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Geophysical assessment for contaminant hydrology in Ujevwu, Nigeria

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ABSTRACT

Indiscriminate dumping of both domestic and industrial waste has been increasing since the beginning of the exploration and exploitation of hydrocarbon in the Niger Delta area of Nigeria and has impacted the groundwater quality. Therefore, this study seeks to evaluate contaminant hydrology from dumpsite around Ujevwu area in relation to a Control site. Three Electrical methods, which include the spontaneous potential, dipole-dipole and the vertical electrical sounding were adopted. Also laboratory water analysis and groundwater/contaminant modelling using VISTA, version 4 were used to evaluate groundwater quality and flow direction/velocity. The low values of 11–515 Ωm and 10 to −160 mV for resistivity and spontaneous potential respectively around the dumpsite area to a depth of about 20 m is a reflection of the redox phenomenon occurring at depth in the contaminated groundwater. Hydrogeochemical parameters from water analysis showed values that are higher around the dumpsites when compared to the control site. Results for conductivity, lead and total viable bacteria count are higher than the permissible limits of the World Health Organisation (WHO) and they range from 380 to 440 μs/cm, 0.2–0.3 mg/l and 4.2–15.8 cfu/mL respectively. The steady state groundwater distribution model of the dumpsite and control site gives an approximate head gradient of about 0.00036 and 0.0007 respectively, and the flow direction in the south west. It is observed that the water level indicates that there is no significant change of the hydraulic gradient with time and therefore, the groundwater flow is assumed to be in steady state with the flow direction in the NE-SW, and a flow rate of 0.0093 m/d or 3.3 m/year, and 0.0197 m/d or 7.0 m/year respectively. From these results, immediate evacuation of the dumps in the area and remediation program should be carried out, as there is a risk of outbreak of water borne diseases in the area.

1. Introduction

Indiscriminate disposal and improper management of domestic and industrial waste in Nigeria has resulted in severe ecological, environmental and health challenges (Kadafa et al., 2013). Many of the municipal waste disposal sites are open and leachate generated as a result of the oxidation and reduction reactions is heavily contaminated with materials that are difficult to deal with when they percolate into groundwater (Ofomola, 2015; Mohammad et al., 2010; Susu and Salami, 2011; Mohajeri et al., 2010; Foul et al., 2009; and Daud et al., 2009). The concentration of the contaminant at any point may vary throughout the year as a result of seasonal influences on recharge, release and reaction times of the contaminant (Jegede et al., 2011). Factors that influence the leachate composition are many and they include; the type of waste deposited, hydrology of the site, age of the dumpsite, and where available, the site design and type of liner used (Rafizul et al., 2011; Kouzeli-Katsiri et al., 1999). Geophysical methods are non-destructive techniques and can be employed for a variety of purposes in groundwater contamination evaluations. Geologic characterisation of the site can be determined and this include assessing the types and strata thicknesses as well as the topography of the bedrock underneath the unconsolidated material, determination of aquifer properties and vulnerability and also identification of contaminant plumes (Russell Boulding and Eastern research group, 1993). Integrated application of geophysical methods offer a vital tool in the description and evaluation of contaminants generated by indiscriminate disposal of wastes (Green et al., 1999; Orlando and Marchesi, 2001). Electrical methods have been found very suitable for such kind of environmental study, owing to the conductive nature of most contaminants. The methods give contrasting

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signature in the contaminated environment and this application is well documented (Bernstone et al., 2000; Aristodemou and Thomas-Betts, 2000). The Ujevwu dumpsites is over 12 years old and because the underlying rocks have high porosity and permeability, there is a possibility of existence of leachate plumes and contamination of groundwater in the area (Ofomola et al., 2016). Therefore, this study is aimed at mapping the existence of leachate plumes and possible contamination of groundwater from dumpsites in the area using electrical resistivity, spontaneous potential and hydrogeochemical methods. This is with a bid to determining the aquifer geoelectric parameters in relation to leachate contamination as well as modelling of the study area for contaminant flow direction and velocity making use of the Groundwater Vistas, version 4.

2. The study area

The dumpsite is located in the Ujevwu area of Udu, near Warri, Delta State, Nigeria. It is situated around geographic coordinates of latitude 5°28.594^{l}N and longitude 5°48.318^{l}E (Fig. 1). The dumpsite covers an area of 150 by 120 m, with a height of about 5 m above the ground level. Another area devoid of contamination, acting as a control was also studied to have a comparison of the contamination around the dumpsite and the control site. The control area is located in the Bendel Estate area, off Airport road, in the heart of Warri city and is situated around geographic coordinates of latitude 5°32.68^{1} N and longitude 5°46.01^{1} E (Fig. 1). It is primarily a well planned residential area, with no dumpsite around, and it is about 8 km from the dumpsite area. Therefore, it is assumed to be relatively free from contamination. The study areas fall within the Benin formation of the Niger Delta area of Nigeria and is characterised predominantly by a slightly seawards sloping topography (Akpokodje and Etu Efeotor, 1987) and also, the low-lying Physiograhic Province Quaternary sands of the Sombriero deltaic plain is underlying the area (Fig. 2). The plain is flat and has a gentle rising towards the north and northeast with a gradient of about 1:960 (Odemerho and Ejemeyovwi, 2007). Also, the elevation of the area generally does not exceed 20 m above sea level.

The water table in Ujevwu area is very close to the ground surface to a depth of about 4 m. The fluctuations in the groundwater level reflects the high degree of precipitation often recorded in the study area over the year. Olobaniyi and Owoyemi (2004) in their study showed that this formation is partly recharged from River Warri. The area has an average annual temperature of about 27 °C, and mean annual rainfall of 2.75 m with 170 rain days per annum (Anomohanran, 2015).

3. Methodology

Geophysical methods employed for this study include the spontaneous potential survey and the geoelectric survey involving the vertical electrical sounding and the dipole - dipole techniques. Results of these studies were used to determine the hydrogeological properties of the aquiferous units and also as input parameters for the contaminant modelling for flow direction and velocity. The details of the studies carried out include the following;

3.1. Spontaneous potential (SP) survey

The SP data acquisition was carried out along two orthogonal traverse lines around the sites in the study area and the control site (Figs. 3 and 4). The gradient and the fixed base techniques were employed with electrode separation of 5 m and 10 m. The two SP techniques were adopted in order to study the lateral variation in ground potential and also the lateral and vertical variation using the fixed base array. The choice of electrode spacing of 5 and 10 m is

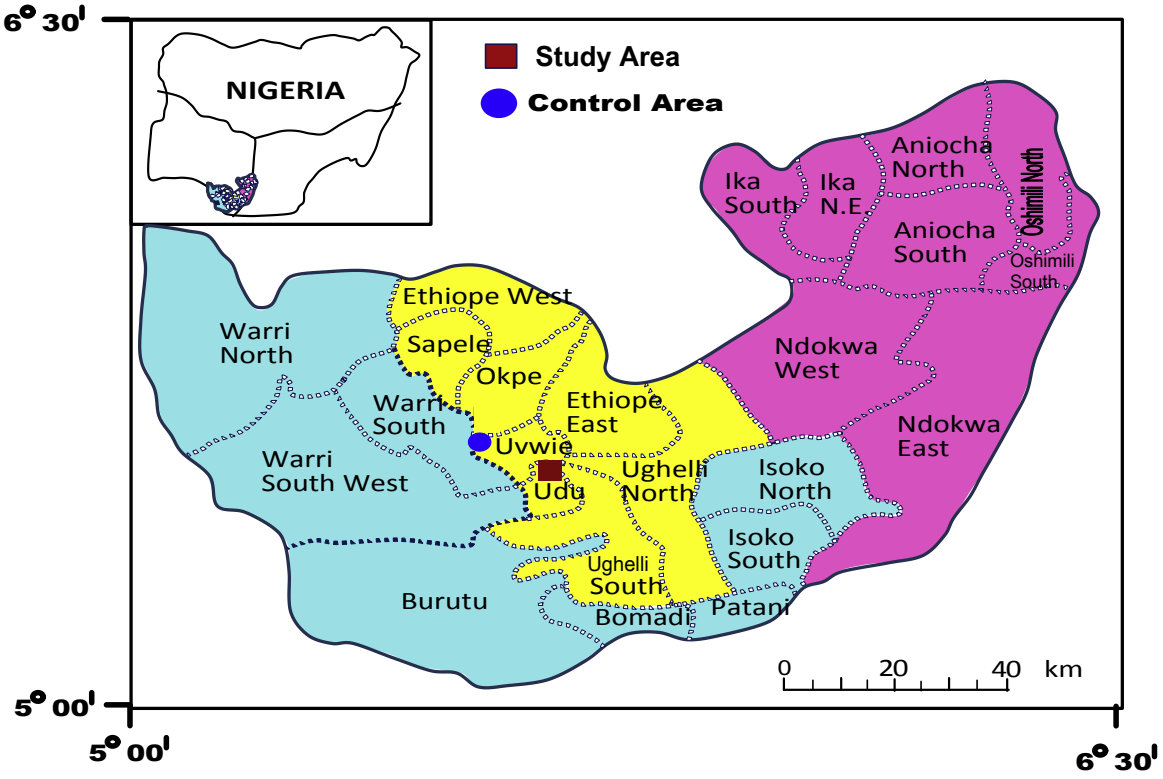

Fig. 1. Map of Delta State showing the study area (After Anomahanran, 2015).