Scientia Africana, Vol. 19 (No. 1), April, 2020. Pp 15-24
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ASSESSMENT OF SOME GEO-PHYSICAL, CHEMICAL AND TECHNICAL CHARACTERISTICS OF SOIL AND GROUNDWATER RESOURCES IN JESSE, SOUTH-SOUTH NIGERIA.

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Received: 12-12-19
Accepted: 10-12-19

ABSTRACT

This study assessed some geophysical, physicochemical and geotechnical characteristics of soil and groundwater resources in Jesse, Delta State of Nigeria. Earth Resistivity Meter was employed for the electrical imaging of the subsurface. Soil and water samples from the area were taken to the Laboratory for the determination of the physico-chemical, geochemical and geotechnical parameters. The results of the resistivity data shows that a high resistive plume with resistivity >2,000 Ohm-m has penetrated the soil beyond 21m beneath the surface in most parts of the surveyed area. The water samples show mild acidity with pH values in the range 4.3-5.4. Total dissolved solids (TDS) is low 29.35- 33.58mg/L and conductivity ranges from 50.60-60.78 µS/cm. Heavy metal presence is within WHO permissible limit, only Iron is high (0.455-0.889mg/L). Groundwater sample analysis show that total petroleum hydrocarbons-TPH, as oil and grease is below detection level (<0.031mg/L). This can be attributed to the sealing of the confined aquifer by impermeable clay, but fairly high in surface water (≈0.4mg/L). The average permeability of the soil is 8.805 x 10^{-3}cm/s indicating good drainage condition. The results have shown that shallow boreholes are polluted and the soils of the area are acidic. Groundwater of the area needs treatment before it can be consumed and periodic investigations should be carried out in the study area.

Keywords: *Groundwater, Hydrocarbon, Pollution, Resistivity, Soil.*

INTRODUCTION

The continual oil spillage in the Western Niger Delta region has been a menace. It has been estimated that between 9 to13 million barrels of oil has spilled since oil drilling started in 1958 in the Niger Delta region (Baird, 2010). Adati (2012) reported over 6000 spills in the 40 years of oil exploitation in Nigeria. In the period 1976 – 1996, 647 incidents occurred resulting in the spillage of 2,369,407.04 barrels of crude oil with only 549,060.38 barrels recovered, while 1,820,410.50 barrels were lost to the ecosystem. Groundwater pollution remediation is difficult, expensive and almost impracticable (Thirumalaivasan and Karmegana, 2001). These highlighted problems informed the need to carry out a study in the area, which hosts an oil rig.

This study therefore seeks to characterize the area that have been polluted and that are prone to pollution, using the geophysical, geochemical and geotechnical techniques.

The Niger Delta is large curve shaped delta which occurs in southern Nigeria like some other deltaic environments in the world. It occupies an area lying between latitude 4^0 - 6^0N and longitude 4^0 - 9^0E. It is bounded in the west by the Calabar flank, in the north by the Anambra platform and in the south by the Atlantic Ocean under which it extends (Figure 1). Both marine and mixed continental depositional environment characterize the Niger Delta of Nigeria (Uko *et al.*,1992). Contaminant load of soil and water is growing steadily each year in parallel with increasing industrialization and energy demand (Wang, 1999). Hydrocarbon pollution constitutes serious problems wherever exploration and exploitation activities are carried out. Oil spills are common events in the Niger Delta region of Nigeria and occur due to a number of causes, including: corrosion of pipelines and tankers (accounting for 50% of all spills), sabotage (36%), and oil production operations (6.5%), along with 1% of the spills being accounted for by inadequate or non-functional production equipment (Adelana *et al*., 2011). These contaminants fluids infiltrate to the soil and water table thereby polluting them.

A report by Ehirim *et al*, (2016) observed that in the Niger Delta region, hydrocarbon contamination of the soil and groundwater showed a characteristic low resistivity anomaly associated with microbial degradation over time. The minimal depth of impact is approximately 13 m below the groundwater table, with a lateral spread in excess of 100 m on either side of the spill point parallel to the pipeline right of way.

Uchegbulam and Ayolabi (2014) observed that a fresh spilled hydrocarbon showed high resistivity, whose values depended on the lithology of the area.

Description of the Study Area

Jesse is located in Delta State, Western Niger Delta. It lies between latitude 5° 52' N and longitude 5° 45' E in geographic coordinate (Figure 1). The city hosts an oil rig and oil pipelines crisscrossing residential areas and are owned by some of the oil and gas companies operating in the country. The area consists of fresh water swamp, coastal plain sands, mangrove swamps, and Sombreiro-Warri plains. Soils are generally hydromorphic and poorly drained.

Natural vegetation occur as fresh water swamp forest, mangrove swamp forest and ever green lowland rainforest, a major source of timber. Ethiope River is the major water body in the area. The region has a humid equatorial climate. The cloud cover is high, with relative humidity and average rainfall above 80% and 3000 mm (Omo-Irabor and Oduyemi, 2006).

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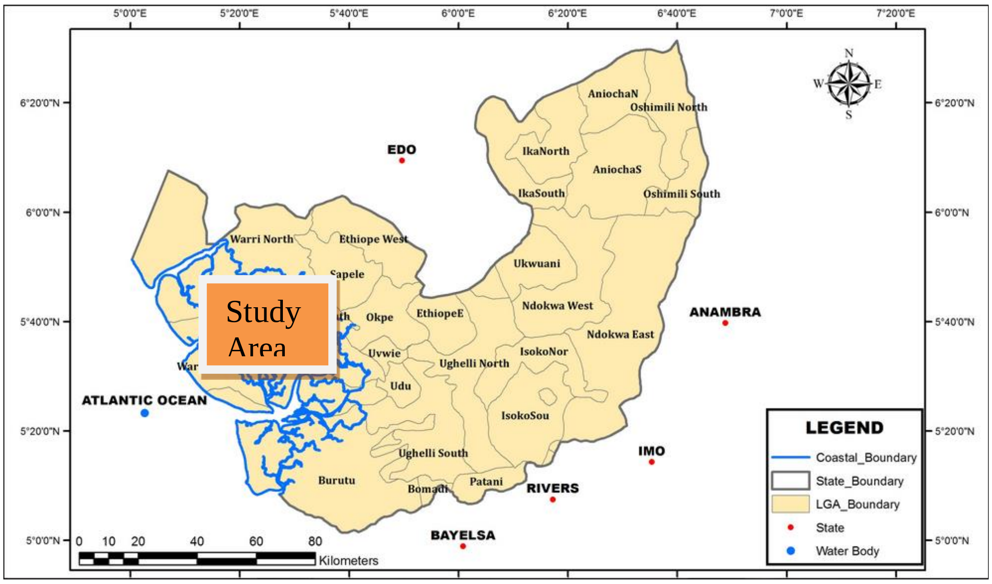

Figure 1: Map of Delta State Nigeria, showing the study area (After GAMERS, 2017).

The pictorial view of a polluted Ethiope River in Jesse area of the study is shown in plate 1.

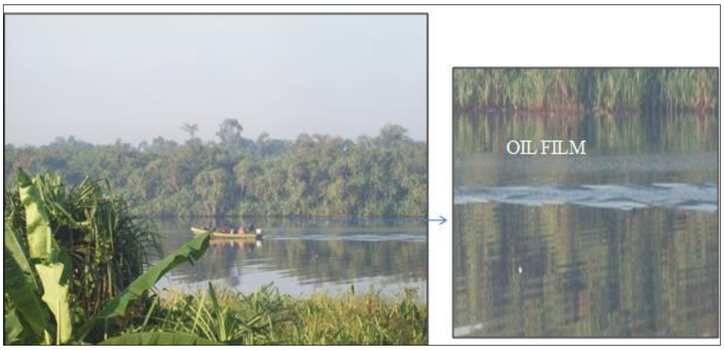

Plate 1: Pictorial view of a polluted Ethiope River in Jesse area of the study.

MATERIALS AND METHODS

Data Acquisition

Electrical Resistivity Data

Earth resistivity meter was used for the electrical imaging with (5-2) m minimum electrode spacing. Traverses covered lateral distances of 126 m. Traverses were occupied proximal to the pipelines which are in residential areas (Figure 2).

A small electrode spacing of (5-2) m was adopted for the resistivity meter in the acquisition of data, in order to be able to provide considerable details of any plume related to leakages from the oil installations and underground pipelines. Wenner and Gradient arrays were chosen in the acquisition of data because Wenner array is relatively sensitive to vertical changes of resistivity below the centre of the array, and Gradient array has advantages of image resolution and target definition and therefore, provides more details of the subsurface.

Water Sampling

Water samples were collected from boreholes and hand dug wells from five (5) locations and stored in glass containers and kept in iced vessels.

In-situ Analysis: Analysis measurements were carried out for the ground water collected. Unstable field parameters namely pH and temperature were analyzed in the field and recorded.

pH: Measurement of the pH was done by using HACH pH-meter which was pre-calibrated on the field by using standard buffers.

Temperature: This was determined by means of thermometer calibrated 0.2 °C units from

0-100 °C.

Sample preservation: The purpose of sample preservation is to retard biological action, retard hydrolysis of chemical compounds and to reduce volatility of constituents. To prevent contamination, all sampling materials and containers were sterilized. Samples were also properly labeled before taken to the laboratory. Oil and grease samples were fixed with $5MH_2SO_4$ for preservation.

Soil Sampling

Soil samples were collected from the survey area within the depth of 1-2 m, which were used for the determination of the permeability.

Permeability of the soil was calculated with the use of Variable Head Permeameter in the soil laboratory.

The Variable head permeability test involves flow of water through a relatively short compacted soil sample connected to a stand pipe which provides the water head and also allows measuring the volume of water passing through the sample.

The time required for the water in the standpipe to drop from the upper to the lower level was recorded. Based on the results obtained, the permeability, K of the samples were estimated using the equation

$$K = \frac{L \log eH_1}{A(t_2 - t_1)H_2} \quad (1)$$

(Chanson, 2004)

Where, L is the sample length and A is the cross sectional area of the sample. H_1 and H_2 are the initial and final heights above the constant head chamber and their measured time t_1 and t_2 respectively. The permeability test of the study area is shown in Table 4. The coefficient of permeability scale by (West 1995) used for interpreting the calculated permeability is shown in Table 5.

Data Processing

Electrical Resistivity data

Res2Dinv software was applied to iterate the acquired data. This software simulates the values of the apparent resistivity and that of the current electrode spacing to obtain a two dimensional (2-D) layered model. Consequently, resistivity and the depths of the layers were estimated. Borehole logs from the area were used as an aid in the interpretation of the resistivity data. The elevation of the study area is about 9 – 10 m.

The google map of the study area showing traverse lines and water wells is displayed in Figure 2.

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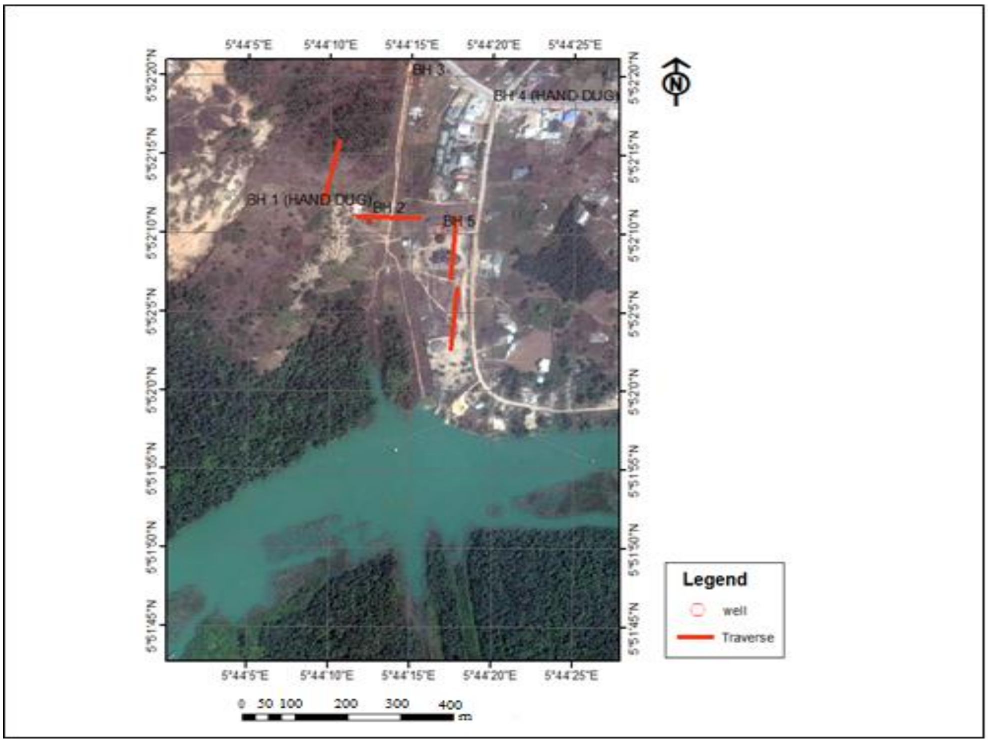

Figure 2: Google image of Jesse, showing traverse lines and water wells.

RESULTS

The results of the resistivity data for traverse 1 are shown in Figures 3 and 4, while Figure 5 show the lithological stratigraphy used in comparing the results.

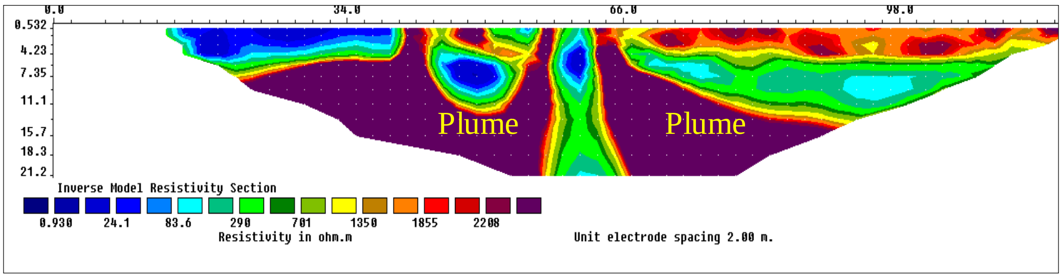

Figure 3: 2D Electrical resistivity image of Jesse along traverse 1 using Gradient array.

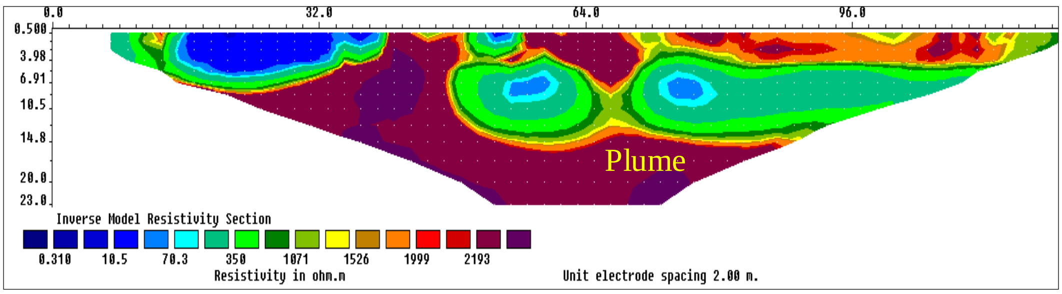

Figure 4: 2D Electrical resistivity image of Jesse along traverse 1 using Wenner array.

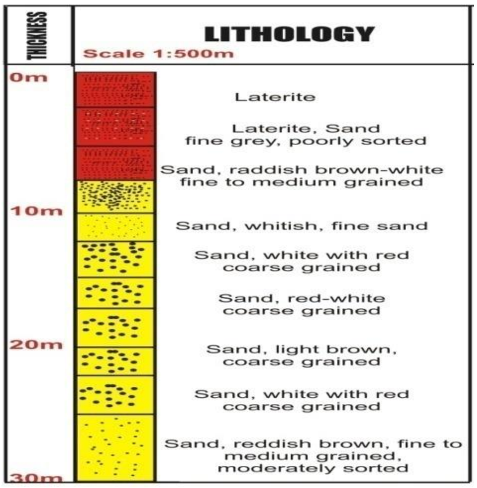

Figure 5: A typical stratigraphy column of a borehole showing the lithologic units of Jesse.

Traverse 2

The electrical image of the resistivity data for traverse 2 is shown in Figure 6

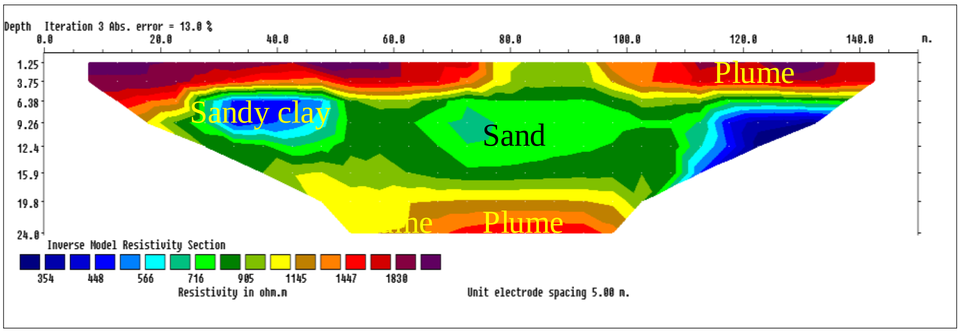

Figure 6: .2D Electrical resistivity image of Jesse along traverse 2 using Wenner array.

Traverse 3

The electrical image of the resistivity data for traverse 3 is shown in Figure 7.

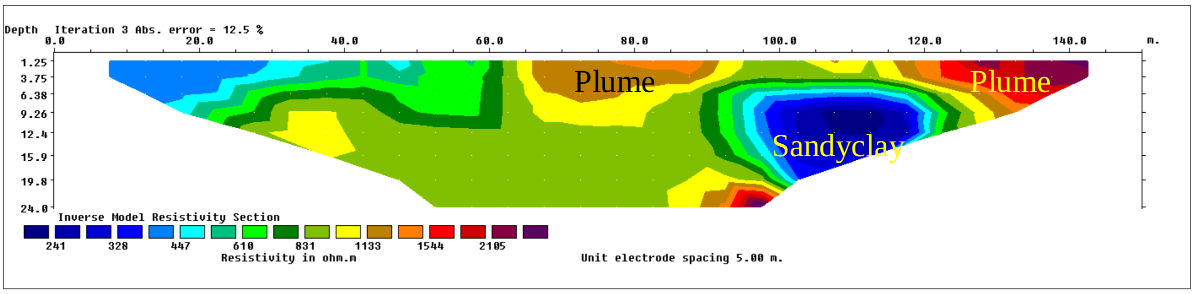

Figure 8: .2D Electrical resistivity image of Jesse along traverse 3 using Wenner array.

The physico-chemical content and heavy metal concentration results are shown in the Tables 1 and 2 respectively. Total Petroleum Hydrocarbons (oil and grease) content in surface and groundwater using Gas Chromatography analysis is shown in Table 3.

The permeability results is shown in Table 4, while the coefficient of permeability of soil types (West, 1995) used for interpreting the results is shown in Table 5.

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Table 1: Physico-chemical content of groundwater in Jesse

	pH	**Temp .^{0}C**	**Cond. μS/cm**	**TDS mg/L**	**Bicarbonate mg/L**
BH 1 (Hand dug)	5.4	29	50.60	29.35	2.20
BH 2	4.7	33	57.90	33.58	1.46
BH 3	4.6	33	55.58	32.24	1.83
BH 4	4.3	28	57.35	33.26	1.22
BH 5	4.3	32	60.78	35.26	1.02
WHO/SON Standard	6.5-8.5	40	1000	500	150

Table 2: Concentration of heavy metals in groundwater in Jesse

	Iron mg/L	**Zinc mg/L**	**Copper mg/L**	**Lead mg/L**	**Cadmium mg/L**
BH 1 (Hand dug)	0.889	0.217	0.192	< 0.002	< 0.005
BH 2	0.455	0.090	0.030	< 0.002	< 0.005
BH 3	0.559	0.123	0.060	< 0.002	< 0.005
BH 4	0.847	0.241	0.191	< 0.002	< 0.005
BH 5	0.645	0.176	0.141	< 0.002	< 0.005
WHO/SON STANDARD	0.3	3.0	0.5	0.01	0.003

Table 3: Total Petroleum Hydrocarbon content of surface and groundwater in Jesse.

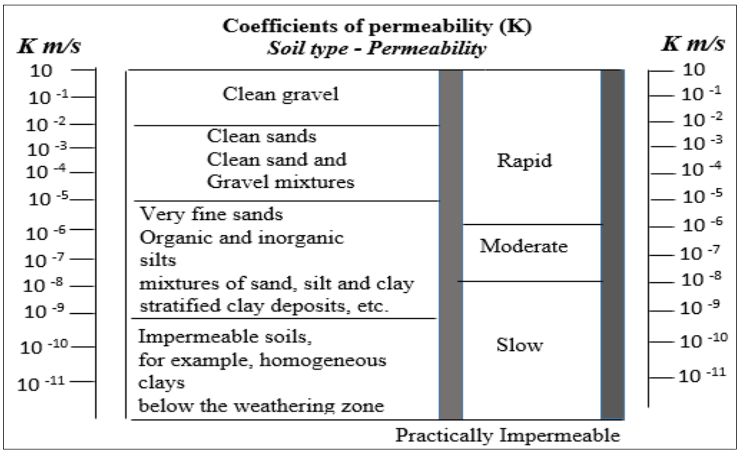
PARAMETERS	**ETHIOPE RIVER**	**JESSE**
		BH 1
TPH mg/L (Oil and grease).	0.36	< 0.031

Table 4: Average Permeability of Jesse.

Test Nos	**Initial stand pipe ht (H_1)mm**	**Final stand pipe ht (H_2)mm**	**Elapsed time (t_2-t_1) secs.**	$\frac{L}{t_2 - t_1}$	**Loge** $\frac{H_1}{H_2}$	**Coefficient of Permeability (K)**
1	900	800	0.5	24.6	0.1178	9.563×10^{-3}
2	800	700	0.6	20.5	0.1337	9.045×10^{-3}
3	700	600	0.7	17.57	0.1542	8.941×10^{-3}
4	600	500	0.9	13.67	0.1824	8.228×10^{-3}
5	500	400	1.1	11.2	0.2231	8.246×10^{-3}

K_{av}= 8.805×10^{-3}cm/sec.

Table 5: Coefficient of permeability scale (West, 1995)



DISCUSSION

Electrical Resistivity Imaging

The two resistivity structures (Figures 3 and 4) show that the subsurface is composed of varying degrees of resistivity as can be seen from the resistivity values (24.1-2238 Ωm), revealing varying degree of conductivity associated with lithology (Figure 5) and fluid type. Recent oil spill area shows a high resistivity anomaly, while mature oil pollution (>20 years) produces a low resistivity anomaly (Sauck, 2000), depending on the lithology of the area. The 2-D section also revealed an anomalously high resistivity (1855-2238 Ωm) structure within a lateral distance of 40-44m; 48-52m; 54-56m; 64-66m; and 68-126m at a depth of 0.5-21.2m; 0.5-4.2m; 0.5-21.2m; 0.5-21.2m; and 0.5-5m respectively. These anomalously high resistivity structures are attributed to the presence of hydrocarbon within the soil which may be due to leakages from various pipelines within the study area or possible spillage. Ehirim (2016) observed a low resistivity anomaly for a biodegraded hydrocarbon.

Traverse two reveals the resistivity profile along the survey line. The electrical image is displayed in Figure 6.

The 2-D array results show that the subsurface has materials with resistivity ranging from 256-1830 Ωm indicative of changing degree of resistivity associated with varying lithology and fluid type (Figure 5). A high resistive substance of range 1145-1830 Ωm has infiltrated into the subsurface within a lateral distance of 5-78m, 95-120m and 60-100m at the depth of 1-9m, 1-8m and 19-22m respectively.

The electrical resistivity along traverse 3 is shown in Figure 7. The 2-D array result also shows that the subsurface has materials with resistivity ranging from 241-2105 Ωm indicative of changing degree of resistivity associated with varying lithology (Figure 5). A high resistive substance with resistivity (1133-2105 Ωm) has infiltrated into the subsurface within a lateral distance of 65-90m, 65-80m, 85-100m and 110-150m at a depth of 1-12m, 19-24m and 1-15m respectively.

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Physico-chemical content and concentration of heavy metals.

The temperature ranges between 28 to 33ºC (Table 1). Temperature affects the density of water, the solubility of constituents (such as oxygen in water), pH, specific conductance, the rate of chemical reactions, and biological activity of water. The groundwater temperature is within the WHO/SON maximum permissible standard of 40^0 C acceptable for domestic purposes.

The pH of a solution is a measure of the effective hydrogen-ion concentration. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia, apparently affect pH. The pH ranges from 4.3 – 5.4, indicating mild acidity.

Ughe (2012) also reported that the groundwater in the Western Niger Delta is equally acidic. The groundwater is fresh as can be seen from the low conductivity (50.60 – 60.78 µS/cm), the values are in agreement with the low Total Dissolved Solids, TDS values (29.35-33.26 mg/L). The low bicarbonate values (1.02 – 2.20 mg/L) are in agreement with the pH values.

There is no incidence of heavy metal contamination as seen in Table 2, as they are within WHO permissible limit; only Iron is fairly high (0.455-0.889mg/L). This may be due to the natural interaction of groundwater with Benin Formation of the Niger Delta. Groundwater sample analysis show that Total Petroleum Hydrocarbons-TPH, as oil and grease is below detection level (<0.031 mg/L). This can be attributed to the sealing of the confined aquifer by impermeable clay, but fairly high in surface water ≈0.4mg/L (Table 3), above WHO/SON permissive level of 0.3mg/L.

Permeability of the Soil

The permeability of soil types of the study area ranges from 8.228×10^{-3} - 9.563×10^{-3} cm/sec (Table 4), which is equivalent to $8.228 \times 10^{-5} - 9.563 \times 10^{-5}$ m/sec. The average permeability of soil in the area is (K_{av}= 8.805×10^{-3}cm/sec = 8.805×10^{-5} m/sec).

Comparing the permeability of soil in the area with the coefficient of permeability scale (Table 5), the drainage is fairly rapid and the soil type is mixture of medium, fine and silt sands. The implication is that any contaminant on the surface will easily drain to the water table, except in cases where impermeable clay seals the aquifer from being polluted by the contaminant.

CONCLUSION

The integrated techniques employed have established the effectiveness of the methods in the assessment of degraded environment. Results obtained have shown that shallow boreholes are prone to contamination by hydrocarbon. There is no danger of heavy metal pollution in the area.

However, for the fact that groundwater in the area is acidic, the water will be more acidic if measures are not taken to check the menace. There may be bioaccumulations over time in the bodies of consumers of the plants and groundwater in the affected area. The area requires routine integrated methods of environmental investigation.

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