IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 4 ISSUE : 07 Print / Issue Publication Date: 07-Jan-2020

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2019.v04i07.048

Indexed In

International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 7, ISSN No. 2455-2143, Pages 285-291
Published Online November 2019 in IJEAST (http://www.ijeast.com)

CHARACTERIZATION OF SOIL AND GROUNDWATER FOR PROJECT DEVELOPMENT IN EKAKPAMRE, DELTA STATE, NIGERIA

Oborie, Ebiegberi
Department of Geology, Niger Delta University,
Wilberforce Island, Bayelsa State, Nigeria

Abam, Tamunoene Kingdom Simeon
Geotechnics Division, Institute of Geosciences and Space Technology,
Rivers State University, Port-Harcourt, Nigeria

Abstract - The possible effect of oil exploration and production activities on the soil and groundwater resources in the surrounding environs of a hydrocarbon flow station was investigated using geochemical analysis and surface geophysical methods. Three groundwater monitoring boreholes were freshly drilled in the study area for the determination of sub-surface stratigraphy/lithology and from which groundwater and soil samples were collected for physicochemical analysis. Visual examination of the recovered cores and geoelectric characterization show that the subsurface layers were of variable resistivity values representing a top layer (100-198 ohm-m) of brownish silty sands. Underlying this layer was an unsaturated clayey zone with characteristically low resistivity value (26.3 - 57.6 ohm-m) down to a depth of about 7m. Below the clay zone is the aquifer composed of saturated silty sands which grades into coarser sands (>100 ohm-m) at the bottom of the borehole profile. Results of the laboratory analysis reveal that both groundwater and core soil samples from the monitoring wells were slightly acidic. Oil and Grease, PAH, BTEX concentrations were below detection limits. TSS in the analyzed groundwater samples was slightly higher than standard stipulated limits. Concentrations of the nutrient elements in the core samples were moderate while heavy metals were generally insignificant. The overall results suggest the soil and groundwater resources have not been adversely impacted by the operations of the oil and gas facility sited in the study area.

Keywords: Geophysical, Physicochemical analysis, Borehole, Lithology, Groundwater, Resistivity

I. INTRODUCTION

Oil and gas exploration and production activities have inherent risk potential of contaminating the environment. Statistics has shown that more than 2.4 million barrels of oil have spilled into the creeks and soil of southern Nigeria in the past 30 years. Some 70 percent of the oil has not been recovered while many spill sites have been abandoned (The Daily Independent, 2010).

Geophysical techniques including electrical resistivity (ER) have been applied to several hydrocarbon contamination investigations as they are considered generally inexpensive, fast and minimally-invasive. The theoretical basis for the use of geoelectrical methods for the detection of groundwater and soil contamination in the subsurface is dependent on the contrasting electrical properties exhibited by different soil types together with their contained pore fluids. Recent hydrocarbon contamination results in high resistivity anomalies, while mature oil contamination produces low resistivity anomalies (Allen et al, 2007; Sauck, 2000).

Spilled hydrocarbon from production and human activities can for instance contaminate groundwater. During precipitation, un-recovered contaminants can percolate through the soil strata into underlying aquifers. Groundwater moves and can join surface water elsewhere, or be harvested for consumption. There is thus the need to monitor groundwater status in areas of oil and gas operations as a measure of safeguarding both the physical and human environment.

The aim of this study is to determine the physico-chemical characteristics of subsurface materials and the condition of groundwater within and around the locality of an operational oil flow station sited in the study area. This is with a view to ensuring the safety and sustainability of the biophysical and human environment while providing an information base on the groundwater and substrata status of the area upon which subsequent monitoring studies and inferences can be made.

II. LOCATION OF STUDY

This study was carried out near Ekakpamre community, in Ughelli North local government area of Delta State which is host to a flow station operated by one of the oil producing companies in Nigeria. Ekakpamre is approximately located between $5^0$25'N and $5^0$30'N and $5^0$40'E and $5^0$50'E. Hydrocarbon exploration and production operations are the major activities in the flow station, whereas economic activities in the host community include farming, hunting, petty trading, and artisanal labour provision to the oil and gas production industry. Ekakpamre community is approximately 2 km north of the flow station. Private boreholes and streams are the major sources of drinking water in the community.

Geology and Geomorphology of the Study Area

The study area is situated in the floodplain sedimentary environment of the fresh water swamp of the Niger delta with extensive sandy deposits. Cratchly and Jones (1965) identified a pre-santonian phase of repeated transgressions in the Niger Delta. This phase coincided with the opening of the Benue trough, which permitted marine influences to reach their farthest limits in the hinterland. The cretaceous and Cenozoic periods witnessed extensive deposition of sediments eroded from the folded structures of the Santonian era. This extensive sedimentation marked the commencement of the second phase of growth of the Niger Delta, which Short and Stauble (1967) have associated with the growth of the proto-Niger Delta. This depositional phase was terminated in the marine transgressions, which occurred in the Paleocene.

The third phase of growth of the Niger Delta began in the Eocene at which time the pile of sediments of the Delta had reached the oceanic crust underneath the modern Niger Delta. The epeirogenic movements of the Western Benin flank and the Eastern Calabar flank at this period, provided added impetus for Delta growth, and hence the continued regressionary phase which characterizes the modern Niger Delta to the present times. Dailly (1976) affirms that the Delta has grown at the rate of 5 kilometers for every one million years over the past 40 million years. The sands constitute the major aquiferous layer in the Niger Delta (Andersen, 1967). Water level in the area is subject to spatial and seasonal variation.

The soil type in the area investigated include the red - yellowish podzol soil overlying loose sands, with surface elevation of about 9-15m above mean sea level (MSL). The lithofacies includes channels and point bar, back swamp etc. The characteristic lithologies include: fine -medium-coarse grained point bar sands and clayey backswamp deposits. The sands form the major aquifers in the area while the clays form the aquitards. The water table in the area varies with season. The water table declines during the dry season. Generally the water table is closer to the surface with a range of about 8-2m below the ground surface depending on the season and closeness to the swamp. During the wet season the swamps are flooded and become relatively dry in the dry season.

The topography of the area is characterized as a gently undulating land form that can be described as flat, monotonous landform. It is a horizontal structure of low relief formed from aggradational materials and presently overlain mainly with secondary rainforest vegetation (Niger Delta Environmental Survey, 1996).

III. MATERIALS AND METHODS

The study was systematically carried out using the following methods: resistivity imaging of the subsurface; drilling, developing and logging of the sub-surface strata of the monitoring boreholes and soil/groundwater analysis for contaminants assessment.

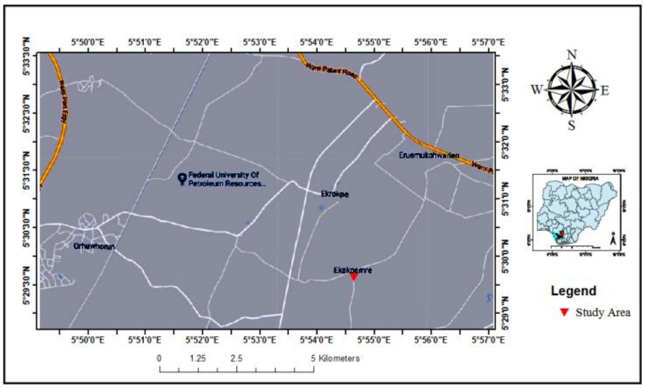


Figure 1: Map of the study area

Geoelectrical Imaging

Three 2D horizontal profiling using the Wenner configuration were conducted in the study area; one at each of the three borehole locations. In this technique, the entire electrode set-up was systematically moved in a leap frog manner to ensure continuous lateral coverage of the subsurface. The aim of the geophysical investigation was to extend the information derived from the borehole to a wider area and thus examine the behaviour of the geological formation. ABEM Terrameter (SAS) 1000 was used for the field measurement and data acquisition. Resistivity techniques in general require the measurement of apparent resistivity ($\rho_{a,}$) which is obtained from the specific electrode configuration used.

The calculated resistivity value is however not the true resistivity of the subsurface but an apparent value which is dependent on the particular electrode arrangement used for the measured resistance. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using computer software program RES2DINV was carried out. The program is an interactive smoothness constrained least-square inversion software which produces a 2-D model of the subsurface. The computer program automatically subdivides the subsurface into a number of blocks and then uses a least square inversion scheme to determine the appropriate resistivity value for each block. The inversion results of thickness and resistivity were used to characterize the subsurface.

Monitoring Boreholes

Three boreholes were drilled at the study area for groundwater quality determination and monitoring and sub-surface Stratigraphy/Lithology investigation. The percussion drilling method was used to drill the boreholes. This method produces uncontaminated samples as no external drilling fluid is used. Representative soil samples at desired depths were collected for in-situ strata description, and laboratory analysis. On reaching the desired aquifer depth, each borehole was cased using 4-inch (100mm) PVC casing worn with a threaded PVC screen attached to a 'Shoe' at the lower end. The borehole was then flushed and allowed a minimum period of about 30 minutes to attain equilibrium. Static Water Levels were measured and the completed borehole was properly 'capped'.

Sample Collection and Laboratory Analysis

The samples for laboratory analysis were preserved and transported in accordance with the Department of Petroleum Resources (DPR) (2004) Environment Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN), Revised Edition. Laboratory analyses of all the collected field samples were carried out in the accredited Thermosteel Laboratories Nig. Ltd., Warri Delta State. Both groundwater samples and soil samples were analysed using standard laboratory procedures.

IV. RESULTS AND DISCUSSION

The general stratigraphy of the subsurface formations in the study area was determined through direct observation from cores recovered during the drilling of the monitoring boreholes (figure 2) and from 2-D Geoelectric Profiling. Groundwater flow direction was determined using the triangulation method (figure 3), while the results of the laboratory analysis of the groundwater and core samples are presented in Tables 4.1 and 4.2 respectively.

Groundwater flow direction

The direction of ground water movement was determined from the three monitoring boreholes drilled in study area. Static water level (SWL) of each borehole was determined after flushing, and allowing a minimum period of thirty minutes to attain equilibrium. The hydraulic heads of the three boreholes were determined by subtraction of the SWL from the ground surface elevation (GSE). Elevation head differences were divided into equal increments by adding the initial water level to each increment. Equipotential lines connecting the increments were subsequently determined using the graphical triangulation method (Fig. 3). These lines represent the water table contours.Figure 3 shows that groundwater in the area flows in north-west to south-east direction. The groundwater flow direction with respect to the study location indicates groundwater resources in the community under investigation are not likely to be vulnerable to percolation and flow of groundwater contaminants from the oil facility. This is because the study area is located north of the operational base of the flow station and the fact that groundwater would generally flow from higher elevation to lower elevation in the direction of maximum change in elevation (Abam, 2004; Oborie and Nwankwoala, 2017).

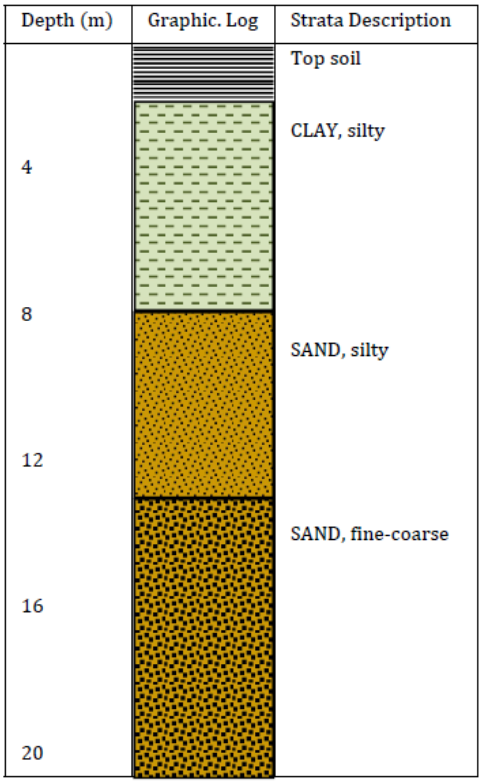


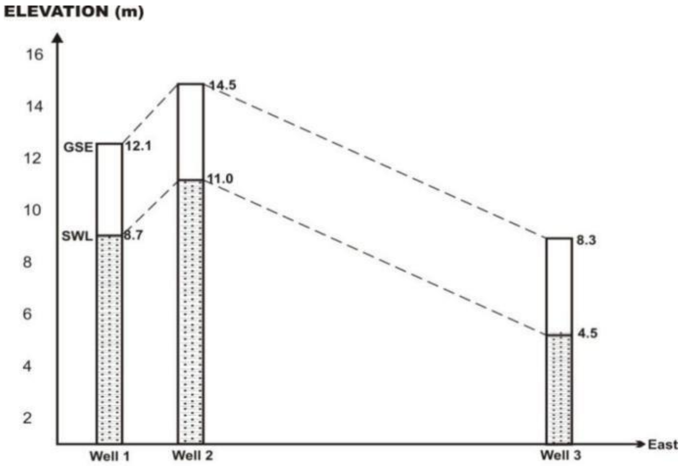
Fig 2: Litholog of monitoring well in the study area

Groundwater analysis

The concentrations of the various parameters analysed from the groundwater samples of are shown in table 4.1 below. The hydrogen ion concentration (pH) of the ground water samples were all slightly acidic but within the permissible limits for drinking water set by the Federal Ministry of Environment (FMENV) and Department of Petroleum Resources (DPR). The pH ranged from 6.5 (BH2) to 6.6 (BH1). Total Suspended Solids concentration in the three boreholes drilled were slightly higher than the FMENV limits. (13.0mg/l in BH2, and 11.1mg/l in BH 3).

Oil and Grease concentrations were below the detection limit of the analytical equipment. Polycyclic Aromatic Hydrocarbon (PAH), Benzene, Toluene, Ethyl benzene, and Xylene concentrations were below detection limits. Iron and copper were the two heavy metals that had significant values though the concentrations were within permissible limits. The concentrations of other heavy metals were below detectable limits.

International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 7, ISSN No. 2455-2143, Pages 285-291
Published Online November 2019 in IJEAST (http://www.ijeast.com)



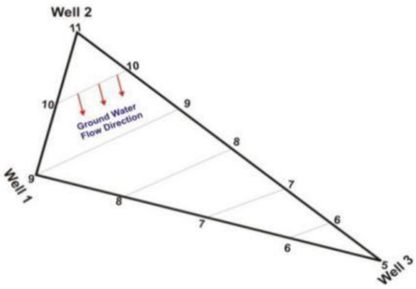


Fig 3: Direction of groundwater movement in study area

Physico-chemical characteristics of core samples.

Four core soil samples at varying depths (3m, 9m, 15m, and 20m, respectively) were collected from each of the monitoring boreholes and analyzed for their physico-chemical characteristics. Groundwater is susceptible to impact of the physical and chemical characteristics of soil strata overlying aquifer material. Contaminants can form plumes and be leached down subsurface materials thereby contaminating the underlying unconfined aquifer. Though soil attenuates itself of contaminants, underlying groundwater can still become contaminated when the appropriate soil chemical and biophysical conditions for the process are not present (USEPA 2004). The results of the physico-chemical characteristics of the core soil samples are shown in Table 2. Field and laboratory analytical results revealed that the core soils from the three monitoring boreholes drilled were acidic. The pH of the core samples ranged from 5.00-6.10. phosphorus, nitrate, sodium, and sulphate (nutrient elements) had moderate concentrations, except for zinc and iron that had significant concentrations; other heavy metals had very low concentrations, or were below detectable limits. Copper (0.00 -0.01meq/100g), nickel (0.00 -0.39meq/100g), barium (0.00-0.02meq/100g). Oil/Grease, PAH, and BTEX contents of the core soil samples were below detectable limits. Of all the heavy metals, relatively higher iron contents have been reported in soils of the Niger Delta (Andersen 1967).

2-D Geoelectric Profiling

The inverse modelled resistivity section generated from RES2DINV computer program (Figs. 4-6) shows the subsurface geology of the underground condition of the study area. The model uses a colour plot to indicate the vertical and horizontal variation in the subsurface resistivity layering. The inverse model resistivity section is generated from the calculated apparent resistivity pseudo-section, thereby giving an approximated true resistivity model of the subsurface.

The results showed variable resistivity values with depth below the surface. The higher resistivity (100-198 ohm-m) top layer indicates the unsaturated, brownish silty sands. Underlying this layer is an unsaturated clayey zone with relatively low resistivity value (26.3 - 57.6 ohm-m) down to a depth of about 7m. The resistivity is reduced by lower permeability in the clays and less water saturation. Below the clay zone is a layer of saturated silty-fine -coarse sands from about 7m to approximately 20m depth. The top clay materials protect the underground water system, thereby making the area less environmentally sensitive.

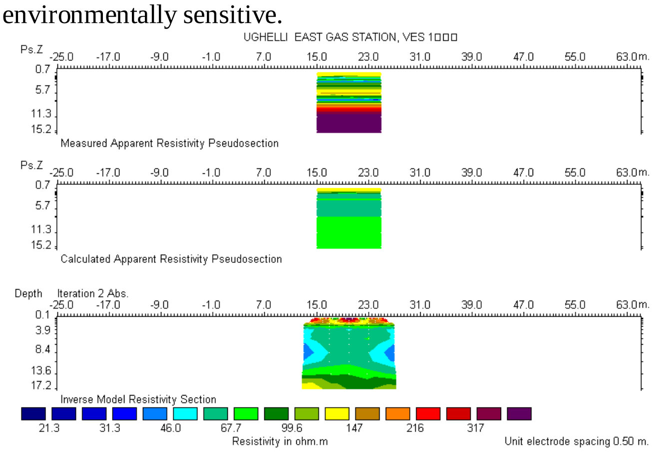


Fig. 4: Inverse model resistivity section across profile 1

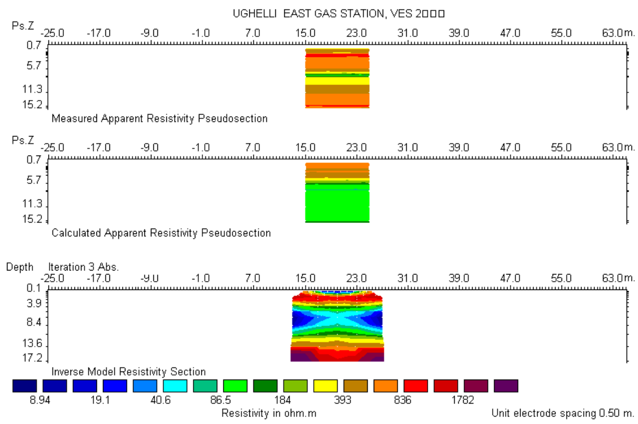


Fig 5: Inverse model resistivity section across profile 2

Table 1: Physicochemical characteristics of groundwater samples in study area

Parameter	**Borehole No.**			Maximum Permissible Limits DPR / FMENV/WHO	Parameter	Borehole No.			Maximum Permissible Limits DPR / FMENV/WHO
	Borehole 1	Borehole 2	Borehole 3			Borehole 1	Borehole 2	Borehole 3	
pH	6.6	6.5	6.5	6.5 – 8.5	Fe (ppm)	0.09	0.15	0.16	1.0
TSS (mg/L)	7.0	13.0	11.1	<10	Pb (ppm)	<0.01	<0.01	<0.01	0.05
TDS (mg/L)	9.13	9.57	10.00	500	Zn (ppm)	<0.01	0.01	0.01	5.0
DO (mg/L)	4.10	4.00	4.15	7.5	Cu (ppm)	<0.01	0.03	0.02	N.S
BOD_5 (mg/L)	3.96	3.86	3.59	0	Ba (ppm)	<0.01	<0.01	<0.01	N.S
Cl (Salinity) (ppm)	6.67	6.67	6.67	250	Cr (ppm)	<0.01	<0.01	<0.01	N.S
NO_3 (ppm)	0.68	0.49	0.46	10.0	Cd (ppm)	<0.01	<0.01	<0.01	N.S
SO_4 (ppm)	<0.01	<0.01	<0.01	500	V (ppm)	<0.01	<0.01	<0.01	0.01
PO_4 (ppm)	<0.01	0.60	0.01	<5.0	O&G (ppm)	<0.01	0.01	<0.01	0.05
HCO_3 (ppm)	8.78	12.69	12.69	200	PAH	0.03	0.01	0.01	N.S
Na (ppm)	1.90	4.10	3.34	200	Benzene	<0.01	<0.01	<0.01	N.S
Ca (ppm)	0.50	0.52	0.85	N/S	Toluene	<0.01	<0.01	<0.01	N.S
K (ppm)	0.11	0.53	1.00	N.S	Ethyl benzene	<0.01	<0.01	<0.01	N.S
		N.S – Not stated			Xylene	<0.01	<0.01	<0.01	N.S

International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 7, ISSN No. 2455-2143, Pages 252-254
Published Online November 2019 in IJEAST (http://www.ijeast.com)

Table 2: Physico-Chemical Characteristics of Borehole cuttings (Detection limit of analytical equipment = 0.01)

Parameters	Borehole 1				Borehole 2				Borehole3				Range
	3m	9m	15m	20m	3m	9m	15m	20m	3m	9m	15m	20m	
p^H (in H_20)	5.32	5.40	5.00	5.13	5.28	5.28	5.25	5.28	6.00	6.00	6.00	6.10	5.00-6.10
Av. P(meq/100g)	1.00	1.00	1.00	1.00	1.12	1.35	1.35	1.35	1.82	1.85	1.85	1.87	1.00-1.87
NO_3^{2-} (meq/100g)	2.13	2.11	2.31	2.40	2.01	2.00	2.10	2.10	2.11	2.11	2.00	2.11	2.00-2.40
SO_4^{2-}(meq/100g)	1.52	1.60	2.00	2.00	1.65	1.63	1.63	1.63	1.42	1.42	1.43	1.45	1.42-2.00
K (meq/100g)	4.13	4.00	4.00	4.26	4.29	4.30	4.29	4.29	4.85	4.88	4.71	4.70	4.00-4.88
Fe(meq/100g)	25.75	26.10	20.10	20.13	18.35	18.35	19.31	19.00	25.36	25.18	25.18	25.19	18.35-26.10
Cu (meq/100g)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NI^+(Meq/100g)	<0.01	0.39	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.02	0.00-0.39
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	1.27	1.31	1.86	1.85	1.86	1.37	1.37	1.42	2.00	2.00	2.00	2.00	1.27-2.00
Cr (meq/100g)	<0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00-0.01
Ba (meq/100g)	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00-0.02
O/G(meq/100g)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PAH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Toluene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ethylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Xylene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Toluene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 7, ISSN No. 2455-2143, Pages 252-254
Published Online November 2019 in IJEAST (http://www.ijeast.com)

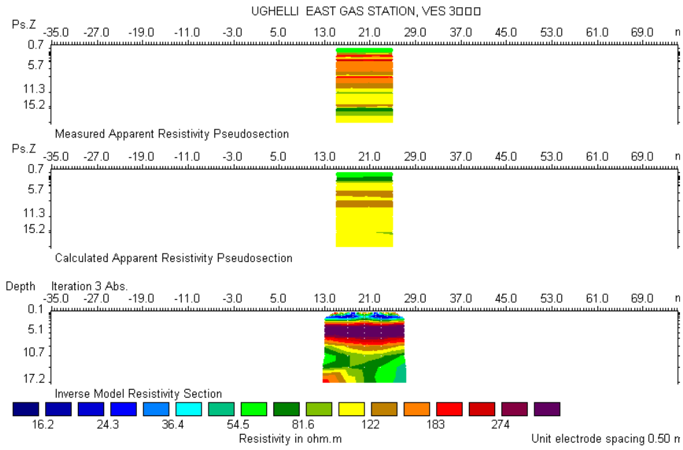


Fig. 6: Inverse model resistivity section across profile 3

V. CONCLUSION

The subsurface materials in the study area are mainly clays from of the existing ground level to a depth of about 7m. The clay unit is overlain by a thin layer of silty topsoil. Below the clay unit, the soil materials have higher proportions of silt and sand fractions. The top of the aquifer zone is encountered at a depth of about 7m from the ground surface. medium - coarse sands (permeable) dominate the aquifer from a depth of about 13-20 m. The aquifer in the study area is unconfined and groundwater is generally recharged by precipitation.

Concentrations of physicochemical parameters in the ground water and aquifer sediments were generally within the permissible limits outlined by the Federal Ministry of Environment, and Department of Petroleum Resources. The quality of the ground water in its present state therefore does not constitute any health risk to people within and around the hydrocarbon production facility.

The subsurface geoelectric models for the study area were similar in the 3 borehole locations. Resistivity values of the subsurface geology decreased with increasing depth to the aquifer. Groundwater movement was in a north-west - south-east direction which is favourable for the study community as it is located north of the operational of the oil facility.

Though the study has revealed that the present groundwater of the investigated area is not contaminated as the parameters analysed are within regulatory standards, safe operational practices for environmental safeguard and regulatory requirements should continuously be upheld. Upholding these policies and requirements will ensure that the groundwater quality of operational areas of oil and gas companies is within acceptable limits. Consequently the status of the ground water within and around hydrocarbon facilities should be periodically monitored to ascertain potable quality.

VI. REFERENCES

1) Abam, T.K.S. (2004). Geohydrology : With Applications To Environmental Management. Pp57-79

2) Allen, J. P., Atekwana, E. A., Duris, J. W., Werkema, D. D., and Rossbach, S., (2007). The microbial community structure in petroleum-contaminated sediments corresponds to geophysical signatures. Applied and Environmental Microbiology, 73(9), 2860–2870.

3) Andersen B. (1967). Report on the Soil of the Niger Delta Special Area. Niger Delta Development Board.

4) Cratchley, C.R and G.P Jones (1965). An Interpretation of the Geology and Gravity Anomalies of the Benue Valley, Nigeria. Overseas Geological Survey.

5) Dailly, G. C (1976). Pendulum Effect and Niger Delta Profilic Belt. AAPG Bull.Vol. 60

6) Department of Petroleum Resources. (2004). Environmental Guidelines and Standards for the Petroleum Industry in Nigeria.

7) Federal Environmental Protection Agency (1991). National Guidelines and Standards for Industrial Effluents, Gaseous Emissions and Hazardous Waste Management in Nigeria.

8) Niger Delta Environmental Survey (1996). The Geology Geomorphology, Soils and Geography of the Niger Delta.

9) Oborie, E. and Nwankwoala HO. (2017). Determination of Groundwater Flow Direction in Yenagoa, Bayelsa State, Nigeria. Journal of Scientific Achievements, 2 (9): 23-27.

10) Sauck W.A., (2000). A model for the resistivity structure of LNAPL plumes and their environs in sandy sediments, Journal of Applied Geophysics 44, pp. 151-165.

11) Short, K.C and Stauble (1967). Outline of Geology of Niger Delta. AAPG. Bull. Vol. 51.

12) The Daily Independent (2010). Shell and the N15 billion oil spill judgement.

13) United States Environmental Protection Agency: (1994) Groundwater and Wellhead Protection

IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

ABOUT IJEAST

International Journal of Engineering Applied Science and Technology (IJEAST) is a peer-reviewed, open access journal that publishes high-quality research papers in the field of Engineering, Applied Science and Technology.

IJEAST aims to provide a platform for researchers, academicians, and professionals to share their innovative ideas, research findings, and practical experiences with the global scientific community.

FOCUS AREAS

- Engineering
- Applied Science
- Technology
- Innovation & Development
- Interdisciplinary Studies

PEER REVIEWED
All submissions are rigorously peer reviewed to ensure quality.

OPEN ACCESS
Free and unrestricted access to research for all.

GLOBAL REACH
Connecting researchers and professionals worldwide.

TIMELY PUBLICATION
We ensure a swift and efficient publication process.

For more information, visit our website
www.ijeast.com

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

editor@ijeast.com
www.ijeast.com
India

2455-2143