



ASSESSMENT OF THE CONTAMINATION OF GROUNDWATER AROUND OPEN WASTE DUMPSITE IN AWOTAN, IBADAN, SOUTHWESTERN NIGERIA, USING INTEGRATED ELECTRICAL RESISTIVITY AND GEOCHEMICAL METHODS



J. O. Coker^{1*}, K. A. Olajide¹, J. A. Agbelemoge¹ and T. A. Laniyan²

¹Department of Physics, Olabisi Onabanjo University, Ago-Iwoye, Ogun State, Nigeria

²Department of Environmental Health Sciences, University of Ibadan, Oyo State, Nigeria

*Corresponding author: coker.joseph@oouagoiwoye.edu.ng, cokerlara@yahoo.com

Received: September 11, 2020 Accepted: February 24, 2021

Abstract: The effects of leachate percolation on groundwater contamination were investigated at Awotan open waste dumpsite using both electrical resistivity and geochemical techniques to assess the quality of hand-dug wells bordering the dumpsite for potable water. Five resistivity traverses were acquired at the dumpsite using Wennerarray with electrode separation ranging from 5 to 25 m. The DIPROWIN 4.01 software was used to process and invert the 2-D resistivity data obtained. Geochemical test was carried out on soil and water samples according to Nigeria Industrial Standard (NIS). The subsurface models of the 2-D resistivity data revealed very low resistivity values below 10 Ω m and suspected to be leachate. The plume is concentrated on the top layer regolith of the dumpsite. The extent of migration is pronounced, suggesting continuous contamination of the shallow groundwater system. The soil analysis shows that, the clay content has values between 14.1 and 19.1% interpreted as low protective capacity. The results of the geochemical analysis revealed that most parameters of groundwater samples are within the limit of Nigeria NIS. However, the concentration of lead recorded was 0.01 mg/dm³ which is exactly the permissible limit set by NIS and *E. coli* with higher concentrations of 0.03 cm³. The study concludes that, people living around the dumpsite are prone to health issues since there is tendency for lead to increase overtime. It is recommended that, periodic evaluation of Water Quality Index (WQI) of water samples bordering the dumpsite should be done regularly to give information on the source of groundwater contamination and management.

Keywords: Contamination, electrical resistivity, geochemical, groundwater, open waste dumpsite

Introduction

On a daily basis, varying types and enormous amounts of wastes are deposited in an indiscriminate manner at various dumpsites across human and industrial settlements in Nigeria. In disposing large volume of wastes generated daily, man has carelessly continued to pollute the environment. In several parts of Nigeria and most other developing countries, control of dumpsites is a major challenge, especially in urban centres. Leachate generated from the municipal waste deposit is generally associated with a high concentration of ions which results in very low resistivities of host rocks or formation (Martinho and Almeida, 2006). The interaction between the dumpsite materials (leachate), the subsurface geologic unit, and groundwater are of great concern; hence pollution of groundwater is a major threat, as leachate infiltrates the aquifer (Osazuwa and Abdullahi, 2008). The major reliance on dumpsites for waste disposal has resulted in the mobilization of toxic fluids (liquid and gas) to which could be leachate or landfill gases, the areas outside the landfills resulting in the pollution of ground and surface water; soil and air. Leachates from open dumpsites usually contain dangerous chemical constituents which poses a great danger to public health (Tesfaye, 2007). As leachate move downward, it mixes with the groundwater in between the pore-spaces within the soil, and this moves through the groundwater's path as plumes of contaminated groundwater. This downward flow may threaten springs at the periphery of the landfill according to Oladunjoye *et al.* (2011).

Dumpsite releases a very large amount of highly concentrated carcinogens, toxic and hazardous chemicals to nearby groundwater, soil and air through leachate and landfill gases, posing a threat to public health. The percolated leachate from landfills is dependent on the moisture content of the waste materials and the quality of water entering the fill. The capacity of the solid wastes to hold water is exhausted and the leachate that is formed creates water pollution.

Ganiyu *et al.* (2015) carried out 2D electrical resistivity survey on Aba Eku dumpsite in Southwestern Nigeria with a

view to map the conductive leachate plume and extent of migration of leachate plumes in the subsurface for possible groundwater contamination. A total of thirteen (13) resistivity traverses were acquired within and outside the dumpsite. The inverse resistivity models of the subsurface from 2D imaging revealed low resistivity value less than 10 Ω m suspected to be leachate infiltration. The extent of leachate migration was up to a depth of about 4 m, an indication that the underlying layer has a greater risk of contamination by leachate and decomposed solid waste materials.

The Awotan dumpsite has played host to lots of inhomogeneous wastes which are largely non-biodegradable and have accumulated for years causing a long interaction between the dumpsite wastes, the soil and the subsurface geological units. Waste disposed into landfill sites undergoes oxidation and corrosion of metallic components and decomposition of organic matter, resulting in the release of leachate impacting on the soil, and groundwater. The aim of the work is to assess the impact of the open waste dumpsite on groundwater in Awotan and the objectives are to determine groundwater quality and its vulnerability to contamination from solid wastes.

Materials and Methods

The study area

Ibadan is the capital of Oyo State, Nigeria with a population of 2.6 million people located approximately on longitude 3° 5' E and latitude 7° 23' N of the Equator, at a distance of some 145 kilometers northeast of Lagos. Ibadan is within the basement complex of the geological setting of South-western Nigeria, which comprises of mainly the metamorphic rocks of Precambrian age with few intrusions of granites and porphyries of Jurassic age. It is underlain by biotite granite gneiss, migmatite biotite gneiss, biotite muscovite granite, hornblende granite, and schists. The rock types include quartz, pegmatites, amphibolites, aplites, dolerite dykes, and Xenolith. The Awotan dumpsite is underlain by migmatite rock (Fig. 1) and of Precambrian in age and undergone a certain degree of weathering (NGSA, 2010). The total area of the dumpsite is about 0.128559 km.

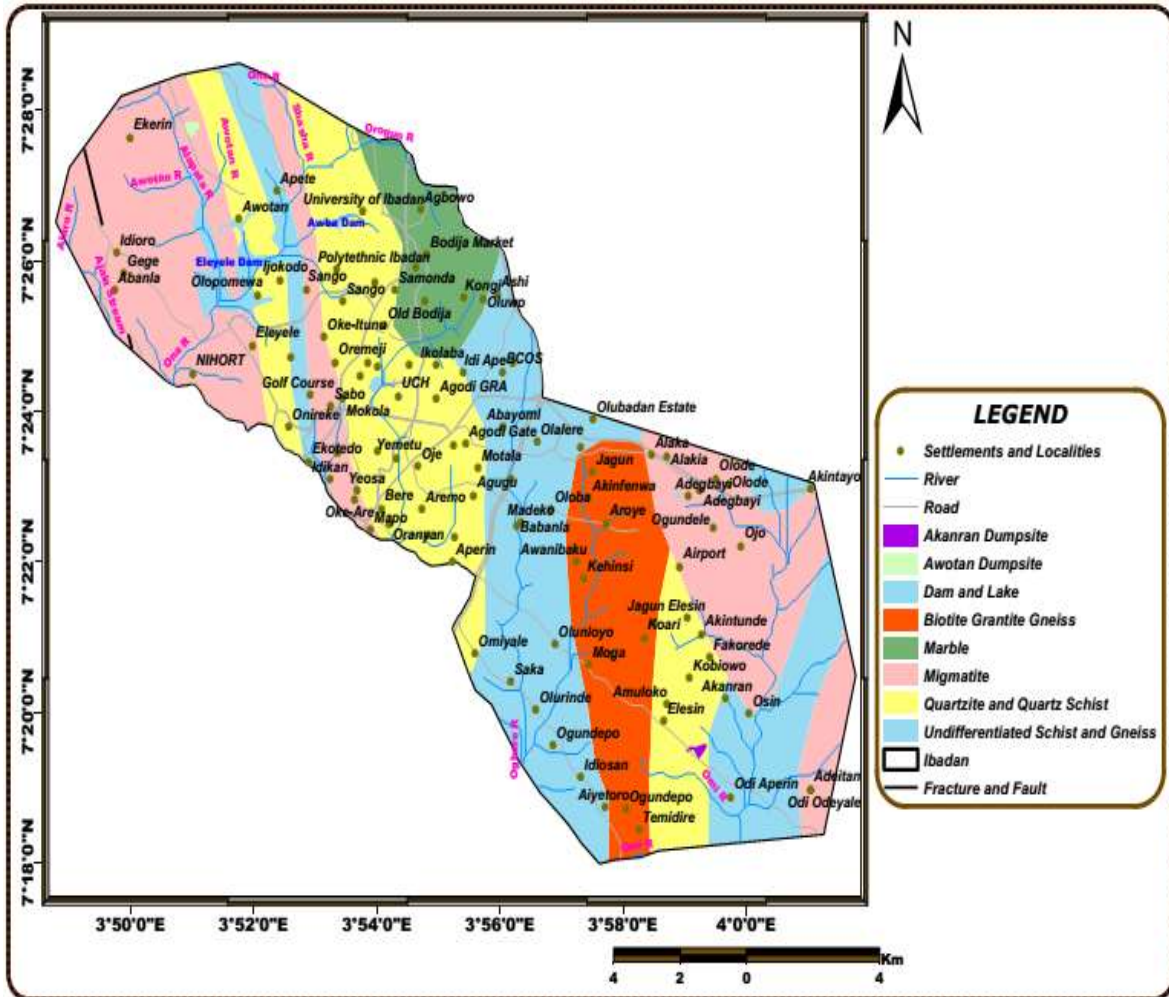


Fig. 1: The geological map of part of Awotan Dumpsite (NGSA, 2010)

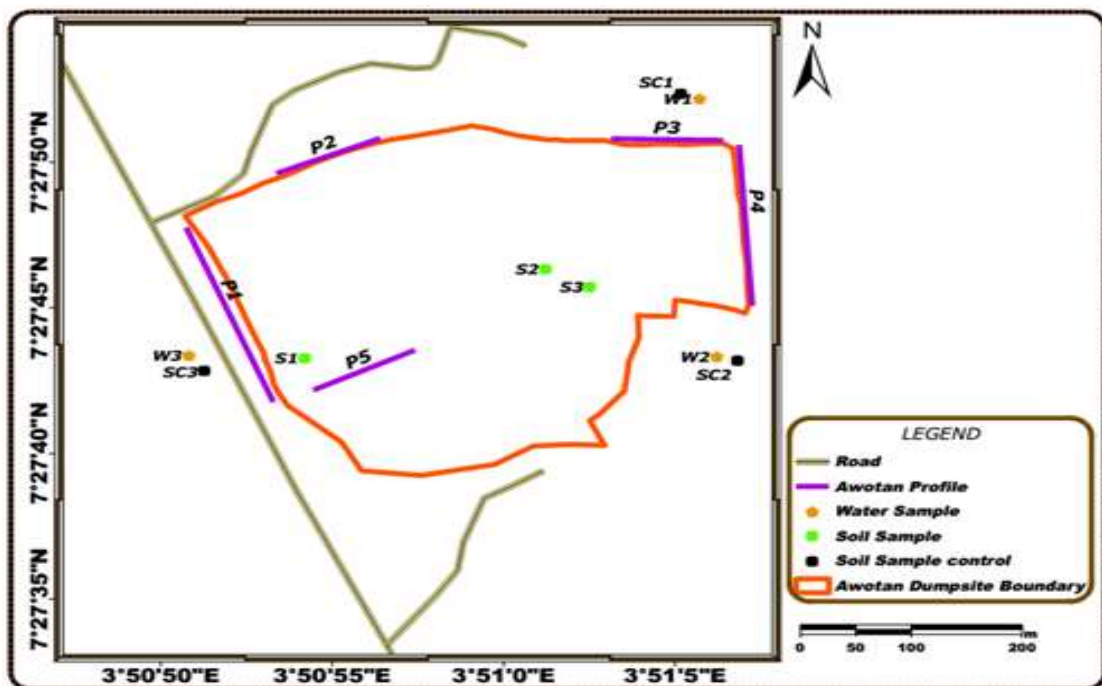


Fig. 2: The map of the dumpsite showing the distributions of the 2-D electrical resistivity profiles, water sample, and soil sample points

Methods

The constant separation traversing is a simple electrical method of geophysical investigation where a configuration of four electrodes is maintained at a constant spacing and moved along the surface to give information on resistivity at a single sounding depth. Using a Wenner array, the increment for such a traverse is typically equal to the electrode spacing (*a*) and the process are repeated by increasing the electrode spacing's of 2*a*, 3*a*, and so on. This permits investigation of the vertical variation in ground properties. A 2-D technique is widely used in the investigation of contaminants at unsaturated and saturated zones (Longe and Balogun, 2009; Coker, 2012; Ohwoyere *et al.*, 2014). The imaging system was done with four electrodes at 5 m electrode spacing and 5 m interval movement by the ABEM Terrameter SAS 1000 by adopting a Wenner array. The matrix used was soil. A total of five image lines each were occupied with the images varying in length from 0 to 100, 170, and 200 m. This effectively gave a maximum depth of imaging of 25 m.

The data acquisition map (Fig. 2) shows the distributions of the 2-D electrical resistivity profiles, soil, and water sample points of the study area. The 2-D resistivity data was processed using DIPROFWIN software.

Twelve (12) samples of soil were collected in-situ at three (3) different points within and outside the study area with those collected outside the dumpsite serving as the control. At each sample point, two samples were collected from 0 – 20 cm and 20 – 40 cm depths using hand soil auger, and a cylindrical core of diameter 5 cm and height 5 cm. The soil samples collected from each point were dried in air, and passed through 2.00 mm sieve to remove any plant materials. Thereafter, sand, silt and clay properties were determined using a Boyoucos hydrometer method described by Grossman and Reinse (2002). The soil textural class was estimated using a textural triangle. Then, a coring method was used to determine the soil bulk density. The sharp end of a cylindrical metal core was driven vertically into the soil. To avoid compaction, another ring of the same size was placed on it to push the first ring completely into the soil. The uniform entry of the ring into the soil was made possible by placing a piece of plank on the ring while hammering it. The plank was hammered at the center until the ring beneath-entered completely into the soil. A hand trowel was used to remove the cylindrical core from the soil while excess soil was trimmed off from it. The soil in the core was emptied into moisture can and dried by the oven to a constant weight at 105°C. Bulk density (Grossman and Reinse, 2002) was evaluated by equation (1):

$$P_b = \frac{M_s(g)}{V_b(cm^3)} \quad (1)$$

Where: *P_b* is the soil bulk density (gcm⁻³); *M_s* being the mass of oven - dried soil (g), and *V_b*, the volume of the soil/cylindrical core (*V_b* = π*r*² *h*; *r* being the internal diameter and *h* the height of the cylindrical core).

Total porosity (*T_p*) is given by equation (2) below:

$$T_p = \left[\frac{1 - P_b}{P_s} \right] \times 100 \quad (2)$$

Where: *P_b* is the soil bulk density (Mgm⁻³); *P_s* is the soil particle density with a constant value of 2.65 Mgm⁻³ and *T_p* is the total porosity (%)

The saturated hydraulic conductivity (*K_s*) was determined using a constant head water permeameter method of Reynolds (1993) and transposed Darcy's equation for a vertical flow of liquid:

$$K_s = \frac{QL}{tA(\Delta H)} \quad (3)$$

Where: *L* is the length of soil column (cm); *Q* is the volume of water that flows through the soil column at equilibrium in

cm³; *A* is the cross-sectional area of flow (soil core) through the soil column in cm²; *t* is a time interval (h.) and *ΔH* is a hydraulic head (cm).

ΔH = *L* + *h_w*, where *h_w* is the head of water above the soil column

A 100 mL glass beaker was prepared and 50 g air-dry soil (< 2 mm) was weighed into it and 50 mL distilled water added using a graduated cylinder or volumetric flask; well mixed with a glass rod and allowed to stand for 30 min. The suspension was stirred at an interval of 10 min during this period. The pH meter was calibrated and the combined electrodes immersed inside the suspension (about 3 cm deep) and read 30 seconds after in one decimal place. Water samples were analyzed to determine the *E. coli*, total organic carbon, total dissolved solids, nitrate, nitrite, COD, pH, sodium (Na), sulphate (SO₄), Iron (Fe), Chromium (Cr), zinc (Zn) copper (Cu), and Lead (Pb).

pH meter was calibrated, 50 ml water sample was poured inside 100 ml flask, the combined electrode was inserted in the water sample (about 3 cm deep). The reading was taken after 30 seconds and the combined electrode was removed from the sample, rinse thoroughly with DI water in a separate beaker, and the excess water was dry with a tissue carefully.

$$Total\ Dissolved\ Solids = \left(\frac{mg}{L} \right) \frac{Wtd+s-Wtd}{V} \times 1000 \quad (4)$$

Where: *Wtd + s* = Weight of dish plus solids (mg), *Wtd* = Weight of dish before use (mg) and *V* is a volume of water sample used for measurement (mL)

Determination of the heavy metals such as: Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, and Cr by Atomic Absorption Spectrophotometer. 0.5 – 1.0 g air-dry soil (0.15 mm) was weighed into a 300 cm³ calibrated digestion tube, 3 cm³ concentrated HNO₃ (in the fume hood) added and swirled carefully, and then placed the tubes in the rack. The tubes rack was now paced in the block-digester, and then a glass funnel was place in the neck of the tubes.

Slowly increase temperature setting to about 145°C for 1 h. Add 4 cm³ concentrated and HClO₄ heat it to 240°C for further 1 h. Lift the tubes rack out of the block-digester, carefully place on a rack holder, and let tubes cool to room temperature. Filter through Whatman No. 42 filter paper and bring to 50 cm³ volume. Each batch should contain at least one reagent blank (no soil). Eventually whatever is the volume of the volumetric flask becomes the dilution ratio which is to be multiplied with AAS reading to give the metal concentration.

Results and Discussion

Discussion on electrical resistivity

Figure 3 presents the inverted 2D resistivity pseudosection and inferred geologic model for profile 1. Layers delineated beneath this profile are layer 1 of very low resistivity values 10 to 24 Ωm. The pseudosection extends laterally all through the profile length except towards the end of the profile from between 160 and 200 m where it becomes thin and has about 5 m depth. This layer is interpreted as the regolith topsoil. It can be inferred from the low resistivity obtained for this layer, that it has been contaminated by the leachate. The plume is concentrated on the top layer regolith around this area of the dumpsite (Ganiyu *et al.*, 2005). Underlying this layer is a zone of moderately low resistivity values between 54 to 275 Ωm which occur at an average depth of 10 m which is part of weathered Zone but it is lateritic. Below the second layer is the intrusion of a basement into the weathered zone towards the central and eastern part of the transverse with layer resistivity of above 1000 Ωm.

Figure 4 shows the second 2-D profile conducted in the direction of north- western part of the area of study. The spread length for the profile was 100 m due to a space constraint. The profile shows a low resistivity zone between 10 to 25 Ωm at the top of the profile and to the end at about 25 m at depth of about 10 m, indicating an occurrence of lateritic topsoil. The thin weathered basement which underlies the first layer has intermediate resistivity of between 78 and 120 Ωm which indicate the presence of lateritic clay. This layer terminates at about 65 m on the profile line and encloses the first layer. The enclosure of the first layer by the lateritic

clay helps restrict the plume to the top left side of the profile. The fresh basement was identified at a depth of 15 m and beyond with resistivity from 200 Ωm and above indicating that the basement may be fractured and the overburden is a little thick as revealed by electrical resistivity tomography conducted. The uneven nature of the top of the basement rock is as a result of uneven weathering that has taken place around the area investigated. It can be deduced from here that the contaminant plume is only found within the topsoil around the area.

AWOTAN PROFILE1 (2-D Resistivity Structure)

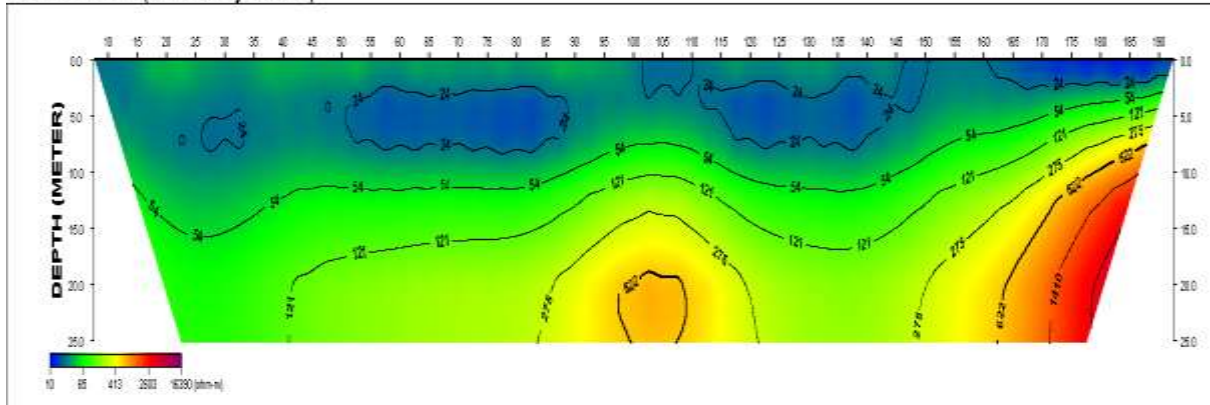


Fig. 3: Inverted 2-D Electrical resistivity pseudosection for profile 1

AWOTAN PROFILE2 (2-D Resistivity Structure)

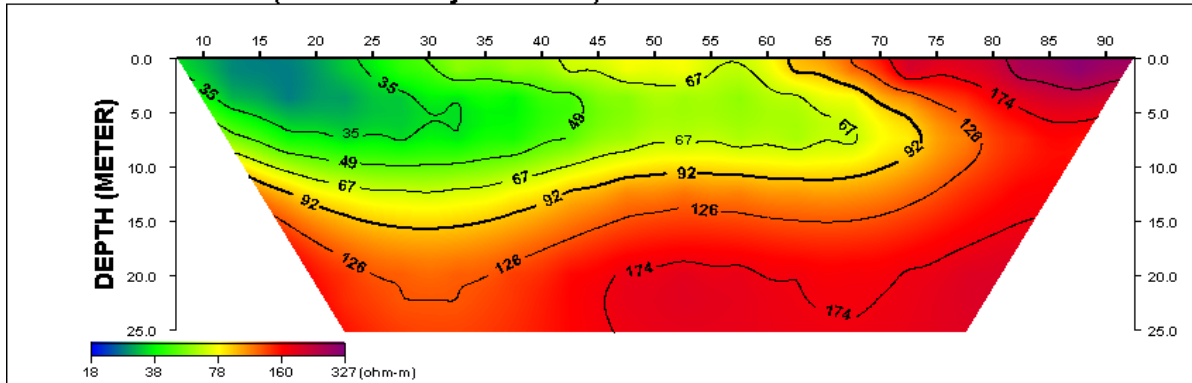


Fig. 4: Inverted 2-D electrical resistivity pseudosection for profile 2

AWOTAN PROFILE3 (2-D Resistivity Structure)

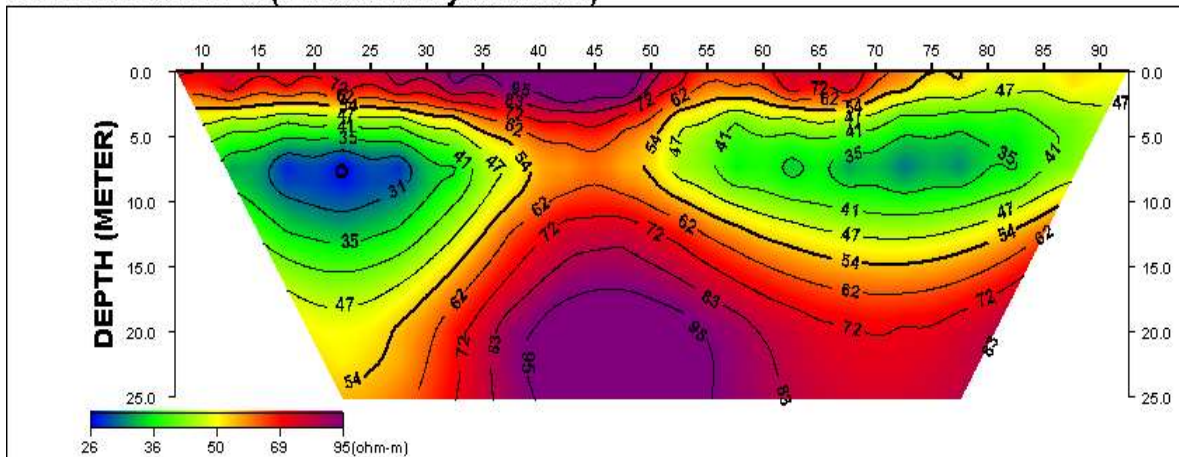


Fig. 5: Inverted 2-D electrical resistivity pseudosection for profile 3

Figure 5 shows the inverted 2D electrical resistivity section for profile 3. The resistivity value at the first layer is between 62 and 95 Ωm at the top of the profile throughout the horizontal distances of 0 to 70 m at a depth of 5 m. It was observed that we have an increase of resistivity with depth throughout the profile. The second layer resistivity value varies between 26 and 60 Ωm at a depth of 25 m which covered a distance between 5 and 40 m at the north-west of the profile and a depth of 15 m at the north-east of the profile. The low resistivity values at the north-west and north-east of the profile could be as a result of the soil layer contamination (Dukya and Abimba, 2010). This interpretation is supported by visual observation during the data acquisition, where the seepage of leachate could be observed from the relatively moist soil layer. The last layer of the profile has resistivity values ranging between 62 and 95 Ωm at a maximum depth of 25 m underlain the second layer. Generally, the resistivity value in this profile is less than 100 Ωm .

Figure 6 shows the second 2D profile 4 conducted at the northeastern part of Awotan dumpsite. The spread length for the profile was 170 m due to a space constraint. The profile shows a low resistivity zone of resistivity value of between 11 to 30 Ωm at the top of the profile which begins at about 100 m

and continuing till the end of profile and has an average depth of about 5 m. This low resistivity top layer is restricted to the top right - hand corner of the pseudosection of the profile which indicates that leachate from the dumpsite has flows to the layer. This part of the profile is adjacent to the end of profile three which showed that the place has truly been contaminated. Also, observed at the top of the section are the intermediate and high resistivity areas. Underlies the top layer is an intermediate resistivity layer which is interpreted as the weathered basement that is lateritic and compacted and has resistivity value ranges between 35 and 100 Ωm which may be the reason the plume is restricted to that area. The fresh basement which is identified at a depth of 12 m and beyond with resistivity from 200 Ωm and above indicates basement which its top might be fractured and the overburden is a little thick as revealed. The fractured zone observed in the section has been protected by the compacted lateritic layer. The uneven nature of the top of the basement rock is as a result of uneven weathering that has taken place around the area investigated (Ewemoje *et al.*, 2017). It can be deduced from here that the contaminant plume is only found within the topsoil around the area.

AWOTAN PROFILE4 (2-D Resistivity Structure)

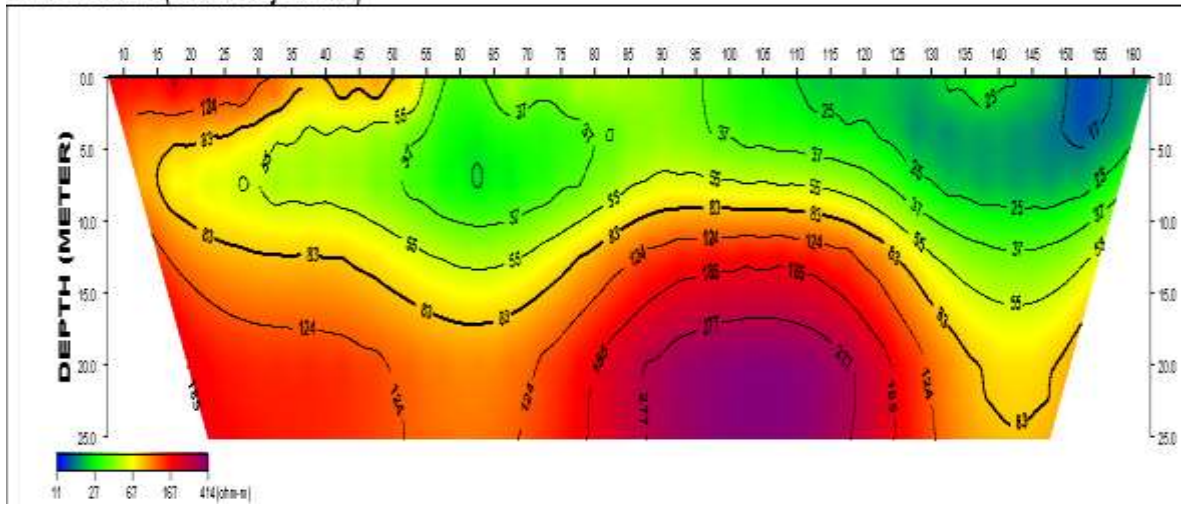


Fig. 6: Inverted 2-D electrical resistivity pseudosection for profile 4

AWOTAN PROFILE5 (2-D Resistivity Structure)

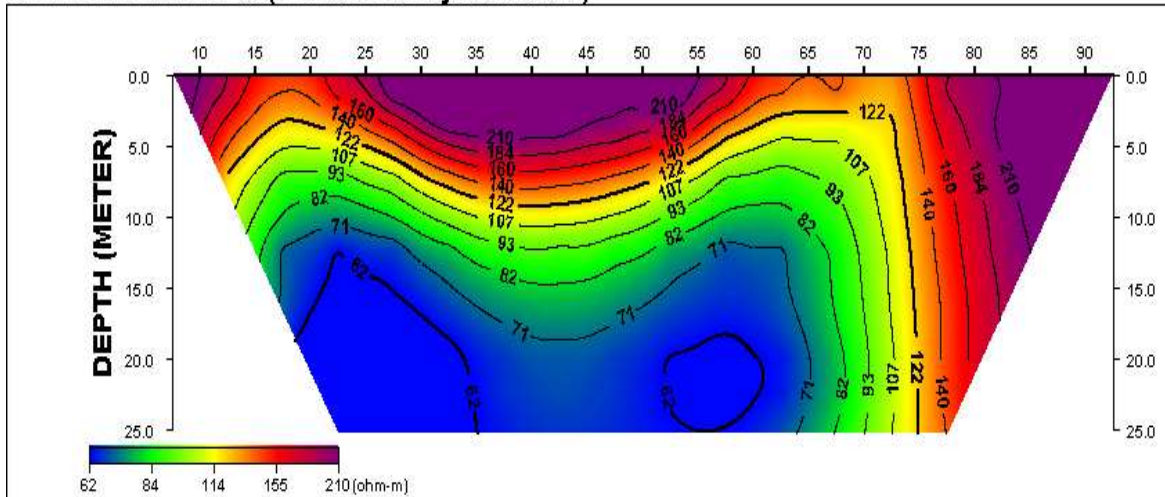


Fig. 7: Inverted 2-D electrical resistivity pseudosection for profile 5

Figure 7 shows 2D electrical resistivity inversion results for profile 5 with a length of 100 m and was conducted along the entrance of the dumpsite. A high resistivity layer (155 Ωm and above) observed at the surface is the top compacted lateritic layer. The layer was compacted as a result of the heavy - duty vehicles that move on it to dump waste at the site. The surface is very hard as observed during the fieldwork when the electrodes are to be driven into the soil. The top compacted layer extends to an average depth of about 8 m. Underlies this layer is the weathered materials from the basement which could be clayey because it does not permeate the plume to seep into it or could be sandy that allows the plume to percolates through it and infiltrate the subsurface layers. This layer has intermediate resistivity (70 to 124 Ωm) as observed from the contour lines on the section. This layer has an average thickness of about 8 m. The base of the section is occupied by a low resistivity layer (60 to 70 Ωm) which could be interpreted as weathered basement zone which has been impacted by the contaminant plume and also could be as a result of deep and prolonged weathering which has converted the weathered basement into clay materials. The former is likely to happen in this area than the latter, whereby the plume has found its way to that depth at the center of the dumpsite and migrate to that depth, then flow in that direction.

Geochemical analysis

Soil Sample analysis

The results of the sieve analysis show that the dominant lithology was sand. This formation is porous and permeable thus implies that leachate from the dumpsite will migrate easily into the unconfined shallow aquifer to contaminate the groundwater system. The soil at the onsite has 61.2% while the offsite has 74% of sand indicating an abundance of loosely soil particles. The silt content for the onsite is 19.1% while the offsite of the dumpsite is 11.9%. The clay content shows relatively low content ranging from 14.1 to 19.1% interpreted as low protective capacity which confirmed easy migration of the plumes/leachate. Other properties include soil pH, bulk density, total porosity, and hydraulic conductivity (Table 1). Table 1 also presents the average pH values of the soil samples from two locations. The highest pH value was recorded at the onsite (6.7) supported the work of Isrimah (2002) with pH values between 6.5 and 7.5 Onsite. As the sand becomes increasingly clayey with depth at the offsite, fluids in the intergranular pores spaces are displaced, thereby increasing the bulk density with average values of 1.55 g/cm³ but at the onsite, the bulk density is low with average value of 1.39 g/cm³. Thus 1.48 is relatively high for a sandy loam soil. Therefore, with 14.1 - 19.1% clay, 11.9 - 19.7% silt, and an average bulk density of 1.48 (relatively high for a sandy loam)

one can say that infiltration of the leachate will be minimal. The soil porosity at the onsite and offsite of the dumpsite ranges from 39 to 48.2% which could be considered high. The hydraulic conductivity of 2.02 cm/hr and 1.45 cm/hr at the onsite and the offsite respectively which are considerably low. By implication, it means that by the end of a day infiltrate (leachate) would have migrated about 2.2 m if the same soil medium continues.

Table 1: The results of sampling location and depth on some properties of the soil

Treatment	pH (1:1 H ₂ O)	Sand (%)	Silt (%)	Clay (%)	Bulk density (g/cm ³)	Total Porosity (%)	Saturated hydraulic conductivity (cm/hr)
Onsite	6.70	61.20	19.70	19.10	1.39	47.70	2.02
Offsite	6.10	74.00	11.90	14.10	1.55	41.60	1.45
Depth							
0-20 cm	6.30	70.50	14.20	15.30	1.48	44.00	2.36
20-40 cm	6.20	70.90	13.60	15.50	1.48	44.20	2.16
CV%	4.00	3.00	20.40	12.50	1.20	1.50	24.60

Water sample analysis

The mean values of organic/inorganic parameters and major ion concentrations were compared with the acceptable limit standards (NIS, 2007).

The pH of the water samples around the dumpsite ranges from 6.45 to 6.86 (Table 2) with a mean of 6.6 (Table 3 and Fig 8), suggesting that the groundwater is acidic due to contamination and this pose health challenges. However, the value is within the permissible level for potable water. The mean concentration of *E. coli* (cfu/100cm³) in the water samples analysed was 0.03 greater than 0.00 cm³ the permissible level limit, indicating the presence of an anomaly in the body of water at minimal concentrations (Table 3 and Fig. 10). The average Total Organic Carbon (TOC) value of 1.10 mg/dm³ is within the recommended value of 5.00 mg/dm³ (Fig. 8). The mean value of Total Dissolved solids (TDS) is 134.5 mg/dm³ and within the permissible level (NIS, 2007) for potable water (Table 3 and Figure 10). The chemical oxygen demand (COD) of 100 mg/dm³ lies within the level limit of the permissible level (NIS, 2007) of 150 mg/dm³ and does not pose a threat (Fig. 9). In this study, the physicochemical analysis of the sampled water showed that the, pH, TDS, and TOC values were below the maximum permissible level recommended by NIS (2007).

Table 2: Summary of the acquired data for water analysis

	<i>E. coli</i> (cfu/100cm ³)	TOC (mg/dm ³)	TDS (mg/dm ³)	Nitrate (NO ₃) (mg/dm ³)	Nitrite (NO ₂) (mg/dm ³)	COD (mg/dm ³)	pH	Sodium (Na) (mg/dm ³)	Sulphate (SO ₄) (mg/dm ³)	Zinc (Zn) (mg/dm ³)	Cu (mg/dm ³)	Pb (mg/dm ³)	Cr (mg/dm ³)	Fe (mg/L)
Awotan 1	0.01	0.32	98.00	1.25	0.04	87.00	6.55	1.96	2.75	0.94	0.07	ND	ND	0.02
Awotan 2	0.01	0.54	104.00	1.27	0.04	93.00	6.45	2.34	3.90	0.88	0.06	ND	ND	0.02
Awotan 3	0.06	2.43	200.00	3.22	0.12	121.00	6.86	3.56	5.92	1.52	0.56	0.01	0.002	0.05

Where: ND is Not Detectable

The mean value of Nitrate is very low 1.91 mg/dm³ (Table 3 and Fig. 9) and it leaches into the groundwater in the form of nitrate if it is not absorbed by the plants or carried away by surface runoff. The value of nitrate is moderate in this study; ranges between 0.04 and 0.12 mg/dm³ (Table 2 and Fig. 10) when comparing with the permissible level (NIS, 2007). The mean concentration value of sodium ions (Na+) around Awotan dumpsite is very low 2.62 (mg/dm³) (Fig. 10) useful in classifying irrigation water because it reacts with soil to

reduce permeability. The primary source of sodium in the groundwater is from the release of soluble products during the weathering of plagioclase feldspars (Davis and Dewiest, 1996). The value of sulphate ranges between 2.75 and 5.92 mg/dm³ with an average value of 4.19 mg/dm³ which falls within the permissible level of 100 mg/dm³ according to (NIS, 2007)

Table 3: Results of water properties and the permissible level

Test elements (cm ³)/(mg/dm ³)	Hand-Dug Wells	Permissible Level (NIS, 2007)
<i>E. coli</i> (cfu/100(cm ³))	0.03	0.00
Total Organic Carbon (mg/dm ³)	1.10	5.00
Total Dissolved Solids(mg/dm ³)	134.50	500.00
Nitrate (NO ₃) (mg/dm ³)	1.91	50.00
Nitrite (NO ₂) (mg/dm ³)	0.07	0.20
Chemical Oxygen Demand (mg/dm ³)	100.00	< 150.00
pH	6.60	6.50–8.50
Sodium (Na) (mg/dm ³)	2.62	200.00
Sulphate (SO ₄) (mg/dm ³)	4.19	100.00
Zinc (Zn) (mg/dm ³)	1.11	3.00
Copper Cu (mg/dm ³)	0.23	1.00
Lead (Pb) (mg/dm ³)	0.01	0.01
Chromium (Cr) (mg/dm ³)	0.001	0.005

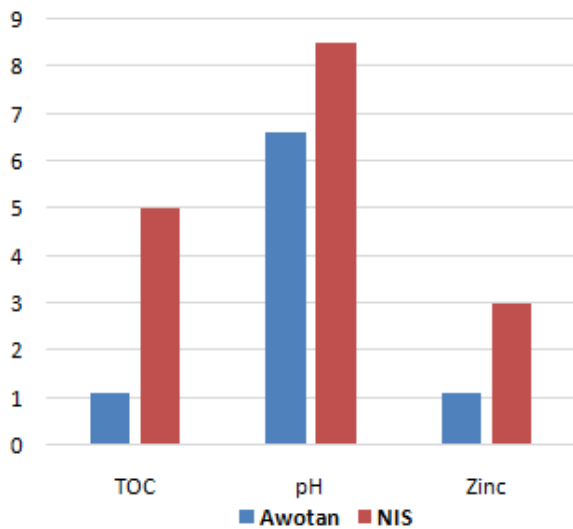


Fig. 8: The mean values for TOC, pH and zinc against NIS values

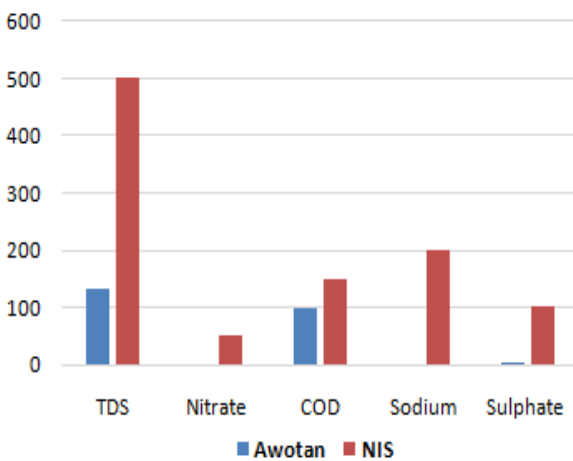


Fig. 9: The mean values for TDS, nitrate, COD, sodium, and sulphate against NIS values

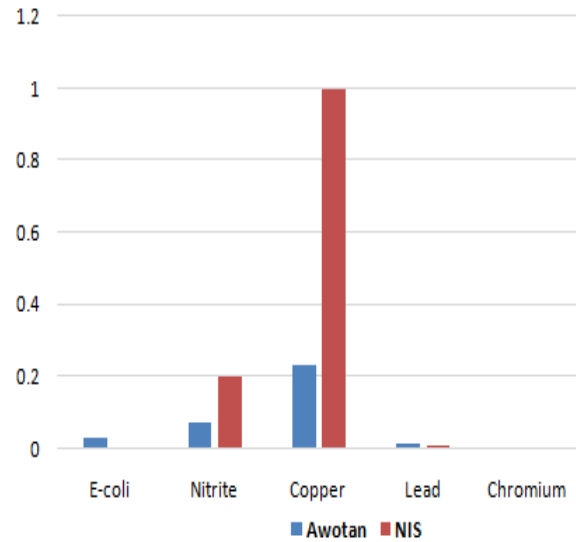


Fig. 10: The mean values for *E. coli*, nitrite, copper, lead, and chromium against NIS values

The heavy metals present in water samples and analysed were Zn (1.11 mg/dm³), Cr (0.001 (mg/dm³)), Pb (0.01 (mg/dm³)), Cu (0.23 (mg/dm³)). The concentrations of zinc, chromium, and copper are within the permissible levels recommended by NIS, 2007 (Figs. 8, and 10, respectively) as confirmed by Nkolika and Onianwa (2011). Lead metal has the same value of concentration 0.01 mg/dm³ (Table 3 and Fig. 10) with the recommended value by the NIS (2007). According to USDA (2000), heavy metal occurs naturally but rarely at toxic levels.

Conclusion

The results of 2-D resistivity survey showed low resistive zones with true resistivity values less than 20 Ωm indicating the presence of leachate. However, the geochemical results also show possible contamination with time. It is an indication that the underlying layer has higher risk of contamination by leachate and decomposed solid waste materials. Similarly, the results of soil and water quality analysis from the hand - dug wells around the dumpsite showed concentrations of organic/inorganic parameters such as *E. coli* exceeding permissible limits.

The ion concentrations are within the permissible limit values. The concentrations of elements such as zinc, copper, and chromium have values within the acceptable limit standards. The lead concentration inside the water analysed has the same value as the permissible limit. This is of concern to the users of shallow wells around the dumpsite for drinking and agricultural purposes because leachate plume might migrate deeply with time during the rainy season when the dumpsite will be saturated.

Recommendation

A more detailed hydrochemical analysis is recommended, periodic evaluation of Water Quality Index (WQI) of water samples bordering the dumpsite will give information on the source of groundwater contamination and management. All those using water from shallow wells around the dumpsite should ensure general hygiene, and water should be boiled, and filtered if necessary before consumption. Houses should be sited away from the dumpsite to minimize pollution of nearby well waters as results from this study indicated that Lead (Pb) has the same value as NIS 2007 standard.

Acknowledgement

The authors hereby acknowledged the support given by the Awotan community heads and the technical personnel.

Conflict of Interest

Authors declare that, there is no conflict of interest related to this work.

References

- Coker JO 2012. Vertical Electrical Sounding (VES) methods to delineate potential groundwater aquifers in Akobo Area, Ibadan, South-western, Nigeria. *J. Geol. and Mining Res.: Aca. J.*; DOI: 10.5897/JGMR11.0144(2): 35-42.
- Davis S & De Wiest R 1996. Hydrogeology. John Wiley & Sons, New York.
- Ewemoje TA, Ewemoje OE & Majolagbe SP 2017. Urbanisation effects on surface and groundwater resources: An assessment of approved dumpsite in Ibadan, Nigeria. *An ASABE Meeting Presentation* DOI: 10.13031/aim.201701388 Paper Number: 170138. ASABE Annual International Meeting Sponsored by ASABE Spokane, Washington July 16-19, 2017.
- Ganiyu SA, Badmus BS, Idowu OA, Oladunjoye MA & Olurin OT 2015. 2D Electrical resistivity imaging investigation of open dump site in basement complex formation. *The African Review of Physics*, 10(0033): 243 – 256.
- Grossman RB & Reinsch TG 2002. Bulk density and linear extensibility, p 201-228. In: Dane JM & GC Topps (eds) *Methods of Soil Analysis, Part 4 Physical Methods*. Soil Science Society of America, Madison, Wisconsin, USA
- Isrimah NO 2002. Understanding the nature, properties, and sources of waste for quality environment. Tom and Harry Publication Limited PHC, Nigeria, pp. 69-114.
- Longe EO & Balogun MR 2009. Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. *Res. J. Appl. Scie., Engr. and Techn.*, 2(1): 39-44.
- Martinho E & Almeida F 2006. 3D Behaviour of contamination in landfill site using 2D resistivity/IP imaging; Case studies in Portugal. *Env. Geol.*, 49: 1070 – 1078.
- NGSA 2010. Nigeria Geological Survey Agency, Nigeria.
- Nkolika IC & Onianwa PC 2011. Preliminary study of the impact of poor waste management on the physicochemical properties of groundwater in some areas of Ibadan. *Res. J. Environ. Sci.*, 5: 194-199.
- Odukoya AM & Abimbola AF 2010. Contamination assessment of surface and groundwater within and around two dumpsites. *Int. J. Envntal. Sci. and Tech.*, 7(2): 367-376.
- Ohwoghere AO, Chiyem FI & Nwankwoala HO 2014. 2D Resistivity Electrical Imaging of Unsaturated and Saturated Zones for Crude Oil Spillage at Agbarha in Ughelli Area of Delta State Nigeria, Technical Report.
- Oladunjoye MA, Olayinka AI & Amidu SA 2011. Geoelectrical imaging at an abandoned waste dumpsite in Ibadan, South-western Nigeria. *Journal of Applied Sciences*, 11(22): 755 – 3764.
- Osazuwa IB & Abdullahi NK 2008. 2D electrical resistivity and induced polarization investigation at an open solid waste dumpsite: Case study from Kaduna, North Central Nigeria. *Journal of Environmental Hydrology*, 16(2a): 1-11.
- Reynolds JM 1997. An introduction to Applied and Environmental Geophysics. Toronto John Wiley and Sons, pp. 417-490.
- NIS/SON 2007. Nigerian Industrial Standard (NIS) for Drinking Water Quality. Standard Organization of Nigeria (SON), 554: 30.
- Tesfaye Z 2007. Groundwater Pollution and Public Health Risk Analysis in the Vicinity of Reppi Solid Waste Dumpsite, Addis Ababa City, Ethiopia. Unpublished M.Sc Thesis, Addis Ababa University, Ethiopia.
- USDA 2000. Diagnosis and Improvement of Saline and Alkali Soils. US Salinity & Laboratory Staff, Government Printing Office, Washington, DC.