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Original Research Paper

Environmental Geological Baseline Study of Obite Gas Plant, Eastern Niger Delta, Nigeria

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ABSTRACT

In this study, a total of six (6) boreholes were sunk with rotary drilling equipment to depths of about 60 ft (about 18.30m) for BH1, BH2 and BH3. Boreholes 4, 5 and 6 were drilled to 13.60m, 12.60m and 12.20m, respectively. The measured static water levels fall between 4.45m, 3.75m, 0.94m, 6.30m, 6.10m and 6.20m for BH 1, BH 2, BH 3, BH 4, BH 5 and BH 6, respectively. All the boreholes are overlain by a reddish brown, fine grained, silty clay overburden of 3.00m to 4.60m in thickness. This is followed by a thinner stratum of dark brown, fine-medium grained, clayey sand in BH4 and BH5, which is absent in BH6. Another layer of silty clay underlies this formation in both the boreholes with a 0.9m thickness of clayey sand in BH4 preceding the sand and gravelly sand aquifer. There is less measure of uniformity in lithostratigraphic correlation between BH6 and the other two boreholes located within proximate vicinity. Below the overlying silty clay soil, BH6 records a rhythmic succession of loose sand and medium to very coarse, and moderately plastic, gravelly silty clay intercalations, before the aquifer (gravelly sand) is encountered. With respect to the area, the subsurface drainage pattern is multi-directional from north-east to the south-west and vice versa, with the migration being more inclined west-wards towards the location of BH3, which records the lowest depth to water table. Leachates introduced at a given point in the area will migrate as pollution plumes along these flow paths.

INTRODUCTION

The uncertainties associated with soil and water degradation caused by pollution and hydrological impacts requires improved hydro-geotechnical data analysis in order to determine local groundwater flow direction and how pollutants reaching groundwater migrates along the flow paths (Rodriguez 2006, Hasfurther & Turner 2008, Nwankwoala et al. 2009).

Obite Gas Plant lies on the Sombreiro-Warri deltaic environment of the Nigerian coastline in the Niger Delta area which is ecologically sensitive. The dense network of rivers and creeks in the area ensures that within the saltwater mangrove swamps, there are small islands with limited area with low ground elevation and shallow depth to groundwater. The water table is also permanently at or near the ground surface. This is mainly influenced in the same way as surface waters, hence the prevailing hydrostatic relationship between the ground and surface water in the area tends to be hydrodynamic.

In the study area, efforts have been made in understanding the engineering and geo-environmental properties of the shallow subsurface soils, which affect production facilities, waste management facilities, etc. that are directly or indirectly related to the oil and gas industry. Therefore, assessment of subsoil characteristics, water level determination and hydro-geological investigations becomes imperative. The impact of recharge and discharge as a measure of the aquifer vulnerability and its temporal dynamics, the contaminant degradation and *in-situ* biodegradation rates and detection of effects by short-term contaminant impacts (if any) can only be corrected through regular geo-environmental monitoring. This study provides environmental impact assessment to guide future development in the area.

GEOMORPHOLOGY AND GEOLOGY OF THE AREA

The geomorphologic setting of the study area is flat to sub-horizontal as it slopes very gently seawards. It lies within the Quaternary Sombriero-Warri deltaic plain with prominent seasonal freshwater swamp, which overlies the Tertiary Benin Formation of the coastal plain sand. This region is made up of variable deltaic sediments of moderate to highly plastic clays that usually occur in the backswamps linking river channels, to sands and cohesive silty and clayey soils that are partly permeable. The thriving freshwater vegetation is characteristic of a tropical rain forest with tall trees and grass undergrowth.

Geologically, the study area is characterized by the Niger Delta sedimentary rocks. Lithostratigraphically, these rocks

Table 1: Quaternary deposits of the Niger Delta (after Etu-Efeotor & Akpokodje 1990).

Geologic Unit	Lithology	Age
Alluvium	Gravel, sand, clay, silt	
Freshwater backswamp, meander belt	Sand, clay, some silt, gravel	
Saltwater mangrove swamp and backswamp	Medium-fine sands, clay and some silt	Quaternary
Active/abandoned beach ridges	Sand, clay, and some silt	
Sombreiro-warri deltaic plain	Sand, clay, and some silt	

are divided into the oldest Akata Formation (Paleocene), the Agbada Formation (Eocene) and the Youngest Benin Formation (Miocene to Recent). Generally, the present knowledge of the geology of the Niger Delta was derived from the works of Reyment (1965), Short & Stauble (1967), Murat (1970) and Merki (1970) as well as the exploration activities of the oil and gas companies in Nigeria. The formation of the so called proto-Niger Delta occurred during the second depositional cycle (Campanian-Maastrichtian) of the southern Nigerian basin. However, the modern Niger Delta was formed during the third and last depositional cycle of the southern Nigerian basin which started in the Paleocene.

The geologic sequence of the Niger Delta consists of three main Tertiary subsurface lithostratigraphic units (Short & Stauble 1967) which are overlain by various types of Quaternary deposits (Table 1).

Hydrogeologically, the major aquiferous formation in the study area is the Benin Formation. It is about 2100m thick at the basin centre and consists of coarse-medium grained sandstones, thick shales and gravels. The upper section of the Benin Formation is the quaternary deposits which is about 40-150m thick and comprises of sand and silt/clay with the later becoming increasingly more prominent seawards (Etu-Efeotor & Akpokodje 1990). The formation consists of predominantly freshwater continental friable sands and gravel that have excellent aquifer properties with occasional intercalations of claystone/shales (Olobaniyi & Owoyemi 2006). According to Etu-Efeotor (1981), Etu-Efeotor & Akpokodje (1990), Offodile (2002) and Udom et al. (2002), the Benin Formation is highly permeable, prolific, productive and is the most extensively tapped aquifer in the Niger Delta. All the boreholes in the study area are drilled into it. The Benin Formation consists of fluvial and lacustrine deposits whose thicknesses are variable but generally exceed 1970 meters (Asseez 1989). The lithologies of the Benin Formation include sands, silts, gravel and clayey intercalations. The sands are fine to coarse-grained, gravelly, poorly sorted and subangular to well rounded.

According to Onyeagocha (1980), the rocks of the Benin Formation are made up of about 95-99% quartz grains, Na + K-Mica 1-2.5%, feldspar 0.5 1.0% and dark minerals 2.3%. These minerals are loosely bound by calcite and silica cement. The clayey intercalations have given rise to multi-aquifer systems in the area. The main source of recharge is through direct precipitation where annual rainfall is as high as 2000-2400mm. The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers. Groundwater in the study area occurs principally under water table conditions. Multi-aquifer systems occur in the study area and the upper aquifers are generally unconfined (Etu-Efeotor 1981, Offodile 2002, Edet 1993, Udom 2004).

MATERIALS AND METHODS

Six (6) boreholes were sunk with rotary drilling equipment to depths of about 60 ft (about 18.30m) each. The wells were cased with PVC plastic casings, which were slotted at pay zones from 45-55 ft in each borehole. BH 4, BH 5 and BH 6 were sunk to maximum depths of 13.60m, 11.60m and 12.20m, respectively. The measured static water levels in the boreholes and 4.45m, 3.75m, 0.94m, 6.30m, 6.10m and 6.20m for BH1, BH 2, BH 3, BH 4, BH 5 and BH 6, respectively. The details of the boreholes are provided in Table 2.

The wells were screened at the aquifer depth, cased with poly vinyl chloride (PVC) plastic pipes, gravel packed and capped, with bases also cemented, which were all done to prevent well collapse and groundwater contamination.

RESULTS AND DISCUSSION

Soil Stratigraphy: The ground elevation and the stratigraphic correlations of the boreholes are depicted in Figs. 1 and 2. All boreholes are overlain by a reddish brown, fine grained, silty clay overburden of 3.00m to 4.60m in thickness. This is followed by a thinner stratum of dark brown, fine-medium grained, clayey sand in BH4 and BH5, which is absent in BH6. Another layer of silty clay underlies this formation in both boreholes, with a 0.9m thickness of clayey sand in BH4 preceding the sand and gravelly sand aquifer. There is less measure of uniformity in lithostratigraphic correlation between BH6 and the other two boreholes located within proximate vicinity (Fig. 2). Below the overlying silty clay soil, BH6 records a rhythmic succession of loose sand and medium to very coarse, and moderately

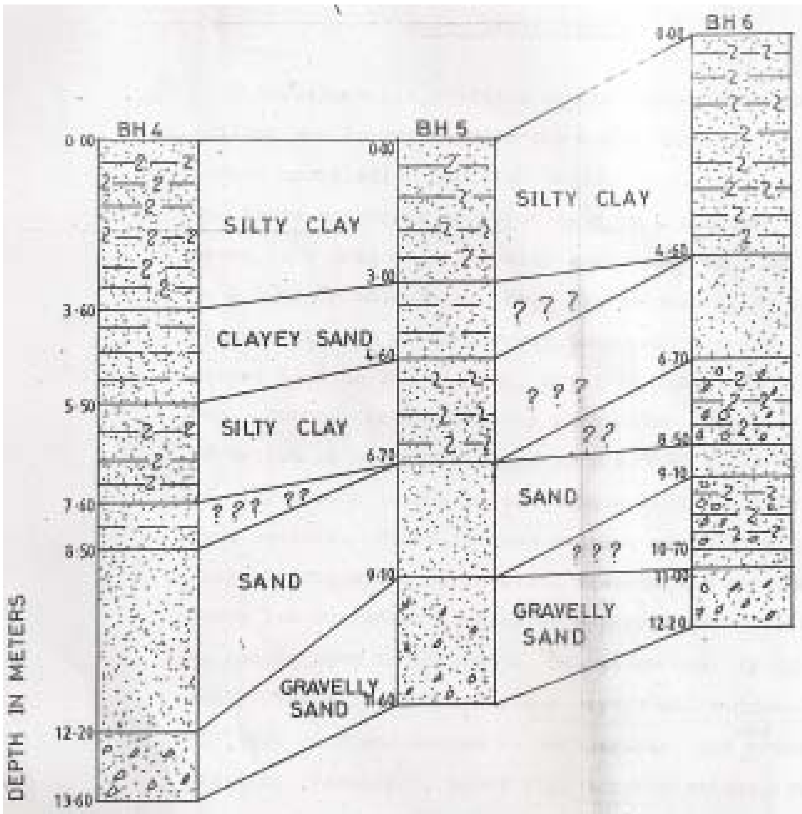

Fig. 1: Ground elevation of borehole lithostratigraphic units.

plastic, gravelly silty clay intercalations, before the aquifer (gravelly sand) is encountered.

Hydrological Conditions: The stratigraphic synopsis of the six (6) boreholes drilled in the area reveal an overburden of aquitards overlying the aquifer. This means that a degree of vertical groundwater (and possibly pollutants) flow into the aquifer is expected (Boonstra 1989). However, such groundwater (and pollutants) movement into the aquifer will be slow over a period because of the generally fine-grained and hence expectedly low permeable nature of the soil deposits. The silty clay materials found in the upper layers of the boreholes (except in BH2) will more effectively restrict flow into the saturated zone. Factors that control infiltration rate include soil type and cover, surface texture, limiting slope value, initial moisture content of soil, and rainfall intensity.

Fig. 3 shows the contour map of the piezometric surface in the area. Flow lines, sketched perpendicular to the contours of the static water levels in the boreholes (Todd 1980) indicate the direction of horizontal movement in the aquifer. Groundwater flows perpendicular to the direction of decreasing head that is from areas of recharge to points of discharge as streams, springs and wells. With respect to the area, the subsurface drainage pattern is multi-directional from north-east to the south-west and vice versa, with the migration being more inclined west-wards towards the location of BH3, which records the lowest depth to water table. Leachates

Table 2: Borehole and groundwater data in the study area.

BH Number	BH Depth (m)	Static Water Level (m)	Ground Elevation (m)	Groundwater Elevation (Hydraulic Head)
BH 1	18.30	4.45	12.27	7.82
BH 2	18.30	3.75	11.20	7.45
BH 3	18.30	0.94	12.03	11.09
BH 4	13.60	6.30	-	-
BH 5	11.60	6.10	-	-
BH 6	12.20	6.20	-	-

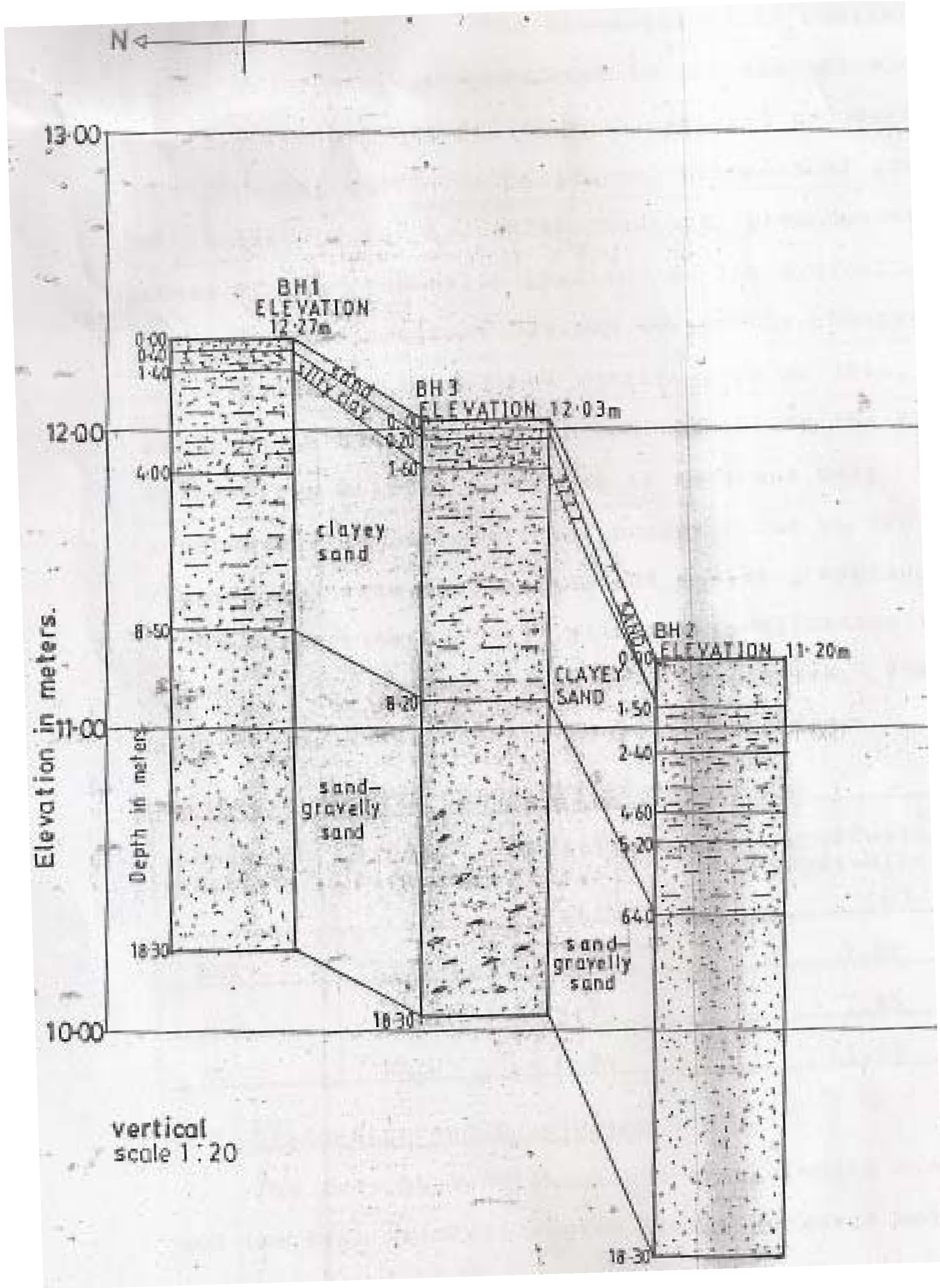

Fig. 2: Stratigraphic correlation of boreholes located at southern wing of the study site.

introduced at a given point in the area will migrate as pollution plumes along these flow paths.

CONCLUSION

This study has revealed that the boreholes are overlain by a reddish brown, fine grained, silty clay overburden of 3.00m to 4.60m in thickness, which is followed by a thinner stratum of dark brown, fine-medium grained, clayey sand in BH4 and BH5, which is absent in BH6. Underlying this formation is a layer of silty clay in both boreholes, with a 0.9m thickness of clayey sand in BH4 preceding the sand and gravelly sand aquifer. There is less measure of uniformity in

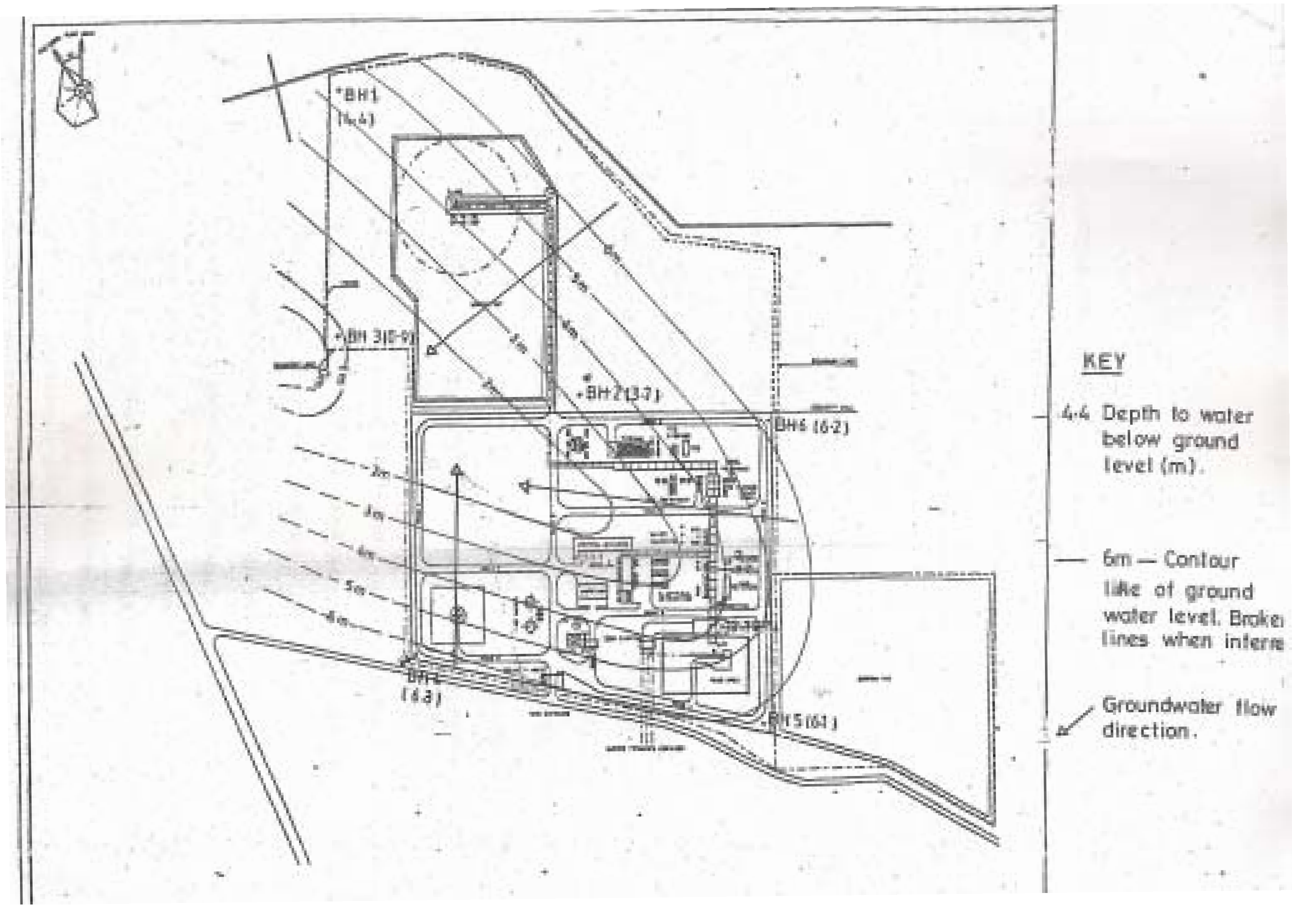

Fig. 3: Groundwater level map of Obite Gas Plant site.

lithostratigraphic correlation between BH6 and the other two boreholes located within proximate vicinity. Below the overlying silty clay soil, BH6 records a rhythmic succession of loose sand and medium to very coarse and moderately plastic, gravelly silty clay intercalations, before the aquifer.

Groundwater flows perpendicular to the direction of decreasing head to points of discharge as streams, springs and wells. With respect to the area, the subsurface drainage pattern is multi-directional from north-east to the south-west and *vice versa*, with the migration being more inclined westwards towards the location of BH3, which records the lowest depth to water table. Leachates introduced at a given point in the area will migrate as pollution plumes along these flow paths.

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