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Time dependent electrical resistivity tomography and seasonal variation assessment of groundwater around the Olushosun dumpsite Lagos, South-west, Nigeria

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A B S T R A C T

Time-lapse electrical resistivity tomography (ERT) and seasonal variation studies of the physicochemical properties of groundwater were carried out on the Olushosun dumpsite in Lagos South-western Nigeria, to monitor, track the depth of leachate contamination, and to investigate the impact of seasonal variation on groundwater quality around the dumpsite. Six 2-D resistivity imaging lines were investigated. The independent inversion of the dipole–dipole and pole-dipole resistivity data indicated that contaminated zones are characterised by resistivity values ranging from 0.63 to 12.5 Ωm, and a maximum depth of 141 m was investigated. The pole-dipole models show clear evidence of vertical migration of contaminant with time, as depth of contamination increased from 106 m in May 2014 to about 120 m in December 2015 around the investigated portion of the dumpsite. Analysis of the seasonal variation of the examined physicochemical properties of the water samples taken from wells and boreholes within and around the site showed that there is increase in concentration of TDS and EC in the dry season study and a corresponding increase in the mean concentration of pH, Ca, Mg, hardness, Cu, Cr, NO_3, SO_4 and Na from the dry season results. Also, there is reduction in the mean concentration of Fe, Zn, Mn, PO_4, Cl, and Ni in the dry season when compared with the wet season analysis. Generally, there is a strong correlation between the ERT results and the physicochemical parameters of ground water quality viz-a-viz the contamination status of the Olushosun dumpsite. This increased trend in the dry season period could be attributed to the increase in concentration of the dissolved metals due to evaporation, and on the other hand, dilution effect of the rainfall during the wet season. South East direction of contaminant flow was established from the water table contour lines produced for the area. The research has clearly shown that the groundwater within the study area has been impacted by the leachate from the decomposed refuse at the dumpsite and may constitute danger to the life of residents living around the dumpsite.

1. Introduction

The Olushosun dumpsite is one of the largest dumpsites located in Nigeria. Like other dumpsites scattered all over the country, waste materials are dumped on excavated lands without recourse to the subsurface environment. In line with International global best practice, dumpsites are supposed to be designed such that their walls are lined with clayey materials or polyethylene geomembrane liner so as to reduce the vertical and lateral migration of the contaminants generated from the wastes materials deposited on the dumpsites. But all around the world, we have a situation whereby excavated lands are converted to dumpsites with indiscriminate dumping of refuse materials. When this happens, we have a situation whereby the biodegradable component of the waste materials decomposes with time, thereby releasing leachate materials generated within the waste into the subsurface environment and emitting bad odour into the atmosphere. Unfortunately, many communities located around these dumpsites get their water resources from these contaminated aquifers.

Time-lapse ERT study and physicochemical measurement of groundwater parameters were conducted at the dumpsite with the aim of tracking, monitoring and investigating the lateral and vertical extent of leachate contamination within the area, and to also examine the impact of seasonal variation on the physicochemical properties of

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groundwater around the dumpsite. The electrical resistivity methods are increasingly being deployed in contamination study due their ability to discriminate between the contaminated zones and the areas free of contamination. Usually the methods are not used to detect contamination directly, but rather, they reveal contamination through sharp variation in subsurface resistivities as a results of the presence of these contaminants. Many chemical pollutants are associated with dumpsites depending on the sources of contamination (Ayolabi et al., 2014). These produce vertical and laterally migrating leachates, commonly reducing resistivity, and the decrease in resistivity can be distinguished from natural, non-saline groundwater using electrical resistivity (Ross et al., 1990). Areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachates originating from the nearby site (Aldecy de Almeida and Shozo, 2008; Nixon et al., 1997). Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment (Mor and Ravindra, 2006).

Municipal landfill leachates are highly concentrated complex effluents which contain dissolved organic matters; inorganic compounds, such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, nickel, zinc among others (Christensen et al., 1998; Lee et al., 1986; Ogundiran and Afolabi, 2008). The greatest contamination threat to groundwater comes from the leachate generated from the materials which most often contain toxic substances especially when wastes of industrial origins are land filled (Longe and Enekwechi, 2007). This research work therefore seeks to deploy time-lapse ERT method with physicochemical parameters analysis of water from existing boreholes and wells to assess contamination and depth of migration viz-a-viz seasonal variation in groundwater quality around the landfill site.

2. Field description

The Olushosun sanitary landfill site is located towards the northern part of the Lagos metropolis in Ikeja Local Government Area of Lagos State (Fig. 1). It is owned and maintained by the Lagos State Waste Management Authority (LAWMA). The landfill was opened in 1989, and it covers an area extent of about 42 ha. (Ayolabi et al., 2014). The landfill site has witnessed rehabilitation which consisted of reclamation of land and construction of accessible road for ease of tipping, spreading, and compaction of waste since inception (Ayolabi et al., 2014). The site receives waste from entire Lagos metropolis and is accessible by tarred road through the Lagos-Ibadan expressway. It is surrounded by residential, commercial, and industrial setups, and the waste stream is made up of domestic, market, commercial, industrial, and institutional origins (Ayolabi et al., 2014).

Basically, there are three major aquiferous units that are being tapped for the purpose of water supply in the Lagos metropolis; these are categorized to first aquifer horizon thought to belong to the recent littoral/alluvial deposit of the Benin formation (Longe et al., 1987). This upper aquifer unit is mostly exploited through hand-dug wells, and it is prone to contamination because of its limited depth. The second aquifer horizon is made up of sands and clay thought to be the coarse sandy estuarine deltaic and continental beds of Ilaro formation (Jones and Hockey, 1964; Longe et al., 1987), while the third aquifer layer consists of alternating sequences of clayey and sandy strata. Only few boreholes tap water from this aquifer (Jones and Hockey, 1964).

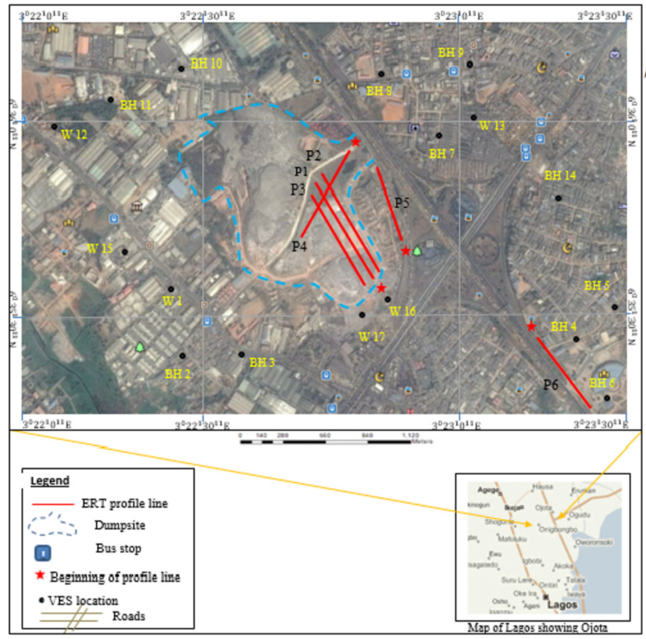

Fig. 1. Map showing the site locations, boreholes, wells and 2D ERT profile lines.

3. Materials and methods

3.1. 2-D resistivity imaging

The ERT surveys were carried out with the aid of a digital readout Super Sting R8 Earth Resistivity/IP metre along six (6) traverse lines (Fig. 1), using a multi-electrode system (84 electrodes). In order to achieve the objective of this research work, a one year and seven months time-lapse ERT experiments were carried out on and around the site in May 2014 (wet season) and a repeat survey in December 2015 (dry season).

The 2D resistivity data were collected along all the traverses using Dipole-Dipole and Pole-Dipole arrays with length of profile line depending on available space on and around the dumpsite. The choice of the electrode arrays was to enable maximum depth of investigation, good horizontal resolution and data coverage (Loke and Barker, 1996). The 2D data were processed and inverted using the Earth Imager inversion algorithm. The algorithm calculates the apparent resistivity values using forward modelling subroutine (AGI, 2003). It generates the inverted resistivity-depth image for each profile line based on an iterative smoothness constrained least-squares inversion algorithm (Loke and Barker, 1996). Generally, the programme automatically creates a 2D model by dividing the subsurface into rectangular blocks and the resistivity of the model blocks was iteratively adjusted to reduce the difference between the measured and the calculated apparent resistivity values (Loke and Barker, 1996).

3.2. Physicochemical analysis of water samples

To establish the level of impact of the leachate on groundwater and to examine the seasonal variation in physicochemical parameters of the groundwater quality around the dumpsite, water samples were obtained from seventeen (17) boreholes and hand dug wells using