Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268 e-ISSN: 2395-3454	Vol. 17	No. 2	pp. 453-458	2018

Original Research Paper | Open Access

Evaluation of Groundwater Pollution Near Municipal Solid Waste Landfill Site Using ERI Technique: A Case Study in Southwestern Nigeria

Kehinde D. Oyeyemi*†, Ahzegbobor P. Aizebeokhai* and Oluwabunmi F. Attat**
*Department of Physics, Covenant University, P. M. B. 1023, Ota, Ogun State, Nigeria
**Department of Geoscience, University of Lagos, Nigeria
†Corresponding author: D. Oyeyemi Kehinde

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 01-06-2017
Accepted: 21-08-2017

Key Words:
Groundwater contamination
Health risk
Landfill
Solid waste
ERI Technique

ABSTRACT

Direct current (DC) geoelectrical resistivity measurements have been conducted to investigate groundwater contamination at a non-engineered, open dumpsite facility in Lagos, southwestern Nigeria. The inferred lithologies from the tomographic imaging include topsoil, sandy-clay and sandy units; the delineated low resistive top layer has resistivity values ranging from 0.64-7.5 Ωm typical of leachates and localized within sandy-clay unit extending to depths of 42-52 metres. The groundwaters from the shallow aquifer units are observed to be hazardously contaminated in area where household, market and industrial wastes are known to be disposed improperly. Thus, deeper aquifer units beyond the contaminated layers should be drilled with screened borehole in order to avert immediate groundwater pollution. This study has further demonstrated the efficacy of using surface geophysical techniques to map contaminant plume in dumpsites and determine the extent of groundwater contamination.

INTRODUCTION

Groundwater is an important resource for water supply (e.g. drinking, irrigation) and for ecosystems throughout the world. However, groundwater is often subjected to contamination from variety of geogenic and anthropogenic sources (Talalaj & Dzienis 2006). A systematic review of the emerging groundwater contaminants by Lapworth et al. (2012) highlighted the contamination of the resource worldwide. Major environmental risks associated with groundwater contamination have been discussed extensively (Stuart et al. 2012, Stuart & Lapworth 2014). Some of the important common anthropogenic contaminant sources include leachates from industrial and municipal landfills, seepages (soakaway) pits, and mining and ore processing wastes. Among these, contaminants from industrial and municipal landfills are important to this study. Understanding the risk of pollution from any anthropogenic sources is of critical importance for the safety of the groundwater and groundwater dependent ecosystems. Efficient management of landfills and dumpsites, which are the ultimate recipients of municipal solid waste, has been a major problem of urban centres in Nigeria and other developing countries. Solid wastes are produced on daily basis as a result of direct consequence of inevitable human activities. Indiscriminate disposal of wastes in rivers and landfills as well as the close proximity of these dumping sites to the markets, health care centres and living quarters constitutes major environmental pollution and health challenge.

The DC resistivity method is found suitable for most environmental pollution investigation, this is generally due to the fact that ionic concentration of the landfill leachate is higher than that of natural groundwater. Thus, the leachate entering the aquifer unit (Fig. 1) results in a large electrical resistivity contrast. Geoelectrical resistivity method will therefore identify these zones as anomalies, this enables the leachate plumes to be detected (Samsudeen et al. 2006).

The serious ambiguities suffer by electrical resistivity data are in distinguishing between equally electrically conductive targets such as electrolytic, metallic-ion contamination plumes from saline and clayey formations (Dahlin et al. 2002). Time domain induced polarization (IP) technique has the potential to differentiate between these targets. Tomography techniques such as electrical resistivity tomography (ERT) are now commonly employed in field surveys. Essentially, tomography is an imaging technique which generates a cross-sectional picture (tomogram) of an object through utilizing the objects response to non-invasive, non-destructive energy of an external source. In this study, direct current (DC) geoelectrical resistivity imaging was conducted to investigate groundwater contamination at an open dumpsite facility in Lagos, south-

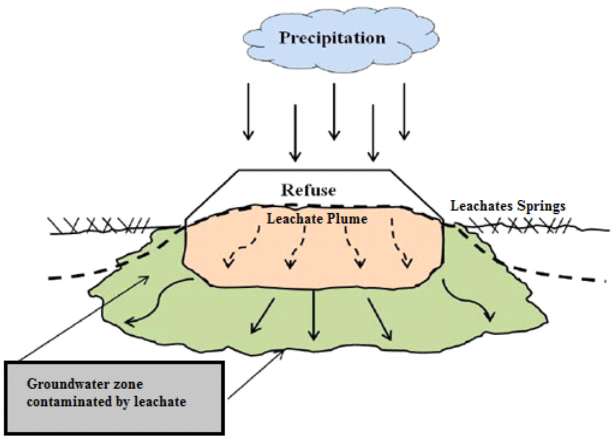

Fig. 1: Conceptual model for groundwater contamination by leachates (WHO 2006).

western Nigeria. Leachates plume localized within a sandy clay unit was delineated, the leachates contaminated the shallow aquifer units in area where household, market and industrial wastes are disposed.

GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

Lagos metropolis is located within the southwestern Nigeria coastal zone, a zone characterised by coastal creeks and lagoons (Pugh 1954, Longe et al. 1987) developed by barrier beaches associated with sand deposition (Hill & Webb 1958). Adegoke et al. (1980) recognized the abandoned beach ridge complex, coastal creeks and lagoons, swamp flats, forested river floodplain and active barrier beach complex as the five geomorphologic sub-units in the coastal landscape. Lagos is underlain by the Dahomey Basin (Fig. 2) with lithologic constituents that are mainly sands, clays and limestones (Longe et al. 1987, Jones & Hockey 1964, Nwankwoala et al. 2011). Dahomey basin is separated from the Niger Delta in the eastern section by the Benin Hinge line and Okitipupa ridge and marks the continental extension of the chain fracture zone (Onuoha 1999). The rocks are generally late Cretaceous to early Tertiary in age (Jones & Hockey 1964, Adegoke 1969, Ogbe 1970, Omatsola & Adegoke 1981, Okosun 1990, Billman 1992, Olabode 2006).

The stratigraphy of the basin has been grouped into six lithostratigraphic formations (Fig. 3) namely, from oldest to youngest, Abeokuta, Ewekoro, Akinbo, Oshosun, Ilaro, and Benin formations. Some workers have described the Cretaceous Abeokuta formation as a group consisting of Ise, Afowo and Araromi formations. Tertiary Ewekoro formation comprising of limestone, clays and shales and the Ilaro

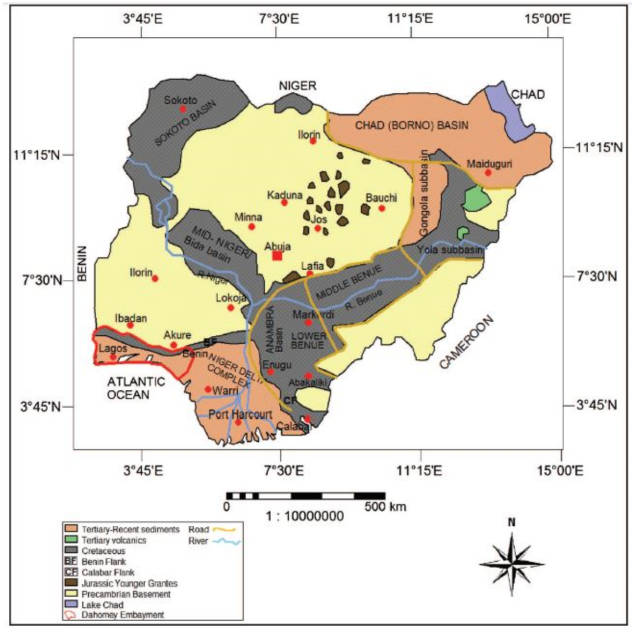

Fig. 2: Geologic map of Nigeria showing the Dahomey embayment.

formation consisting of clays and shales followed by the poorly sorted coastal plain sands and recent alluvial deposits. The latter which consists of littoral and lagoonal sediments of the coastal belt is characterized by mangrove (saltwater) and freshwater swamps where aquifers, are readily recharged by copious rainfall thus making them vulnerable to leachate contamination in areas proximal to landfills. The lithological disposition of the aquifers give rise to artesian and sub-artesian conditions in places. Within the Lagos metropolitan area, the coastal plain sand units are the major aquifers generally exploited by low and medium income earners for water supply.

MATERIALS AND METHODS

The ABEM (SAS1000) Terrameter with LUND Imaging System that uses 64 multi-electrodes (Fig. 4) were employed for the geoelectrical resistivity survey. The measurement protocol was controlled using a laptop microcomputer together with an electronic switching unit that automatically select the relevant four electrodes for each measurement. The acquired apparent resistivity data were inverted to produce 2D inverse model of the estimated true subsurface resistivity distribution. This procedure utilizes Gauss-Newton least-squares method (Loke et al. 2003) based on the initiation of a finite element model of the subsurface. In electrical resistivity tomography, an array of regularly spaced multi-electrodes is deployed for the data measurements. The multi-electrodes are connected to a central con-

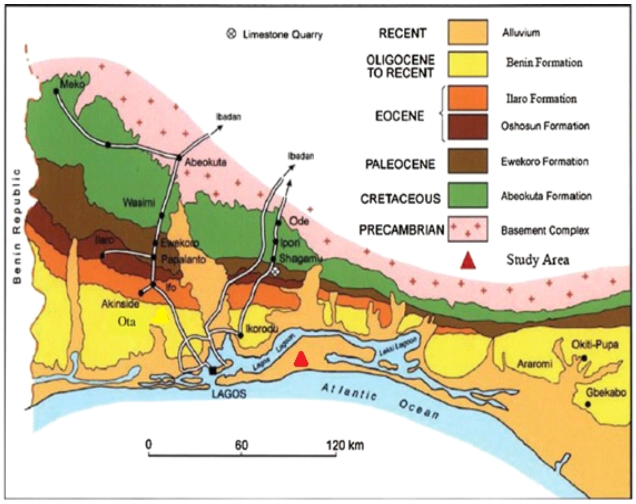

Fig. 3: Geological map of the Nigerian part of the Dahomey embayment (modified after Gebhardt et al. 2010).

Fig. 4: Laying of Terrameter Lund imaging cable during data acquisition.

trol unit via multicore cables. The arrays commonly deployed include dipole-dipole, Schlumberger and Wenner, depending on the application and resolution desired. The relative advantages and disadvantages of these arrays are used to select the most appropriate electrode configuration in each case.

The dipole-dipole (Fig. 5) in which the spacing between the current electrode dipole AB (a) is the same as the distance between the potential electrodes dipole MN was selected for the data measurements in this study. The same process is repeated for measurements with different dipole spacing ("25a" to "na"). The apparent resistivity is calculated with $k = (n(n + 1)\,(n + 2)\,a$, where n is the spacing between the current and potential dipoles. The median depth of investigation dipole-dipole array also depends on the n-factor, as well as the dipole length a (Pomposiello et al. 2012). The apparent resistivity data are then recorded via complex combinations of current and potential electrode pairs to build up a pseudo-cross-section of apparent resistivity beneath the survey profile. 2D electrical resistivity tomography surveys were conducted along the two profile lines (T1 and T2) across the area. The electrical resistivity tomography was obtained using a minimum dipole length of $a = 3m$.

The resistivity profiles cover the entire length, width, and diagonal extent of the investigated dumpsite with a view to mapping the conductive pathways where contaminant plumes can be found. The dipole-dipole spacing of $a = 3m$ enabled the possible detection of plumes and or structures till 85 metres depth which was considered satisfactory for the required information about the near surface possible groundwater contamination due to the presence of landfill in the study area. The geoelectrical data acquired were processed by means of the Earth Imager, AGI resistivity computer program in order to perform 2D geoelectrical data inversion. The inversion routines are based on the smoothness-constrained least squares method (Loke & Baker 1995, Tsourlos 1995) and the forward resistivity calculations were executed by applying an iterative algorithm based on a finite element method. The inversion program divides the subsurface into a number of small rectangular prisms and attempts to determine the resistivity values of the model prisms directing toward minimizing the difference between the calculated and the observed apparent resistivity values.

The results obtained from the processing and inversion of the observed field data are presented as 2D resistivity structures, pseudo-sections, and theoretical pseudo-sections. These results are relevant in imaging the causes of subsoil and groundwater contamination, and are discussed in terms of the inverse model resistivity or conductivity values with respect to the corresponding depths of occurrence.

RESULTS AND DISCUSSION

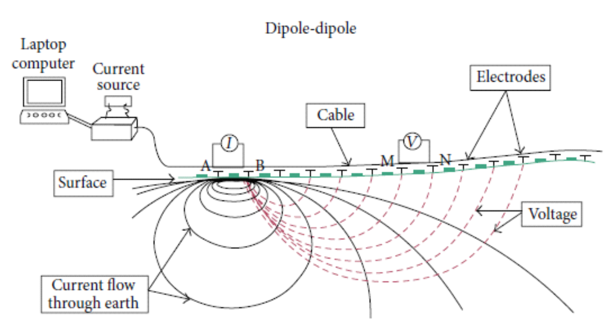

Fig. 5: Multichannel dipole-dipole survey set-up with a number of electrodes along a straight line attached to a multi-core cable.

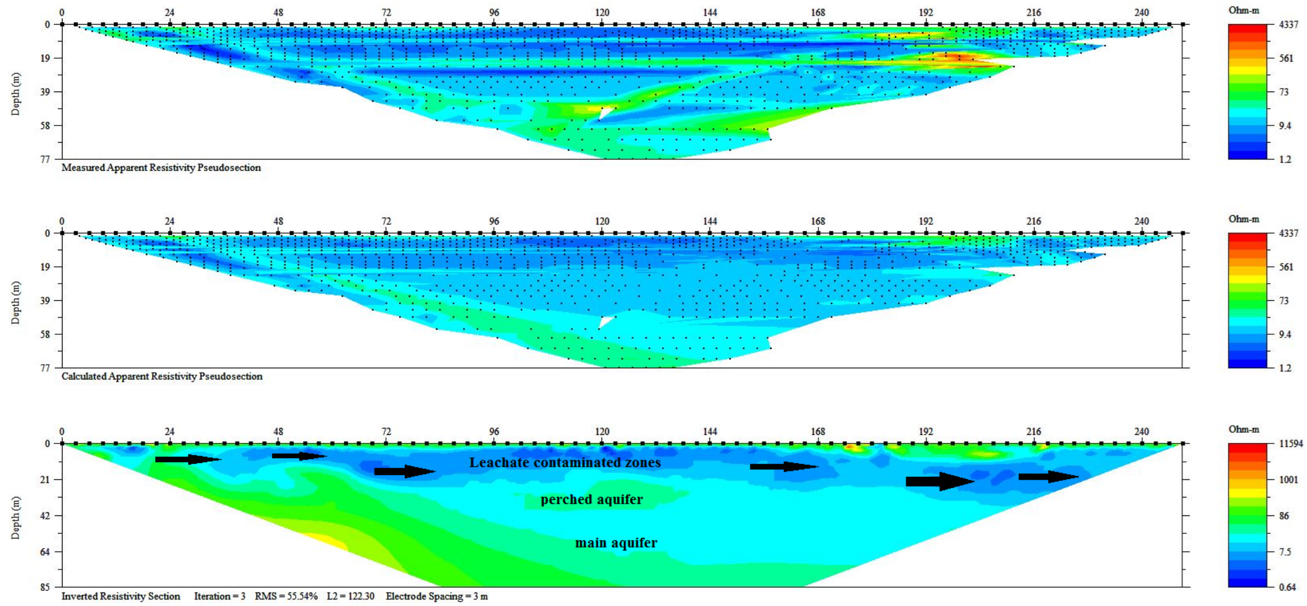

Fig. 6: Inverted resistivity section along traverse T3.

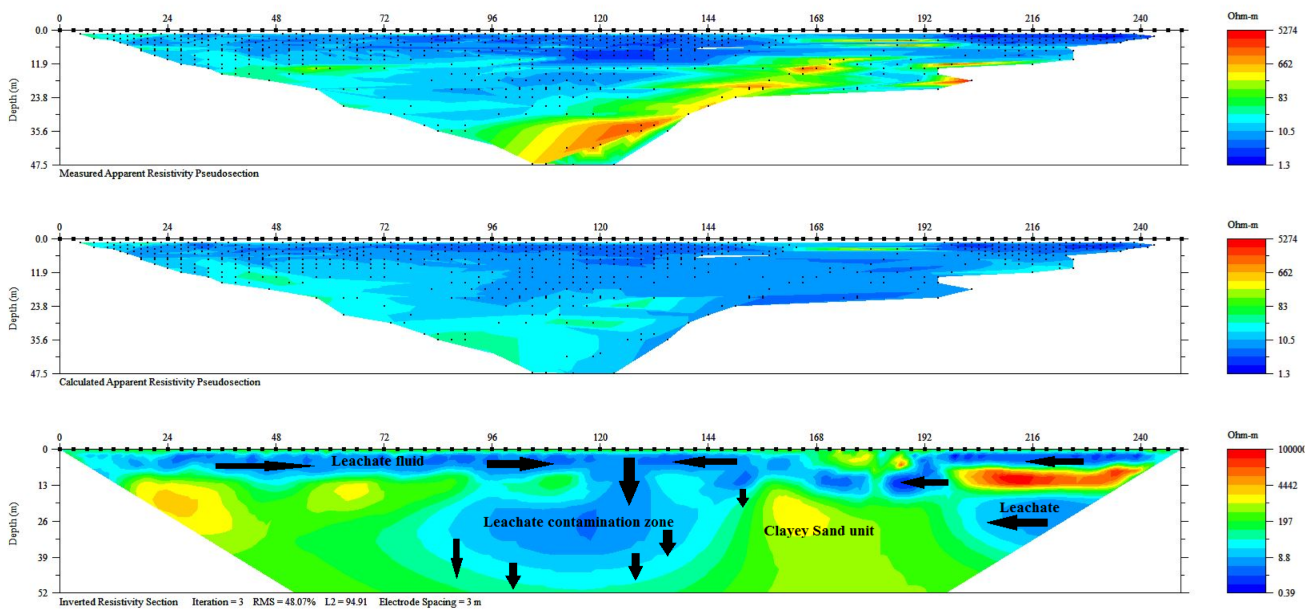

Fig. 7: Inverted resistivity section along traverse T4.

The geophysical investigation in this study involves two traverses (T1 and T2) of 2D geoelectrical resistivity imaging. T1 is situated along the central part of the dumpsite, while T2 is sited closer to the swamp situated towards the southern part of the dumpsite. The inverse model of the 2D geoelectrical resistivity imaging along T1 (Fig. 6) shows a thick resistive sand unit prograding from 20 m with steep slope down to the base. A low resistive top layer with model resistivity values of between 0.64-7.5 typical of leachates (Samsudeen et al. 2006, Olayinka & Olayiwola 2001, Longe & Enekwechi 2007) localized within sandy-clay units was delineated in the 2D resistivity images. The leachates flow eastward and percolated to a depth of about 42 m from the surface.

This is followed by a thick layer laterally extending between 20 m and 400 m which appear to be the aquiferous zone in the study area. Fig. 6 also shows a lateral infiltration of the groundwater aquifers by the suspected leachate plumes. The result of the second traverse T2 indicates depth of investigation as shown from the electrical resistivity inversion model up to 52 metres (Fig. 7). Lenses of dry clay units can be seen to be localized towards the North-eastern section of the inversion model. The swamp closer to this traverse serves as a good conduit for the migration and percolation of the leachates from the top layer into the thick sandy clay unit extending beneath. The flow and percolation of the leachate in this part of the study area is observed at the central part of this traverse, where the leachate extends to the depth of about 52 m below the surface.

CONCLUSION

2D geoelectrical resistivity imaging has been used to study the presence of leachates in an open waste disposal site located within the Lagos metropolis. The preferential flow percolation of the leachates is investigated. They flow vertically downwards penetrating the deeper aquiferous zones thereby causing groundwater contamination in the area.

The stratigraphy of the subsurface lithologies was also established, with the resistivity values suggesting leachate contamination in clayey sand and sandy units with the latter being the main aquifer in the study area. Moreover, the 2D geoelectrical resistivity images shows that the leachate contaminants occur from the near surface to the depth of about 42 m and 52 m in Traverses T1 and T2 respectively, with resistivity value ranging 0.64-75 reaching the deeper aquiferous zones. The contaminant is predominant in the shallow and central portions of the study area. Consequently, sub-soil and shallow sandstone aquifers have been polluted by the leachate.

This dumpsite is non-engineered and therefore has neither bottom liner nor leachate collection and treatment system. This makes it possible for generated leachates to find their way into underground water system. It is essential that feasibility studies should be done prior to choosing a landfill site within the Lagos metropolis. The state government should enact environmental protection laws in order prevent indiscriminate dumping of refuse. Also, boreholes for potable water supply in this area should be drilled beyond the shallow aquifers, and the boreholes should be screened in order to mitigate against the infiltration and percolation of leachate contaminants.

REFERENCES

Adegoke, O. S. 1969. Eocene stratigraphy of Southern Nigeria. Bull. Bureau Econ. Geol. Mineral Mem., 6: 23-26.

Adegoke O. S., Ako, B. D. and Enu, E. I. 1980. Geotechnical investigations of the Ondo State bituminous sands. Report of Geological Consultancy Unit, Geology Department, Obafemi Awolowo University, Ile Ife, Nigeria, 257: 27-36.

Billman, H.G. 1992. Offshore stratigraphy and paleontology of Dahomey (Benin) Embayment. NAPE Bull., 70(2): 121-130.

Dahlin, T., Leroux, V. and Nissaen, J. 2002. Measuring Techniques in induced polarization imaging. J. App. Geoph., 50: 279-298.

Gebhardt, H., Adekeye, O.A. and Akande, S.O. 2010. Late Paleocene to initial Eocene thermal maximum foraminifera biostratigraphy and paleoecology of the Dahomey basin, southwestern Nigeria. Gjahrbuch Der Geologischem Bundesantalt, 150: 407-419

Hill, M. B. and Webb, J. E. 1958. The ecology of Lagos lagoon II. The topography and physical features of the Lagos harbor and Lagos lagoon. Philosophic. Trans. Royal Soc. London, 241: 307- 417.

Jones, H. A. and Hockey, R. D. 1964. The geology of part of southwestern Nigeria. Geol. Survey Nigeria Bull., 31: 101.

Lapworth D. J., Baran, N., Stuart, M. E. and Ward, R. S. 2012. Emerging contaminants: A review of occurrence, sources and fate in groundwater. Environmental Pollution, 163: 287-303.

Loke, M. H., Acworth, I. and Darlin, T. 2003. A comparison of smooth and blocky inversion methods in 2D electrical imaging surveys. Geophysics, 35: 266-271.

Loke, M. H. and Barker, R. D. 1995. Least-squares deconvolution of apparent resistivity pseudosections. Geophysics, 60(6): 1682-1690.

Longe, E. O. and Enekwechi, L. O. 2007. Investigation on potential groundwater impacts and influence of local hydrogeology on natural attenuation of leachate at a municipal landfill. Int. J. Environ. Sci. Tech., 4(1): 133-140.

Longe, E. O., Malomo, S. and Olorunniwo, M. A. 1987. Hydrogeology of Lagos metropolis. J. Afr. Earth. Sci., 6(3): 163-174.

Nwankwoala, H. O., Udom, G. J. and Ugwu, S. A. 2011. Some heavy metal investigations in groundwater sources in Yenegoa, Bayelsa State, Nigeria. Journal of Applied Technology in Environmental Sanitation, 1(2): 163-170.

Ogbe, F.A.G. 1970. Stratigraphy of strata exposed in the Ewekoro quarry, Western Nigeria. In: Dessauvagie, T.F.J., Whiteman, A.J. (eds.) African Geology. University of Ibadan Press, Nigeria, pp. 305-324.

Okosun, E. A. 1990. A review of the cretaceous stratigraphy of the Dahomey embayment, West Africa. Cretac. Res., 11: 17-27.

Olabode, S. O. 2006. Siliciclastic slope deposits from the Cretaceous Abeokuta Group, Dahomey (Benin) Basin, southwestern Nigeria. J. Afr. Earth Sci., 46: 187-200.

Olayinka, A.I. and Olayiwola, M.A. 2001. Integrated use of geoelectrical imaging and hydrochemical methods in delineating limits of polluted surface and groundwater at a landfill site in Ibadan area, South West Nigeria. J. of Mining and Geology, 37(1): 53-68.

Omatsola, M. E. and Adegoke, O. S. 1980. Tectonic evolution and cretaceous stratigraphy of the Dahomey Basin. Niger J. Mining and Geology, 18(1): 130-137.

Onuoha, K.O. 1999. Structural features of Nigeria's coastal margin: an assessment based on age data from wells. J. Afr. Earth Sci., 29(3): 485-499.

Pomposiello, C., Dapena, C., Favetto, A. and Boujon, P. 2012. Application of geophysical methods to waste disposal studies. In: Xiao-Ying Yu (Ed.) Municipal and Industrial Waste Disposal, pp. 3-26.

Pugh, J. C. 1954. A classification of the Nigeria coastline. Journal of the West African Science Association, 1: 3-22.

Samsudeen, A.R., Rahim, B.E.A., Yaacob, W.Z.W. and Hamzah, U. 2006. Mapping of contamination plumes at municipal solid waste disposal sites using geoelectrical imaging technique: A case study in Malaysia. J. Spatial Hydrol., 6(2): 13-22.

Stuart, M.E. and Lapworth, D.J. 2014. Transformation products of emerging organic compounds as future groundwater and drinking water contaminants. In: Lambropoulou, D.A. and Nollet, L.M.L. (eds.) Transformation Products of Emerging Contaminants in the Environment: Analysis, Processes, Occurrence, Effects and Risks. Wiley, pp. 65-86.

Stuart, M.E., Lapworth, D.J., Crane, E.J. and Hart, A. 2012. Review of risk from potential emerging contaminants in UK groundwater. Science of the Total Environment, 416: 1-21.

Talalaj, I.A. and Dzienis, L. 2006. Influence of leachate on quality of underground waters. Polish J. Environ. Stud., 16(1): 139-144.

Tsourlos, P. 1995. Modeling interpretation and inversion of multi-electrode resistivity survey data. University of York (D.Phil. Thesis).

World Health Organization (WHO) 2006. Protecting Groundwater for Health: Managing the Quality of Drinking Water Sources. Edited by O. Schmoll, G. Howard, J. Chilton and I. Chorus. ISBN: 1843390795. Published by IWA Publishng, London, UK.