Hindawi Publishing Corporation
Journal of Geological Research
Volume 2013, Article ID 895160, 8 pages
http://dx.doi.org/10.1155/2013/895160

Research Article

Application of 2D Electrical Resistivity Tomography in Landfill Site: A Case Study of Iku, Ikare Akoko, Southwestern Nigeria

Cyril Chibueze Okpoli

Department of Geology, Faculty of Science, Adekunle Ajasin University, PMB 1, Akungba-Akoko, Ondo State, Nigeria

Correspondence should be addressed to Cyril Chibueze Okpoli; okpolicyril@gmail.com

Received 3 June 2013; Revised 5 September 2013; Accepted 9 September 2013

Academic Editor: Umberta Tinivella

2D resistivity tomography was used in x, y, and z directions to delineate the extent of leachate plumes around a solid waste landfill in Ikare Akoko, Ondo State, behind the secretariat. I access the geometry and depth contamination extent of the landfill repository using dipole-dipole method and Global positioning system to ascertain the image of the subsurface and the position at the earth surface. The study area is underlain by Precambrian basement rocks. Quantitative interpretation of pseudosection results shows that in traverse 1, stations 7, 8, and 9 form a conductive path at the depth of 1–10 m and penetrate to depth of 25 m; the second traverse shows a layer of highly conductive structure extending diagonally across the study area, while the third traverse is partly conductive and largely resistive due to its closeness to fresh basement rocks. The 2D structure has shown various conductive path ways via fractures and openings, thus, contaminating the groundwater. I recommend that further geochemical analysis of the water should be done to ascertain the level of contamination.

1. Introduction

Recent studies have shown that the problem of environmental contamination and waste management is one of the main concerns of geoscientists and researchers from other related fields of science around the globe. Fast industrial development and the uncontrolled growth of the urban population result in the production of toxic solid wastes. Urban waste materials, mainly domestic garbage, are usually disposed of inadequately in waste disposal sites posing a high risk to the underground water resources, the environmental pollution, and the community health. Moreover, older waste sites often lack reliable geological or artificial barriers, so that leaching of pollutants into the groundwater is a concern. Contamination problems are particularly severe for waste dumped in abandoned gravel pits, many of which extend to below the groundwater table. Being small and unregulated, the exact location, structure, and contents of such landfills are either unknown or poorly documented. The solution to the day-to-day problems of modern urban societies demands fast and effective geophysical methods. One of the most frequent demands in metropolitan areas is to determine the landfill's geological and geotechnical structure shape and extend, together with the excavation and dumping history [1–3]. Details on the contents of a landfill may be difficult to acquire but are essential for evaluating the level of risk associated with leaking pollutants. In such context, the integrated use of geophysical methods provides an essential tool in the characterization and evaluation of contaminants generated by urban residues (domestic and/or industrial) [4–8]. Among those geophysical methods, electrical resistivity tomography has been found very suitable for such kind of environmental studies, due to the conductive nature of most contaminants. The use of electrical resistivity tomography applied to environmental studies is well documented [9–11].

The management of solid waste landfills has been a major problem of our urban centers in Nigeria and other developing countries as well as the disposal of waste indiscriminately in rivers and landfills and mostly their proximity to the living quarters. The landfill constituents are predominately household waste. Other waste comes from shops, offices, and chemical and manufacturing industries. These wastes

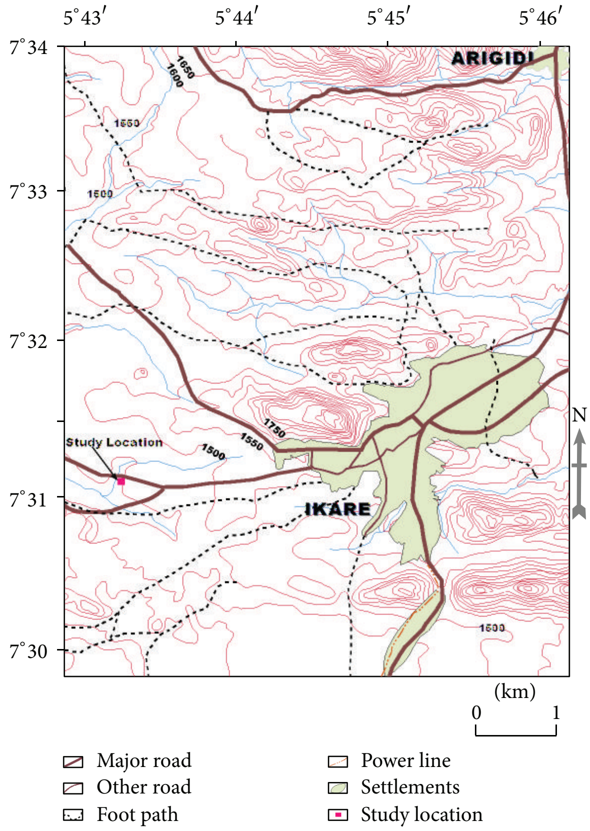

Figure 1: Topographical map of the study area (modified after GSN, 2001).

Figure 2: Showing the dumpsite study area.

may contain toxic substances as they are decomposed or biodegraded, with the preference of infiltrating water, to produce organic liquid known as leachate.

Sometimes, especially during the peak of the raining season, the landfills are covered by flood water. This also contributes to the leachate plumes, which contains liquid that permeates into the solid and water system through the landfill. This result pollutant to load on the environment which depends on the quantity and quality of the water that percolates through the dumpsite and penetrates down to the ground water [12].

Ikare Akoko municipality is a cosmopolitan town in Ondo State, southwestern Nigeria. Characterized by a beehive of activities as a result of the communication and banking

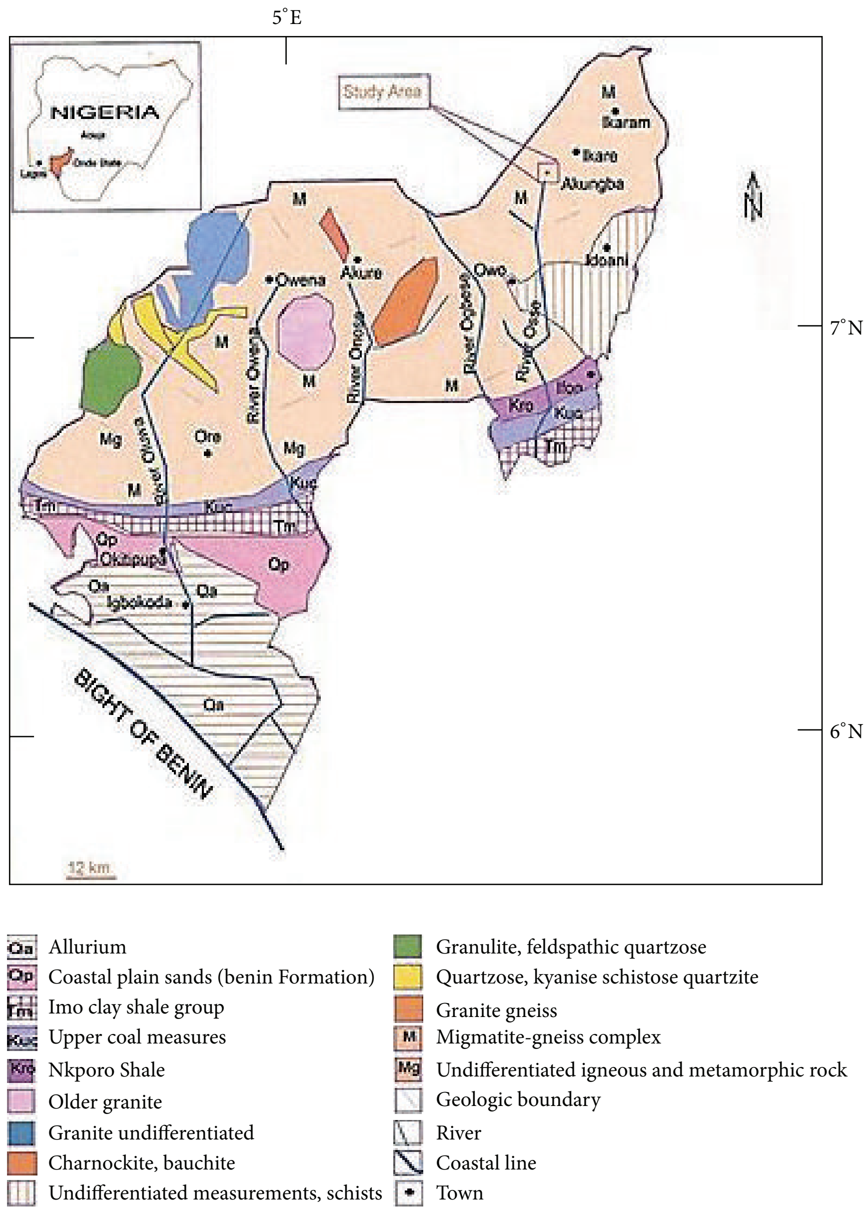

FIGURE 3: Geological map of Ondo state, Nigeria showing the study area on a regional scale (modified after GSN, 2001).

sectors as well as other economic activities and has witnessed tremendous increase in population recently.

Trochobanogous et al. [13] said that CO_2 and methane are the principal gases produced from the anaerobic decomposition of the biodegradable organic waste components in municipal solid waste. Because only limited amounts of oxygen are present in a landfill when methane concentrations reach this critical level, there is little danger that the landfill will explode. However, methane mixtures in the explosive range can form if landfill gas migrates off-site and mixes with air. This work is aimed to investigate the effects of Iku dump site located in Ikare, southwest Nigeria on groundwater by employing 2D electrical resistivity imaging in order to delineate the leachate plumes.

1.1. Location and Accessibility. The topographical map of the study area is shown in Figure 1. Ikare is located in Akoko northeast Local Government Area of Ondo State. It lies within the Precambrian basement complex area of southwestern Nigeria. The study area lies within latitude N7°31′ 291″—N7°31′ 317″ and longitude E5°46′ 133″—E5°46′ 151″. The area is easily accessible due to the availability of effective flat lying surface area. The survey is behind Akoko northeast Secretariat Ikare Akoko.

1.2. Vegetation and Climate. The study areas is thinly covered by vegetation. This is as a result of urban development leading to the cutting down of economic tress like Iroko, Ogbese, and so forth. Away from Ikare Town, that is, its extreme

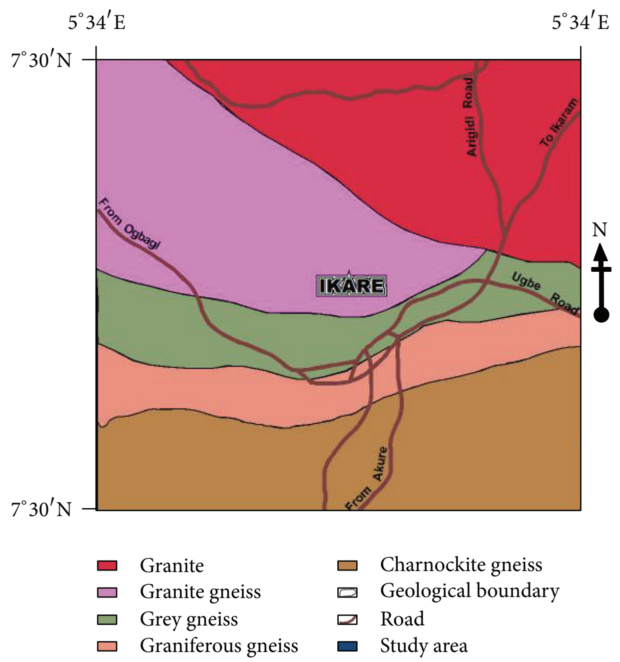

Figure 4: Geological map of Ikare showing the study area (modified after GSN, 2001).

ends, there is present a thickly vegetated area like Iku, Ekan, Ishakunmi, Okeagbe, along Ogbaji road. Although the area is a basement complex area, the soil that eventually stand as the support, must have resulted from the weathering of the basement rocks present in the areas.

The study area falls under a tropical region called subequatorial south. It has characteristically two climate seasons which are wet and dry seasons. The wet season is characterized by heavy rainfalls, which start in April and ends in September, while the dry season stars in October and ends in March. Although minor rains in March and October are sometimes observed, the mean annual rainfall is 150 cm and mean annual relative humidity is above 80% and the mean annual temperature is about 22°C [14].

1.3. Description of the Study Area. Figure 2 shows the landfill site of the study area, which is the Iku, Ikare Akoko. The area is located in part of Ikare Akoko in Akoko northeast Local Government area of Ondo State, Nigeria. The area lies within latitude N7°31′ 291″—N7°31′ 317″ and longitude E5°46′ 133″—E5°46′ 151″.

2. Geology of the Study Area

Figure 3 shows the geological map of Ondo state, Nigeria, on a regional scale and is composed of Precambrian basement complex to the north and central as well as benin basin (sedimentary) to the south. The study area is predominantly made up of gneissic rocks (Figure 4). It covers about 65% of the total study area trending in the north-south direction all dipping to west.

The colour varies from light to dark grey and it is usually medium to coarse grained with porphyroblastic texture. There is several quartzite intrusions which are cutting across the host rock. They occur mostly as hills and flat lying exposures; the minerals are oriented randomly and consist of quartz biotic (with highest percentage), biotite, and feldspar with some trace element like garnet which is coarse grained. Its lithological banding is defined by the presence dark bands and white bands.

3. Methodology

3.1. Data Acquisition and Processing. The ABEM LUND 1000 Terrameter was employed for smooth apparent resistivity inversion to produce 2D model of the estimated true subsurface resistivity. This procedure uses Gauss-Newton least squares method [15] based on the initiation of a finite-element model of the underground surface. In an electrical tomography an array of regularly—spaced electrodes is deployed. They are connected to a central control unit via multicore cables. The common arrays used are dipole-dipole, Schumberger and Wenner, depending on application and the resolution desired. The advantages and disadvantages of these arrays will be used to choose the appropriate configuration in each case. The dipole-dipole array is present in Figure 5. In this case, the spacing between the current electrodes pair, AB is given as "a" which is the same as the distance between the potential electrodes pair MN. The same process is repeated for measurements with different spacing ("$2a$" to "na"). The apparent resistivity is calculated with $k = (n(n+1)(n+2)a$, where n is the level. The median depth of investigation of this array also depends on the "n" factor, as well as the "a" [16].

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 3 profile lines across the area as depicted in Figure 6. The electrical resistivity tomography was obtained using 5 m electrode spacing of dipole-dipole configuration. A total of 3 profiles spanning the length, width, and diagonal extent of the dumpsite have been investigated with a view to mapping the conductive pathways via fracture opening where contaminant plumes can be found. The dipole-dipole spacing a was 5 m enabling the possible detection of plumes and or structures till 25 m depth which could be considered satisfactory for the required information about the near-surface possible environmental pollution due to siting of landfill in the study area.

The geoelectrical data collected have been processed by means of the DIPROFWIN modeling software in order to perform 2D geoelectrical data inversion. The inversion routines are based on the smoothness-constrained least squares method [17–21] 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

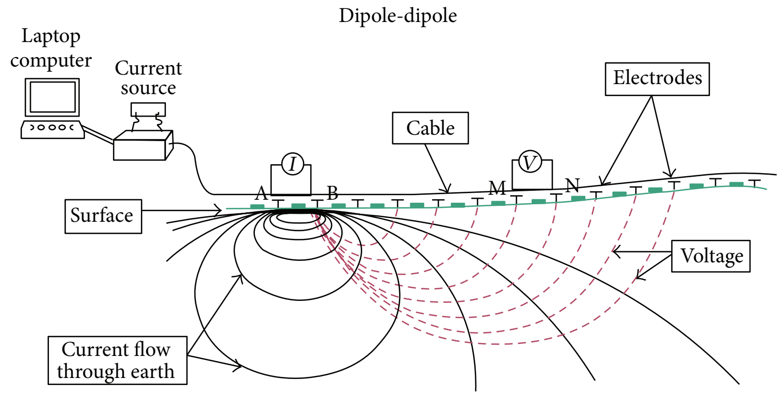

FIGURE 5: Multichannel dipole-dipole surveys.

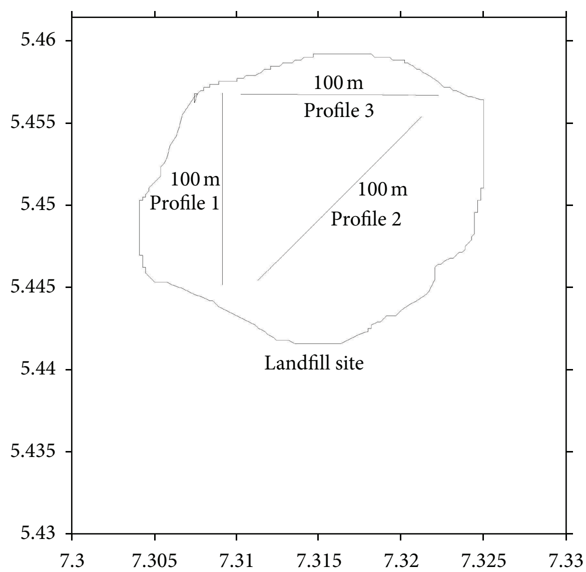

FIGURE 6: Map showing the acquisition map of the study area.

the calculated and the observed apparent resistivity values. The quality of the fit is expressed in terms of the RMS error. The results obtained from the processing/presentation of field data are presented as 2D resistivity structures, pseudosections, and theoretical pseudosections from which the relevance of this result used in imaging, the causes of soil, and groundwater contamination are discussed in terms of resistivity and conductivity with respect to their depths of occurrence.

4. Results and Discussion

4.1. Electrical Resistivity Tomography (Length). The 2D resistivity structure along traverse one (Figure 7) shows a thick resistive rock buried beneath stations at the with depth extent of 25 m. The 2D resistivity structure delineated a low resistive top layer of resistivity values of between 123 and 299 ohm meter typical of sandy clay as observed in Figure 7. This is followed by a layer of resistivity values of between 299 and 728 ohm-meter which has the composition similar to lateritic clay and lastly the basement rock.

The first traverse shows a predominantly resistive area with pockets and flanks of conductive structures present at various points in the pseudosection. A profile of conductive structure is observed extending from the first rectangular prism. This profile extends beneath the surface towards the seventh eighth and ninth blocks, to form a conductive pathway, which is conductive. This structure is indicative of a fracture through which fluids can flow towards or into the aquifer zone, as well as serving as conduits for the migration of leachate plume to groundwater.

4.2. Electrical Resistivity Tomography (Diagonal). Figure 8 shows the 2D resistivity structure along the second profile line which runs diagonally in the landfill site. The pseudosection shows a thick resistive rock buried beneath block 8 to the end of the traverse at a rock head depth of about 25 m.

Block 8 is about the geologic contact between the resistive rock and a relatively low resistive rock. The upper layer along traverse two shows a moderate resistivity value range of between 246 and 624 ohm-m typical of sandy clay/clayey sand or lateritic clay at stations 5, 6, and 7. Topsoil appears with a considerable thickness between stations 5 and 11; the weathered layer is only evident between stations 5 and 7, resistivity range of 287–456 ohm metre.

Furthermore, the 2D resistivity structure in the second traverse depicts a layer of highly conductive structure running diagonally across the study area. This traverse is generally more conductive than the length and width profile lines. A pocket of highly conductive structure is located within blocks/stations 5 and 7 at a depth range of around 5 meters to 10 meters. This structure is located in the midst of a less conductive area, which indicates that the leachate have migrated to form a plume. A layer of the less conductive structure extends over towards the thirteenth station although it has a shallow depth of less than 10 meters. The rest of the pseudosection is filled with more resistive structures with a pocket of slightly conductive structure present at the fifteenth station towards the last station at a depth of around 10 meters.

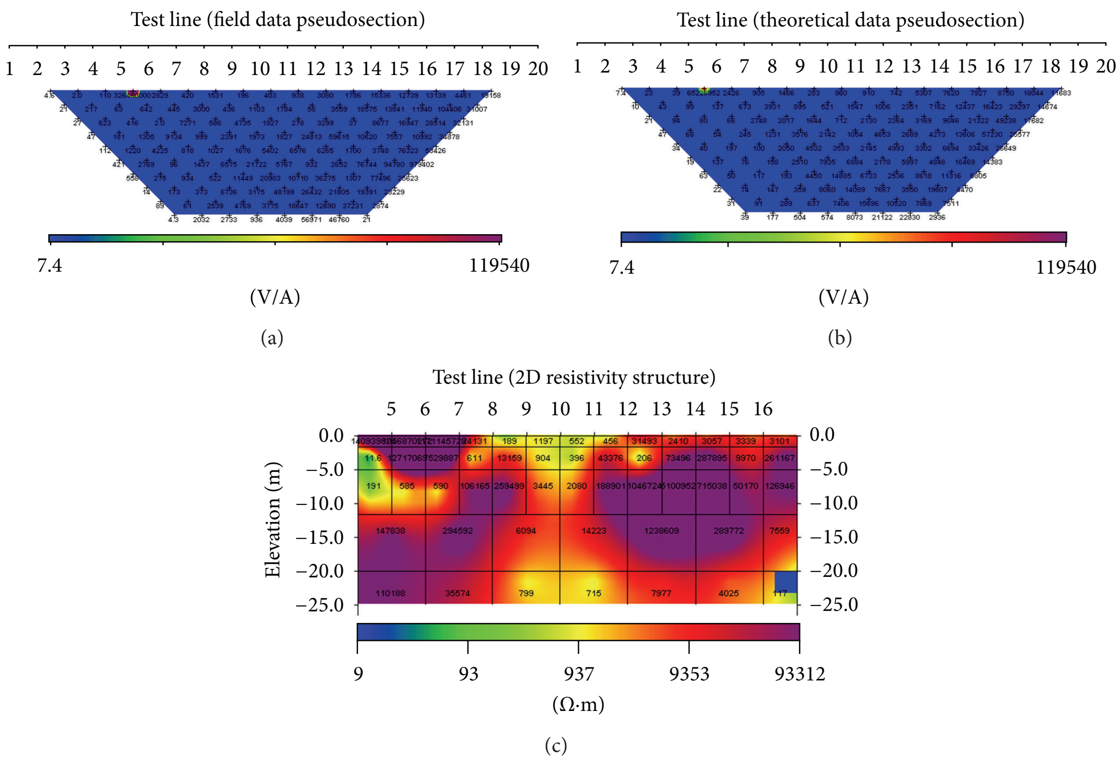

Figure 7: Inverted resistivity section along traverse 1.

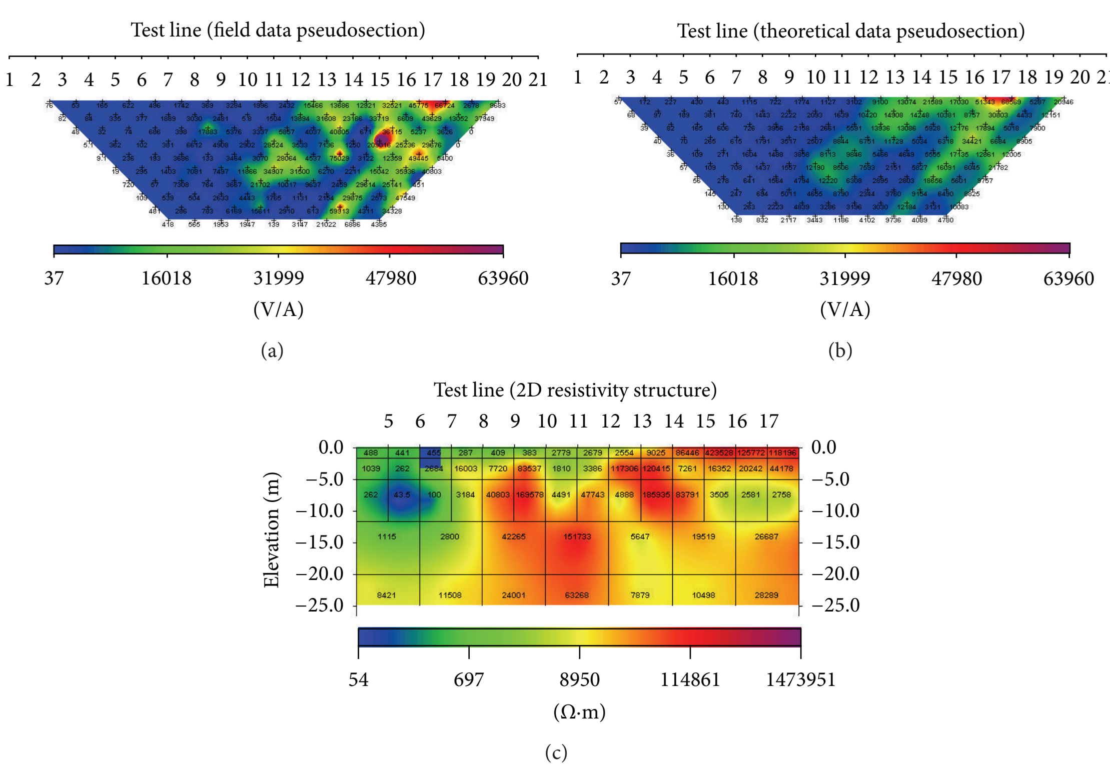

Figure 8: Inverted resistivity section along traverse 2.

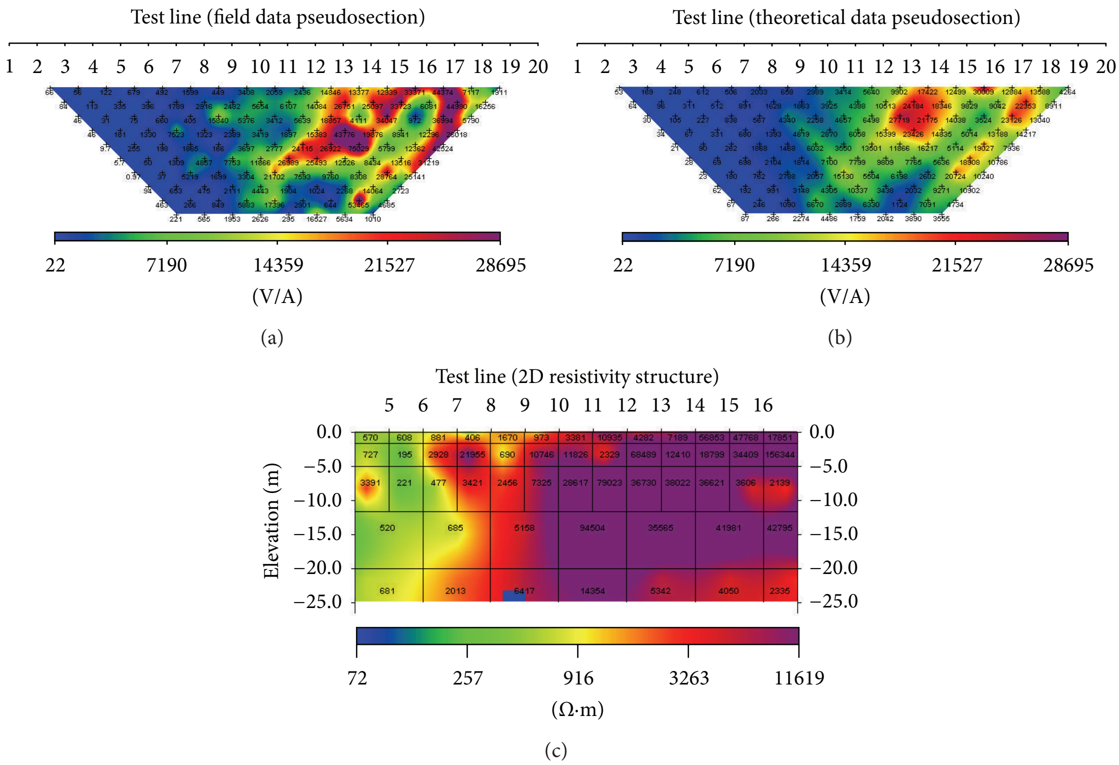

Figure 9: Inverted resistivity section along traverse 3.

4.3. Electrical Resistivity Tomography (Width). In Figure 9 the resistivity values vary across this traverse, with some parts of the traverse being highly resistive, while some other parts are conductive. This structure is observed between the first station number and the fifth station, where pocket of resistive structure (3391 Ωm) at a depth between 5 m and 10 m surrounds a more conductive structure that spreads from the first station towards the 7th station. Resistivity values averaging (3268 Ωm) is characteristic of the body structure which extends from the 6th station towards the middle of 9th and 10th station. This body is extensive but possesses a thin layer of less resistive bodies as top soil.

Extending from the 9th station towards the last station number is a body of highly resistive structure with resistivity average of (11618 Ωm) which covers the entire area but with pockets and sheets of less resistive bodies being observed; for example, within the 15th and 16th station is a pocket of less resistive material between the depths of 5 m–10 m. Also, at depths greater than 20 m, there is presence of similar body which spreads from 12th station towards the last station. The zones of high resistivity in this traverse shows/signifies "safe zones" where there as little or no movement of contaminants. However, the weak zones of high conductivity and low resistivity as abundantly witnessed at the first few station positions are weak and susceptible to movement of contaminants emanating from the dumpsite. Critical affection must be paid to these zones of weaknesses.

2D resistivity structure as shown in Figure 9 indicates a partly resistive area and partly conductive area, demarcating the rectangular prism almost in two halves. The first stations extending to the eighth station are conductive with a pocket of resistive structure located within the seventh and eighth station at a depth around 5 meters. There is possible migration of leachates to the groundwater system, from the first to the seventh station/block.

5. Conclusion

The 2D electrical resistivity successfully delineated the lateral and vertical extent of the contaminated zones as well as fractures as subsurface contaminant pathways. The results of the resistivity imaging delineated leachate plume as low resistivity zones. The results of 2D resistivity imaging has helped characterize the landfill subsurface, such as landfill geometry, leachate plumes, and landfill disposal trenches in Ikare Akoko municipality. The result revealed that the surrounding soil and groundwater within and around the landfill area have actually migrated into the aquifer system, thereby contaminating to depth of 25 m which is well within the aquifer system in the area.

References

[1] A. R. Allen, A. Dillon, and M. O'Brien, "Approaches to landfill site selection in Ireland," in *Engineering Geology and the Environment*, P. G. Marinos, G. C. Koukis, G. C. Tsiambaos, and G. C. Stournaras, Eds., pp. 1569–1574, Rotterdam, The Netherlands, 1997.

[2] J. D. Mather, "Preventing groundwater pollution from landfilled waste-is engineered containment an acceptable solution?" in *Groundwater Quality*, H. Nash and G. J. H. McCall, Eds., pp. 191–195, Chapman & Hall, London, UK, 1995.

[3] I. Georgaki, P. Soupios, N. Sakkas et al., "Evaluating the use of electrical resistivity imaging technique for improving CH4 and CO2 emission rate estimations in landfills," *Science of the Total Environment*, vol. 389, no. 2-3, pp. 522–531, 2008.

[4] A. Green, E. Lanz, H. Maurer, and D. Boerner, "Template for geophysical investigations of small landfills," *Leading Edge*, vol. 18, no. 2, pp. 248–254, 1999.

[5] K. H. Heitfeld and M. Heitfeld, "Sitting and planning of waste disposal facilities in difficult hydrogeological conditions," in *Engineering Geology and the Environment.*, P. G. Marinos, G. C. Koukis, G. C. Tsiambaos, and G. C. Stournaras, Eds., pp. 1623–1628, Rotterdam, The Netherlands, 1997.

[6] E. Lanz, L. Jemmi, R. Muller, A. Green, A. Pugin, and P. Huggenberger, "Integrated studies of Swiss waste disposal sites: results from georadar and other geophysical surveys," in *Proceedings of the 5th International Conference on Ground Penetrating Radar (GPR '94)*, pp. 1261–1274, 1994.

[7] L. Orlando and E. Marchesi, "Georadar as a tool to identify and characterise solid waste dump deposits," *Journal of Applied Geophysics*, vol. 48, no. 3, pp. 163–174, 2001.

[8] V. Saltas, F. Vallianatos, P. Soupios, J. P. Makris, and D. Triantis, "Application of dielectric spectroscopy to the detection of contamination in sandstone," in *Proceedings of the International Workshop in Geoenvironment and Geotechnics*, pp. 269–274, Milos Island, Greece, September 2005.

[9] C. Bernstone, T. Dahlin, T. Ohlsson, and W. Hogland, "DC-resistivity mapping of internal landfill structures: two pre-excavation surveys," *Environmental Geology*, vol. 39, no. 3-4, pp. 360–371, 2000.

[10] E. Aristodemou and A. Thomas-Betts, "DC resistivity and induced polarisation investigations at a waste disposal site and its environments," *Journal of Applied Geophysics*, vol. 44, no. 2-3, pp. 275–302, 2000.

[11] C. B. Dawson, J. W. Lane Jr., E. A. White, and M. Belaval, "Integrated geophysical characterization of the Winthrop landfill southern flow path, Winthrop, Maine," in *Proceedings of the Smposium on the Application of Geophysics to Engineering and Environmental Problems*, p. 22, Environmental and Engineering Geophysical Society, Las Vegas, Nev, USA, February 2002.

[12] L. Bengtsson, D. Bendz, W. Hogland, H. Rosqvist, and M. Akesson, "Water balance for landfills of different age," *Journal of Hydrology*, vol. 158, no. 3-4, pp. 203–217, 1994.

[13] G. Trochobanogous, H. Theisen, and S. Vigil, *Integrated Solid Waste Management*, McGraw Hill, New York, NY, USA, 1993.

[14] S. O. Ojo, "Factor productivity in maize production in Ondo state Nigeria," *Applied Tropical Agriculture*, vol. 15, pp. 57–65, 2000.

[15] M. H. Loke, I. Acworth, and T. Darlin, "A comparison of smooth and blocky inversion methods in 2D electrical imaging surveys:," *Geophysics*, vol. 35, pp. 266–271, 2003.

[16] C. Pomposiello, C. Dapeña, A. Favetto, and P. Boujon, "Application of geophysical methods to waste disposal studies," in *Municipal and Industrial Waste Disposal*, X.-Y. Yu, Ed., 2012.

[17] C. Degroot-Hedlin and S. Constable, "Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data," *Geophysics*, vol. 55, no. 12, pp. 1613–1624, 1990.

[18] M. H. Loke and R. D. Barker, "Least-squares deconvolution of apparent resistivity pseudosections," *Geophysics*, vol. 60, no. 6, pp. 1682–1690, 1995.

[19] M. H. Loke and R. D. Barker, "Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method," *Geophysical Prospecting*, vol. 44, no. 1, pp. 131–152, 1996.

[20] M. H. Loke and R. D. Barker, "Practical techniques for 3D resistivity surveys and data inversion 1," *Geophysical Prospecting*, vol. 44, no. 3, pp. 499–523, 1996.

[21] P. Tsourlos, *Modeling interpretation and inversion of multi-electrode resistivity survey data [DPhil thesis]*, University of York, 1995.