Impact Assessment of Oil Exploration on Soil and Surface Water at Omerulu, Rivers State, Nigeria

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Abstract: *The current work focused on assessing the impact on soil and water associated with oil drilling activities at Umerulu by first comparing the physicochemical properties with those of background values and standards and secondly by estimating values of some quality indices using appropriate models. Soil and water samples were collected from the area and analyzed for physicochemical properties and heavy metals using standard methods. Physicochemical properties of the soils were within the recommended limit except for organic matter ( ) and ash contents (). pH and electrical conductivities, show that the soil is normal and non-saline. Anions such as chloride and nitrate were considered moderate in the soils. The soils are still fertile with cation exchange capacity of 43.78± mg/kg. Parameters showed significant differences (p < 0.05) sampling directions (East, West, South and North). Temperature was moderate for both stream and borehole water, which were within the recommended limits. Acidic pH was observed due to dissolved organic matter as indicted by the high total organic matter in both water. High electrical conductivity, total dissolved solids, and total suspended solids was obtained when compared controls. Cations in the waters were below the recommended limits. The highest cation was calcium while the least was potassium in both the stream and borehole water. Borehole water showed good water quality while stream showed poor water quality as revealed by the water quality index.*

Keywords: *Crude oil, Drilling, Envirionment, Pollution, Soil index.*

1. INTRODUCTION

The generation and discharge of Oil field drilling fluid and chemical products with associated pollutants, the use of improper technology during exploration and production activities of oil and gas pose enormous and complex problems to surrounding environment. This phenomenal trend is expected to increase in the next millennium when crude oil reserves will increase to 30 billion barrels and its production is estimated to rise to 3 million barrels per day by 2020 according to Federal Government of Nigeria projection in a position paper presented at the SPE Conference by Dr. Rilwanu Lukman (NAICE, Abuja).

These challenges of Oil field drilling activities have been in existence since the discovery of Oil and Gas in commercial quantity in 1956 in Oloibiri and Imo River in 1959. Then the problem of environmental issue was not paramount in the scale of preference of oil and gas operators. Poly Aromatic Hydrocarbons (PAH) and Notable Natural Occurring Radioactive Materials (NORM) transmitted from the ground are also generated and introduced into the environment during the E&P operations. Some of the stable parameters and the PAH had been identified or suspected carcinogens or causing other tumor related effects. Also, radiation from Radium 226 and 228 base forms from NORM can be extremely detrimental to human health with time if inhaled and ingested. In the advanced countries such as the USA, the NORMS are targeted for regulation by the government laws.

These drilling fluid wastes from the drilling structure in the Omerelu field drilling fluid waste are dumped around the vicinity of the drilling operation and later hauled to Oyigbo dumpsite. The spent drilling fluid at the drilling site eventually enters receiving waters by transport mechanism and also enter subsurface environment by infiltration causing leachate problem. The presence of these pollutants presumably arises from petroleum related pollution that is detrimental to the Omerelu field communities over time.

This apprehension or state of affairs have engineered pressure groups (Movement for the survival of Ogoni people, the Ijaw National Congress, the Environmental Rights Activists and other non-governmental groups) to press on the Federal Government to aggressively embark on position representations to address the environmental issue squarely. The disruptions of flow stations by youth's restiveness have led to loss of lives and drastic reduction in the production of oil and gas as well as economic losses to the Exploration & Production companies and Federal Government of Nigeria. This trend critically affects the Federal Government budget since some of the companies can no longer meet its contractual obligation to supply oil to its customers.

From post-independent time, Nigeria witnessed increased in Exploration & Production activities resulting in the increased rate of environmental pollution. The problems were not noticed until in 1976 (as indicated in **Decree No. 58 of 1988** as amended by **Decree No. 59 of 1992**). The decree mandates the Federal Environmental Protection Agency (EIA) Decree No. 886 of 1992 is a response to increased public opinion on lack of concern for environmental degradation and protection. There was also the **Petroleum decree No. 57 of 1969.** It is also worthy to mention that the National policy on environment only launched in November 1989 makes provision for waste management stipulation that waste should be treated to the secondary level where discharge will not pose danger to the life and property. In cases where the industries produce toxic and hazardous wastes, treatment should proceed beyond secondary level.

The regulation that stipulates the treatment of waste in the petroleum industry includes the petroleum (Drilling and production) Regulation cap 350 LFN 1990, The National Environmental Protection (Pollution Abatement in industries and Facilities Generating Wastes (Special criminal Provisions, etc.) Act, Cap 165 LFN 1990. Under The Petroleum (Drilling and Production) Regulation, Wastes should be drained in special receptacles, which should be constructed in accordance with safety regulations under the Petroleum Act; the Mineral Oil (Safety) Regulation, which is the regulation under the Petroleum Act, does not make any reference to the construction of receptacles. However, the Department of Petroleum Resources **(DPR)** ensures that receptacles are properly constructed. The disposal of any such waste must be done in a manner approved by the director of DPR or as provided by any other applicable regulation. These laws have proved ineffective especially in their implementation. Another issue that may not aid compliance is the low fine stipulated in the regulation. A fine of N100.00 only or a term of 6-months imprisonment is the sentence for the offence in the refining regulation for example. The term of imprisonment might have acted as a deterrent but this might be difficult to implement. For the petroleum (Drilling and Production) Regulation where any company that contravenes any provision in the regulation may have their licenses revoked, here also, it is unlikely that the Special Adviser to the Presidency on Petroleum matters would revoke SPDC or any of the E&P license for instance due to the pollution activities of an oil company because of the sole dependence of oil and gas as source of revenue.

This environmental issue was not promptly reflected in the environmental sector budget until the 1981-1985 Development Plan when the first specific allocation to environmental planning and protection was made. The sum of N25 million was allocated to the sector representing only 0.001% of the total budget. When compared to Defense which took about 10% of Nigeria's budget over the last one decade. The environmental sector budget shows no change despite the emphasis on integrating the environmental component into national development. This further magnifies the gross under-funding of the environmental sector and other issues relating to Oil well drilling mismanagement.

Several techniques and methods for safe drilling operation have been evolved since the evolution of the petroleum industries especially in countries where there are high price tags for complying with stringent environmental regulation. They now resorted to pollution prevention and the use of the best available technology such as highly engineered electronic and mechanical devices as well as other best available technology not entailing excessive cost like the use of computer aided modeling in evaluation process. These numerous options can be combined to achieve effective and efficient management of spent drilling fluid and other pollutants that result from oil and gas well drilling operation.

2. METHODOLOGY

The Omerelu oil field is located in OML 53 about 42 kilometers as the crow flies North West of Port Harcourt in Rivers State, Nigeria. The field is estimated to hold a recoverable reserve of 13 MMSTB of oil and 16 Bscf of gas; OML 53 is owned and operated by Niger Delta Petroleum Resources (NDPR). Omerelu is a community in Ikwerre Local Government Area of Rivers State which lies roughly within the coordinates of $4°:50N5°: 15N, 6°: 30E.7: 15E$. The geology and geomorphology of the area are intimately associated with that of the Niger delta which was created in the Holocene by the process of erosion and sedimentation.

Soil of the study area is brown loams and sandy loams and is found mostly in the fresh water zone of the state. The levee which forms the common land of this zone are made up of rich loams at their crests, changing to more acidic and more clayed soils along their crests, changing to more acidic and more clayed soils along their slopes (NDEBUMOG., 2010).

3. SAMPLING

Water: Water was collected from boreholes sank in the community without interference of debris directly into clean 50 mls plastic bottles.

Soil: A hand held auger was used in digging, a shallow hole, at least 20 cm to 25cm deep and collected into polyethylene pots.

3.1. Samples Pretreatment

This involves three means of preparing samples prior to digestion: Freeze-drying, Air-drying at room temperature, Accelerated air-drying, for about 95°C.

The detection limit and linear concentration range of each procedure for each element is dependent on the atomic adsorption spectrophotometer or other technique employed and may be k)und in the manual accompanying the instrument used. The sensitivity of this practice can be adjusted by varying the sample size (14.2) or the dilution of the sample (14.6), or both.

Extractable trace elements analysis provides more information than total metal analysis for the detection of pollutants, since adsorption, complexation, and precipitation are the methods by which metals from polluted waters are retained in sediments.

3.2. Sample Preparation

Completely thaw frozen samples before unsealing

Drying of Samples

Preparation I: Freeze- drying was rapid and results in loose samples.

Preparation II: Air-drying at room temperature was accomplished by spreading the sample out on Petri dishes and drying to constant weight. This procedure requires a long time to complete and the sample must be covered to avoid dust contamination.

Preparation III: Accelerated air- drying the sample, for example, 95°C is followed by allowing the sample to cool in desiccators.

Dried to constant weight: Often, constant Weight is achieved by drying overnight, however, constant weight must be obtained for consecutive measurements.

Reagents

Purity of Reagents- Reagent grade chemicals were used in the tests. All reagents conformed to the specification of DPR guidelines.

Purity of Water- References to water is related to be understood as reagent water conforming to specification D1193, Type I 1, which was free of metallic contaminants.

Metal Stock Solutions, -prepared metal stock solutions, each containing 1000 mg/I. of a metal of interest and either negligible or known concentrations of interfering metals.

Experimental Procedure

4g of dried sample was weighed into a 250-mi beaker. The sample weight was recorded to the nearest 0.1 mg. An empty beaker in each analysis set as a reagent /glassware blank was recorded.

The following was added to each sample and blank:

I. Water, 1000 ml

2. Concentrated HNO_3 1.0 ml. A foaming reaction indicated the presence of carbonates, in such case the acid was added s1owy.

3. Concentrated 1-IC1, 10 ml

The beaker was then covered with ribbed watch glasses and healed on a hot plate at 95°C .To prevent splatting, the solutions was not allowed to boil or bump. Each beaker was removed from the hot plate when the solution was remaining 10 'to 15 ml, and the content allowed cooling to room temperature.

Filtration of each solution was done and quantitatively transferred to a 50-nil volumetric flask and diluted to volume then eventually transferred to the appropriate detection equipment.

Physicochemical Characterization of Soil

Determination of Temperature: The temperature of each soil samples was measured onsite using Mercury-in-glass thermometer that was inserted at 20cm beneath the research area soil for 5minutes to stabilize for accurate reading. This was done at all locations during sample collection and results recorded as mean of three determinations as the playground soil temperature in degrees centigrade (°C).

3.3. Determination of pH

pH of soil sample was assessed with a Jenway 3505 pH meter model TS-2 in a 2:1 soil/deionized water mixture. pH meter was calibrated and pH 4 and 7 buffer as per the normal procedure. Then it was placed into the buffer pH 7.0, and the calibration knob of the instrument pressed on. It was allowed for a stable display and then the reading was accepted by pressing yes knob. The process was repeated with buffer pH 4.0 solutions. The electrode was again placed in the buffer pH 7.0 and when the display was stable, the reading was accepted. The electrode was rinsed with distilled water, followed by the sample. The sample was shaken and the electrode was placed in the sample. When the reading is stable, the pH was recorded (Hesser, 1997).

Determination of Conductivity: The reading of the conductivity 1413 μs/cm standard was taken before calibration, the conductivity meter was calibrated by rinsing the electrode first with distilled water, and then with buffer of conductivity 1413 45μs/cm.

The electrode was placed in the buffer 1413 μs/cm, and calibration knob of the instrument pressed on. After a stable display the reading was accepted by pressing enter. Sample conductivity was recorded by rinsing electrode in much distilled water, followed by samples and then result recorded when figure stabilizes, The samples were shaken very well and the electrode was placed in the sample. When the reading was stable, the sample conductivity was record (Hesser, 1997).

Determination of Soil Moisture: A porcelain crucible washed and placed in oven preheated to temperature of l05°C and left for 2 hours and then allowed to cool to room temperature in a desiccators. The empty crucible was weighed. 10 g of sample was placed in the crucible and both weighed. The crucible was kept for 12 hours in the oven at 105 °C then cooled to room temperature. The moisture was determined by expressing weight of dried soil over original weight times by 100.

%Moisture $= \frac{(B-C)x100\%}{c-A}$ …………...3.1

B: is weight of crucible and soil sample

C: is weight of soil sample

A: is weight of dry crucible (Hesser, 1997).

Determination of Cation Exchange capacity (CEC): The CEC was estimated as shown in equation 3.2 as sum total of exchangeable bases viz: Ca^{2+}, Mg^{2+}, Na^+, K^+ according Kackson, 1962.

$$CEC = \sum[Na^+] + [K^+] + [Ca^{2+}] + [Mg^{2+}] \ldots\ldots\ldots 3.2$$

Where $\sum$ refers to summation and square bracket, [ ] refer to the concentration of cation in moldm^{-3}

Determination of organic matter: First the organic carbon by Walkley and Black, (1934) method using wet combustion before proceeding to organic matter determination as follows: Into two beakers one gram of prepared sample was added followed by 10mI 1N $K_2Cr_2O_7$ solutions agitated slowly to achieve mixing of sample. Oxidized for ten minutes with concentrated H$_2$SO4 (20ml) comp1eted, and then dilution followed to a 250m1, before adding 0.5M ferrous ammonium sulphate and titrating against 0.4 M potassium permanganate under conditions of carbon was estimated with the formula below;

$$OC = \frac{Meg\ K2Cr2O7 - Meg\ (NH4)2\ FeSO4.12H2O)\ 0.003x100F}{Wt\ fo\ air - Wt\ of\ dry\ soil} \ldots\ldots\ldots\ldots..3.3$$

Correction factor F = 1.33

Meq is normality of solution x ml of solution used, Percentage fo matter that is organic in soil was then calculated as;

Organic matter = % Organic carbon x 1.724 ………..3.4

Analysis of Physicochemical Parameters of Water

The electrical conductivity was measured using HANNA HI8733 EC METER in **Electrical Conductivity (EC) (μs/cm)**. Calibrated using KC1. The EC probe is then introduced into the water sample for 60seconds and readings is taken. The pH was determined using JENWAY 3510pH METER which was calibrated using buffer 4 and buffer 7 by dissolving one capsule each in 100 ml of distilled water respectively. The pH was determined also with the same method used for the EC measurement.

Dissolved oxygen concentration of the water samples was determined with a Jen-way 9071 digital oxygen analyzer by inserting the probe into the water samples.

TSS (Total Suspended Solid) (mg/L) Three filters were rinsed with 20-30 mL De-Ionised water to remove any solids that may remain from the manufacturing process. The filters were placed in separate, labeled aluminum weighed pans, then dried in a 104 °C oven for 30 minutes, then it (filter and pan) were placed in a desiccators, and a constant weight were obtained by repeating the oven and desiccation steps.

TSS measurement was done according to Verla *et al*., 2018. 100 mL of sample was filtered through each pre-weighed filter. Each paper was placed in its aluminum weighed pan in the 104 °C oven for 1 hour. Cool the filter and pan in a desiccator and a constant weight were obtained by repeating the drying and desiccation steps. Calculation: TSS mg/L = (average final weight in g - average inital weight in g)(1000mg/L) / sample volume in L.The phosphorus was determined by the vanadate colorimetric method. The phosphorus were determined as phosphate by the vanadium phosphomolybdate (Vanadate) colorimetric method in which the phosphorus present as the orthophosphate reacts with a vanadate-molybdate reagent to produce a yellow complex, the absorbance reagent of which is measured 420nm.

Nitrate (NO$_3^2$) (mg/L) One test tube was rinsed and filled to the 2.5 mL with water from the sample bottle. Then it was diluted to 5 mL with the Mixed Acid Reagent. Capped and mixed. Then it was allowed to stand for 2 minutes. Using 0.1 g spoon to add one level measure (avoided any 50-60 times in one minute) for 10 minutes. Then the test tubes were inserted into the Nitrate Nitrogen Comparator. The sample colors were matched to the color standard. The result were recorded as mg/L(ppm). Chloride was done using Argentometric method The water sample was digested using aqua-regia. 1 mL of the water sample was weighed into a test tube and was digested with 24 mL of aqua-regia for 3days. The supernatant is then filtered using a sieve. The concentrations of Na, K, Mg and Ca in the respective water samples were then determined using Buck 210 GP Atomic Absorption Spectrophotometer.

3.4. Data Analysis

The data were analyzed for means, standard deviation and level of significance using SPSS version 18.0 and reported as means ± standard deviation of triplicate analysis were appropriate. P- values were considered significant at $P < 0.05$.

4. RESULTS

Physicochemical Analysis of Soils

The physicochemical characteristics result of soils around the different axis (i.e South East, SE; South West, SW; South South, SS; and South North, SN) of the oil wells is presented in Table 4

**Table1.** *Physicochemical characteristics of soil around the oil well*

Parameter	SE1	SE2	SE3	SE4	Mean	SW1	SW2	SW3	SW4	SW5	SDV
Temp (º C)	28.7	27.88	28.1	28.3	28.12	28.2	28.4	28.5	27.85	28.4	0.26
Ph	6.7	6.6	6.8	6.8	6.64	6.3	6.8	6.8	6.8	6.7	0.22
EC (µS/cm)	118.2	118.5	118.7	127.4	121.6	120.61	138.29	135.97	135.6	142.65	8.32
Cl⁻(mg/kg)	27.41	21.15	23.19	27.33	24.54	26.43	26.05	26.2	26.32	21.29	2.22
NO$_3^-$ (mg/kg)	14.27	14.08	13.9	14.2	13.81	12.77	13.2	13.42	13.07	13.88	0.42
TOM (%)	4.6	4.23	4.67	4.67	4.75	4.28	4.31	4.06	4.5	4.35	0.16
Ash (%)	18.5	18.56	18.21	18.6	18.51	18.31	18	18.91	18.49	18.52	0.33
Na (mg/kg)	8.96	7.62	7.81	7.3	7.75	8.25	8.28	8.36	8.31	8.27	0.04
K (mg/kg)	23.62	23.6	19.84	23.16	22.81	24.79	24.76	24.05	24.05	24.01	0.40
Ca (mg/kg)	7.41	6.33	6.57	7.6	7.01	7.24	7.48	7	6.84	6.62	0.34
Mg (mg/kg)	5.27	5.67	5.51	5.33	5.37	5.34	5.25	5.24	5.21	5.17	0.06
Parameter	SS1	SS2	SS3	SS4	Mean	SN1	SN2	SN3	SN4	Mean	SDV
Temp (º C)	28.3	27.46	28.1	28.31	28.13	28.2	28.2	28	27.85	27.5	0.29
pH	6.5	6.7	6.7	6.3	6.54	6.7	6.7	6.5	6.6	6.4	0.13
EC (µS/cm)	116.5	116.2	192.6	137.4	140.14	116	117.5	152	115	108.5	17.23
Cl⁻(mg/kg)	26.5	26.7	25.85	137.4	70.89	116	117.5	152	115	108.5	17.23
NO$_3^-$ (mg/kg)	14.31	14.42	13.95	13.9	14.17	12.88	13.54	14.35	12.45	12.3	0.85
TOM (%)	4.85	4.83	4.32	4.41	4.55	4.78	3.31	4.06	4.64	4.33	0.58
Ash (%)	18.15	18.06	18.55	19.53	18.60	18.5	18.51	18.3	18.3	18.13	0.16
Na (mg/kg)	8.82	8.21	8	8.7	8.39	8.11	7.48	7.26	7.06	7.4	0.40
K (mg/kg)	23	23.82	23.75	23.42	23.52	22.88	22.42	22.42	22.41	23.24	0.37
Ca (mg/kg)	7.56	8.52	7.61	7.55	7.78	7.07	7.05	7	7.2	7.28	0.12
Mg (mg/kg)	5.29	5.16	5.08	5.02	5.19	5.41	5.16	5.01	5.08	5.07	0.16

Mean Values of Physiochemical Properties of Water near Borehole

Property	SW1	SW2	SW3	SW4	SW5	SWC
Temp	28.2	28.0	28	27.00	27.5	27
PH	6.3	6.3	6.4	6.4	6.7	6.7
Ec	2882	2811	2091	1700	800	192
TSS	1400	1400	1500	1007	472	240
TDS	160	140	129	114	218	81
TOM	0.85	0.80	0.62	0.65	0.58	0.26
K⁺(mg/L)	0.866	0.691	0.792	0.977	1.022	0.375
Na⁺{mg/L)	1.755	1.649	1.878	1.384	1.675	0.561

Property	BW1	BW2	BW3	BW4	BW5	BWC
Ca^{++}(mg/L)	22.85	24.761	22.560	23.137	24.558	21.099
Mg^{++}(mg/L)	2.13	1.889	2.227	2.183	2.319	2.153
Property	BW1	BW2	BW3	BW4	BW5	BWC
Temp	28.41	27.6	27.00	27.00	27.4	27.00
pH	6.80	6.53	6.54	6,47	6.5	6.40
Ec	1244	625	292	241	243	200
TSS	609.50	298	101	158.7	157.5	151
TDS	1205	256	241	210	215	315
OM	0.750	0.147	0.108	0.125	0.105.	0.46
K^+(mg/L)	0.898	1.209	0.891	0.887	0.965	0.882
Na^+(mg/L)	1.873	1.920	1.673	1.227	1.668	1.441
Ca^{j+} (mg/L)	24.60	24.18	26.00	24.49	23.877	12.471
Ca^{2+} (mg/L)	2.18	2.22	2.13	2.13	2.28	2.18

Soil temperature depends on the ratio of the energy absorbed to that lost. Normally, the temperature of soil range between -20 to 60 °C and it is controlled by season, time of day, and local conditions of climate (Kekane et. al., 2015). In this study, temperature was 28.12±0.42 °C, 28.27±6.68 °C, 28.13±6.54 °C, 27.95±6.58 °C in the four different axis i.e SE, SW, SS and SN respectively with overall mean 28.12 ºC (Figure 4.1a).The temperature is considered normal and similar to temperatures reported in other studies. Apakama *et. al*., (2017) while assessing crude oil polluted soils in Ohaji/Egbema, Imo State reported temperature range of 27.93 ± 0.20 °C to 28.78 ± 0.50 °C.
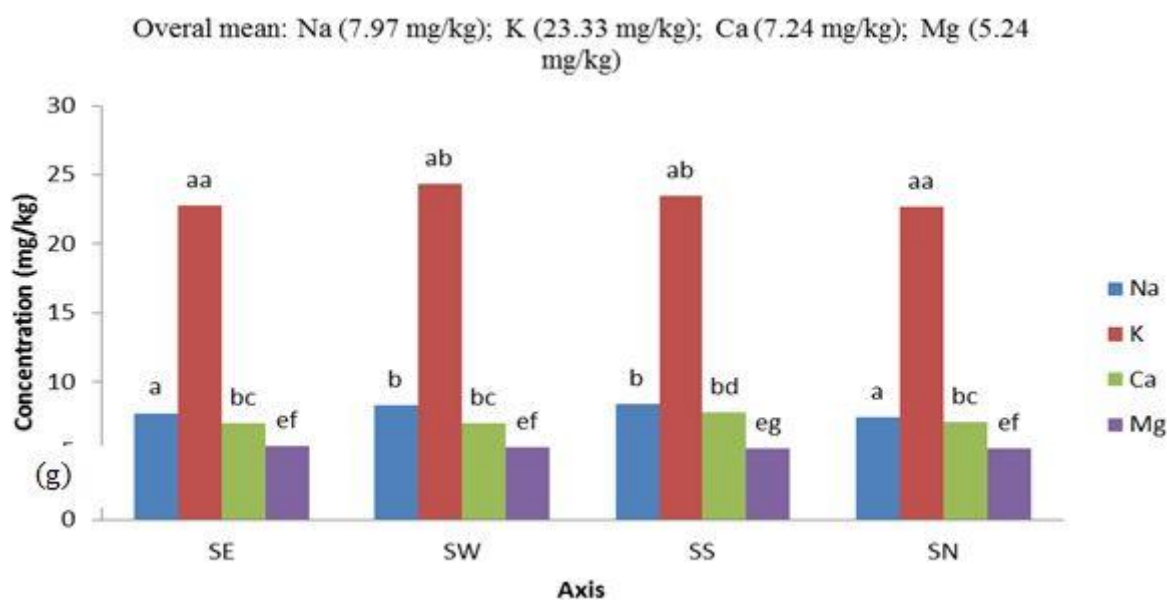
Figures   (4.1 a-g). Bar plots showing the mean concentrations of parameters (a) Temperature (b) pH (c) EC (d) TOM (e) ash (f) anions (g) cations. Bars with dissimilar alphabets are significantly different at p < 0.05.

However, there were significant differences (p < 0.05) in temperature based on the axis. SE and SS showed significant differences from SW and SN while no significant differences (p > 0.05) was shown between SE and SS (Figure 4.1a).

The most significant property of soil is its pH level, its effects on all other parameters of soil (Enyoh et. al., 2017). Therefore, pH is considered while analyzing any kind of soil. Further, it is a function of H^+ and plays an important role in metals availability for uptake by plants and animals (Verla et. al., 2017). If the pH is less than 6 then it is said to be an acidic soil, the pH range from 6-8.5 it's a normal soil and greater than 8.5 then it is said to be alkaline soil (Kekane et. al., 2015). The mean pH result showed normal soils with pH values of 6.64±0.20, 6.66±0.22, 6.54±0.17 and 6.58±0.13 for SE, SW, SS and SN respectively with overall mean 6.61 (Figure 4.1b).Lower pH (mean 5.65) compared to this study was reported in crude polluted soils in Ohaji/Egbema in Imo State (Apakama et. al., 2017) while very comparable with the mean value of 6.10 reported by Verla et. al., (2017) in surface soils

collected in the city of Portharcourt, Rivers state and mean of 6.67 reported for Ihube soils, Okigwe, Imo State by Enyoh et. al., (2017). Although these values are expected as they are common for tropical soils (alloway, 1997; Okoro et al, 2015; Enyoh et. al., 2017)**.** The acidity pH of the studied soils could also be due to the parent material from which the soils are derived (Ahukaemere *et al,* 2016).The pH values were all significantly different ($p < 0.05$) from one another.

The electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it (Enyoh *et al,* 2017).The United State Department of Agriculture (USDA) classified EC of soils as: non-saline

(0 µS/cm to 2000 µS/cm); slightly saline (2100 to 4000 µS/cm), moderately saline (4100 µS/cmto 8000 µS/cm), strongly saline (8100 µS/cm to 16000 µS/cm); and very saline (>16000 µS/cm). From result of the study, the EC is classified as non-saline since the mean for the soils are129.54 µS/cm; shown in Figure 4.1c.EC usually correlates strongly to soil texture and Cation exchange capacity (CEC) (Verla et al, 2015). Similar non-saline soils were reported by other authors (Verla *et. al.*, 2017; Apakama *et. al.*, 2017; Enyoh et. al., 2017; Eghomwanre *et. al.,* 2020). Except for SE and SN ($p >$ 0.05), all axis showed significant differences ($p < 0.05$) between them.

The total organic matter (TOM) showed mean values of 13.81 %, 13.27 %, 14.17 % and 13.10 % for SE, SW, SS and SN respectively with overall mean 13.58 % (Figure 4.1d). Normal soil TOM should range from 1 % to 6 %(Frederick and Louis, 2005; Enyoh *et. al.,* 2017). Therefore high TOM was recorded in the current study, suggesting that the crude oil related activities being conducted in the area may have impacted the soil negatively with high nutrient and thus causing impairment in the soil structure. When compared with other studies (Enyoh *et. al.*, 2017; Verla *et. al.*, 2017; Eghomwanre et. al., 2020), higher TOM was recorded in the current study. The different axes were significantly different ($p < 0.05$) for TOM of the soils.

The ash content (%) of the soil ranged from 18.35 % to 18.60 % with overall mean of 18.48 % (Figure 4.1e).Ash content is the fraction in biomass that is composed of incombustible mineral material. The obtained ash content in the soil is considered high, which maybe from combustion processes conducted by petroleum industries in the area. The ash may have been built up overtime as typically, the ash value of oil is in the range of 0.03–0.07% by weight (Dipak, 2015).

The results for anions such as chloride and nitrate in the soils are presented in Table 4.1. Chloride and nitrate ranges from 25.26 mg/kg to 121.8 mg/kg and from 13.10 to 14.17 mg/kg respectively. In comparison with other studies, the overall mean (60.62 mg/kg for chloride and 13.59 mg/kg for nitrate) is higher than 0.48 mg/kg reported for Portharcourt city, Rivers state (Verla et. al., 2017) while lower than the 29.11±16.11 to 60.06±10.76 mg/kg for open dumpsite soil reported by Eghomwanre et. al., (2020). Burning of fossil fuels in power plants and cars, and all internal combustion engines that usually result in the production of nitric acid ammonia as air pollution is source of nitrate in the environment. Industrial applications of nitrate as an oxidizing agent, in the production of explosives and as purified potassium nitrate for glass making are also potential sources of environmental nitrate (Morgan et al., 1989). When nitrogen undergoes natural processes of photochemical oxidation during lightening and thunderstorm, it gives oxides of nitrogen, which is a source of nitrate in the environment (Udofia, 2005). When in excess in the environment, it can be hazardous to health, especially for children and pregnant human. The concentration of nitrate in all axes does not show any significant differences ($p > 0.05$) while for chloride only SE and SW showed no significant difference ($p > 0.05$), all other axes showed significant differences ($p < 0.05$) for chloride concentrations (Figure 4.1g).

The overall mean results for cations such as Na, K, Ca, and Mg were 7.97 mg/kg, 23.33 mg/kg, 7.24 mg/kg and 5.24 mg/kg respectively. The total number of these positively charged ions is known as the Cation Exchange Capacity (CEC). The cation exchange capacity gives an indication of the number of sites where +ve ions can attach and hence the higher the figure the greater the potential fertility of a soil. Where the cation exchange capacity of the soil is <5 the soil is considered inherently infertile. Here, the mean CEC is 43.78 mg/kg suggesting the soils are fertile and may allow plant growth. Comparison with literature data also revealed that the study data for the soils around the oil wells was more higher than reported for urban city like Portharcourt (Verla *et. al.*, 2017) and agricultural soils in Ihube, Okigwe, Imo State (Enyoh *et. al.,* 2017).

Physicochemical Analysis of the Surface and Ground Water

The characteristics of stream water often exhibit some properties of various sources such as anthropogenic inputs and geological matrix (Yuan *et al.* 2014). Sometimes they could reveal the conditions of the surrounding water environment. The result for stream and borehole water analysis is presented in Tables 4.6 and 4.7.The temperature of water depends on its intended use. Temperature of water, according to WHO standard ranges between 20-30°C.The temperature obtained ranged from 27.5 $^{\circ}$C to 28.2 $^{\circ}$C with mean of 27.74±0.49°C while in the ground water it ranged from 27°C to 28.4 $^{\circ}$C, all fell within the standard limit and slightly higher than the control temperature of 27 $^{\circ}$C.These findings is in agreement with other studies (Verla et. al., 2018; Enyoh et. al., 2018; Verla et. al., 2020; Ibe *et. al*., 2019).

Table4.6. *Physicochemical characteristics of stream water around the oil well*

Properties	StW1	StW2	StW3	StW4	StW5	Mean	SDV	StWC (Control)
Temp	28.2	28.0	28	27.00	27.5	27.74	0.49	27
pH	6.3	6.3	6.4	6.4	6.7	6.42	0.16	6.7
EC	2882	2811	2091	1700	800	2056.8	859.91	192
TSS	1400	1400	1500	1007	472	1155.8	426.46	240
TDS	160	140	129	114	218	152.2	40.43	81
TOM	0.85	0.80	0.62	0.65	0.58	0.7	0.12	0.26
K^+(mg/L)	0.866	0.691	0.792	0.977	1.022	0.87	0.13	0.375
Na^+(mg/L)	1.755	1.649	1.878	1.384	1.675	1.67	0.18	0.561
Ca^{++}(mg/L)	22.85	24.761	22.560	23.137	24.558	23.57	1.01	21.099
Mg^{++}(mg/L)	2.13	1.889	2.227	2.183	2.319	2.15	0.16	2.153

The pH of water is an esthetic quality which measures its degree of acidity or alkalinity. The pH for the stream water ranged from 6.3 to 6.7 with mean of 6.42±0.16(Table 4.6) while for borehole water, pH ranged from 6.47 to 6.8 (Table 4.7). The mean pH indicate that the water is weakly acidic and lower than the control pH of 6.7 and 6.4 for stream and borehole water respectively. Low pH value in the water was attributed to anthropogenic acidification of all ochthonous organic matter such as ammonia from decaying aquatic life form or leaching materials which causes drastic change manifesting as low water pH. Low pH values have also been obtained in other surface water (Manila and Frank, 2009; Ekere, 2012; Verla *et. al.,* 2018; Verla *et. al*., 2020; Ibe *et. al*., 2019) and groundwater studies (Duru *et.al*, 2017; Charity *et. al*., 2018; Enyoh *et. al*., 2018). However, the pHs were within the recommended limit of 6.5-8.5 set by World Health Organization (WHO).

Table4.7 *Physicochemical characteristics of borehole water around the oil well*

Properties	BW1	BW2	BW3	BW4	BW5	Mean	SDV	BWC
Temp	28.41	27.6	27.00	27.00	27.4	27.48	0.58	27.00
pH	6.80	6.53	6.54	6.47	6.5	6.57	0.13	6.40
EC	1244	625	292	241	243	529	430.51	200
TSS	609.50	298	101	158.7	157.5	264.94	205.86	151
TDS	1205	256	241	210	215	425.4	436.22	315
TOM	0.750	0.147	0.108	0.125	0.105	0.28	0.31	0.46
K^+(mg/L)	0.898	1.209	0.891	0.887	0.965	0.97	0.14	0.882
Na^+(mg/L)	1.873	1.920	1.673	1.227	1.668	1.67	0.27	1.441
Ca^{++}(mg/L)	24.60	24.18	26.00	24.49	23.877	24.63	0.82	12.471
Mg^{++}(mg/L)	2.18	2.22	2.13	2.13	2.28	2.19	0.06	2.18

Electrical conductivity, total suspended and dissolved solids recorded in this study fell below the control for both stream (Table 4.6) and borehole water (Table 4.7). The conductivity depends on water temperature and is the measure of water capability to pass electric flow. The conductive ions may come from dissolved salts and inorganic materials in the River. The dissolved materials are mainly from anthropogenic activities which may be associated with petroleum related activities experienced in the area. High EC cum TSS and TDS is an indication that the water samples may be high in heavy metal concentrations dissolved in it (Verla *et. al.,* 2020). Further, High TDS and TSS will affect water users especially at downstream who abstract the water for domestic use (Muhammad *et. al.*, 2011) and if consumed, it may lead to gastrointestinal diseases. It also affects aquatic ecosystems causing gill damage that may lead to death of fishes and increase water treatment costs.

Total organic matter (TOM) is derived from decaying plant and animal matter. TOM is highly variable and relative concentrations of individual compounds can vary significantly from source to source. The total organic matter in the water samples showed higher concentration compared to controls.

(Tables 4.6 and 4.7). The high TOM is due to anthropogenic activity and it is attributable to low water pH and high temperature. Duru and Nwanekwu (2012) explain that due to human activity, surface water can be enriched with high organic content, which is a quality suitable for aquatic organisms and microorganisms. Following the same explanation, groundwater may receive high organic matter from soil during leaching of pollutant. Therefore, high TOM could be due to petroleum related activities experienced in the area.

The major cationic concentrations were low generally when compared to WHO (2007) standard, but higher than the control concentrations for both stream and borehole water. In the stream, the mean concentration was 0.87 ± 0.13 for K, 1.67 ± 0.18 mg/L for Na, 23.57 ± 1.01 mg/L for Ca and 2.15 ± 0.16 mg/L for Mg while these cations were slighty higher in borehole water which ranged from 0.97 ± 0.14 for K, 1.67 ± 0.18 mg/L for Na, 24.63 ± 0.82 mg/L for Ca and 2.19 ± 0.06 mg/L for Mg. Calcium showed the highest concentration in both water types. Calcium (Ca^{2+}) ions are common in natural waters and are essential elements for all organisms (Hydrology Project Training Module, 1999). It are responsible for the hardness of natural waters when combined with dissolved materials in the water. WHO reported that hard water has no known adverse health effect (Sengupta, 2013) and could provide an important supplementary contribution to total calcium intake (Garlan *et. al.*, 2002). However, prolong consumption of water with high magnesium can cause hypercalcemia if the consumer have significantly decreased ability to excrete calcium (Chandra *et. al.*, 2013). Hypercalcemia is associated poor bone health kidney stones, abnormal heart and brain function.

Water Quality Assessment

The water quality index was computed as described in previous studies presented in equations 3 and 4 (Duru *et. al.,* 2017; Enyoh *et. al*., 2018; Charity et. al., 2018; Duru *et. al*., 2019). The SI is the subindex of ith parameter; qi is the rating based on concentration of ith parameter (calculated as the ratio of determined concentration to the recommended limits) and Wi is the relative weight of each parameter (Table S1) while WQI is the water quality index.

$$SI = W_i X q_i \tag{3}$$

$$WQI = \sum SI \tag{4}$$

The model gives a single value which provides information on the suitability of consuming the sachet water samples. The computed WQI for the water samples is presented in Figure 4.2. The classification for WQI is associated with a qualitative scale of parameter intensity and can be classified; excellent (WQI < 50); good (50 < WQI < 100); poor (100 < WQI < 200); very poor (200 < WQI ≤ 300); unsuitable for drinking (WQ1 ≥ 301) (Duru et. al., 2017; Enyoh et. al., 2018; Verla et. al., 2019a). Results obtained are presented in Figure 4.2. All control samples showed excellent water quality i.e BWC (WQI = 49.17) and StWC (WQI = 48.52) while the borehole water showed good quality (WQI = 64.84) and poor quality was exhibited by the stream water (WQI = 103.15) (Figure 4.2.). It could be concluded that only the borehole water is good for domestic use while the stream water isn't. The general physiochemical parameter of the water is therefore in line with the value of WQI observed and the characterization of the water as good and poor.
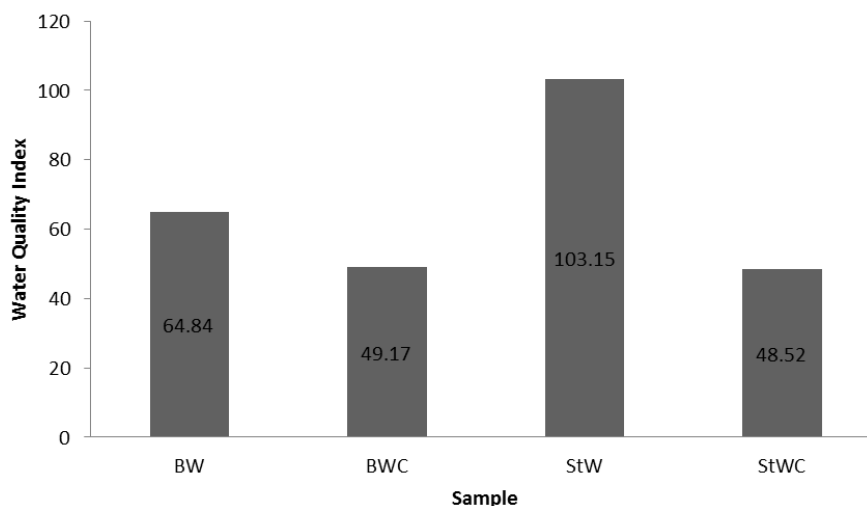
Figure4.2. *Water quality index for borehole (BW) and stream water (StW)*

Comparing the results for WQI with other study, Abdul *et. al.,* (2010) also reported WQI of Dokan Lake to be within good water quality to poor water quality from 2000 to 2009 with values 53.18 to 101.26 respectively. However, Verla *et. al.,* (2018) reported WQI for River Uramiriukwa to be of good quality with WQI < 50 for dry and wet season. Further, Verla *et. al.,* (2019) reported very high WQI of > 300 for Orashi River, which showed that the water is unsuitable for drinking or use for domestic activities. According to the authors, the area is experiencing high pollution from petroleum industry located in area with over 4000 oil spillage. Etim *et. al.,* (2013) found that streams in the Niger Delta region to be of good quality with WQI of 55.05 to 84.94, lower than the current study.

For borehole water, poor water quality (WQI of 153.3) was reported by Duru *et. al.,* (2017) for reclaimed automechanic village in Orji, Owerri while study of Enyoh *et. al*., (2018) showed that the same area generally had excellent (50 % of sample), good (30 % of samples) and unsuitable (20 %) water quality, attributed to automechanic activities. Further, Etim *et. al*., (2013) found that borehole water in the Niger Delta region to be of excellent quality with WQI of 38.52 to 48.67, lower than the current study.

This chapter presents the summary of findings, conclusion and recommendation.

5. CONCLUSION

The study has successfully characterized the soils, surficial water and groundwater around the oil well in Omerelu community, Ikwerre local government area of Rivers state using different chemometric models. The soils from area are still fertile and will support the growth of plant. However, the surface and borehole water were of poor and good quality respectively with WQI of 64.84 and 103.15 respectively. The contamination was majorly from petroleum related activities. Waste or effluent discharged into the environment must be treated to meet the standard of Federal Ministry of Environment or Department of Petroleum Resources. Regular examination of aquatic animal such as fish and plants should be analyzed for heavy metal bio concentration as data obtained will expose possible health threat to human through fish and vegetable consumption. Inhabitant and users who frequent the streams should be enlightened about polluted state of the river and the role they will play in its remediation.

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