ability of soil to sustain environmental quality and biological productivity as well as sustain plant and animal health (Karlen et al., 1997; Gary et al., 2005). The physicochemical and biological characteristics of soil are determined to assess the soil quality, identify the physicochemical parameters that can affect the soil function, and determine how changes in soil management affect the soil function (Daniel et al., 2004). pH measures the acidity and alkalinity of soil; pH is an important parameter that controls other factors, such as the mobility of heavy metals and the retention of cations in soil (Gary et al., 2005; Akan et al., 2013) for example, heavy metals in the soil increase mobility at pH < 7 (Akan et al., 2013). Electrical conductivity (EC) estimates the salt content in the soil; EC measures the soil salinity (Ahmad, 2016). Saline soil has low nutrients, stressed microbes, and reduced biodiversity (Rietz and Haynes, 2003; Ahmad, 2016).

Soil quality is vital for the survival and health of humans because soil provides nutrients, air, and support for plants, maintains water quality due to its ability to filter pollutants from water, and itrecharge groundwater which is a source of drinking water (Gary et al., 2005; Richard et al., 2020). The farm productivity, surface water, and groundwater quality in the Obodo community are linked to the quality of thesoil in the community. This study examines the physicochemical characteristics and applies pollution indices to measure the degree of contamination to ascertain if the various industrial activities in the community have a deteriorating effect on the soil quality.

2. MATERIALS AND METHOD

2.1 The study area

Obodo is an industrial area in the Warri South Local Government Area of Delta State, Nigeria. The study area lies between latitude 050 71’ 85.93” N and longitude 050 42’ 85.51” E. Thevegetation in the study area is freshwater swamps, mangrove swamp forests, and food crops. The main occupations of the people in the Obodo community isarefishing, farming, and trading. Fig 1 is the map of the study area showing the sampling points.

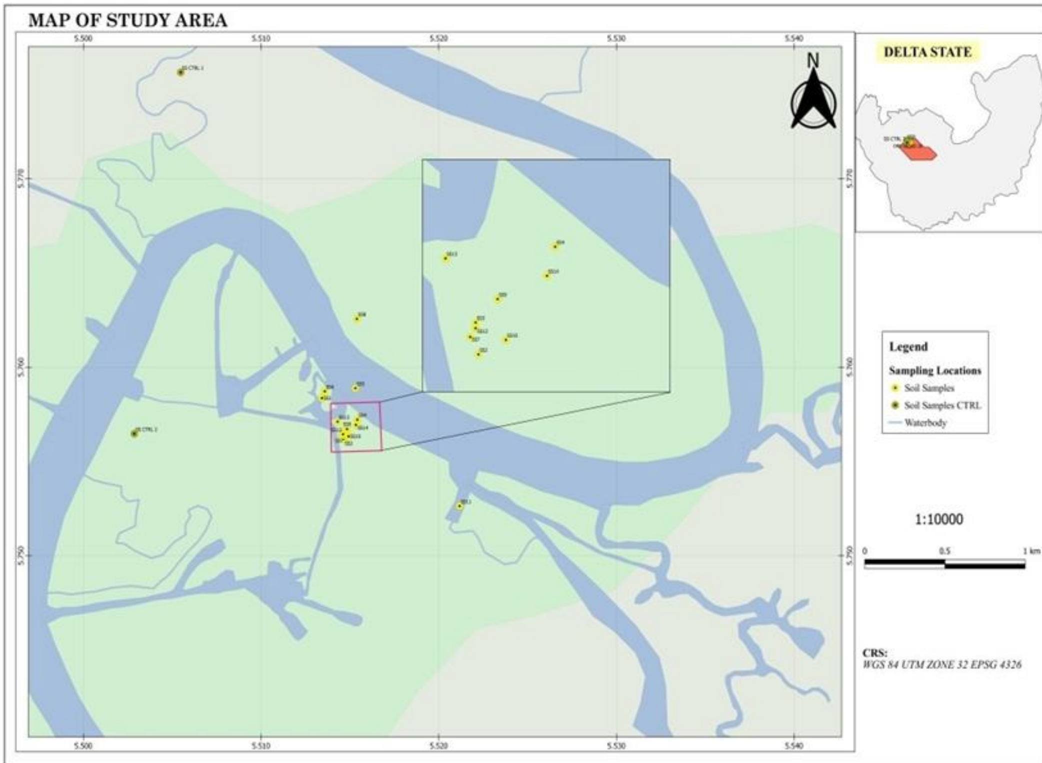

Fig 1: Map of Study Area

2.2 Soil Sampling

Soil samples were collected from pre-determined points in the Obodo community in areas not too far from industrial activities in two sampling seasonsrepresenting thedry and wet seasons of the year. The control stations were inareas with aninfinitesimal influence from industrial activities. Soilsamples were collected from 14 sampling stations and 2 control points and all points were geo-referenced. At each of the sample stations, three random spots were, augured at two depth levels of 0 – 15cm (topsoil) and 15- 30 cm(sub-soil), with the aid of a 9cm diameter Dutch auger at about the center of the sample station. The soil samples were bulked together to give composite samples. The soil samples were collected in polythene bags and labeled accordingly. All soil samples were taken in that state to the Dukoria laboratory limited for treatment and analysis

2.3 Analytical methods

pH, conductivity, and salinity were determined in-situ using the multiple–parameter water quality monitor (Model 6000 UPG) (Puyate and Rim-Rukeh, 2008). Prior to sampling, the instrument was checked and calibratedproperly. Particle size distribution was determined using the hydrometer method. Sulphate in the soil samples was determined using the turbidimetric method. THC and TPH method of extraction wasby the Dutch standard method; to determine TPH and THC in the soil sample, gas chromatography described in ASTM D3921 was used. Sample digestion for heavy metals procedures was according to ASTM D5198. Heavy metals were determined in the soil samples using Varian 200 Atomic Absorption Spectrophotometer (AAS) according to APHA 3111B.The analytical methods were adapted from APHA, 2012 and NUPRC, 2018standard methods and validated inatDukoria Laboratory limited.

2.4 Indices and Statistical Analysis

The results of the physicochemical parameters determined in this study were subjected to descriptive statistical analyses to compute the mean and standard deviation with Microsoft Excel, and Office 365.

2.4.1 Pollution Indices

Pollution indices are tools applied to assess soil quality (Adaikpoh, 2013; Amadi et al. 2017; Ayobami et al. 2017). In this study, the Index of geo-accumulation (Igeo) and contamination factors were the pollution indices applied.

Index of geo-accumulation (Igeo)

The index of geo-accumulation (Igeo) determines the extent of pollution of heavy metals in the soil based on Muller (1969) equation below.

$$Igeo = \log_2 (Cn / 1.5 \times Bn)$$

Cn is the concentration of the enriched sample (heavy metal concentration in the samples obtained from the study area)

Bn is the background concentration (heavy metal concentration in the samples obtained from the control stations)

1.5 is a constant factor used because of possible variations of the background data due to

Lithogenic effect (Christos et al., 2010). The degree of contamination in the Index of geo-accumulation has seven categories (Table 1)

Table1: Index of geo accumulation categories proposed by Muller (1969).

Class	Value	Soil Quality
0	≤ 0	Uncontaminated
1	0 -1	Uncontaminated to moderately contaminated
2	1 - 2	Moderately contaminated
3	2 - 3	Moderately to heavily contaminated
4	3 - 4	Heavily contaminated
5	4 - 5	Heavy to extremely contaminated
6	5 < Igeo	Extremely contaminated

2.4.2 Contamination Factor (CF)

In this study, the CF was measured based on the method described by Jimoh et al. (2020); Sharhabil et al. (2021). Heavy metal concentrations recorded in the study area are compared to the background value. CF is calculated based on the expression:

CF = Cm / Bm

Where Cm is the mean concentration in the study area

Bm is the background value or NUPRC, (2002) acceptable limits of heavy metals in soil.

Table 2 presents the CF classification used to evaluate the degree of contamination in this study.

Table 2: Contamination factor andclasses of contamination

Contamination Factor	Soil Quality
CF < 1	Low contamination factor
1 < CF < 3	Moderate contamination factor
3 < CF < 6	Considerable contamination factor
6 < CF < 7	Very high contamination factor

Source: (Jimoh et al. 2020).

3.0 RESULTS AND DISCUSSION

The summary of the physicochemical parameter results offorsoil from the Obodo community during the wet and dry seasons is presented in Table 3. The results of the Index of geo-accumulation (Igeo) and contamination factor are presented in Table 4 and Table 5.

3.1 Soil Texture

Soil texture is the percentage of sand, clay, and silt in the soil (Gray et al. 2005). The mean particle size of 89.22 % (sand), 6.62 % (clay), 4.15 % (silt) in the topsoil and mean values of 90.00 % (sand), 6.15 % (clay), 3.85 % (silt) in the sub-soil, was observed in the study area during the wet season while the dry season had the mean values of 89.38 % (sand), 7.30 % (clay), 2.95 % (silt) in the topsoil, and mean values of 90.36% (sand), 6.90 % (clay), 2.73 % (silt) in the sub-soil. The mean particle size of 89.65 % (sand), 6.95 % (clay), 4.40 % (silt) in the topsoil and mean values of 89.40 % (sand), 7.00 % (clay), 3.60 % (silt) in the sub-soil, was observed in the control area during the wet season. During the dry season, 89.38 % (sand), 7.30 % (clay), 2.95 % (silt) was observed in the topsoil while 92.20 % (sand), 6.60 % (clay), 1.20 % (silt) was recorded in the sub-soil in the control area. The particle size distribution observed in the study and control areaswere in the order of magnitude sand > clay > silt (Figure 2). The textural class of soil in this study is sandy soil. Sandy soils have low nutrients, cannot hold water, and are poorly aggregated and susceptible to erosion (Okon and Ogba, 2018). Compared to sandy soil, clay particles retain morea higherconcentration of heavy metals (Pikuła and Stepien, 2021). Olayinka, et al. (2017)reported a similar textural class.

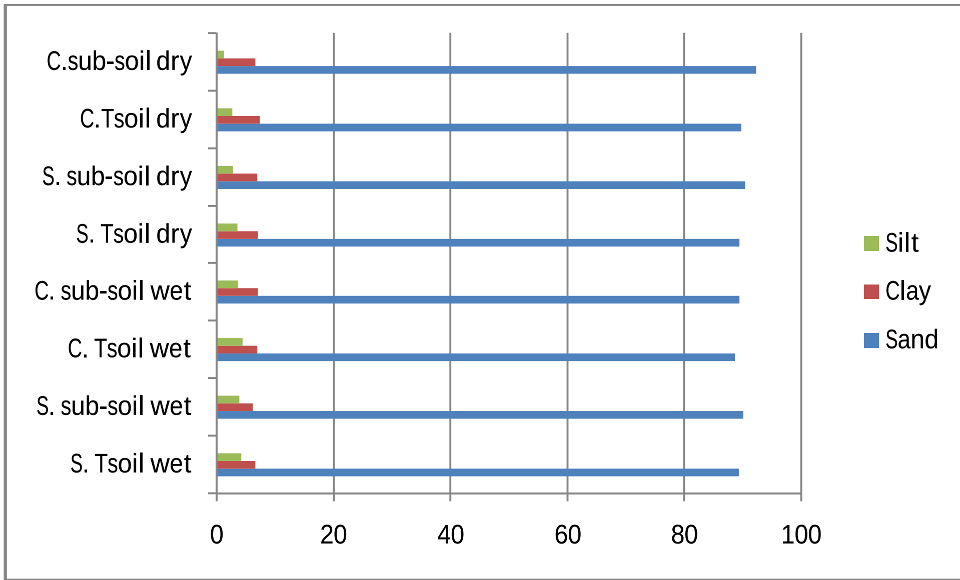

Figure 2: Particle size distribution in study area and control for both seasons.

pH

The study area had pH values of 5.1 (topsoil) and 4.8 (subsoil), while the control area recorded 5.2 (topsoil) and 4.65 (subsoil) during the wet season. During the dry season, the study area had pH values of 4.46 (topsoil) and 4.38 (sub-soil), while the control area had pH values of 5.52 (topsoil) and 4.75 (subsoil). pH in the study area is comparable to pH values obtained in the control area. In this study, the pH values observed indicated slightly acidic soil. The southern part of Nigeria is known to have slightly acidic soil; due to heavy precipitation in the region; which causes basic cations to leach out (Nnaji and Egwu, 2020). Iwegbue et al. (2013) reported similar pH values.

Electrical Conductivity (EC)

The study area had mean values of 285.93 µS/cm (topsoil) and 233.78 µS/cm (subsoil) during the wet season and EC values of 117.57 µS/cm (topsoil) and 103.94 µS/cm (sub-soil) during the dry season. The control area had mean values of 240 µS/cm (topsoil) and 190 µS/cm (subsoil) during the wet season and EC values of 75 µS/cm (topsoil) and 87.30 µS/cm (subsoil) during the dry season. Soil with EC > 4000 µS/cm is saline soil (Gary et al. 2005). The EC values observed in this study indicate a non-saline environment in both seasons. Ogbonnaya et al. (2021) reported similar values in a study conducted around oil-producing communities in Afam, anarea of Port Harcourt, Niger Delta, Nigeria.

Total Organic carbon (TOC)

Total organic carbon measures all forms of organic carbon in soil, such as carbon in organic matter and petroleum hydrocarbons (Wang et al. 2009). In the study area, TOC values observed in the topsoil and subsoil were 5.27 % and 4.13 % (wet season), with lower mean values of 1.65 % and 1.58% during the dry season. The control area had higher TOC values of 10.21% and 4.19 % (wet season); and lowerTOC values of 4.18 % and 4.17 % (dry season). The high TOC values observed in the study area during the wet season are consistent with elevated TPH values recorded in the wet season; this infers that TPH may have contributed significantly to the TOC concentration in the study area. In the study area, TOC decreasesslightly with the increase in soil depth. Edori and Iyama, (2017) reported higher TOC values. Ogbonnaya et al. (2021) reported lower TOC values.

Total hydrocarbon content (THC)

THC of the topsoil and subsoil of the study area was 138.45 mg/kg and 147.66 mg/kg (wet season); and 172.94 mg/kg and 151.46 mg/kg (dry season). The control area had lower THC concentrations of 14.75 mg/kg and 13.45 mg/kg (wet season) and 24.69 mg/kg and 22.19 mg/kg (dry season) in the topsoil and subsoil. THC increased with increased soil depth in the study area in both seasons (Figure 3). The elevated concentration of THC in the study area compared to thelower THC concentration in the control area (Figure 3) indicates anthropogenic influence in the study area that may be due to oil spillage. THC concentration in this study agrees with the THC concentration reported by Okon and Ogba, (2018). Onojake and Frank, (2013) had higher THC concentrations in a similar study.

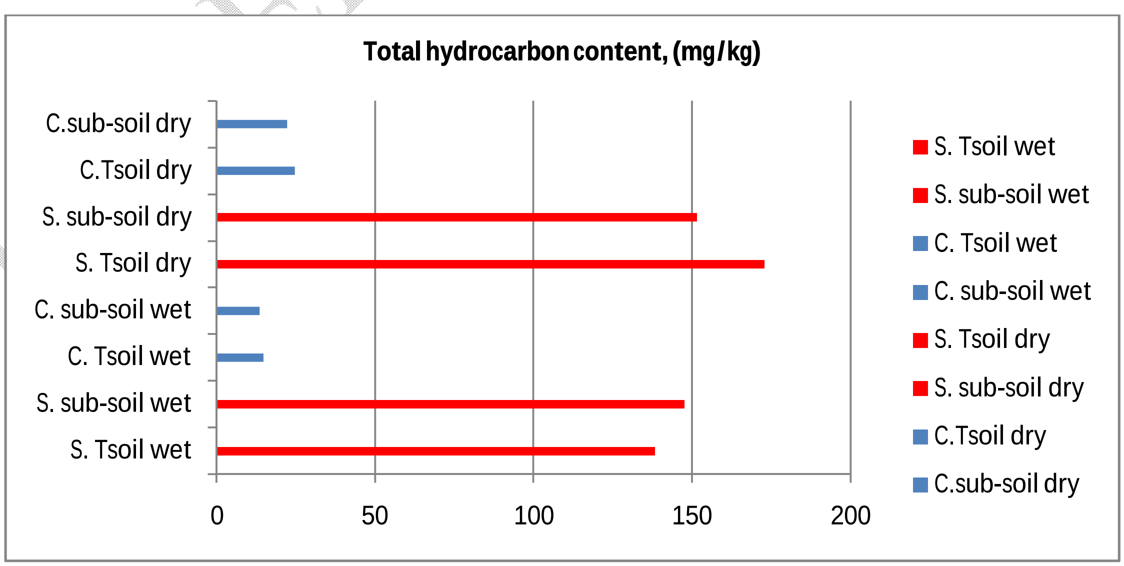

Figure 3: Total hydrocarbon content in the study area compared to the control area.

Polycyclic aromatic hydrocarbons (PAHs)

The PAHs values in the study stations were 52.62 mg/kg (topsoil) and 30.01 mg/kg (subsoil) during the wet season and PAHs values of 11.11 mg/kg (topsoil) and 10.25 mg/kg (sub-soil) during the dry season. The control area had lower PAH values of 10.52 mg/kg (topsoil) and 3.35 mg/kg (subsoil) during the wet season and 2.59 mg/kg (topsoil) and 2.33 mg/kg (subsoil) during the dry season. PAHs values decrease with increased soil depth (Figure 4). Xiaoyang et al. (2017) noted that PAHs tend to accumulate in the topsoil because of their strong sorption for organic matter in soil and other absorbing material. PAHs in the present study exceeded the NUPRC (2018) desirable limit of 1 mg/kg of PAH in both seasons. PAHs contamination in soil may be due to emissions of motor exhaust during transportation, incomplete combustion of coal and garbage, use of contaminated waters for irrigation, and oil spillage (Tsibart and Gennadiev, 2013).

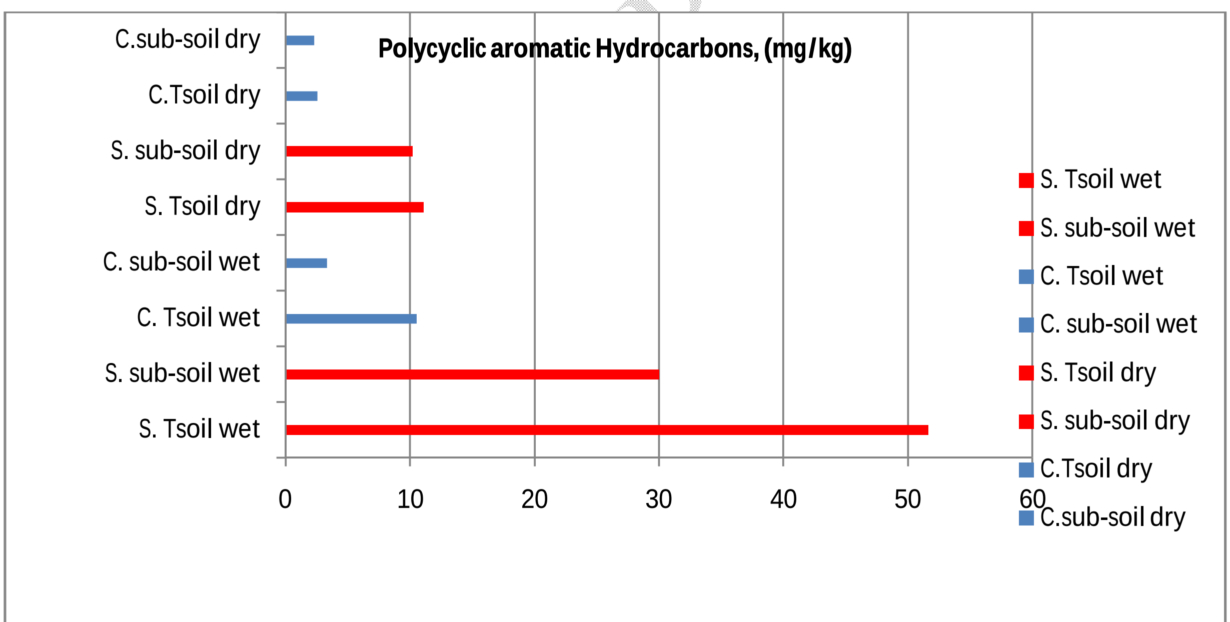

Figure 4: Polycyclic aromatic hydrocarbons in the study area and the control area

Total petroleum hydrocarbon content (TPH)

TPH of the topsoil and sub-soil of the study stations was 229.95 mg/kg and 160.33 mg/kg (wet season) and a lower mean concentration of 19.63 mg/kg and 17.99 mg/kg (dry season). The control stations had lower TPH values of 5.60 mg/kg and 6.1 mg/kg 2 (wet season) and 4.72 mg/kg and 4.24 mg/kg (dry season) in the topsoil and sub-soil. The difference in TPH Concentration observed in the study areaand the control areain both seasons (Figure 5) indicates that there may have been oil spillage in the study area. Adewuyi et al. (2012) reported higher TPH concentrations in soils.

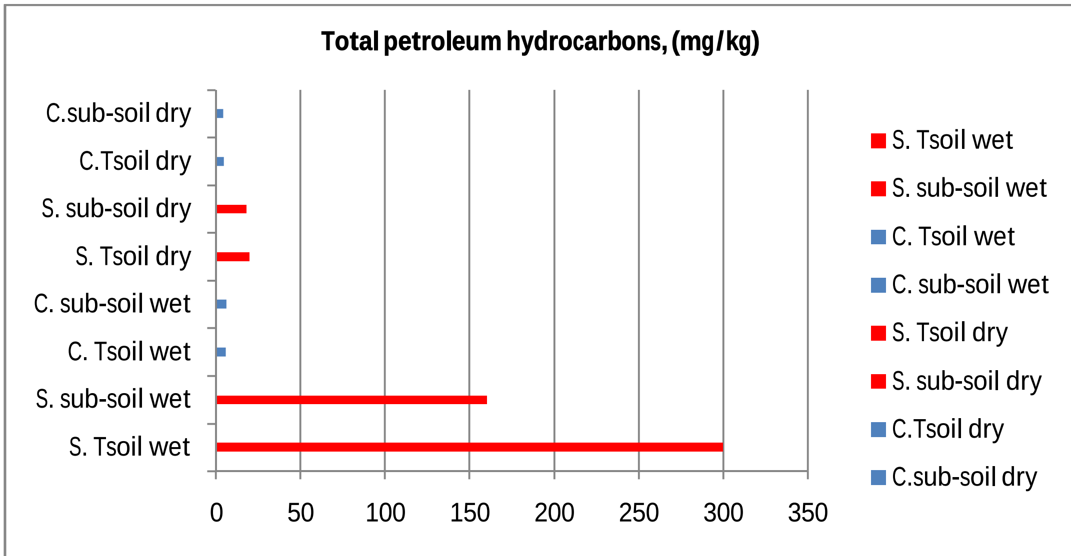

Figure 5: Total petroleum hydrocarbon in the study area and the control area

Anions

Sulphate

Sulphate is an essential element required by plants and animals (Ogeh et al. 2012). Sulphate values in the topsoil and subsoil of the study area were 54.89 mg/kg and 44.88mg/kg (wet season); and 22.57mg/kg and 19.95mg/kg (dry season) whereas in the control area, the topsoil and subsoil had lower mean values of 5.77 mg/kg and 20.14 mg/kg(wet season) and 14.40 mg/kg and 16.76 mg/kg (dry season). The difference in sulphate values in the study and control areas (Figure 6) with higher values observed in the study areasinfers anthropogenic influence. The high sulphate concentration in the study area may be due to the presence of sulphur in crude oil, oxidized to sulphate and the use ofinorganic fertilizer (Ogeh et al. 2012; Nnaji and Egwu, 2020). The sulphate concentration recorded in the study area is comparable to sulphate reported by Nnaji and Egwu, (2020).

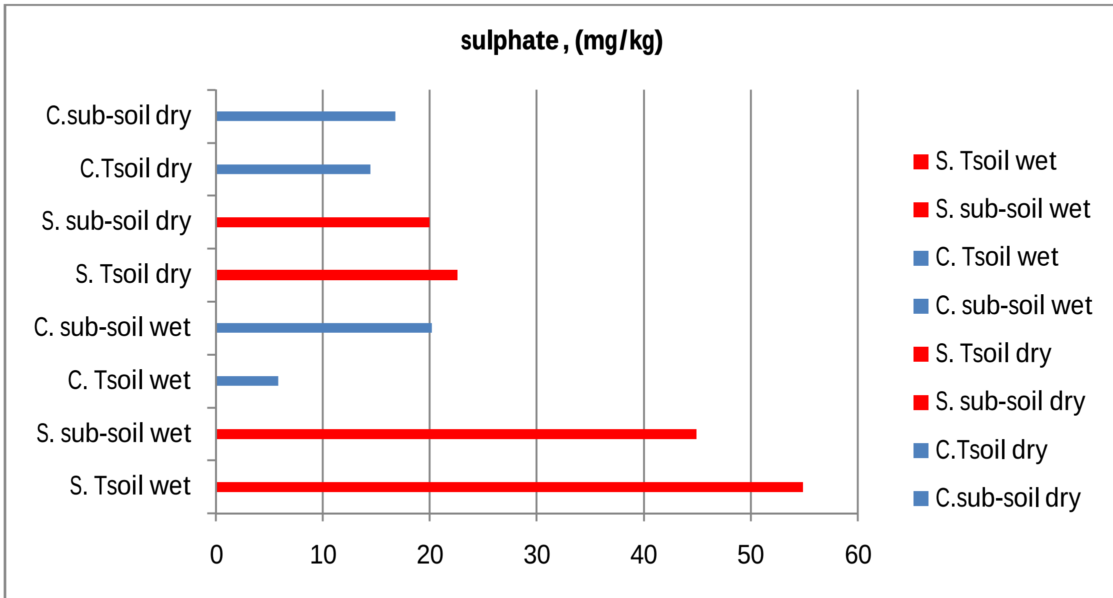

Figure 6: Sulphate Levels in the study area and control area

Nitrate

Nitrate values observed in topsoil and subsoil in the study area were 1.52 mg/kg and 1.18 mg/kg (wet season) and 0.01 mg/kg and 0.01 mg/kg (dry season). The topsoil and subsoil of the control area had lower mean concentrations of 0.27 mg/kg and 0.15 mg/kg (wet season). Nitrate was not detected inat the topsoil in the control stations during the dry season but had a mean value of 0.02 mg/kg in the subsoil. The low concentration of nitrate observed in this study is consistent with the textural class of the soil (sandy soil), which has a low capacity to hold on to nutrients. Osakwe, (2014) reported similar low nitrate concentrations and textural classes.

Cations

The mean concentration values for cations in the topsoil of the study area during the wet season were 33.71 mg/kg, 13.31mg/kg, 16.58mg/kg, and 42.47mg/kg for Ca^{2+}, Mg^{2+}, K^+, and Na^+, respectively while the subsoil were 30.27mg/kg, 10.88mg/kg, 13.55mg/kg and34.72mg/kg respectively. Corresponding mean values of 37.66mg/kg, 11.17mg/kg, 13.92mg/kg, and 35.65mg/kg for Ca^{2+}, Mg^{2+}, K^+, and Na^+, in the topsoil and mean values of 35.33mg/kg,

8.84mg/kg, 11.02mg/kg, and 28.22mg/kg for Ca^{2+}, Mg^{2+}, K^+, and Na^+, respectively in the sub-soil, was recorded in the control area during the wet season. During the dry season, the mean concentration values for cations in the topsoil were 14.98mg/kg, 5.47mg/kg, 6.81mg/kg, and 17.46mg/kg for Ca^{2+},

$Mg^{2+,}K^{+}$, and Na^{+}, respectively while the sub-soil had mean concentrations of 13.24, 4.84, 6.02, and 15.43 respectively was obtained in the study area.The control area had Comparable mean values of 9.55mg/kg, 3.49mg/kg, 4.33mg/kg, and 11.10mg/kg for $Ca^{2+,}$ $Mg^{2+,}$ K^{+}, and Na^{+}, respectively, in the topsoil, whereas mean values of 11.13mg/kg, 2.06mg/kg, 5.06mg/kg, 12.96mg/kg for $Ca^{2+,}$ $Mg^{2+,}$ K^{+}, and Na^{+}, respectively were observed in the subsoil during the dry season. The concentrations of cations decreased with increased soil depth in the study and control area in both seasons. Acidification of the soil causes cations to gradually leach from the soil (Gary et al., 2005). The decrease in cations with increased soil depth in the study and control area is consistent with the difference in pH observed in the topsoil and subsoil. Lower concentrations of cation were observed (Osakwe, 2014; Okon and Ogba, 2018)

Heavy metals

Iron (Fe)

TheFe concentration measured in the topsoil and subsoil in the sampling stations was 142.74 mg/kg and 145.39 mg/kg (wet season), with higher mean values of 254.67 mg/kg and 291.97 mg/kg during the dry season. The topsoil and sub-soil of the control stations had lower mean values of 120.58 mg/kg and 116.94 mg/kg (wet season) and 206.48 mg/kg, and 174.17 mg/kg (dry season). Iron is the most abundant metal in the study area compared to other heavy metals determined in this study. The high concentration of Fe observed in this present study agrees with the reports in various studies that Fe is abundant in Nigerian soil (Amusan et al. 2005; Sharhabil et al. 2021). Geo-accumulation index showed that the study area is unpolluted with Fe (Table 4).

Zinc (Zn)

The Zn concentration in the topsoil and subsoil of the study area was 2.20 mg/kg and 2.08 mg/kg during the wet season and 5.47 mg/kg and 4.88 mg/kg in the dry season; while A lower mean concentration of 2.45 mg/kg and 2.18 mg/kg (wet season) and 1.95 mg/kg and 2.45 mg/kg (dry season) for the topsoil and sub-soil of the control area. The geo-accumulation index and contamination factor showed that the study area was unpolluted with Zn in the topsoil and subsoil in both seasons (Table 4 and Table 5). The Zn concentration observed in this study is similar to Zn concentration observed by Adewuyi et al. (2012).

Chromium (Cr)

The study area had mean Cr values of 1.00 mg/kg and 0.81 mg/kg for the topsoil and sub-soil during the wet season; and mean values of 0.62mg/kg and 0.37mg/kg for the topsoil and sub-soil during the dry season. The control area had 0.4mg/kg (topsoil), Cr was not detected in the subsoil in the control station during the wet season. The topsoil and sub-soil of the control area had mean values of 0.3 mg/kg and 0.5 mg/kg during the dry season. Results of the Index of geo-accumulation and contamination factor showed that the study area is unpolluted with Cr in both seasons (Table 4 and Table 5). Asagba, (2013) reported ahigher Cr concentration in a similar study.

Lead (Pb)

Pb values measured in topsoil and subsoil in the study area were 1.77 mg/kg and 1.53 mg/kg (wet season) andwithcorresponding mean values of 1.10 mg/kg and 0.82 mg/kg (dry season). The topsoil and subsoil of the control area had mean values of 2.70 mg/kg and 3.07 mg/kg (wet season) and 0.60 mg/kg and 0.09 mg/kg (dry season). Results of the Index of geo-accumulation and contamination factor revealed that the sampling stations are unpolluted with Pb in both seasons (Table 4 and Table 5). Pb concentration observed in this study is lower than the mean value of 2.67 mg/kg reported by Ogbannaya et al. (2021). Adaikpoh, (2013); Akporido and Asagba, (2013) reported higher Pb values.

Copper (Cu)

Copper is an essential plant micronutrient in soil which could become toxic if Cu exceeds the permissible limit in soil (Akan et al.,2013; Salman et al., 2019). The mean concentrations of Cu observed in topsoil and subsoil in the study area were 1.96 mg/kg and 1.88 mg/kg (wet season) and 4.14 mg/kg and 2.90 mg/kg (dry season). The topsoil and sub-soil of the control area had mean values of 2.38 mg/kg and 1.98 mg/kg (wet season) and 1.24 mg/kg and 0.89 mg/kg (dry season). The geo-accumulation and contamination index results were thatthoseof uncontaminated soil in the study area in both seasons (Table 4 and Table 5). The Cu concentration reported by Nwaichi et al. (2016) in a similar study is consistent with the Cu values recorded in this study.

Cadmium (Cd)

The mean values of Cd in the topsoil and subsoil of the sampling points were 0.90 mg/kg and 0.74 mg/kg (wet season); and 0.31 mg/kg and 0.20 mg/kg (dry season), whereas in the control points, the topsoil and subsoil had mean values of 0.16 mg/kg and 0.95 mg/kg (wet season) and 0.38 mg/kg and 0.33 mg/kg (dry season). The geo-accumulation index results revealed moderate pollution with Cd in the topsoil of the study area during the wet season (Table 4). The subsoil in the wet season and Cd concentration recorded during the dry season was thatwere thoseof an unpolluted environment (Table 4 and Table 5). The sources of the high concentration of cadmium observed in the study area could be petroleum products, theuse of fertilizer on farms, and detergents (Ibrahim et al., 2004). Adaikpoh, (2013) reported a higher Cd concentration of 1.18 mg/kg.

Nickel (Ni)

Ni values recorded in topsoil and subsoil in the study area were 0.98 mg/kg and 0.77 mg/kg (wet season) and 1.12 mg/kg and 0.91 mg/kg (dry season). The topsoil and subsoil of the control area had lower mean values of 0.09 mg/kg and 0.09 mg/kg (wet season) and 1.84 mg/kg and 1.17 mg/kg (dry season). Ni values in this study were thatthoseof an unpolluted category of Geo-accumulation and contamination factor index. Adaikpoh, (2013) reported higher mean values in similar studies.

Barium (Ba)

Ba values recorded in the topsoil and subsoil of the study area were 0.39mg/kg and 0.47 mg/kg(dry season). The topsoil and subsoil of the control area had lower mean values of 0.11 mg/kg and 0.15 mg/kg (dry season). Ba was not detected in the study andorcontrol during the wet season. The geo-accumulation index and contamination factor calculations showed that the soil was unpolluted with Ba (Table 4 and Table 5). Onojake and Frank (2013) reported higher Ba values.

Table 3: Physiochemical parameter results for the topsoil and sub-soil in Obodo Community during the wet and dry seasons.

	Wet season				Dry season				
	Study area		Control area		Study area		Control area		NUPRC, 2018
Physicochemical parameters	**Topsoil 0 – 15 cm**	**Sub-soil 15 – 30 cm**	**Topsoil 0 – 15 cm**	**sub-soil 15 – 30 cm**	**Topsoil 0 – 15 cm**	**Sub-soil 15 – 30 cm**	**Topsoil 0 – 15 cm**	**Sub-soil 15 – 30 cm**	
	Mean	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**	
pH	5.1	4.89	5.2	4.65	4.46	4.38	5.52	4.75	-
Electrical conductivity μS/cm	285.90	233.78	240	190	117.57	103.94	75	87.30	-
Particle size %									
Sand	89.22	90	88.65	89.40	89.38	90.36	89.75	92.20	-
Clay	6.62	6.15	6.95	7.00	7.05	6.9	7.30	6.60	-
Silt	4.15	3.85	4.40	3.60	3.55	2.73	2.59	1.20	-
Organic mg/kg									
Total hydrocarbon content (THC)	138.45	147.66	14.75	13.45	172.94	151.46	24.69	22.19	-
Polycyclic aromatic hydrocarbons (PAHs)	51.62	30.02	10.52	3.35	11.11	10.25	2.59	2.33	1
Total petroleum hydrocarbons (TPH)	299.95	160.33	5.60	6.12	19.63	17.99	4.72	4.24	-
Total organic carbons (TOC), %	5.27	4.13	10.21	4.19	1.65	1.58	4.18	4.17	-
Anions mg/kg									
SO_4^-	54.89	44.88	5.78	20.14	22.57	19.95	14.40	16.76	-
NO_3^-	1.52	1.18	0.27	0.15	0.01	0.01	0.00	0.02	-
Cations									
Calcium	33.72	37.66	30.28	35.34	14.98	9.56	13.25	11.13	-
Magnesium	13.31	11.18	10.89	8.85	5.47	3.49	4.84	4.07	-
Potassium	16.58	13.92	13.56	11.02	6.82	4.35	6.03	5.07	-
Sodium	42.47	35.65	34.73	28.22	17.46	11.14	15.44	12.97	-
Fe	142.74	145.39	120.58	116.94	254.67	291.97	206.48	174.17	
Zn	2.20	2.08	2.45	2.18	5.47	4.88	1.95	2.45	140
Cr	1.00	0.81	0.40	0.00	0.62	0.37	0.3	0.50	100
Pb	1.77	1.53	2.70	3.07	1.10	0.82	0.60	0.09	85
Cu	1.96	1.88	2.38	1.98	4.14	2.90	1.24	0.89	36
Cd	0.90	0.74	0.16	0.95	0.31	0.20	0.38	0.33	0.8
Ni	0.98	0.77	0.09	0.09	1.12	0.91	1.84	1.17	35
Ba	-		-		0.39	0.47	0.11	0.15	200

NUPRC-Nigerian Upstream Petroleum Regulatory Commission

Table 4: Geo- accumulation results for Selected Heavy Metals in the Study Area.

E	0 – 15 (topsoil)		15 – 30 (bottom soil)	
Heavy metals (mg/kg)	Wet season	Dry season	Wet season	Dry season
Fe	- 0.34	-0.28	-0.27	0.16
Zn	-0.74	0.90	-0.65	0.40
Cr	0.74	0.46	0	-1.02
Pb	-1.19	0.29	-1.59	2.60
Cu	-0.87	1.16	-0.66	1.12
Cd	1.91	-0.94	-0.88	-1.31
Ni	2.78	-1.30	-0.95	-1.31
Ba	-	1.24	-	-0.95

Table 5: Contamination factor results for Selected Heavy Metals in the Study Area

	0 – 15 (topsoil)		15 – 30 (bottom soil)	
Heavy metals (mg/kg)	Wet season	Dry season	Wet season	Dry season
Zn	0.02	0.01	0.04	0.03
Cr	0.01	0.001	0.001	0.004
Pb	0.02	0.01	0.01	0.009
Cu	0.05	0.05	0.11	0.08
Cd	1.13	0.93	0.39	0.002
Ni	0.03	0.02	0.03	0.03
Ba	-	-	0.002	0.002

In this study, the results revealed a high concentration of polyaromatic hydrocarbons (PAHs), total hydrocarbon content (THC), sulphate, and total petroleum hydrocarbons (TPH) in the soil. These high concentrations observed indicate human influence on the soil quality that might be due to oil spillage, emissions from vehicle exhausts, incomplete combustion of fossil fuels, and the use of inorganic fertilizer. The index of geo-accumulation (Igeo) and contamination factor results showed that soils in the study area is unpolluted with heavy metals, except for cadmium in the topsoil of the study area during the wet season. Anthropogenic sources of cadmium include crude oil products, detergents, and fertilizer. The elevated concentrations of PAHs, THC and TPH observed may be due to influencesfrom anthropogenic and industrial activities around the study area. It is therefore recommended that monitoring of these parameters be carried out to enable point source determination and source apportionment.

4.0 CONCLUSION

The physicochemical and pollution indices of soils in Obodo, an oil producing community hashavebeen determined to ascertain the levels of possible contamination in study. The results of the index of geo-accumulation and contamination factor showed that the levels of heavy metals were thatthoseof unpolluted soil except for thecadmium concentration observed in the topsoil of the study area, which showed moderate pollution during the wet season. The low pH values and a higher percentage of sand in the soil infer that the low heavy metal concentration observed in this study may be due to cations leaching down the aquifer; this, however, gives rise to athepossibility of examining groundwater quality for further studies.

REFERENCES

1. Nnaji JC, Egwu AC (2020). Physicochemical characteristics of oil spill impacted agricultural soils in three areas of the Niger Delta. Singapore Journal of Scientific Research 10: 137-144.
2. Osuji LC, Samuel AO (2005). Extractable Hydrocarbons, Nickel and Vanadium Contents Of

Ogbodo-Isiokpo Oil Spill Polluted Soils In Niger Delta, Nigeria. Environmental Monitoring and Assessment 110: 129–139.

3. Vineethkumar VV, Sayooj VV, Shimod KP, Prakash V(2020). Estimation of pollution indices and hazard evaluation from trace elements concentration in coastal sediments of Kerala, Southwest Coast of India. Bulletin of the National Research Centre 44: 198.
4. Ibrahim AM (2004). Soil pollution: Origin, Monitoring and Remediation. 2nd Edition. Springer
5. Pashin YV, Bakhitova LM (1979). Mutagenic and carcinogenic properties of polycyclic aromatic hydrocarbons. Environ Health Perspect 30, 185-9.
6. Gan S, Lau EV, NG HK (2009). Remediation of Soils contaminated with Polycyclic Aromatic Hydrocarbons. Journal of harzadous Material 172(2): 532 -549.
7. Hinrich LB, George AO, Brian LM (2001). Soil Chemistry. 3rd Edition. John Wiley and Sons Inc.
8. Gary MP, Thomas JS, George FV (2005). Soil and Environmental Quality. 3rd Edition. CRC Press.
9. Ray RW, Nyle CB (2017). The Nature and Properties of Soils. 15th Edition. Pearson.
10. Karlen DL, Mausbach MJ, Doran JW, Cline RG, Harris RF, Schuman GE (1997). Soil Quality: A Concept, Definition, and Framework for Evaluation.Soil Science American Journal 61, 4–10.
11. Daniel H, Cynthia R, David P, Kate S, Michail S, Donald S(2004). Encyclopedia of Soils in the Environment. 1st Edition. Elsevier/Academia Press.
12. Akan JC, Audu SI, Mohammed Z, Ogugbuaja VO (2013). Assessment of Heavy Metals, pH, Organic Matter and Organic Carbon in Roadside Soil in Makurdi Metropolis, Benue State, Nigeria. Journal of Environmental Protection 4, 618 -628.
13. Ahmad P. Plant Metal Interaction Emergency Remediation Techniques. 1st Edition. Elsevier, 2016.
14. Rietz, D.N., Haynes, R.J., 2003. Effects of irrigation-induced salinity and sodicity on soil microbial activity. Soil Biol. Biochem. 35 (6), 845–854.
15. Richard VP, Deborah SP, Toral P, Linda HG (2020). Forest and Rangeland Soils of the United States Under Changing Conditions: A comprehensive Science Synthesis. 1stEdition. Springer International Publishing.

16. Puyate YT, Rim-Rukeh A (2008). Some physico-chemical and biological characteristics of soil and water samples of part of the Niger Delta area, Nigeria. Journal of Applied Sciences and Environmental Management 12(2): 135 – 141
17. APHA (2012). American Public Health Association/American Water Works Association/Water Environment Federation. (2012). *Standard Methods for the Examination of Water and Wastewater.* 22nd Edition, Washington DC, USA
18. Adaikpoh EO. Distribution And Enrichment of Heavy Metals In Soils From Waste Dump Sites
19. Within Imoru and Environs, Southwest Nigeria. Journal of Environment and Earth Science 2013;3
20. (14): 45 – 54.
21. Amadi AN, Ebieme EE, Musa A, Olashinde PI, Ameh IM, Shuaibu AM (2017). Utility Indices in Assessment of Soil Quality Around Madaga Gold Mining Site, Niger State, Northern – Central Nigeria Ife Journal of Science 19 (2): 417 – 430.
22. Ayobami OA, Allen TE, Azibaola KI, Sylvester C (2017).Assessment of some selected heavy metals and their pollution indices in an oil spill contaminated soil in the Niger Delta: a case of Rumuolukwu community. Biotechnol Research 3(1):11-19.
23. Muller G (1969) Index of geoaccumulation in sediments of the Rhine River. Geol J 2(3):108–118.
24. Christos N, Ilias Z, Vasileios M, Theodore C (2010). Heavy Metal Pollution Associated with an Abandoned Lead – Zinc Mine in the Kirki Region, NE Greece. Bulletin for Environmental Contamination and Toxicology. DOI 10.1007/s00128-010-0079-9.
25. Jimoh A, Agbaji EB, Ajibola VO, Funtua MA (2020) Application of Pollution Load Indices, Enrichment Factors, Contamination Factor and Health Risk Assessment of Heavy Metals Pollution of Soils of Welding Workshops at Old Panteka Market, Kaduna-Nigeria. Open Journal of Analytical and Bioanalytical Chemistry 4(1): 011-019.
26. Sharhabil MY, Fatima A,Nafu A (2021). Ecological Risk Assessment of Heavy Metal-Contaminated Soils Of Selected Villages In Zamfara State, Nigeria. Springer Nature Applied Sciences 3:168 | https://doi.org/10.1007/s42452-021-04175-6.
27. NUPRC (2018). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria. Lagos.

28. Okon IE, Ogba CO (2018). The Impacts of Crude Oil Exploitation on Soil in Some Parts of Ogoni Region, Rivers State, Southern NigeriaOpen Access Library Journal 5:e4297. https://doi.org/10.4236/oalib.1104297
29. Pikuła, D, Stepien W (2021). Effect of the Degree of Soil Contamination with Heavy Metals on Their Mobility in the Soil Profile in a Microplot Experiment. Agronomy 11, 878. https://doi.org/ 10.3390/agronomy1105087
30. Olayinka OO, Akande OO, Bamgbose K, Adetunji MT (2017). Physicochemical Characteristics and Heavy Metal Levels in Soil Samples obtained from Selected Anthropogenic Sites in Abeokuta, Nigeria. Journal of Applied Science and Environmental Management 21 (5): 883-891.
31. Iwegbue, CM., Bassey, FI., Tesi, GO., Nwajei, GE., Tsafe, AI., (2013). Assessment of heavy metal contamination in soils around cassava processing mills in sub-urban areas of Delta State, Southern Nigeria. Nigeria Journal of Basic and Applied Science 21(2): 96-104.
32. Ogbonnaya I, Ngwoke M, Ukah UB, Ubido OE (2021). Assessment of the physicochemical qualities of groundwater and soils around oil-producing communities in Afam, area of Porthacourt, Niger Delta Nigeria. Applied Water Science 11, 74. https:// doi.org/10.1007/s13201- 021-01393-6.
33. Wang X, Feng J, Zhao J (2009) Effect of crude oil residuals on soil chemical properties in oil sites, Momoge wetland, China. Environ Monit Assess 161(1–4):271–280.
34. Edori OS, Nna PJ (2018). Determination of Physicochemical Parameters of Effluents at Discharge Points into the New Calabar River along Rumuolumeni Axis, Port Harcourt, Rivers State, Niger Delta, Nigeria. Journal of Environmental & Analytical Toxicology 8: 585. doi: 10.4172/2161-0525.1000585.
35. Onojake MC, Frank O (2013). Assessment of heavy metals in a soil contaminated by oil spill: a case study in Nigeria. Chemistry and Ecology 3(29): 246 – 254.
36. Xiaoyang L, Zhongke B, Qinfei Y, Yingui C, Wei Z (2017). Polycyclic aromatic hydrocarbons in the soil profiles (0–100 cm) from the industrial district of a large open-pit coal mine, China Royal Society of chemistry 7, 28029 – 28037.
37. Tsibart AS, Gennadiev AN(2013)Polycyclic Aromatic Hydrocarbons in Soils: Sources, Behavior, and Indication Significance (A Review) Eurasian Soil Science 7(46): 728–741.

38. Adewuyi GO, Etchie AT, Etchie OT. Evaluation of Total Petroleum Hydrocarbons (TPH) and Some Related Heavy Metals in Soil and Groundwater of Ubeji Settlement, Warri Metropolis, Nigeria. Terrestrial and Aquatic Environmental Toxicology 2012; 6 (1): 61- 6
39. Ogeh JS, Uzu F, Obi-Ijeh OD (2012). Distribution of Sulphur in Soils Formed from Different Parent Materials in Southern Nigeria. Nigerian Journal of Basic and Applied Science 20(1): 73-77.
40. Osakwe, SA (2014). Evaluation of Physicochemical Characteristics of Soils in the Flood Disaster Affected Areas of Isoko Region of Delta State, Nigeria. Journal of Applied Chemistry 5(1): 24-31.
41. Amusan A, Ige D, Olawale R (2005) Characteristics of soils and crops' uptake of metals in municipal waste dump sites in Nigeria. Journal of Human Ecology 17(3):167–171.
42. Akporido SO, Asagba SO (2013). 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 18(1): 1 -16.
43. Salman AS, Salah AMZ, El-Montser MS, Mahmoud AA (2019). Soil characterization and heavy metal pollution assessment in Orabi farms, El Obour, Egypt. Bulletin of the National Research Centre 43:42 https://doi.org/10.1186/s42269-019-0082-1.
44. Nwaichi OE, Chuku LC, Ighoavwogan E (2016). Polycyclic Aromatic Hydrocarbons and Selected Heavy Metals in some Oil Polluted Sites in Delta State Nigeria. Journal of Environment Protection 7, 1389 – 1410