



Comparative assessment of aquifer susceptibilities to contaminant from dumpsites in different geological locations



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ABSTRACT

Geophysical and hydro-chemical investigations have been undertaken within the vicinity of Arapaja, Apete and Sabo dumpsites monolithically underlain by three different rock types namely; Migmatite Gneiss, Quartzite, and Granitic Gneiss respectively in a basement complex of Ibadan, southwestern Nigeria. This was with a view to assessing the pollution potential of the dumpsites on the soil and groundwater in the study locations. Electrical Resistivity methods involving Dipole-Dipole profiling and fifteen (15) Schlumberger Vertical Electrical Soundings (VES) were carried out across two orthogonal traverses established in each of the study locations. A maximum of three subsurface layers namely the topsoil, the weathered layer, and the fresh basement were identified from the geoelectric sections in the three locations. The weathered layer, which constitutes the major aquifer units in the areas and the overlying topsoils were suspected to have been impacted by leachates from the waste dumpsites in the three locations as revealed from characteristic relatively low resistivity values of these layers on the geoelectric sections and the 2D resistivity structures. The hydrochemical analysis of samples from wells in the three locations shows that majority of the analysed cations and anions in the three study locations were within the WHO permissible limits. However, there were indications that parameters such as Pb and Fe^{2+} in Arapaja and EC, TDS, K^+ , NO_3^- , Pb, and Fe^{2+} in both Apete and Sabo dumpsites were higher than the acceptable limits which revealed possible contamination impacts of infiltrating leachates from these dumpsites on the ambient groundwater in the three locations. This is in agreement with the pollution index rating of these parameters which indicates that they fall within the strongly polluted and seriously polluted classes of 4 and 5. It is further concluded that Arapaja which is underlain by the Migmatite Gneiss rock shows least impact of the infiltrating leachates from the dumpsite relative to other dumpsite locations in Apete and Sabo where the underlying rock types are quartzite and granite gneiss respectively. This can be attributed to the nature of the resulting weathered profile of these rock types which is mostly characterized by impermeable clayey materials in Arapaja and by permeable sandy materials in Apete and Sabo locations.

1. Introduction

The growing rate of groundwater contamination, most especially in the developing countries has become a problem that has gained the attention of both academic scholars and stakeholders in the management of water resources in recent times (Harter, 2003; Celik, 2002). Groundwater is inherently susceptible to contamination from both natural and anthropogenic sources. While there are cases of contamination induced from dissolution of natural minerals as groundwater moves through iron bearing strata, limestone and salty formations, groundwater contaminations attributed to anthropogenic sources have raised the scale tremendously (Harter, 2003). One important source of groundwater

contamination in the developing countries is the poor solid waste management whereby municipal wastes are disposed off indiscriminately openly and are often subjected to open burning (Simsek et al., 2006). This unsanitary manner of waste disposal/creating dumpsites has impact on the quality of groundwater in an area as leachates generated from biodegradation of the wastes can be saturated with rainwater and percolates down to pollute the subsurface aquifer system (Kassenga and Mbluligwe, 2009). Researchers have confirmed the potential health hazard a waste dump constitutes for people depending on ambient groundwater as source of drinking water or for other domestic purposes (Schneider, 1970; Odewande, 1999).

In view of the importance of groundwater, prevention of groundwater

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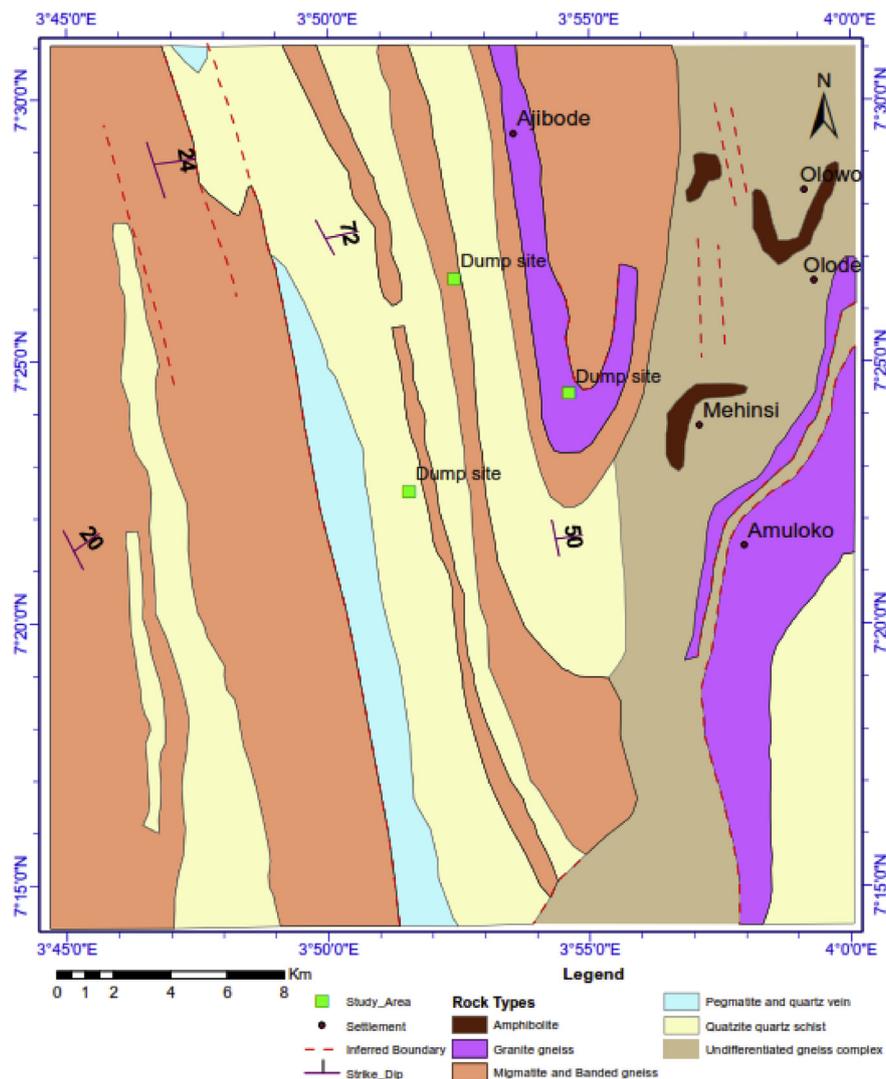


Fig. 1. Geological map of Ibadan showing the three dumpsites (Okunlola et al., 2009).

contamination is critical to effective water resource management as remediation can be very expensive and often impractical (Thirumalaivasan and Karmegan, 2001). Consequently, it has become imperative to carry out aquifer vulnerability assessment in order to predict areas at potential risk of contamination.

Such vulnerable zones could then be enforced with restricted land use or become a focus of attention at preventing contamination of the underlying groundwater resources.

Several studies on aquifer vulnerability have revealed that the protection of aquifer hinges on the permeability of the overlying media to the transportation of contaminants into underlying aquifer units (Simsek et al., 2006). In the Basement Complex, numerous attention have been given to the morphology of the vadose zone in assessing the susceptibility of underlying aquifers to infiltration of contaminants (e.g. Omosuyi and Oseghale, 2012). The rate and extent of leachate infiltration is controlled primarily by the ease with which the subsurface layers beneath the dumpsite and its surroundings allow contaminants migrate. Reports have shown that permeable sandy materials allow rapid infiltration of contaminants while less permeable clayey materials provide geological barrier that retards its movement (Olla, 2011; Ayuk et al., 2013; Awoniyi, 2013). Therefore the need to understand the subsurface soil profile has become pertinent to assess the impact of any overlying dumpsite on the underlying aquifer system.

Meanwhile, the morphology of the subsurface media in a location is

unique to the processes and forces in play in its formation through geological history. While there are other factors controlling the makeup of soil profile, Amundson et al. (2003) revealed that the type of parent rock materials greatly influences the morphology of the surface media in a location. Consequently, aquifer susceptibilities may be varied in locations with different basement rock types. Ibadan southwest Nigeria is one of the largest and most densely populated cities in West Africa (Fourchard, 2003); this in turn accounts for the huge wastes produced in the city. Many of the huge wastes produced on daily basis across the city are disposed off indiscriminately in a number of dumpsites. For the purpose of this study, Apete, Sabo and Arapaja dumpsites were chosen due to the fact they were underlain by different rock types, besides this, the age of each of these dumpsites was established, through oral interview with inhabitants of the areas, to be about 40 years old. They are active refuse dumpsites that have been receiving mix of solid wastes from within and around the area. The heterogeneous composition of the waste dump ranges from domestic wastes (such as paper, garbage, wood scrap, nylon, rubber, can, glass, ceramics, aerosol etc); agricultural wastes (farm manure, animal dung and crop residue) to industrial wastes (such as chemicals, vehicle spare parts etc). The biodegradation of these wastes generates leachate plume that can contain both chemical and biological constituents (Dauda and Osita, 2003; Slomczynska and Slomczynski, 2004). These leachates are typical sources of groundwater contamination especially where they infiltrated the subsurface layers to pollute the

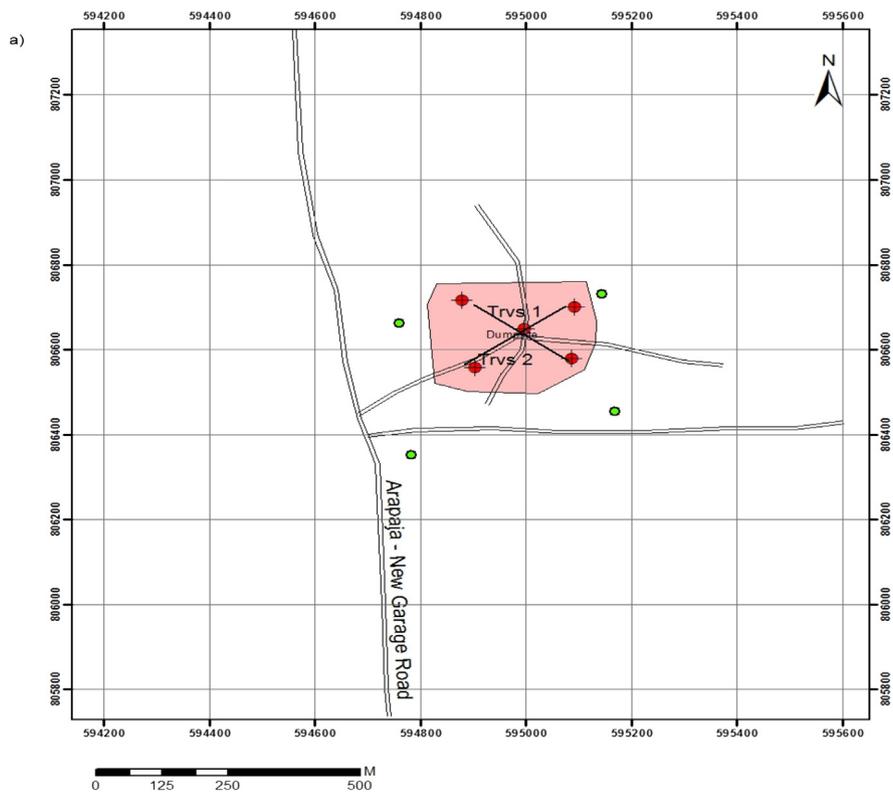


Fig. 2a. Data Acquisition Map for Location 1 (Arapaja).

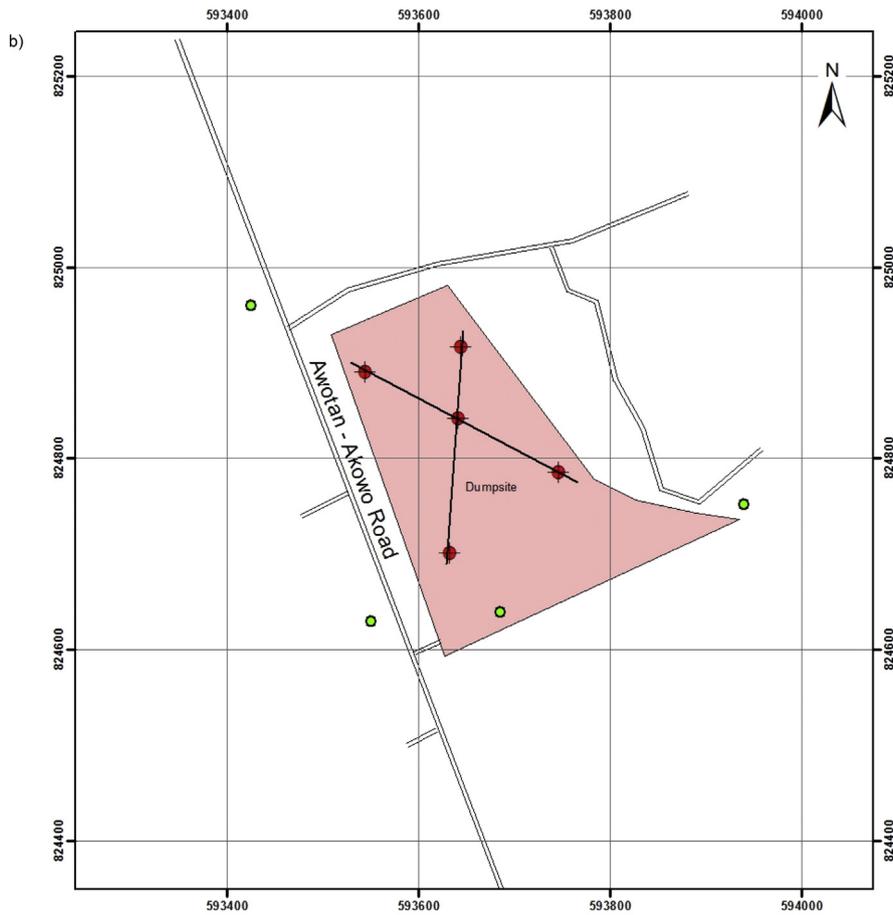


Fig. 2b. Data Acquisition Map for Location 2 (Apete).

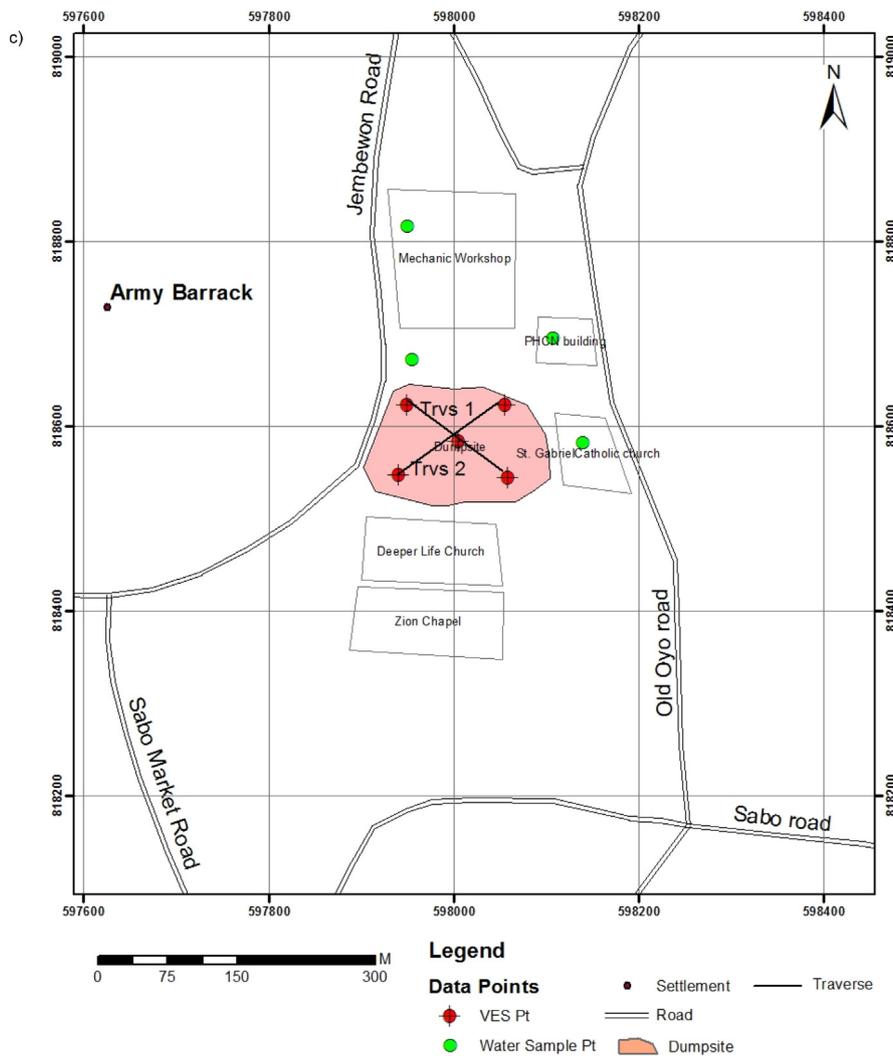


Fig. 2c. Data Acquisition Map for Location 3 (Sabo).

aquifer system. The susceptibilities of underlying aquifers to contaminants infiltrating the subsurface media tend to be varied based on the morphologies of the subsurface in different geological locations. The subsurface geology impacts the disposition of infiltrating contaminants in terms of their movement, distribution and attenuation. The permeability of subsurface geological materials deriving from parent rock in a locality may significantly differ in various geological localities which are subject to the varied conditions of weathering in place. The weathered profile in a locality may provide a confinement for ambient aquifers by restricting or limiting further movement of the infiltrating contaminants while in another locality the ambient aquifers may be unconfined. Thus, the susceptibility of the ambient aquifers to contaminants in these two scenarios will be different. Hence a comparative assessment of aquifer susceptibilities to contaminants from dumpsites in different geological locations may provide information on geological controls on disposition of contaminants in the subsurface which is pertinent for safe location of dumpsites and protection of aquifers. In order to achieve this aim, the study will attempt to:

- i. delineate the lithological sequence and map the subsurface geological structures e.g faults and fracture zones;
- ii. determine the geoelectric parameters of the delineated subsurface layers and identify the aquifer unit;
- iii. establish whether or not the subsurface layers have been contaminated by leachate;

- iv. evaluate the quality of the groundwater in the study areas;
- v. determine the pollution index of the groundwater in the study areas; and
- vi. use i-v to assess the degree and extent of impact of the waste dumpsites on the quality of the groundwater in the study area.

1.1. Geology & geomorphology of the study area

Three dumpsites, situated in Ibadan southwest Nigeria, were utilized for this study. These dumpsites are ancient, extensive and active repositories for solid mix of diversified refuse that ranges from domestic and animal wastes to human wastes generated from and around the study area. They are openly operated and often exposed to intermittent open-air incineration.

Ibadan falls within the Precambrian basement complex of South-western part of Nigeria and dominated by rock types such as granite and granitic schist of the metasedimentary series, banded gneiss and granite gneiss, augen gneiss and migmatite complex (Okunlola et al., 2009) (Fig. 1). The three areas of investigation are located on different geological formations. The areas are monolithic each as preliminary geological investigations revealed that the Apete dumpsite is underlain by mainly quartzite while Arapaja and Sabo dumpsites are underlain by migmatite and granite gneiss respectively.

The mean annual rainfall in Ibadan ranges between 788 mm and 1884

Table 1
Summary of the VES interpreted results.

VES NO	Layers geoelectric parameters (Resistivities (Ohm-m)/ thicknesses (m))	Curve type	Possible lithologic equivalence
Arapaja			
1	41/1.2; 19/4.5; 113	H	Top soil/ weathered basement/ fresh basement
2	35/1.3; 16/6.9; 251	H	Same as VES 1
3	35/1.5; 12/4.5; 173	H	Same as VES 1
4	16/0.7; 33/1.1; 8/2.6; 294	KH	Top soil/ weathered basement/ weathered basement/ fresh basement
5	33/1.3; 14/2.6; 94	H	Same as VES 1
Apete			
1	11/1.1; 32/2.7; 12/3.2; 373	KH	Same as VES 4
2	48/1.6; 16/6.1; 34	H	Same as VES 1
3	43/1.7; 12/5.1; 514	H	Same as VES 1
4	13/0.9; 31/2.4; 10/3.1; 452	KH	Same as VES 4
5	14/1.3; 11/3.4; 242	H	Same as VES 1
Sabo			
1	62/2.7; 15/7.4; 493	H	Same as VES 1
2	54/0.8; 5/2.2; 178	H	Same as VES 1
3	87/0.9; 15/7.0; 434	H	Same as VES 1
4	39/1.0; 7/7.1; 818	H	Same as VES 1
5	53/1.1; 16/3.4; 571	H	Same as VES 1

mm while the mean annual temperature is 26.6 °C (Iloeje, 1980). Humidity is relatively high during the wet season and low during the dry season (Iloeje, 1980). The vegetation in the study area is rain forest type. It consists of thick vegetation comprising multitude of evergreen trees that yield tropical hardwoods.

2. Material and methods

The instrument employed for the geophysical survey was the Ohmgea resistivity meter and its accessories. 2-liters white plastic bottles were used to collect water samples from the wells situated around the dump-site. These water samples were used for the hydrochemical analysis. The method of study engaged for this research work was carried in four phases which include reconnaissance survey, geophysical data acquisition, collecting of water samples and hydrochemical analysis.

The reconnaissance survey involved identification of the available hand-dug wells in the study areas for sampling and measurements and establishment of geophysical traverses. Twelve hand-dug wells (four from each location) were identified. The geographical coordinates of these well were taken using the geographical positioning system. Two orthogonal traverses with traverse length of 140 meters were established for each of the three locations (Fig. 2a-c).

The geophysical measurements utilizing electrical resistivity method involving Vertical Electrical Sounding (VES) and combined horizontal profiling and sounding techniques using Schlumberger and Dipole-

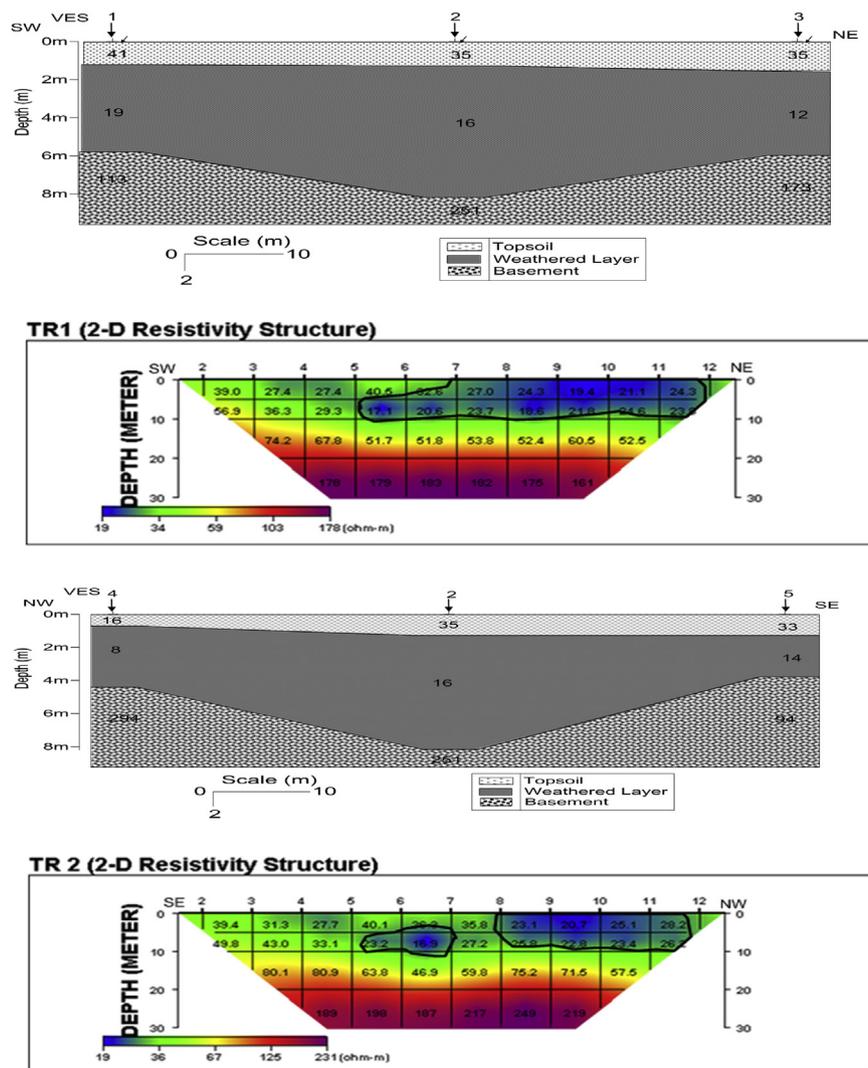


Fig. 3. Combination of the 2-D resistivity structure and the geoelectric sections along traverses 1 and 2 in Arapaja.

Dipole electrode array configurations respectively were undertaken. Six (6) traverses were established in all, two (2) traverses in each location parallel to the orientation of the dumpsite along which the geophysical data were obtained. The geographical coordinates of the study area, traverse lines, VES station points and sampled wells were acquired using Global Positioning System (GPS) in order to geo-reference them on the base map.

The combined horizontal profiling and sounding survey was undertaken along the two orthogonal traverses in each locations using electrode separation of five (5) meters. An expansion factor n ranging from 1 to 5 was employed, this allows the potential electrodes to move five times along the 5 meters station separation while the current electrodes remain in place. The whole electrode arrangement was then moved to the next station for subsequent measurements. The Ohmega resistivity meter was used to acquire the field data and the respective elevations of the occupied stations were recorded using the GARMIN '12 channel personnel navigation Geographic Positioning System (GPS) unit. The results from the combined horizontal profiling and sounding survey enabled selection

of location for Vertical Electrical Sounding (VES). The data were qualitatively and quantitatively interpreted.

The water samples collected from the field were stored separately in 2 liters white plastic bottles that were already washed thoroughly with 1M Hydrogen Chloride (HCL). The water containers were securely corked with plastic lids after sample collection and then taken to the laboratory for analysis on such parameters as electrical conductivity, turbidity, anions, cations and trace elements (heavy metals).

The conventional volumetric method of titration was used for the analysis of the anions (NO_3^- , SO_4^{2-} , Cl^- and PO_4). The reagents used for the analysis were silver nitrate (AgNO_3), sodium chloride (NaCl) and Potassium Chromate (K_2CrO_4) indicators.

The Atomic Absorption Spectrophotometry (AAS) Buck 210 model was used for the analysis of the cations. 500 ml of the water samples were transferred into an evaporating dish. 15 ml of concentrated HNO_3 was added and evaporated on a steam bath to approximately 25 ml. The resulting solution was transferred into 50 ml acid-cleaned Volumetric Flask and filled up to volume with de-ionized water. These working

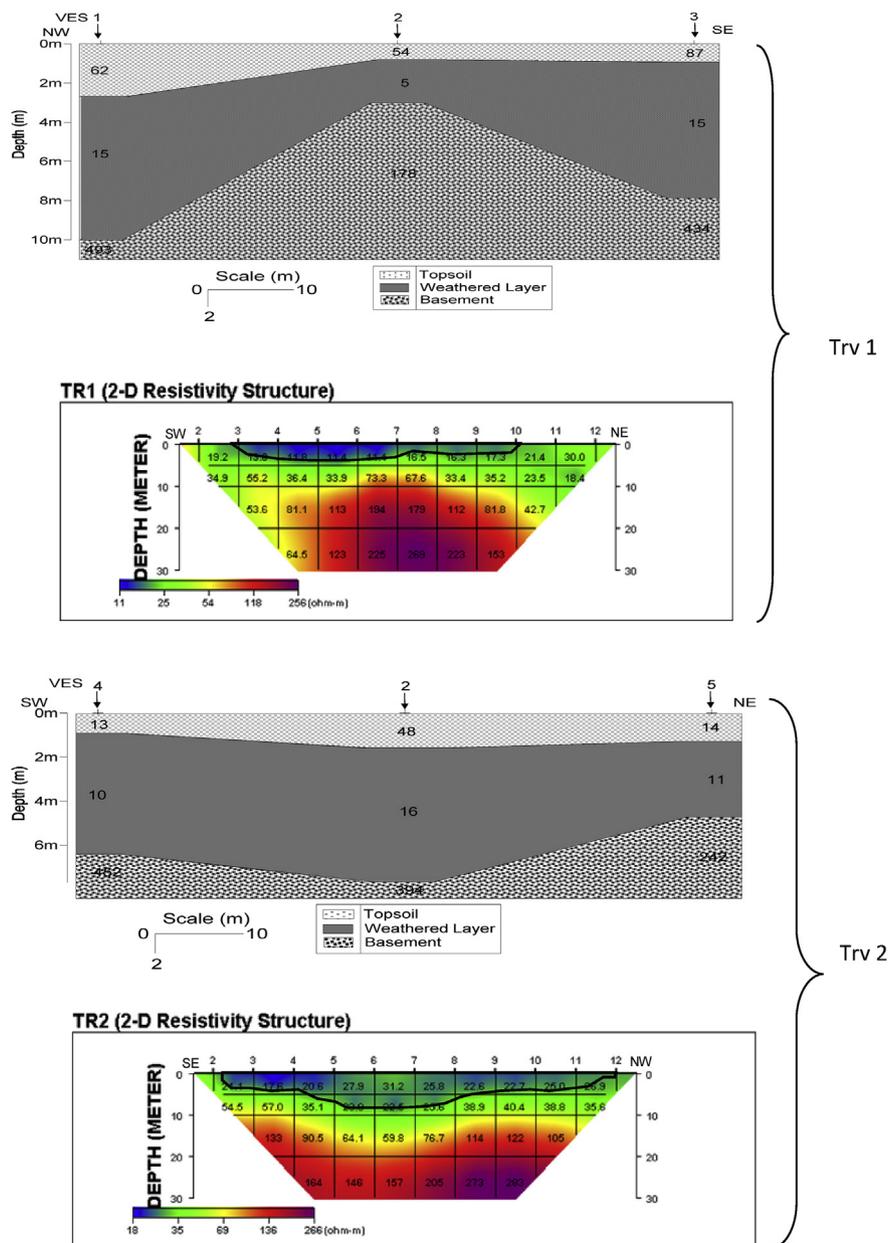


Fig. 4. Combination of the 2-D resistivity structure and the geoelectric sections along traverses 1 and 2 in Apete.

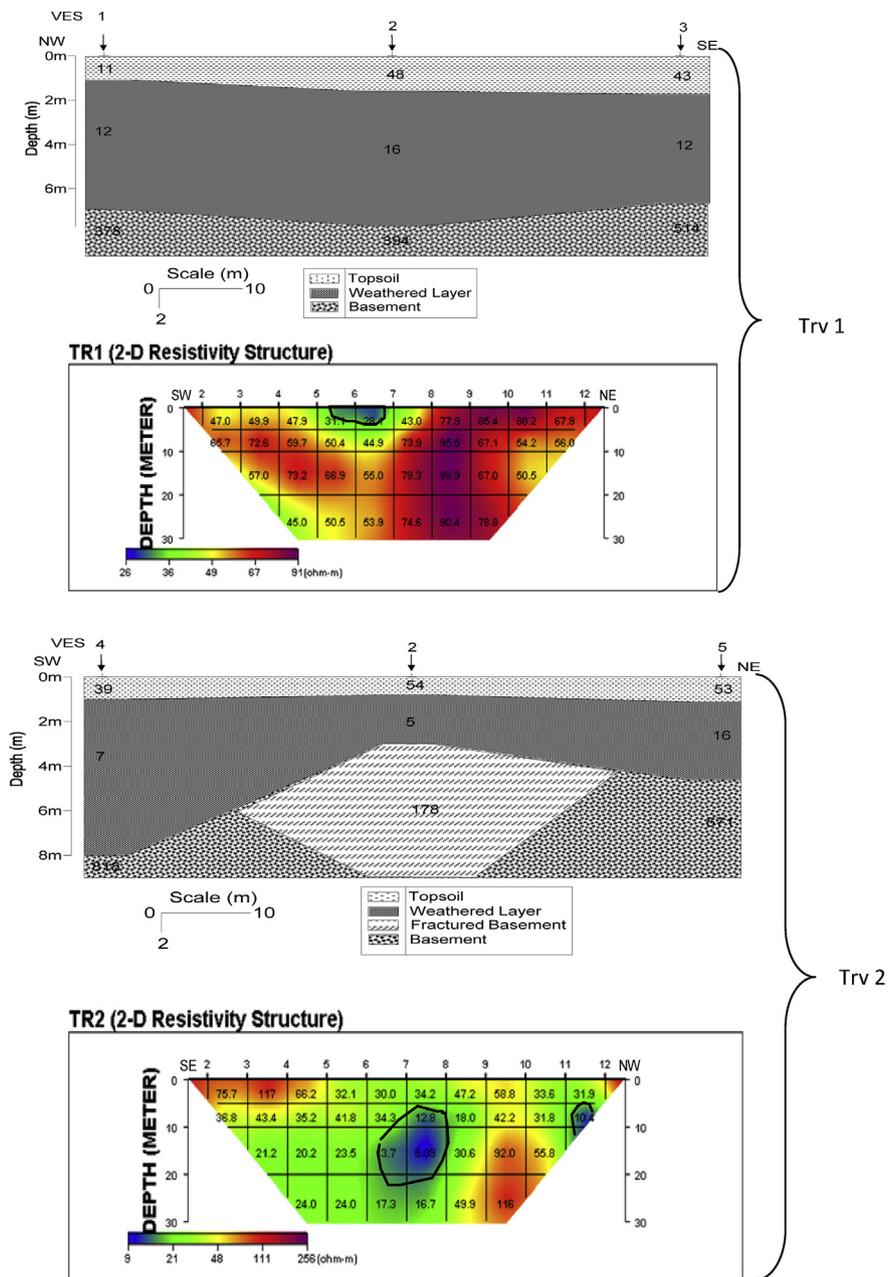


Fig. 5. Combination of the 2-D resistivity structure and the geoelectric sections along traverses 1 and 2 in Sabo.

standards were then aspirated to AAS buck 210 model. The absorbances of the standards for each element were recorded against concentration and were plotted.

The trace elements analysed were Lead (Pb), Zinc (Zn) and Iron (Fe). The analytical procedure for the concentration of these heavy metals is the same as that already contained in the analysis of the cations.

Pollution index (PI) is a method of rating that shows the composite influence of individual parameters on the overall quality of water (Amadi, 2011, 2012). The rating has values starting from zero to five or above, reflecting the relative importance of individual quality parameter and divided by the recommended standard (Si) for the maximum plus the minimum values and the summation divided by two as shown in Eq. (1) below. Water quality and its suitability for drinking purpose can be examined by determining its quality index (Caerio et al., 2005; Prasad and Kumari, 2008; Prasad and Mondal, 2008; Amadi, 2012).

$$PI = \sqrt{\frac{\left(\frac{Ci}{Si}\right)_{max}^2 + \left(\frac{Ci}{Si}\right)_{min}^2}{2}} \quad (1)$$

Where: *PI*: pollution index; *Ci*: mean concentration and *Si*: WHO Standard for Drinking Water Quality (WHO, 2011).

3. Results and discussions

Table 1 shows the summary of the interpreted VES results in the study area. The curve types obtained in the study areas have been classified, on the basis of aquifer types into two which are:

- i. Group I: H
- ii. Group II: KH

Table 2

Summary of the physical and chemical analysis results in comparison with control, NAFDAC (2007) and WHO (2011) standards for drinking water in Arapaja.

Location	Arapaja		Mean	Maximum permissible NAFDAC Standard (2007)	Maximum permissible WHO Standard (2011)	Pollution index	Rock type
	Range						
	Lowest	Highest					
PH	5.87	6.42	6.14	6.5–8.5	6.5–8.5	0.69	Migmatite Gneiss
Zn	0.12	0.54	0.31	-	3	0.02	“
BOD				-	-	-	“
EC (μ /cm)	228	531	326	1000	1000	0.17	“
Turbidity (NTU)	0.10	0.10	0.10	5	5	0.0004	“
T.D.S (mg/L)	114	457	239	500	500	0.44	“
DO (mg/L)	6.57	7.78	7.26	100	10	0.52	“
Pb (mg/L)	0.10	0.17	0.12	-	0.01	194.5	“
Na ⁺ (mg/L)	17.80	21.00	18.43	-	200	0.01	“
Mg ²⁺ (mg/L)	3.02	3.78	3.5	-	150	0.001	“
K ⁺ (mg/L)	32.30	39.00	36.95	10	12	8.90	“
Ca ²⁺ (mg/L)	30.70	47.50	37.9	75	100	0.16	“
Fe ²⁺ (mg/L)	1.02	2.08	1.34	0.3	0.3	29.82	“
NH ₃ (mg/L)	2	2	2	-	-	-	“
NO ₃ ⁻ (mg/L)	15.07	55.59	33.29	10	50	0.66	“
SO ₄ ²⁻ (mg/L)	25.21	53.89	35.84	100	100	0.18	“
PO ₄ ³⁻ (mg/L)	2.06	5.06	4.06	-	100	0.002	“
Cl ⁻ (mg/L)	5.33	20.93	76.41	100	250	0.004	“
HCO ₃ ⁻ (mg/L)	7.9	21.73	13.67	-	100	0.03	“
CO ₃ ²⁻ (mg/L)	80.61	255.88	260.1	-	-	-	“

Group I: the aquifers in this group are unconfined in nature by virtue of their respective thin overlying layer. They constitute about 80 % of the curve types in the area. These aquifers are those of weathered/partially weathered layer and are most likely vulnerable to near-surface contaminants in the area.

Group II: The aquifers in this group are confined in nature and correspond to the partly weathered/fractured basement within the subsurface. They constitute 20 % of the curve types obtained from the area. The vulnerability of such aquifers to pollutants is usually low and is equally of good yield (Jones, 1985; Acworth, 1987; Wright and Burgess, 1992; Chilton and Foster, 1995).

The integration of the results of the dipole-dipole profiling and vertical electrical sounding showing good correlation in the delineation of the suspected saturation of the contaminant plumes from the dumpsite.

The interpretation of the geo-electric sections along traverses one and two in Arapaja location (Fig. 3) shows that the subsurface media

underlying the dumpsites are characterized by relatively low resistivity values which range between 11 and 87 Ω m for the topsoil and 5 and 19 Ω m for the weathered layer. It is suspected that the topsoil and weathered layer in the study area have been infiltrated by leachate plumes from the dumpsite (<19 Ω m) which is supported by the works of Olla et al. (2015) in the study area. This is also in agreement with the results of the combined horizontal profiling and sounding where zones defined by blue colour band (<15 Ω m) have been inferred to image the leachate saturation across the traverses (Fig. 3).

The interpretation of the geo-electric sections along traverses one and two in Apete location shows that the subsurface media underlying the dumpsites are characterized by relatively low resistivity values which range between 13 and 87 Ω m for the topsoil and 5 and 16 Ω m for the weathered layer. It was observed that the topsoil and weathered layer in the study area have been infiltrated by leachate plumes from the dumpsite (<87 Ω m). This is in agreement with the results of the

Table 3

Summary of the physical and chemical analysis results in comparison with control, NAFDAC (2007) and WHO (2011) standards for drinking water in Apete.

Location	Apete		Mean	NAFDAC (2007)	Maximum permissible WHO Standard (2011)	Pollution index	Rock type
	Range						
	Lowest	Highest					
PH	5.86	7.10	6.62	6.5–8.5	6.5–8.5	0.76	Quartzite
Zn	0.141	0.705	0.41	-	3	0.03	“
BOD	1.62	2.03	1.73	-	-	-	“
EC (μ /cm)	326	1950.5	1031.5	1000	1000	1.96	“
Turbidity (NTU)	0.2	0.2	0.2	5	5	0.002	“
T.D.S (mg/L)	163	975.25	515.75	500	500	1.96	“
DO (mg/L)	6.51	8.205	7.25	100	10	0.55	“
Pb (mg/L)	0.105	0.202	0.16	-	0.01	259.15	“
Na ⁺ (mg/L)	16.70	24.00	19.95	-	200	0.011	“
Mg ²⁺ (mg/L)	3.096	4.121	3.46	-	150	0.001	“
K ⁺ (mg/L)	31.50	40.00	35.28	10	12	9.001	“
Ca ²⁺ (mg/L)	32.80	48.40	42.23	75	100	0.17	“
Fe ²⁺ (mg/L)	1.233	2.162	1.88	0.3	0.3	34.41	“
NH ₃ (mg/L)	2	2.5	2.13	-	-	-	“
NO ₃ ⁻ (mg/L)	22.02	136.92	74.22	10	50	3.85	“
SO ₄ ²⁻ (mg/L)	18.205	69.66	42.74	100	100	0.26	“
PO ₄ ³⁻ (mg/L)	2.005	2.23	2.14	-	100	0.0004	“
Cl ⁻ (mg/L)	80.81	98.09	72.79	100	250	0.09	“
HCO ₃ ⁻ (mg/L)	7.9	16.07	10.63	-	100	0.016	“
CO ₃ ²⁻ (mg/L)	78.71	255.88	179.73	-	-	-	“

Table 4

Summary of the physical and chemical analysis results in comparison with control, NAFDAC (2007) and WHO (2011) standards for drinking water in Sabo.

Location Parameters	Sabo		Mean	NAFDAC (2007)	Maximum permissible WHO Standard (2011)	Pollution index	Rock type
	Range						
	Lowest	Highest					
PH	6.42	7.06	6.69	6.5–8.5	6.5–8.5	0.76	Quartzite
Zn	0.18	0.95	0.54	-	3	0.05	“
BOD	1.28	3.29	2.22	-	-	-	“
EC (μcm)	468	1638	2531.75	1000	1000	1.45	“
Turbidity (NTU)	0.20	0.80	0.5	5	5	0.01	“
T.D.S (mg/L)	234	3583	1265.81	500	500	25.79	“
DO (mg/L)	4.89	8.21	7.04	100	10	0.46	“
Pb (mg/L)	0.100	0.19	0.132	-	0.01	230.5	“
Na ⁺ (mg/L)	16.90	29.50	22.4	-	200	0.02	“
Mg ²⁺ (mg/L)	3.019	4.908	3.81	-	150	0.001	“
K ⁺ (mg/L)	30.00	45.00	36.23	10	12	10.16	“
Ca ²⁺ (mg/L)	33.100	53.500	40.28	75	100	0.20	“
Fe ²⁺ (mg/L)	1.010	2.291	1.62	0.3	0.3	34.83	“
NH ₃ (mg/L)	2	6	3.25	-	-	-	“
NO ₃ ⁻ (mg/L)	0.35	151.51	64.31	10	50	4.59	“
SO ₄ ²⁻ (mg/L)	26.59	74.89	55.37	100	100	0.32	“
PO ₄ ³⁻ (mg/L)	2.075	9.94	5.55	-	100	0.01	“
Cl ⁻ (mg/L)	12.55	99.52	62.17	100	250	0.08	“
HCO ₃ ⁻ (mg/L)	16.31	21.73	19.02	-	100	0.04	“
CO ₃ ²⁻ (mg/L)	152	1360.63	478.45	-	-	-	“

combined horizontal profiling and sounding where zones defined by blue colour band ($<47 \Omega\text{m}$) have been inferred to image the leachate saturation across the traverses (Fig. 4).

The interpretation of the geo-electric sections along traverses one and two in Sabo location shows that the subsurface media underlying the dumpsites are characterized by relatively low resistivity values which range between 11 and 54 Ωm for the topsoil and 5 and 16 Ωm for the weathered layer. The topsoil and weathered layer in the study area have been infiltrated by leachate plumes from the dumpsite ($<54 \Omega\text{m}$). It is pertinent to note that, the result is consistent with the resistivity ranges delineated and verified using geochemical analysis by Olla et al. (2015). This is in agreement with the results of the combined horizontal profiling and sounding where zones defined by blue colour band ($<28 \Omega\text{m}$) have been inferred to image the leachate saturation across the traverses (Fig. 5).

All the parameters analyzed were subjected to pollution indexing using the approach presented in section 2 and the results obtained were as shown in Tables 2, 3, 4. The results shown on the Tables are then compared with the pollution index standard shown in Table 5. A closer look at the results revealed that; at Arapaja location, all the parameters falls under the class 1 indicating no pollution, except for Fe²⁺, K⁺ and Pb that falls under the seriously polluted. Parameters analyzed from Apete location revealed that the parameters falls under the class 1, class 2, class 4 and class 5 which are no pollution, slightly polluted (EC, TDS), strongly polluted (NO₃⁻) and seriously polluted (Pb, K⁺, Fe²⁺) respectively. Parameters analyzed from Sabo location revealed that the parameters falls under the class 1, class 2, class 4 and class 5 which are no pollution, slightly polluted (EC), strongly polluted (NO₃⁻) and seriously polluted (TDS, Pb, K⁺, Fe²⁺) respectively. This implies that the hand-dug wells in the study area have experienced varying degree of contamination as a result of infiltration of leachates from the waste dumpsite and unhealthy sanitary habit exhibited by the people in the area. However, Arapaja, underlain by Migmatite Gneiss, is found to be less contaminated. This may be as a result of weathering end product of the rock which are mostly clayey formation while Apete and Sabo are highly contaminated. This may also be as a result of the weathering end product of the rock in the area which is mostly sandy formation.

4. Conclusion

Geophysical and hydro-chemical investigations have been undertaken within the vicinity of Arapaja, Apete and Sabo dumpsite located in

three different rock types environments of Migmatite Gneiss, Quartzite, and Granitic Gneiss respectively in a basement complex of Ibadan, southwestern Nigeria. This was with a view of assessing the contaminant impact of the dumpsite on the soil and groundwater in the area. Electrical Resistivity methods involving fifteen (15) Schlumberger Vertical Electrical Sounding (VES) and combined horizontal profiling and sounding across two orthogonal traverses in each of the study area.

The geoelectric sections identified maximum of three subsurface layers namely the topsoil, the weathered layer, and the fresh basement. The weathered layer constitutes the major aquifer unit in the area. It is suspected that the weathered layer as well as the overlying layer has been impacted by leachates from the waste dumpsite in the three locations.

Similarly, the 2D resistivity structure revealed that the subsurface layers have been contaminated by the leachate from the dumpsite especially in places characterised by typically low resistivity values ($<15\Omega\text{m}$), imaged as blue colour bands.

Hydrochemical analysis of samples from wells in the three locations shows that Arapaja which is underlain by the Migmatite Gneiss rock has all its results fall within the WHO permissible limits for potable water except for Pb and Fe²⁺ which were slightly higher than the acceptable limits and thus have the least effect of pollution. This may be due to the weathering end product of the rock underlying the area. The rock has high clay content that will hamper the migration of leachates into the groundwater. While in Apete and Sabo location, EC, TDS, K⁺, NO₃⁻, Pb, and Fe²⁺ were higher than the WHO permissible limits for potable water. This may be due to the fact that the area is underlain by Quartzite and Granite Gneiss respectively. The weathering end product of these materials is sand, which is highly porous and has a high susceptibility to pollution.

The results of the Pollution index (PI) employed in all the study area revealed that; at Arapaja location, all the parameters fall under the class 1

Table 5

Water quality classification based on pollution index (Caerio et al., 2005, Amadi, 2012).

Class	Pollution index (PI)	Status
Class 1	PI < 1	No pollution
Class 2	PI: 1–2	Slightly polluted
Class 3	PI: 2–3	Moderately polluted
Class 4	PI: 3–5	Strong polluted
Class 5	PI: >5	Seriously polluted

indicating no pollution, except for Fe^{2+} , K^+ and Pb that fall under the seriously polluted. Parameters analyzed from Apete location revealed that the parameters falls under the class 1, class 2, class 4 and class 5 which are no pollution, slightly polluted (EC, TDS), strongly polluted (NO_3^-) and seriously polluted (Pb , K^+ , Fe^{2+}) respectively. Parameters analyzed from Sabo location revealed that the parameters falls under the class 1, class 2, class 4 and class 5 which are no pollution, slightly polluted (EC), strongly polluted (NO_3^-) and seriously polluted (TDS, Pb , K^+ , Fe^{2+}) respectively.

The study reveals that the hand-dug wells in the study area have experienced varying degree of bacteriological contamination as a result of infiltration of leachates from the waste dumpsite and unhealthy sanitary habit exhibited by the people in the area. However, Arapaja, which is underlain by Migmatite Gneiss, is found to be less contaminated. This may be as a result of weathering end product of the rock which is mostly clayey formation. While Apete and Sabo are highly contaminated. This may also be as a result of the weathering end product of the rock in the area which is mostly sand formation.

Declarations

Author contribution statement

K.A.N. Adiat: Conceived and designed the experiments; Wrote the paper.

A.A. Adegoroye: Conceived and designed the experiments; Analyzed and interpreted the data.

A.D. Adebisi, B.E. Akeredolu: Analyzed and interpreted the data.

A.A. Akinlalu: Analyzed and interpreted the data; Wrote the paper.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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