Detection and Delineation of Soil and Groundwater Contamination Zones using Geophysical and Geochemical Methods around Oke-Eleke Dumpsite, Ilorin, Southwestern Nigeria

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Abstract

A combined geophysical and geochemical investigation was carried out at Oke-elele waste dumpsite in Ilorin, Kwara state, Nigeria. The aim is to determine the geoelectrical characteristics and groundwater chemistry to delineate the subsurface lithologies and assess the degree of soil and groundwater contamination. Nine (9) Vertical Electrical Sounding (VES) stations and four (4) Dipole-Dipole profiling (One as control traverse) were occupied for the geophysical investigation, while the hydrochemical investigation involved the chemical and physical analyses of the groundwater samples from the wells within the study area. The geo-electric sections, correlated with borehole data show that the study area is underlain by a maximum of six subsurface layers which include: topsoil (20 - 113 Ωm, 0.4-1.2 m); laterite (67-102 Ωm, 0.5-1.6m); Clay and plume infected layers have resistivity and thicknesses (8 - 20 Ωm, 1.1 – 4.7m); weathered/Partly weathered Basement (11 -211 Ωm, 1.5 – 17.2m); fractured basement (10 - 23 Ωm, 5-10m); and fresh bedrock (375- 99982 Ωm, infinity). Significantly low resistivity values (2.4-11.6 Ωm) were observed within the upper 25 m at regions suspected to be fractures or highly infected within the waste boundaries, showing that pollution plumes from the dumpsite have infiltrated the subsoil. In comparison, the resistivity values of > 20 Ωm were observed beneath the unimpacted subsoil. The hydrochemical analyses of the water samples from wells have shown that the anions (HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, and PO_4^{3-}) and cations (Ca^{2+}, Na^+, and K^+) of the sampled water fell within the World Health Organization (2006) and Nigeria Industrial Standard (2007) thresholds for potable water. However, the values of EC (1375-2000 μS/cm), turbidity (8.45-8.90), TDS (625-1025 mg/l), total hardness (238-406 mg/l$CaCO_3$), pH (6.25-6.33), manganese (6.58-7.82 mg/l), aluminium (5.45-6.46 mg/l), lead (0.02 mg/l), and cadmium were higher than the standard thresholds, an indication of groundwater pollution. Due to the increase in urbanization, it is recommended that erosion channels be improved upon, and the dumpsite and its environs should be regularly assessed.

Keywords: *Analysis, Geoelectrical, Hydrochemical, Groundwater Contamination, Dumpsite.*

Introduction

Solid waste mismanagement is a global issue regarding environmental contamination, social inclusion and economic sustainability (Ferronato and Torretta, 2019). Waste Management is a demanding undertaking in all countries, with important implications for human health, environmental preservation, sustainability and circular economy (Vaverkova, 2019).

One of the major sources of pollution of groundwater is seepage from ground storage tanks and septic tanks. Others include solid and liquid wastes from landfills, dumpsites and agricultural leaching (Sule *et al.,* 2020). The association of high ion concentrations and the resulting low resistivity of the rock formations containing the leachates make their resistivity much lower than that of the natural groundwater (Cristina *et al.,* 2012).

The subsurface resistivity distribution can be determined by geoelectrical surveying at the surface. The introduction of practical electrical tomography field systems, like the geoelectrical Wenner pseudosection, followed by effective processing and inversion software, has provided an appreciable tool for delineating the degree and extent of contamination owing to the resistivity contrast between the contamination zone and immediate vicinity (Sule *et al*., 2020). The resistivity contrast between the contamination area and the surroundings has provided an essential tool for determining the level, migration path, and extent of the contamination (Onoja and Akinola, 2016). The suitability of the electrical resistivity method as an aid for contamination plume mapping has been extensively proven in the different published works of several authors (Adebisi *et al.,* 2021).

This study will delineate the contaminated zones and their impact on the soil and groundwater system around the Oke-elele dumpsite using the electrical resistivity imaging and physicochemical analysis method. The electrical resistivity method helps determine the contamination level, migration direction and extent. It might give significant anomalies as ion concentrations in the leachate plume produced at a waste disposal site. Regarding identifying groundwater contamination and other environmental issues, the technique is quick and cost-effective.

Location and Geology of the Study Area

The study area (Oke-elele dumpsite) is part of the Ilorin metropolis in Kwara state, Nigeria (Figure 1). It has an area of approximately 11,000 m^2 and is situated between latitudes 8.51062 N and 8.51165 N and longitudes 4.54784 E and 4.54893 E (Figure 1). The dumpsite is situated in a built-up area, and the number of dipole-dipole profiles and their spread size are limited. The topography is generally flat, with a maximum elevation difference of 4 m.

The study area lies in the Nigerian Basement Complex rocks. According to Balogun (2019), 'Kwara State is underlain by the Migmatite–Gneiss–Quartzite complex of Precambrian to Cambrian age intruded by suites of granitic bodies (porphyritic granite, medium/coarse-grained biotite granite, hornblende granite, granodiorite and granite gneiss) known as the older granites, which are of Pan-African age in the northern, central and southwestern regions. Younger metasedimentary rocks, probably of Pan-African age, underlie the state's southeastern part.

The Oke-elele study area is underlain by migmatite and granite gneiss (Figure 1). Geophysical studies and borehole logging in this area show that groundwater is generally sourced

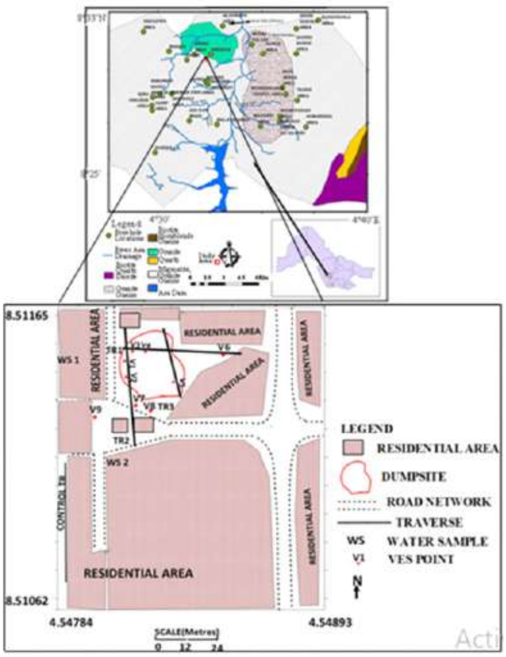

Figure 1: The sketch map of the Oke-elele Dumpsite shows the four profiles. Inset is the geological map of Ilorin, showing the study area and the map of Kwara State (After Ashaolu *et al.,* 2016).

From the fractured bedrock and the overburden, where the overburden is thick, and the rocks are highly fractured, the yield is high and vice-versa (Aina, 1998).

Methods

Two methods, geophysical and geochemical, were employed. The geophysical investigation engaged the electrical resistivity method involving 2D Dipole-Dipole subsurface imaging and 1D Vertical Electrical Sounding (VES) technique. The 2D profiling utilized inter-electrode spacing of 5 m and expansion factor, n, that was varied from 1 to 5. The VES Schlumberger half-current electrode spacing was varied from 1 to a maximum of 100 m. Nine Schlumberger VES stations, with traverses trending in the E-W and N-S Directions, were occupied using the Herojat™ resistivity meter.

The conventional partial curve matching technique first interpreted the data with two-layer master curves in conjunction with an auxiliary point diagram. This gave an estimate of the layer resistivity and thickness, which were used as input data for computer-assisted interpretation with RESIST software to obtain the various layers' true resistivity and thickness (Figure 2) (Anomohanran, 2015). Results were interpreted to prepare geo-electric sections (Figures 3 and 4). The Dipole-Dipole profiling also utilized inter-electrode spacing of 5 m and expansion factor, n, that was varied from 1 to 5. The data obtained were inverted with DIPRRO™ 4.01 (Figures 5-8).

The hydrochemical analysis involved the analysis of two water samples collected from a hand-dug well and a borehole located 77m and 55m, respectively, from the waste dumpsite for water quality testing. The colour, total dissolved solid (TDS), turbidity, PH, hardness, and conductivity were analyzed. The values obtained were compared with the tolerable values by the World Health Organization (WHO) and Nigeria Industrial Standard (NIS). Mineral analyses were carried out for cations [Ca^{2+}, Mg^{2+}, Na^{+}, Al and K^{+}], anions [HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, and PO_4^{3-}] and heavy metals [Cd, Fe, Mn, and Pb].

Results and Discussions.

The VES Curves

The VES interpretation results in the study area indicated three to six lithologic units: the top, the lateritic soil, the weathered/partly weathered basement, the fractured basement and the fresh bedrock. The curve types (Figure 2) range from H (V4 and V6), QH (V3), HKH (V5 and V8), HA (V9), KHKH (V1), QHKH (V2) to KHA (V7) in the study area. The H and HKH types are the most predominant, accounting for more than 44 % of the curve types. The weathered and fractured basements constitute the main aquifer units in the study area.

The H and HKH type predominance shows that most of the area is underlain by either fractured and/or weathered basement (i.e. aquiferous layer). This could be one of the reasons for easy plume infection and spreading in this environment. All the VES curves except the KHKH type are characterized by decreasing layer resistivity within the upper two to three geo-electric layers, as observed by Orakwe *et al*. (2018) at waste pollution-impacted sites. The VES curves, the lithologies and their respective resistivities, thicknesses and depths are recorded in Table 1.

The Geoelectrical Sections along Traverses 1 and 2

Figures 3 and 4 are the geo-electric sections along traverses 1 and 2 (Figure 1). In Figure 3 (Traverse 1), the lithologies include: the topsoil (20-113 Ωm), weathered basement (11-39 Ωm), fractured basement (15 Ωm), partly weathered basement (45-211 Ωm) and fresh bedrock (1,774 Ωm).

The location of the overburden directly below the dumpsite makes them easily vulnerable to contamination and acts as a passage for leachates to other areas while their generally low resistivities (especially the layer classified as a fractured basement) show that they might have been impacted. Inorganic leachate increases liquid conductivity owing to the presence of dissolved salts. Hence, leachate's electrical resistivity is often much lower than natural groundwater (Ugwu *et al*., 2016). The presence of H curve type from V4 to V6 along traverse 1 could be associated with groundwater contamination.

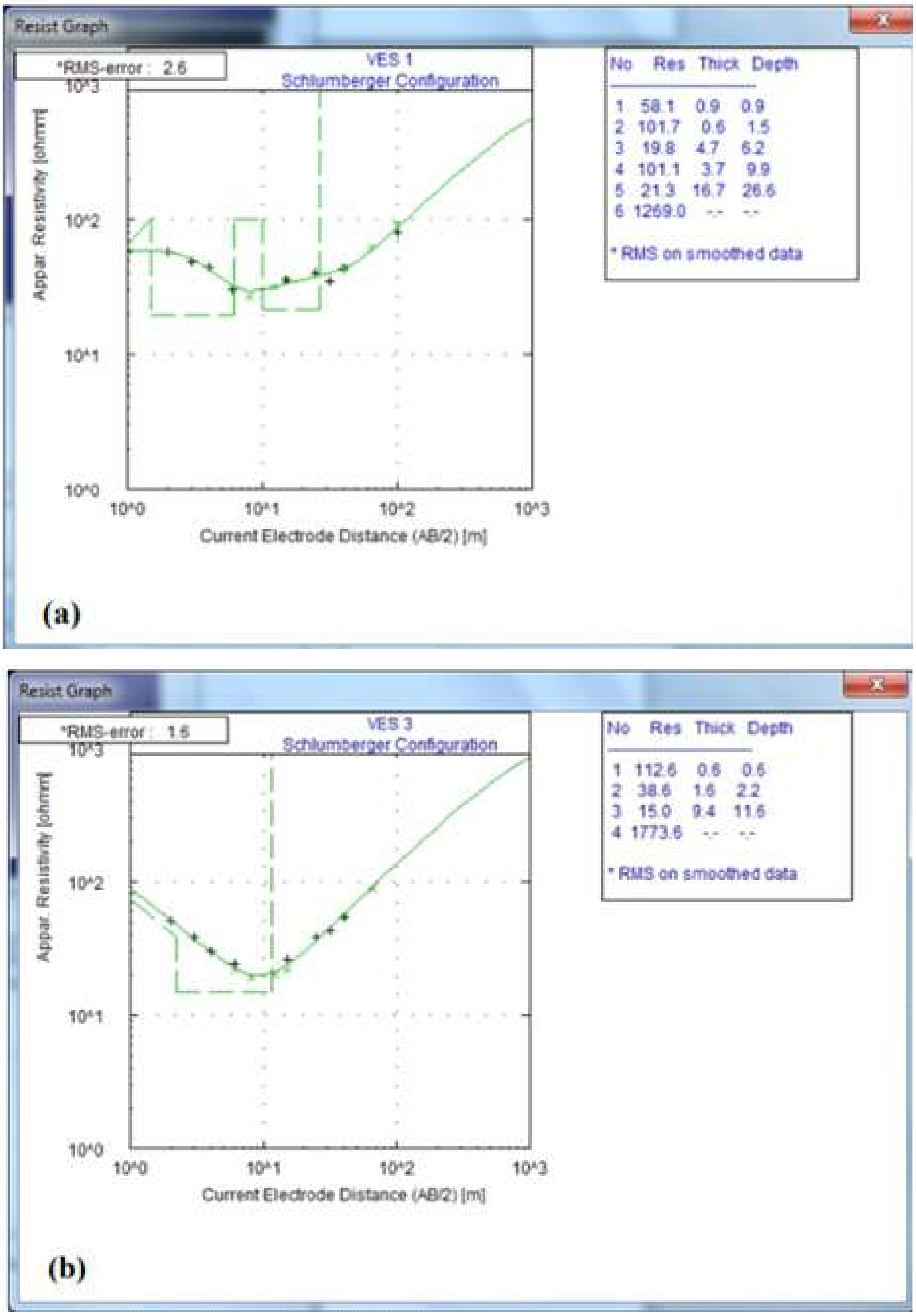

Figure 2: Typical VES Type Curves at Oke-elele (a) KHKH (b) QH

Table 1: Summary of Results of the VES Data Interpretation for V1 to V9

VES	Resistivity ($\rho_1,\rho_2..$) Ωm	Thickness ($h_1,h_2..$)m	Curve Type	Probable Lithology based on borehole information (Layers 1, 2,)
V1	58, 102, 20, 101, 21, 1,269	0.9, 0.5, 4.7, 3.7, 16.7, inf	KHKH	Topsoil, Lateritic soil, *Clay, Weathered basement, Fractured basement, Fresh bedrock
V2	123, 67, 16, 96, 23, 99,982	0.6, 1.6, 4.7, 5.1, 17.2, inf	QHKH	Topsoil, Lateritic soil, *Clay, Weathered basement, Fractured basement, Fresh bedrock
V3	113, 39, 15, 1,774	0.6, 1.6, 9.4, inf	QH	Topsoil, Weathered basement, *Fractured basement, Fresh bedrock
V4	113, 14, 211	1.2, 7.3, Inf	H	Topsoil, *Weathered basement, Partly weathered basement
V5	32, 8, 64, 10, 51,000	0.7, 2.7, 1.5, 8.7, inf	HKH	Topsoil, *Clay, Weathered basement, Fractured basement, Fresh bedrock
V6	19, 11, 45	0.7, 5.2, inf	H	Topsoil, *Weathered basement, Partly weathered basement
V7	27, 69, 15, 90, 375	0.5, 1.0, 2.7, 36, inf	KHA	Topsoil, Lateritic soil, *Clay, Weathered basement, Fresh bedrock
V8	105, 17, 41, 23, 1,621	0.4, 1.7, 10, 10, inf	HKH	Topsoil, *Clay, Weathered basement, Fractured basement, Fresh bedrock
V9	131, 21, 47, 244	0.6, 1.1, 16.6, inf	HA	Topsoil, Clay, Weathered basement, Fresh bedrock

***Plume-infected layer** **Source: Field Work, 2021**

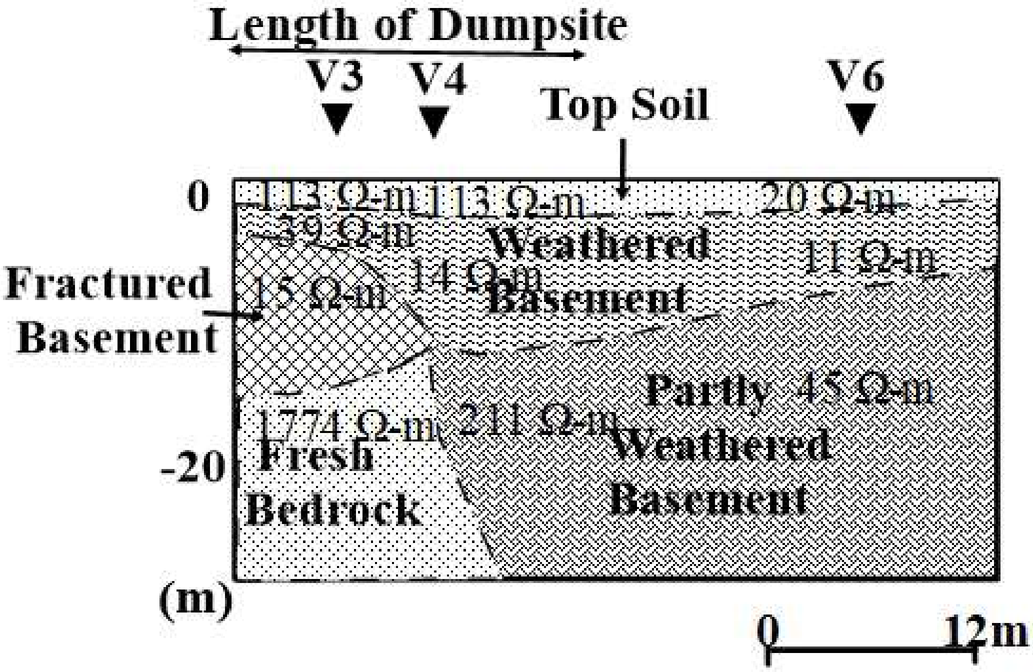

Figure 3: Geo-electric section along traverse 1

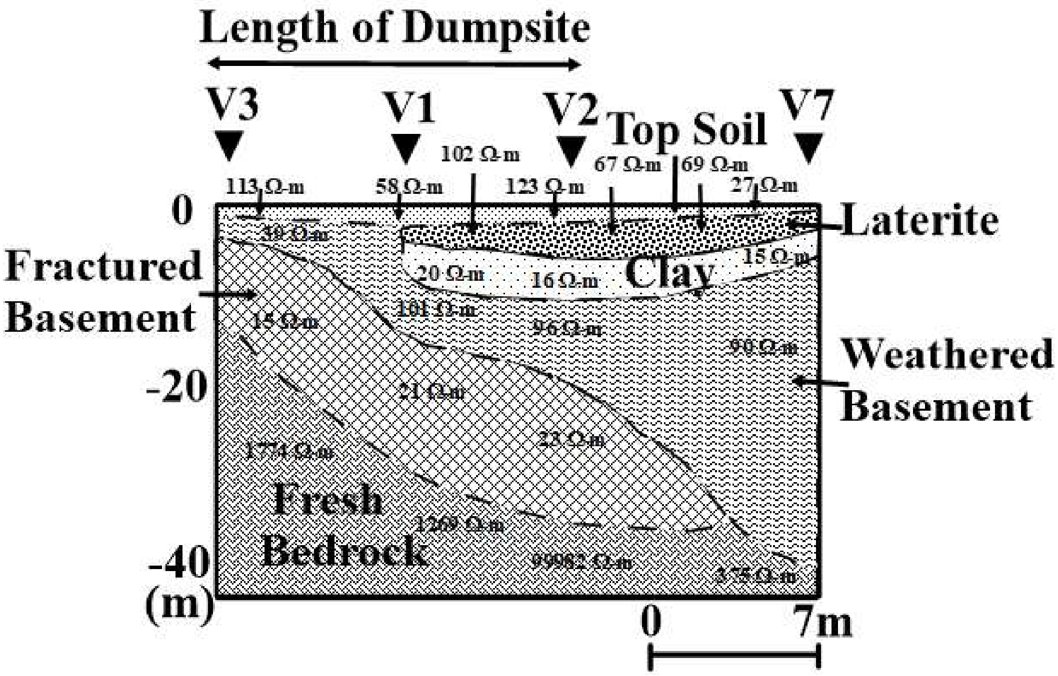

Figure 4: Geo-electric section along traverse 2 (V3 –V7)

In Figure 4 (Traverse 2), the lithologies include the topsoil (27-123 Ωm), laterites (67-102 Ωm), clay (15-20 Ωm), (weathered basement (39-101 Ωm), fractured basement (15-23 Ωm) and fresh bedrock (375-99,982 Ωm). The location of the overburden directly below the dumpsite makes them easily vulnerable to contamination and acts as a passage for leachates to other areas, while their generally low resistivities (especially the layer classified as clay) show that they might have been impacted. However, the presence of a suspected clay substratum that extends from the centre of the dumpsite to other parts of the study area may prevent the fast spreading of contaminants by acting as a shield or cover to the other substrata.

The Dipole-Dipole Sections

The field and theoretical (or synthetic) data pseudo sections and the 2-D structures obtained from the inversion of the Dipole-dipole data are presented and discussed as follows:

Control Traverse

The field and theoretical data pseudo sections with the 2D resistivity structure under the control traverse are shown in Figure 5. The control traverse and the dumpsite are separated by a network of tarred roads (12 m width each) prevents waste spreading and contamination. The 2D resistivity structure (Figure 5c) shows the lateral and vertical resistivity variations under the traverse and is used to establish the study area's baseline subsurface geology/lithologic characteristics. The image generally depicts the topsoil/weathered layer in blue/green colour band and the fresh bedrock in yellow/red color band. The topsoil and the weathered layer merged to constitute the overburden with thicknesses ranging from 5 to 15m below stations 2 and 11.

The topsoil/weathered layer resistivity values range from 10.7 to 36.5 Ωm but generally > 20 Ωm, while that of the fresh basement ranges from 45 to 136 Ωm. Evidence of fracturing within the basement rock is observed between stations 5 and 7, while the closure or an aquiferous zone is seen between stations 10 and 12, with both characterized by relatively low resistivity values.

Information obtained from borehole logs at Oke-elele area gave weathered basement resistivity values of 36 and 40Ωm with overburden thicknesses of 18 and 26m, respectively, for Oja Ago and Oju Ekun. The geo-electric characteristic of the subsurface layers (i.e. generally > 20 Ωm for topsoil/weathered layer and > 57 Ωm for fresh bedrock) beneath the control traverse, therefore, define the characteristic of the unimpacted subsoil and the baseline for assessment of pollution within and near the waste dump site.

'Biodegraded wastes oftentimes lead to the generation of low resistivity contaminant plume with a high concentration of dissolved salt/solute and consequently decrease in the resistivity of the near-surface subsoil and water resource' (Adepelumi *et al.*, 2001). A significant reduction in the baseline geo-electric characteristic will, in subsequent 2D resistivity images for traverses that cut across the waste dumpsite, be interpreted as an impacted/polluted zone

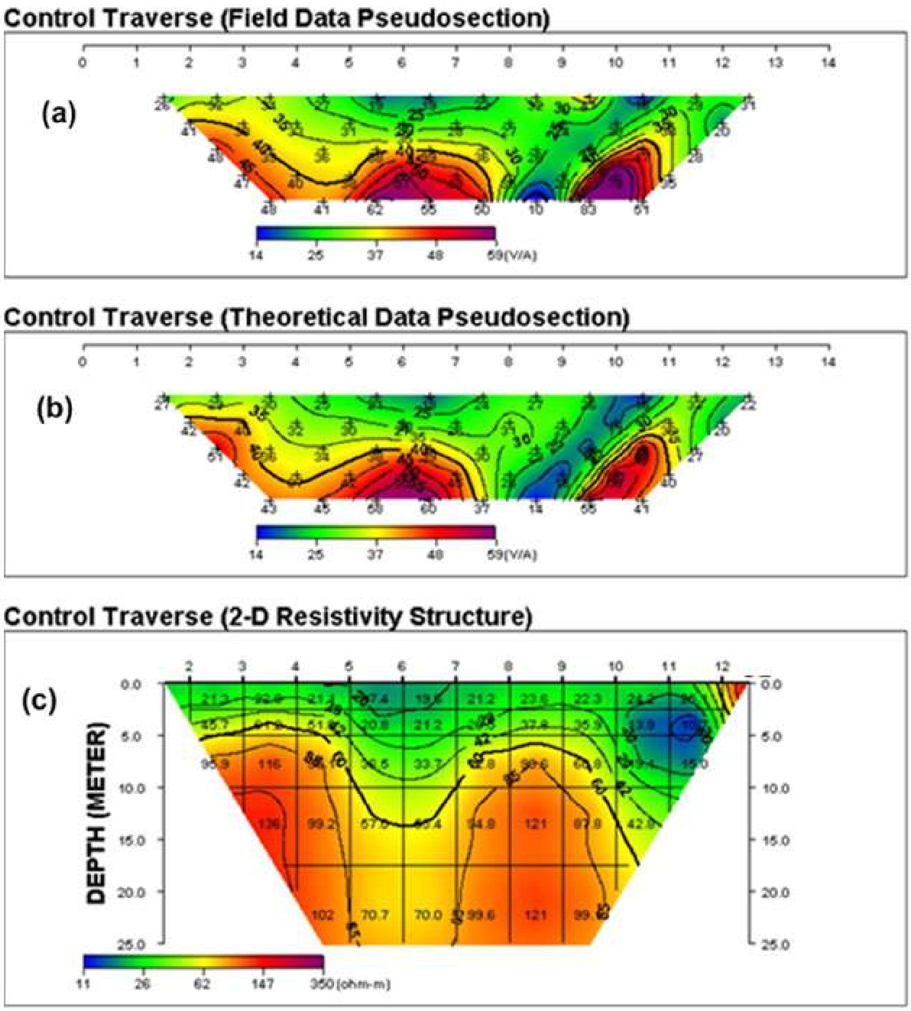

Figure 5: Dipole-dipole section along the control traverse at Oke-elele waste dumpsite (a) Field data pseudo-section (b) Theoretical data pseudo-section, and (c) 2D Resistivity structure.

Traverse1

Presented in Figure 6 are the field and theoretical data pseudo sections and the 2D resistivity image beneath Traverse 1. The 2D resistivity structure (Figure 6c) reveals the subsurface configuration and is divided into the topsoil/weathered layer (blue/green colour band) and the fresh basement (yellow/red/purple colour band). The topsoil merged with the weathered layer to constitute the overburden with thickness ranging from 5 to 10 m.

The topsoil/weathered layer resistivity values range from 3.7 to 43 Ωm, while that of the fresh basement ranges from 57 to 1,181 Ωm. As established on the control traverse where the baseline resistivity characteristic of unimpacted subsoil is greater than 20 Ωm, the very low (<11.6 Ωm) resistivity (blue colour band) zone between stations 2 and 6 in the field and theoretical data pseudosections and the 2D resistivity structure are indications of contaminant leachate plume.

The resistivity image shows no evidence of pollution between stations 6 and 11 within the waste dumpsite. The result indicates a vertical migration of the leachate plume to a depth of 5m and lateral migration at the left-hand side.

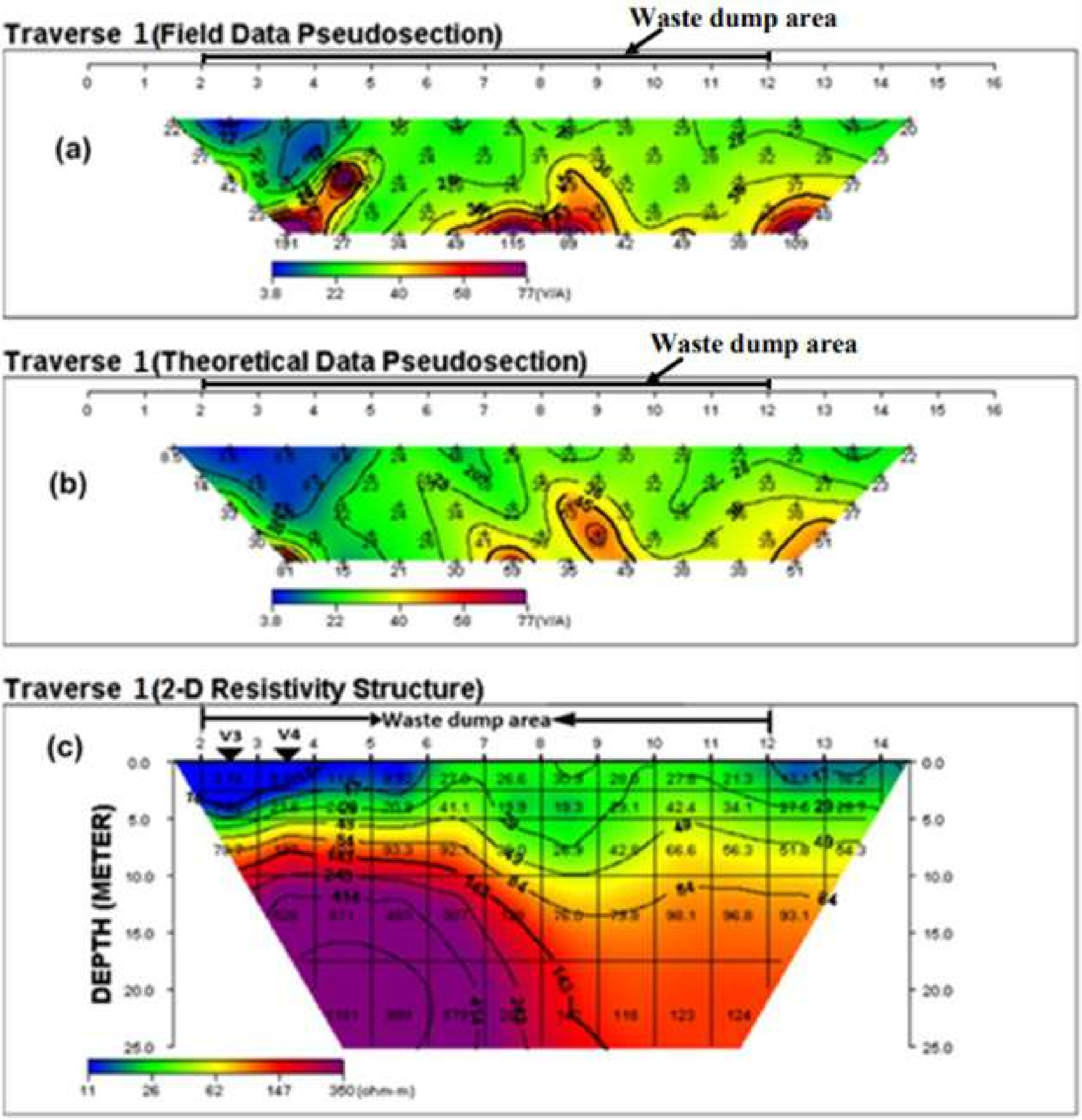

Figure 6: Dipole-dipole section along traverse 1 at Oke-elele waste dumpsite (a)Field data pseudo-section (b) Theoretical data pseudo-section and (c) 2D Resistivity structure.

Traverse 2

Figure 7 shows the field and theoretical data pseudo sections and the 2D resistivity structure beneath. This traverse has a part of its length within the dumpsite and the other part outside the waste dump. Although subsurface layer distinction on the 2D resistivity structure (Figure 7c) is not very apparent, the image is characterized by the overburden beneath stations 4-6.5 and stations 11-13.5. These are the topsoil\weathered layer (blue/green/red colour band) and the fresh basement (green/yellow colour band).

The topsoil merged with the weathered layer to constitute the overburden with relatively shallow thickness/depth to rock head of between 2.0 and 5.0 m. The topsoil\weathered layer resistivities range from 2.5 to 37 Ωm but generally less than 18.7 Ωm. The fresh bedrock resistivity values range from 21.5 to 69 Ωm, with relatively high resistivity values observed outside the waste dump site.

Generally, very low resistivity values (2.4 - 11.9 Ωm) in the blue colour band characterized this traverse both at near surface (< 10 m) and at depth (> 25 m). These values are significantly less than the baseline characteristic (> 20 Ωm) of the unimpacted subsoil as established beneath the control traverse, indicating pollution/impacted zone. The low resistivity zones (blue colour band) between stations 2 and 11 significantly correlated with the field observed boundaries of the dumpsite but with depth extent greater than 25 m. The result, therefore, indicates a major vertical migration of the leachate plume (beneath stations 6 - 11) with little lateral migration (between stations 2 and 4) on the left-hand side and (13 and 14) on the right-hand side.

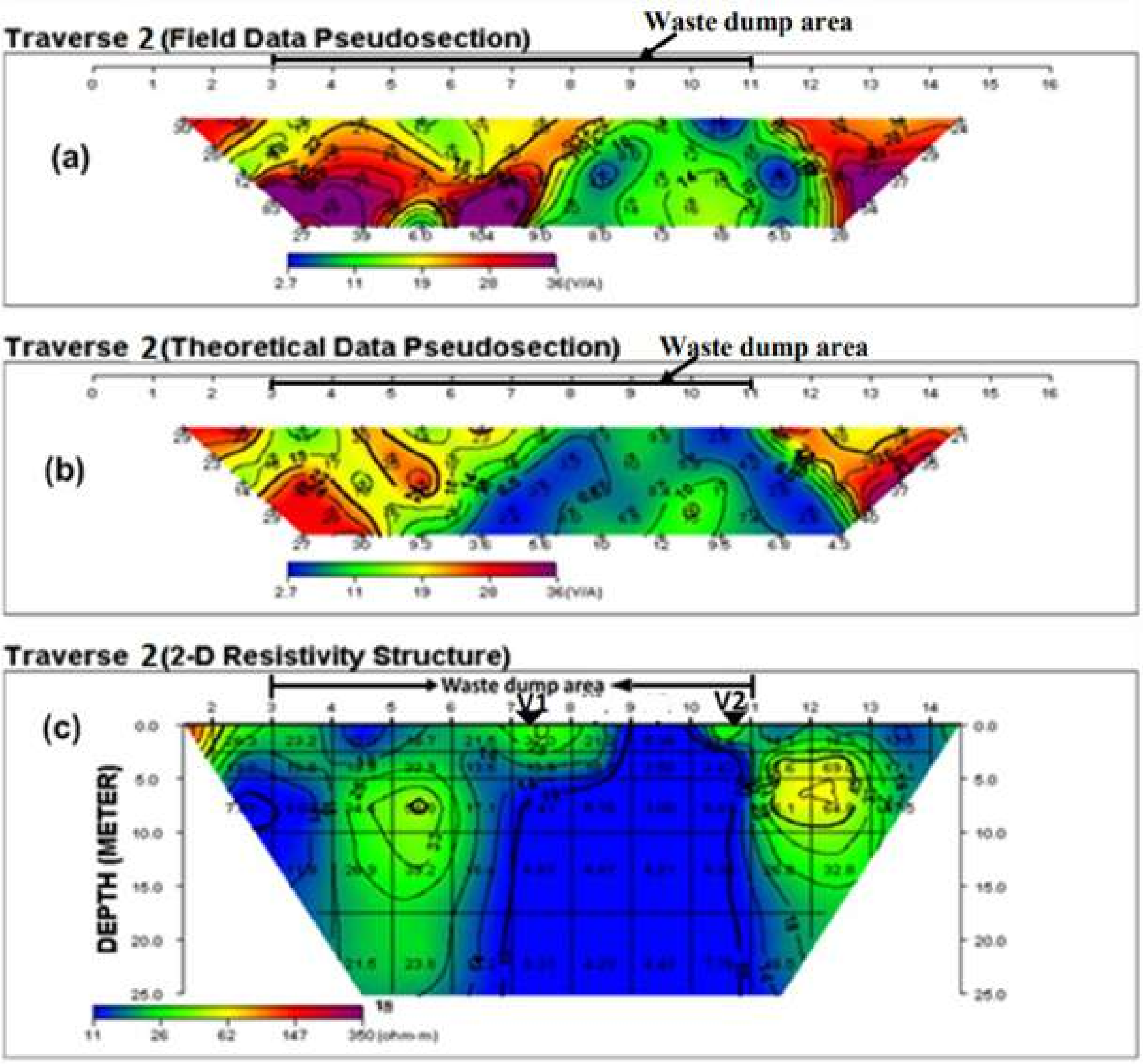

Figure 7: Dipole-dipole section along traverse 2 at Oke-elele waste dumpsite (a) Field data pseudo-section (b) Theoretical data pseudo-section, and (c) 2D Resistivity structure

Traverse 3

Figure 8 presents the field and theoretical data pseudo sections and the 2D resistivity structure beneath Traverse 3. The 2D resistivity image reveals the subsurface configuration. These are the topsoil/weathered layer (blue/green colour band) and the fresh basement (yellow/red/purple colour band). The topsoil merged with the weathered layer to constitute the overburden with thicknesses ranging from 8 to 12 m. The topsoil/weathered layer resistivities range from 7.9 to 40 Ωm while that of the fresh basement ranges from 54 to 300 Ωm. Using the baseline geo-electric characteristic of < 20 Ωm for impacted/polluted subsoil, the low resistivity subsoil (in blue colour band) between stations 2 and 10, within the upper 8 m, is therefore impacted with pollution plume. The impacted low resistivity zone correlated perfectly with the field observed boundary of the dumpsite at the left-hand side of the traverse. With this correlation, the waste dump could be attributed as the source of the leachate plume that had infiltrated up to a depth of about 8 m. The result indicates both vertical and lateral (in the right-hand direction) migration of leachate plume. For easy comparison, the results from traverse 1, 2, 3, control and the boreholes in Oke-elele area is presented in Table 2.

Table 2: Interpretation Results of Traverses 1, 2, 3, Control and Borehole Information from Okelele Area

S/N	Location	Inferred Lithology (Layers 1, 2,)	Resistivity (ρ_1,ρ_2..) Ωm	Thick-ness ($h_{1,2..}$) m	Remark
1	Traverse 1	Topsoil/ Weathered layer (Overburden)	3.7-43	5-10	*Contaminant leachate plume between stations 2 – 6 in the 2D Structure (<11.6 Ωm). Vertical and lateral migration of leachate plume observed.
		Fresh Bedrock	57 - 1,181	inf	
2	Traverse 2	Topsoil/ Weathered layer (Overburden)	2.5 – 37 (Generally <18.7)	2 - 5	* Contaminant leachate plume between stations 2 – 11 in the 2D Structure, with depth > 25 m. Vertical (beneath stations 6 – 11) and lateral (between stations 2 – 4) migration of leachate plume observed.
		Fresh Bedrock	21.5 - 69	Inf.	
3	Traverse 3	Topsoil/ Weathered layer (Overburden)	7.9 - 40	8 - 12	*Contaminant leachate plume between stations 2 – 10 in 2D Structure (within the u pper 8m). At the boundary area of dumpsite (Left Hand Side).
		Fresh Bedrock	54 - 300	Inf	
4	Control Traverse	Topsoil/ Weathered layer (Overburden)	10.7 – 36.5	5 - 15	Un-impacted control traverse. No c ontaminant leachate plume. The apparent resisitivity is generally > 20 Ωm for Topsoil/Weathered layer (Overburden) and > 57 Ωm for fresh bedrock.
		Fresh Bedrock	45 - 136	inf	
5	Borehole 1 (Oju Ekun)	Weathered layer	40	26	Un-impacted.No contaminant leachate plume. The apparent resisitivity is generally > 20 Ωm for Topsoil/Weathered layer (Overburden) and > 57 Ωm for fresh bedrock.
		Fresh Bedrock	Not Available	Inf.	
6	Borehole 2 (Oja Ago)	Weathered layer	36	18	Un-impacted.No contaminant leachate plume. The apparent resisitivity is generally > 20 Ωm for Topsoil/Weathered layer (Overburden) and > 57 Ωm for fresh bedrock.
		Fresh Bedrock	Not available	Inf.	

***Plume infected layer** **Source: Field Work, 2021**

Hydrochemical Analysis Result

Table 3 shows the results of the hydrochemical analyses of water samples from a hand-dug well and a borehole located 77m and 55m, respectively, from the waste dumpsite in the study area. The discussion of the results based on the physical and chemical parameters and the heavy metals are hereby presented

Table 3: Comparison of the concentration of the analyzed parameters with the WHO (2006)/NIS (2007) Standards.

Parameters	Water Sample (WS 1)	Water Sample (WS 2)	**NIS Standard (2007)**	**WHO Standard (2011)**
PH	6.25	6.33	6.5 - 8.5	6.5 - 8.0
Electrical Conductivity (μScm^{-1})	1375	2200	1000	1000
Turbidity	8.904	8.449	5	5
Temperature (°C)	28	28	-	-
Colour (TCU)	0.135	0.279	15	15
PO_4^{3-} (mg/l)	0.03	0.055	-	-
SO_4^{2-} (mg/l)	0.08	0.255	100	250 – 500
NO_3^- (mg/l)	0.086	0.075	50	50
$CaC0_3$ (mg/l)	238	406	150	200
HCO_3^- (mg/l)	1.602	1.094	-	-
Cl^- (mg/l)	24.915	20.928	250	250
Cd (mg/l)	0.013	0.01	0.003	0.003
Ca^{2+} (mg/l)	7.079	13.141	-	75
Fe (mg/l)	0.02	0.02	0.3	0.3
K^+ (mg/l)	33.769	54.764	-	-
Mg^{2+} (mg/l)	6.584	7.816	0.20	-
Mn (mg/l)	0.016	0.018	0.2	0.5
Na^+ (mg/l)	19.324	19.454	200	50
Pb (mg/l)	0.02	0.02	0.01	0.01
TDS	625	1025	500	1000
Al (mg/l)	5.453	6.459	0.2	0.1 - 0.2

Source: Field Work, 2021

Anthropogenic Pollution Determinant Parameters.

From the laboratory analyses of the water samples, the anthropogenic pollution determinant parameter at a tolerable level with the World Health Organization's (WHO, 2006) and Nigerian industrial standard's (NIS, 2007) thresholds for potable water includes true colour unit (TCU) rating (0.135 to 0.279).

The items that are not at tolerable levels with the WHO and NIS thresholds for potable water include the total dissolved solids (TDS) (625 to 1025 mg/l), high TDS will cause undesirable taste (Sule *et al*., 2020) and lower resistivity; total hardness levels (238 to 406 mg/l), conductivity (1375 to 2200 μScm^{-1}), Turbidity levels (8.904 to 8.449 NTU), PH (6.25 to 6.33, high PH could favour both indicator and pathogenic microorganisms growth (Akankpo and Igboekwe, 2011)).

The parameters measured in the two water samples are high and within the same range in most cases, probably because one well is directly beside (50m) the dumpsite while the borehole is on the erosion channel (77m) from dumpsite, though separated by tarred road.

Cations

The Cations at tolerable levels with the WHO (2006) and NIS (2007) thresholds for potable water include the potassium (33.769 to 57.764 mg/l), calcium (7.079 to 13.141 mg/l) and sodium (19.324 and 19.454 mg/l). Those that are not at tolerable levels include: magnesium (6.584 to 7.816 mg/l) and Aluminum (5.453 and 6.459 mg/l). Excessive magnesium, aluminum and other cations may produce undesirable taste and badly impact health. Higher concentrations of the cations are noticeable in water sample 2 than in water sample 1.

Anions

The anions in the analyzed water samples, i.e. Bicarbonate, Chloride, Sulphate, Nitrate, and Phosphate (1. 094–1.602 mg/l; 24.928–20.915 mg/l, 0.08 – 0.255 mg/l, 0.075– 0.086 mg/l, and 0.03 – 0.055 mg/l respectively) might be within the standard drinking water thresholds, yet, caution must be taken in consuming the water because of its proximity to waste dump site.

The high concentrations of Chloride, Nitrate and Bicarbonate have alluded to the high conductivity but low resistivity values which is attributable to the dumpsite impact. However, there is no set value for the maximum amount of phosphate in drinking water, but Oram (2014) suggests a maximum phosphate concentration of 0.1 mg/l.

Heavy Metals

From the laboratory analyses of water samples, the heavy metals concentrations include Cadmium (Cd) 0.01 – 0.013 mg/l, Iron (Fe) 0.02 – 0.02 mg/l, Manganese (Mn) 0.016 – 0.018 mg/l, and Lead (Pb) 0.02 – 0.02 mg/l. Lead and cadmium concentrations were significantly higher than the WHO (2006) and NIS (2007) permissible levels for potable water. Mn concentration is higher in water sample 2 than in water sample 1. Water samples 1 and 2 have equal amounts of lead and iron concentrations, but water sample 1 has a higher cadmium concentration. High concentration (>0.003 mg/l) of cadmium is toxic to the kidney (Sule *et al.,* 2020).

Conclusion

The presence of dumpsite in Oke-elele area of Kwara prompted a geophysical and hydrochemical analysis investigation in the vicinity to assess possible pollution/contamination within the subsoil and groundwater in the area. The geo-electric sections show that a maximum of six subsurface lithologies underlie the study area. These lithologies and their geo-electric parameters include topsoil (20 - 113 Ωm, 0.4-1.2 m); laterite (67-102 Ωm, 0.5-1.6m); Clay/plume infected layer (8 - 20 Ω-m, 1.1 – 4.7m); weathered/Partly weathered Basement (11 -211 Ωm, 1.5 – 17.2m); fractured basement (10 - 23 Ωm, 5-10m); and fresh bedrock (375- 99982 Ω-m, infinity).

The 2D resistivity images generally delineated the overburden (merged topsoil/weathered and fractured basement) and fresh bedrock. Resistivity values of > 20 Ω-m were observed beneath the control traverse, which typified the geo-electric characteristic of unimpacted subsoil in the study area. Relative to this baseline resistivity characteristic, significantly low values (2.4-11.6 Ωm) were observed within the upper 25 m at locations within and outside the waste boundaries. This indicates that pollution plumes from the dumpsite have infiltrated the subsoil and leachate migration is both in the vertical and lateral directions.

Also, the hydrochemical analyses of the water samples from wells have shown that the anions and cations of the sampled water fell within the WHO (2006) and NIS (2007) thresholds for potable water. However, the values of EC, turbidity, TDS, total hardness, pH, manganese, aluminium, lead and cadmium were higher than the standard thresholds, an indication of groundwater pollution.

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