(RESEARCH ARTICLE)

Geophysical investigation of the effects of waste dump on groundwater quality in Rukpokwu, Port Harcourt Metropolis

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Abstract

Vertical Electrical Sounding (VES) was carried out in Rukpokwu, Obio/Akpor Local Government Area, Rivers State, Nigeria to investigate the effect of waste dump on groundwater quality in the study area. An ABEM SAS 300 terrameter was used. Schlumberger configuration was adopted for the sounding to acquire a 4 point data, and at Rukpokwu adjudged to be free from waste dumps which served as control. The result of the resistivity survey was interpreted by IPI2WIN computer software, revealing the subsurface lithology, thickness of lithology, prolific auriferous zones, curve types and zones of contamination. The Niger Delta has a shallow water table which makes it prone to easy contamination. Different resistivity values were obtained; high resistivity values are an indication of uncontaminated subsurface lithologic zones while low resistivity values are an indication of contaminated subsurface lithologic zones as a result of dissolved ions and metals from waste dumps decomposing through biochemical reactions, hydrolysis, oxidation and reduction processes which subsequently leads to the formation of leachate. This leachate is in hydraulic continuity with groundwater flow which eventually leads to groundwater contamination. Therefore a geophysical survey is essential and necessary before a borehole drilling project is carried out in order to ascertain the depth to prolific aquifer which will give potable water free from contamination.

Keywords: Geophysical investigation; Resistivity; Waste Dump; Groundwater; Rukpokwu; Rivers State

1. Introduction

Waste (industrial and domestic) has been defined as useless unwanted materials which arise from human activities and are not free flowing[1].Wastes when well managed could be harnessed into a profitable channel for mankind but then poor management of solid waste has resulted to a lot of disastrous effects such as groundwater contamination. Waste dump sites have become one of the major environmental problems in most Nigerian cities; for instance Port Harcourt.The importance of groundwater as a valuable source of portable water cannot be over emphasized. Groundwater forms the most important natural resources of any region and compliments surface sources in the provision of portable water for domestic and industrial applications. The continuous contamination of groundwater gradually leads to its pollution. Ground water pollution may occur due to the contamination of leachate from waste dump [2].Ground water provides a medium through which wastes mostly organics can undergo degradation into simpler forms through biochemical reactions involving dissolution, oxidation, and reduction processes. These wastes being organic have organic carbon present in them largely in the form of fulvic acids [3] which migrate downward and contaminate the groundwater. During the peak of the rainy season, dumpsites are covered by flood water and this contributes to the formation of leachate. It is this leachate that forms a "plume" that moves outwards and downwards into the surrounding and underlying aquifers [4].

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In groundwater investigations, groundwater contamination challenge has been overcome by utilizing geophysical technique prior to the drilling of boreholes for groundwater extractions. Geoelectric method has been found very suitable for this kind of environmental study. This is due to the fact that generally, ionic concentration of leachate is much higher than that of groundwater and so when the leachate enters the aquifer, it results in a large contrast in electrical properties and this method helps in identifying these zones as an anomaly which enables the leachate plume to be detected.The electrical resistivity method (DC method) particularly vertical electrical sounding (VES) serves as the cheap and fastest means for groundwater studies. This research therefore adopts the use of vertical electrical sounding (VES).The aim of this study is to determine the effect of waste dump on groundwater quality in the study area using a geophysical method, electrical resistivity, vertical electrical sounding (VES).

2. Location and Geology of the Study Area

2.1. Description of the Studied Area

The study area is a major Nigerian Upstream Regulatory Commission (NURC) formerly Department of Petroleum Resources (DPR) approved dumpsite located in Obio-Akpor Local Government Area, along the international Airport Road, Port Harcourt, Rivers State Nigeria.It is accessible through the International Airport Road, Obio-Akpor Local Government Area. There's a DPR signpost serving as a landmark.

Figure 1 Map of the studied area

2.2. Relief and Drainage

The relief of the area is quite low; the land surface of the area is generally less than 20m above sea level.

2.3. Climate and Vegetation

The studied area, experiences a tropical climate characterized by two distinct seasons; the wet season (April to mid-August, September to mid-November) and dry season (November till March) usually with sparse rainfall in-between [5]. The rainfall exhibits a double maxima regime with peaks in July and September, with a little dry season in August. In the dry season, high evapotranspiration rate induced by dry conditions helps to increase water losses in the region [6].The vegetation of the Niger Delta is classified into 2 main regions namely; The swamp forest region and the rainforest region, The swamp forest is further subdivided into two (2) fresh water and salt water swamp which divides the Niger Delta into these vegetation regions. The characteristic vegetation of the salt water swamp forest is the presence of mangrove trees in its varieties. The secondary forest on the other hand represents the vegetation type derived from other activities that combined to degrade the original forest vegetation.

2.4. Hydrogeology of the Study Area

The studied area falls within the Benin Formation. The formation has been identified as fresh water bearing sand;[7][8] and all aquifers in the deltaic region occurs within this lithostratigraphic unit. [9]Have been able to identify five aquifer horizons in the Niger Delta.

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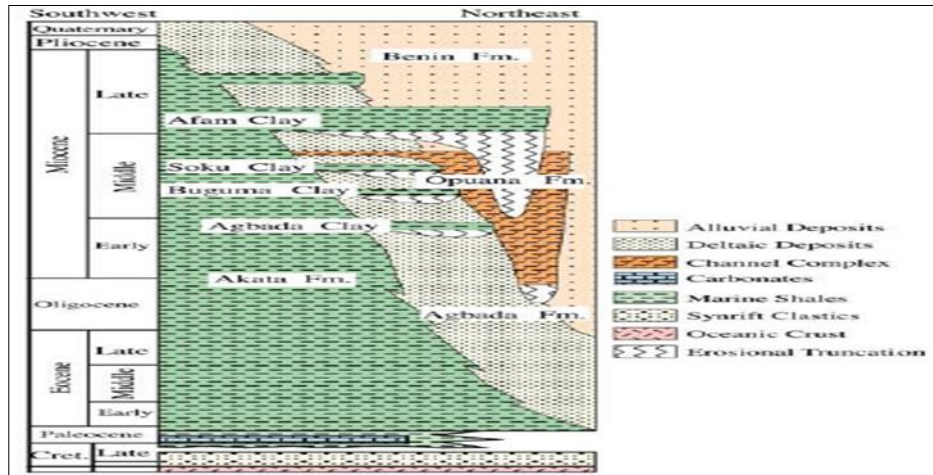

Figure 2 Stratigraphic Column of Niger Delta Formations [11]

The Niger Delta consists of three stratigraphic units; the base of the Delta is the Akata Formation (Paleocene-Eocene) which consists of marine shales and silts. The Agbada Formation (Eocene-Oligocene) overlies the Akata Formation and is made up of paralic sequence consisting of sands and shales. Their lateral equivalents at the surface are the Ogwashi-Asaba Formation and Ameki Formation of Eocene-Oligocene age ([7], [12]. Above the Agbada Formation is the Benin Formation (Oligocene-Recent) which comprises of continental/fluvial sand sand gravels. The Benin Formation is however overlain by the QuatenarySombreiro-Warri Deltaic Plain Deposits which are 40 - 150 m thick, an unconfinedaquifer sequence comprising rapidly alternating sequences of sand and silt/clay, with the latter becoming increasingly prominent seawards, are thought to have been laid down during the Quaternary interglacial marine transgression[13];[14];[9]. The hydraulic conductivity of the sands varies from 3.8 x 10-3 m/s to 9x10-2 m/s which indicates potentially productive aquifer[15].
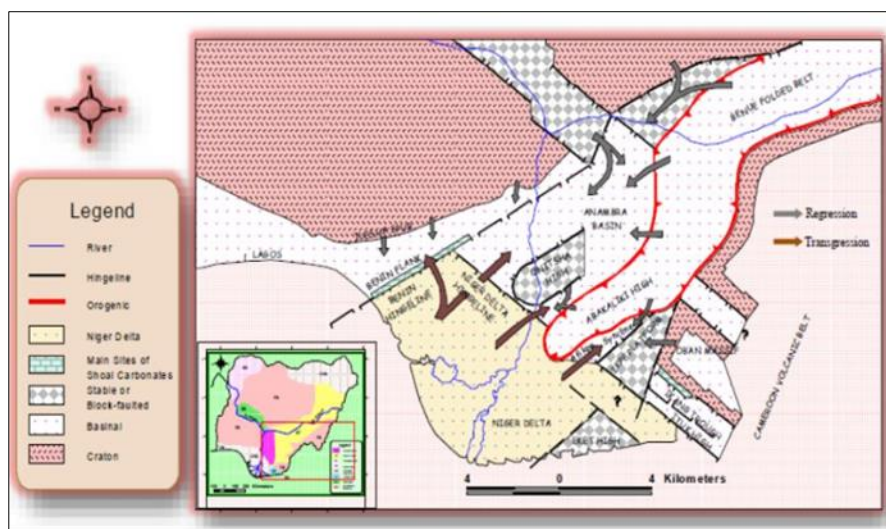

Figure 3 Tectonic Map Showing the Niger Delta (Modified after Kogbe, 1989)

3. Materials and methods

3.1. Surface Investigation

Four (4) dc-resistivity vertical electrical sounding (VES) soundings were run in Schlumberger array with an ABEM SAS 300 model Terrameter using current electrode spacing (AB) ranging from 2m - 300m. Three points was acquired around the dumpsite (NURC formerly DPR Approved dumpsite) while the fourth point, was approximately 2km metres away from the Dumpsite. First point was around an excavated part the dumpsite (burrow pit), second point was around a stagnant body of filthy water (leachate) and the third point was very close to Dump, where fresh dumps were being deposited on the already existing dump while the survey was been carried out. The fourth VES was carried out 2km away from the dump site adjudged to be free from contamination. The current electrode (C1C2) is moved outward symmetrically, keeping (P1P2) fixed at the centre. The adopted configuration entails not moving the potential electrode until the potential difference becomes too small to be measured accurately. The initial interpretation of the VES data was accomplished using conventional partial curve matching techniques utilizing two-layer master curves [16] and their corresponding auxiliary point diagrams [17]. The resistivities and thicknesses obtained were used in a computer programme for refining the partial curve matching interpretative results which reduced errors to acceptable levels [18]. The programme, win Resist version 1.0 based on the work of [19] was used.
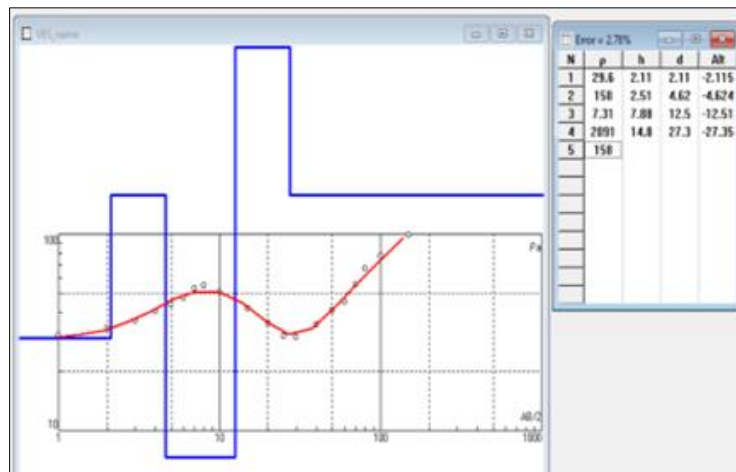

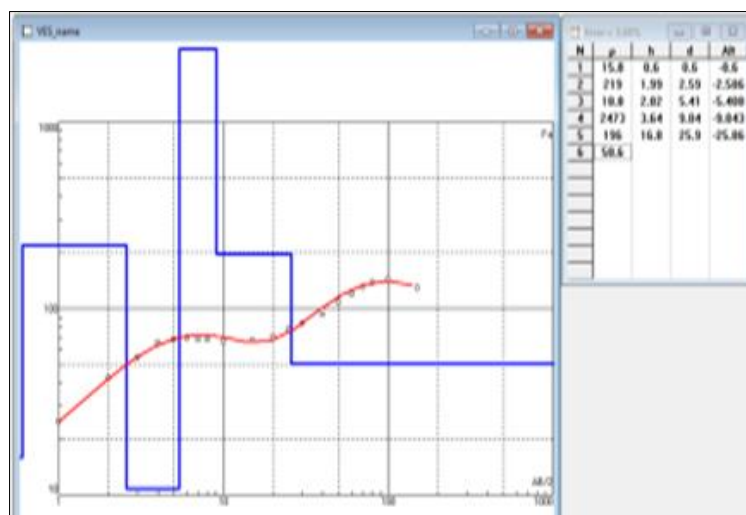**Figure 4** Typical VES curves for the studied area location 1

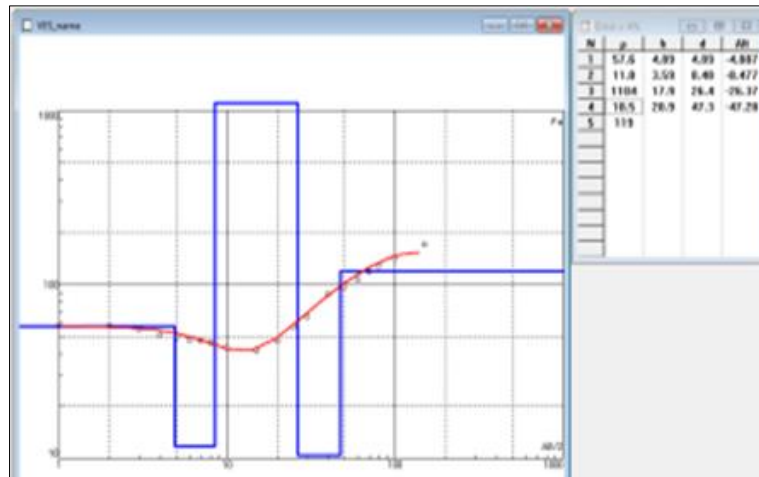**Figure 5** Typical VES curves for the studied area location 2

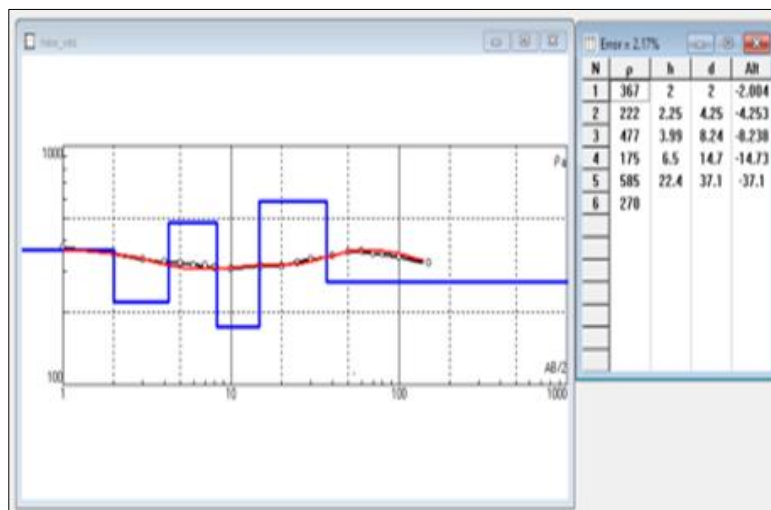**Figure 6** Typical VES curves for the studied area location 3

Figure 7 Typical VES curves for the studied area location 4

4. Results and discussion

The depth sounding curves (figure 4, 5, 6 & 7) shows that there are 4 layers and 5 layers of the subsurface materials with different resistivity values respectively. Resistivity values from VES 1 to VES 4 vary with progressive electrode spacing (current and potential electrode). The low resistivity values of 7.31Ωm, 10.8Ωm,11.8Ωm from VES 1, VES 2 and VES 3 indicates that the layers associated with these values is polluted,[20]. This is as a result of leachate plumes reacting with ground water in the subsurface. Leachates usually contain biological and chemical constituents. Organic matter decomposing under aerobic condition produces carbon dioxide which acts with leaching water to form carbonic acid $CO_2 + H_2O$ -------H_2CO_3. This in turn acts upon metals in the refuse and other calcareous materials in the soils and rocks resulting in increasing hardness and conductivity of contaminated water [21].The depth and thickness of the fourth layer of VES 1, the fifth layer of VES 2, the fourth layer of VES 3, with resistivity values of 158Ωm, 50Ωm, and 119Ωm respectively could not possibly be reached, occurring after depths of 27.3m, 25.90m, and 47.3m and as such suspected to be a fresh water uncontaminated layer. VES 4 which serves as control and adjudged to be from waste has its highest resistivity value to be 585.00Ωm at the fifth layer, is also suspected to be a fresh water zone, with respect to the high resistivity value invariably implying low conductivity of the fifth layer. The fourth, third and fourth layer of VES 1, VES 2 and VES 3 at the dumpsite is polluted due to their low resistivity values.
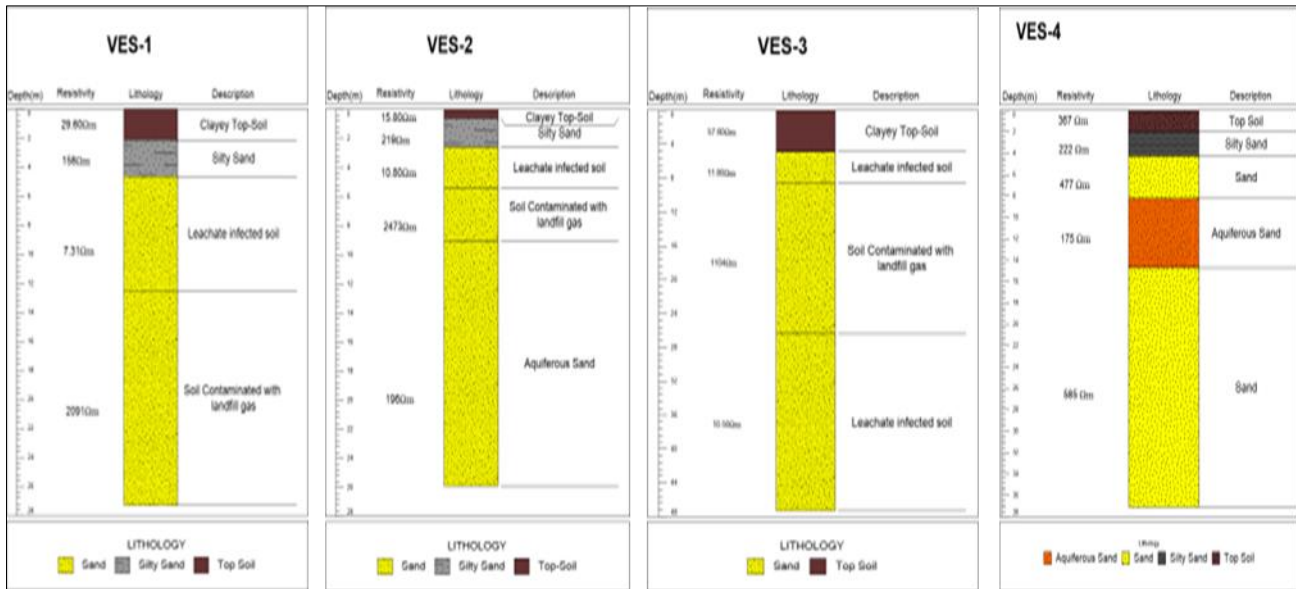
Figure 8, 9, 10 & 11 Geoelectrical section of ves1, 2, 3, 4 respectively

5. Conclusion

A surface and subsurface resistivity survey was carried out with the aim of evaluating the effect of waste dump on groundwater potential and its quality. The surface study revealed four and five geoelectric layers. The geoelectical sections VES 1 and VES 3 revealed 4 layers respectively in which leachate infected soil and soil contaminated with landfill were in the third layers of VES 1 (at the average depth of 7.31m) and fourth layers (at the average depth of 2091m) respectively while leachates infected soil and soil contaminated with landfill were on the second layer of VES 3(at the average depth of 11.80m) and in the third layers(at the average depth of 11.04m) respectively. Interpretation of geoelectric sounding of refuse dumpsite has yielded information on groundwater contamination as indicated by the values of subsurface resistivity and thickness. The essence of this study is to show that boreholes sited at these areas are likely contaminated and therefore to access potable water in this area, a geophysical data is highly recommended. Geolectrical resistivity sounding method has been no doubt helpful in the detection of groundwater contamination within the study area and as such serves as a very useful tool in groundwater studies, therefore before any drilling project is done, a geophysical resistivity assessment of the area needs to be carried out in order to ascertain water quality in the environment as this would serve as a guide for the success of drilling potable and sustainable water supply.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors declares that there is no conflict of interest.

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