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Contamination Assessment of Ilokun Waste Dump using Electrical Resistivity Method Ado-Ekiti, Ekiti State Nigeria

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Abstract
Soils and water in Ilokun area prune to contamination via the leachate emanating from a nearby waste dump. Hence, assessment of Ilokun waste dump in Ado-Ekiti, was carried out using vertical electrical sounding (VES) and 2-D electrical resistivity methods with a view to delineate various subsurface lithologies, obtain imagery of the subsurface and the leachate contaminant plumes. A total of seven VES stations were occupied while the dipole-dipole technique was carried out along three different traverses across the waste dump site. Both partial curve matching and computer iteration were used in the interpretation of the data obtained from the soundings. Results of the interpreted data revealed KQH, KH, QHA, H, KHK, QKHA, HKH curve types respectively. The VES interpretation indicated three to five geo-electric layers comprising of topsoil, lateritic soil, weathered layer and fractured/fresh basement. The weathered layer had the lowest resistivity (26 – 89Ωm) signifying evidence of leachate from the dumpsite percolating into the subsurface. The 2-D resistivity structure showed that the topsoil and the weathered layer virtually merged and characterized by relatively low resistivity of <40Ωm. The relatively low resistivity values in the weathered layer were as a result of high degree of leachate saturation. Traverse 1 showed the lateral flow of leachate plume from about 25m to 100m while traverses 2 and 3 revealed a hollow with more dumpsite weathered layer of low resistivity oriented along North – South direction of the study area. The groundwater within the vicinity of the investigated dumpsite has been contaminated to an estimated depth of about 25m thick with leachate flowing in the east to western direction of the waste dumpsite. This study has determined the extent of groundwater contamination indicating the northern part of the study area to be uncontaminated and suitable for hand dug well and borehole drilling.

Keywords: Leachate, computer iteration, weathered zone, resistivity, contamination

Introduction:

Waste dumps constitute a crucial and efficient means of maintaining a clean environment in urban settings. However, the generation of wastes (municipal and industrial) in tons is increasing significantly especially within the industrialized and highly populated cities. Percolation of leachates from the waste dumps into the soil and groundwater of the environment may impact the standard of the groundwater negatively which can consequently have adverse effects on humans' health (Ramakrishnaiah *et al.*, 2009).
Growth in population in industrialized and concrete cities has resulted into corresponding increase in wastes generation/dumping. Groundwater and soil pollution arising from source pollution of waste dump is one in every of the most important concerns of the world scientists and researchers worldwide. Dumpsites aren't properly designed or constructed as landfill in many cities in Nigeria. Consequently, waste dump at dumpsites biodegraded over the years related to an unquantifiable stench (Bayode *et al*., 2012). Most of the cities in Nigeria have solid waste management problems like poor waste collection, inadequate waste disposal equipment, indiscriminate dumping of wastes on streets and canals, siting of waste dumpsite within residential areas without recourse to local geology and hydrogeology of the environment. Emanating from the solid waste management problems is the groundwater

contamination which could be a challenging issue in Nigeria. Environmental pollution and possible contamination of groundwater within the area of urban waste materials pose a high risk to community health (Soupios *et al.*, 2006).

Groundwater occurs in a porous and permeable geological formation (aquifer) saturated with water and capable of transmitting significant quantities of water to wells under normal field conditions. Porosity of an aquifer is one in every of the determing factors of the amount of groundwater it can contain. Its quality depends on the standard of recharged water, amount and quality of generated waste, sewage treatment and subsurface geochemical processes (Rizwan and Gurdeep, 2010). Leachate emanating from the decomposed solid waste infiltrates and pollutes the water level. Groundwater in such environment constitutes health risk to both humans and therefore the natural environment (Andrea *et al.*, 2012).

Groundwater serves as the subsurface transporting agent for dissolved chemicals and contaminants. The chemicals within the waste are dissolved by water and transported by groundwater flow. The pollution of groundwater results mostly from percolation of pluvial water (rich in dissolved salts) and the infiltration of contaminants through the soil (Atekwana *et al*., 2013; Edet and Worden, 2009). The extent of threats pose by contaminated groundwater to humans and therefore the environment rely on the concentration and toxicity of contaminants in leachates, types and permeability of geologic strata, depth of water level and therefore the direction of groundwater flow. The frequent requests of individuals within the environment with regards to the negative impacts of waste dumps include the detection of the source and extent of contamination patches/plumes in affected areas.

Electrical resistivity method is one of the most favorable geophysical methods for dumpsite investigation because it delineates contaminated zones of groundwater effectively because of conductive nature of most contaminants (Atekwana *et al*., 2000; Karlik and Kaya, 2001). The electrical imaging technique that's environmental friendly, measures low resistivity in polluted groundwater and soil is beneficial in mapping contamination plumes generated from solid waste dumps. Electrical resistivity method is fast, cost-effective and a non-destructive geophysical technique for mapping the shallow subsurface anomaly (Kumar, 2012). Electrical resistivity of soil depends on various factors including soil type, water content and pore fluid property (George *et al*., 2015).

Ilokun waste dumpsite is Ekiti State Government approved open area for the dumping of wastes. It covers an aerial extent of about 246,980.76m^2. The open area isn't designed or constructed as landfill sites. The wastes within the dumpsite comprise mainly of the domestic, hospital, agricultural and industrial materials that are capable of undergoing biodegradation over the years (Olagunju et al., 2018). Other researchers (Odeyemi, 2012, Lateef et al., 2015, Okunade et al., 2019) worked on varied research topics. Odeyemi (2012) researched into the "Antibiogram Status of Bacterial Isolates from Air round the Ilokun waste dump" and concluded that the air round the waste dump was bacteriologically polluted. Okunade et al. (2019) assessed groundwater quality around Ilokun open dumpsite and discovered that the groundwater at the dumpsite has been heavily contaminated and unfit for human consumption or usage. Leachate from the dumpsite pollutes the atmosphere and subsequently the hydrosphere. The leachates from the waste dumps is also rich in mobile ions and mineral nutrients needed by plants for agricultural productivity but toxic metals (arsenic and zinc) were of high values that rendered agricultural activities ineffective as reported in the research of Olagunju et al. (2018). The main focus of individuals dwelling within the environment is on the polluted groundwater and possible remediation measures that will ameliorate matters. Thus Ilokun waste dump constitutes serious threats to the environment and humans' health. Though there are previous research works on the waste dump, thecurrent research becomes necessary due to the importance attached to humans' health and the dynamic nature of hydro-geophysical processes. Hence, Ilokun waste dump contaminant level was assessed employing a vertical electrical sounding technique to delineate various subsurface lithologies and the leachate contaminant plumes. The extent of the groundwater polluted area was demarcated from an uncontaminated zone that's suitable for hand-dug wells and boreholes' drilling.

Location and Geology of the Study Area

The Ilokun dumpsite is located at Ado-Ekiti, Southwestern Nigeria. It lies between the geographic coordinates (UTM) of latitudes 850200 to 850500 and Longitudes 749150 and 749500 (Fig. 1). The study area is within the Tropic of Capricorn with two main seasons; rainy and dry seasons. The rainy season often spans between April and October while the dry season is from November to March each year. This generalization may have minor variation due to the effects of climatic change word wide. Generally, the climate is characterized by annual temperatures that range from 21-28^{0}C and high relative humidity (Olayinka and Olayiwola, 2001, Kottek et al., 2006). Ado-Ekiti generally is underlain by Pre-Cambrian Basement Complex rocks including migmatite, migmatite gneiss, quartzite, granites and charnokites (Fig. 1). Field relationship of the rocks indicated common age for the granites and charnockites (Omotoyinbo, 1994). Rocks which constitute the Basement Complex of Southwestern Nigeria are known to be overlain by thick overburden. Many Researchers (Rahaman 1976, 1988, Odeyemi 1978) carried out extensive study on the rocks of the Precambrian Basement Complex of Nigeria. They concluded that the rocks in the basement have undergone polycyclic deformation under many thermo tectonic events. The main rock at the study area is migmatite (Fig. 1).

Research Methods

Reconnaissance survey was made to the study area to verify and ascertain the maturity and geologic/hydrogeologic situations of the dump site. During the visits accessibility to site, cutting of profiles in readiness of VES operations were embarked upon. Information from reconnaissance survey was used where necessary in the preparation for the geophysical survey of the study area. Geophysical methods are indirect site investigation techniques and predominantly non-intrusive. Vertical electrical sounding (VES) and 2D electrical resistivity (dipole–dipole technique) were adopted for this study. VES furnishes detailed information on the vertical lithological successions and their thicknesses, their hydrogeological significance and the protective capacity or vulnerability of the subsurface layers to possible pollution (Ogundana and Talabi, 2014). The Schlumberger array, in which the fraction of the electric current penetrating the ground increases with an increased separation of the current electrodes, was employed for this study. The assumption is that the wider the current electrode spacing, the deeper the earth being probed. Multiplication of the values of resistance (R) obtained on the field with the Schlumberger geometric factor (G) gave the apparent resistivity. The sounding curve for each point was obtained by plotting the apparent resistivity on the ordinate against half current-electrode spacing on a bilogarithmic paper. Parameters such as apparent resistivity and thickness obtained from partial curve matching were used as input data for computer iteration modeling using the WinResist software. Seven (7) VES locations were occupied using a Campus Omega SAS 1000C Terrameter.

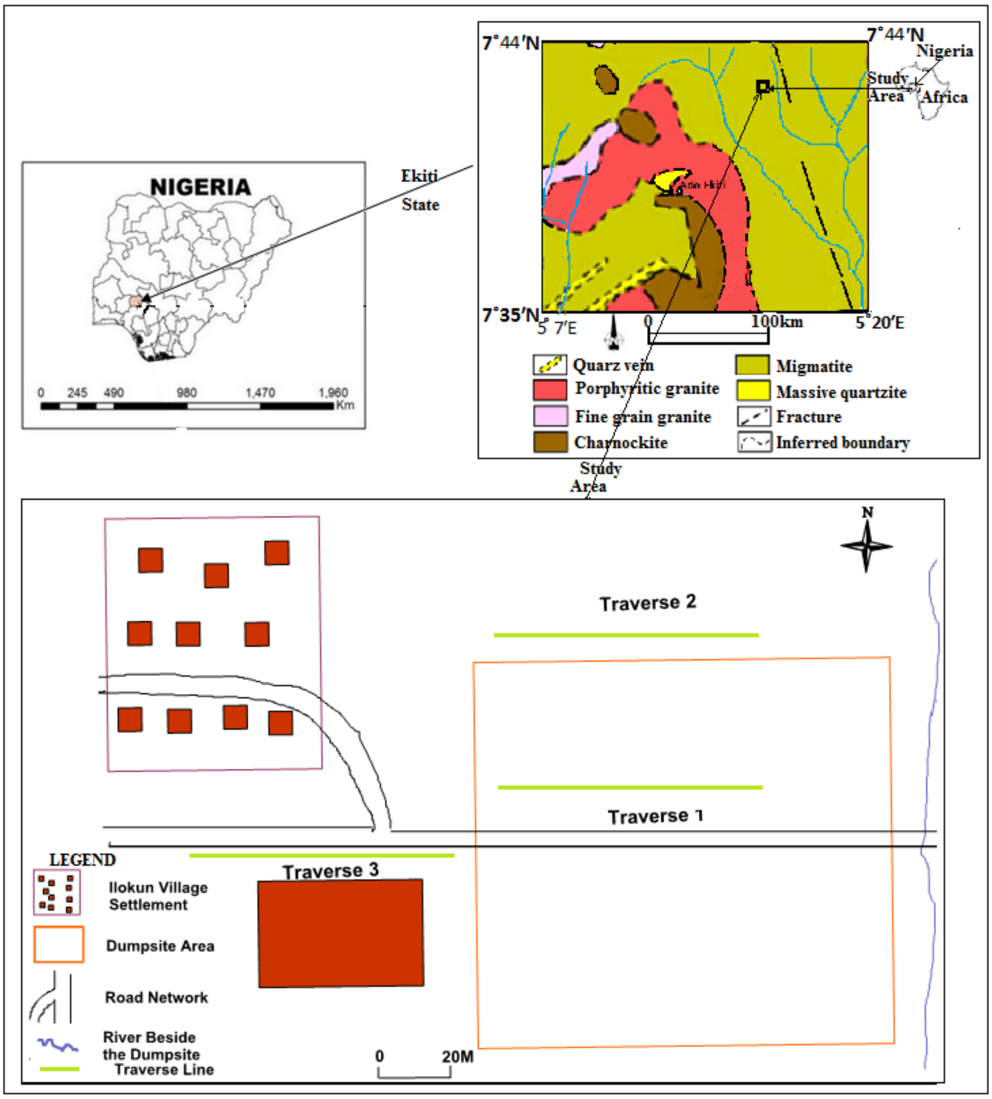


Fig. 1: Location of the Study Area

The 2-D resistivity survey was further employed to image the sub surface of the study area because it takes care of the limitation of the 1-D resistivity survey. Both horizontal and vertical changes in the layer resistivity were observed as the resistivity changes in both directions along the survey line. It is therefore a more accurate model of the subsurface (Loke, 2000, Sarker et al, 2012). The dipole–dipole array technique was adopted for 2-d electrical resistivity. In this case, the spacing between the current electrodes pair, AB is given as "a" which is the same as the distance between the potential electrodes pair MN (Fig.2). The same process is repeated for measurements with different spacing ("2a" to "na"). The apparent resistivity is calculated with $k = \pi(n(n + 1)(n + 2)a)$, where n is the level. The midpoint depth of investigation of this array also relies on the "n" factor, as well as the "a" parameter (Param and Arkoprovo, 2016).

Three (3) traverses occupied by the dipole–dipole survey were conducted with a dipole–dipole expansion factor n varying from 1 to 5 m and dipole spacing of a = 5 m.

Fig. 2: Dipole-dipole electrode Array

Result and Discussions

Two main geophysical surveys were employed in this study. The geoelectrical investigation involving Vertical Electrical Sounding (VES) was conducted to have foreknowledge of underground resistivity, the subsurface lithologies and the leachate contaminant plumes while the 2-D survey revealed both the horizontal and vertical variations in the subsurface of the study area.

Vertical Electrical Soundings (VES)

Seven (7) sounding stations along 3 traverses were occupied in this study (Fig. 1). The data obtained from the VES soundings were interpreted and presented in form of tables (Tables 1and 2), geo-electric curves (Fig. 3) and geo-electric sections (Fig4 (A-C)). The geo-electric properties of the various subsurface layers were used in delineating the depth to which leachates from the dumpsite have contaminated the groundwater of the study area. The interpreted result revealed the following geo-electric curves respectively KQH ($\ell 1 < \ell 2 > \ell 3 > \ell 4 < \ell 5$), KH ($\ell 1 < \ell 2 > \ell 3 < \ell 4$), QHK ($\ell 1 > \ell 2 > \ell 3 < \ell 4 > \ell 5$), ($\ell 1 > \ell 2 < \ell 3$), KHK ($\ell 1 < \ell 2 > \ell 3 < \ell 4 > \ell 5$), QHKH ($\ell 1 > \ell 2 > \ell 3 < \ell 4 > \ell 5 < \ell 6$) and HKH ($\ell 1 > \ell 2 < \ell 3 > \ell 4 < \ell 5$). Three to five geo-electric layers were established comprising of topsoil, lateritic soil, weathered layer and fractured/fresh basement.

4.1.1 Geo-electric Section

The geo-electric section (Figs. 4) shows the variations of resistivity and thickness values of layers within the depth penetrated in the study area. Geo-electric section along W-E profile revealed 4-5 geo-electric layers based on the geological formation of the study area and the rate of contamination of the leachates within the study area (Figs. 4A – 4B). The first layer consist of the topsoil or from 0.5 – 5.7 m with resistivity value range of 71 – 1014 Ωm. The second layer consists of weathered basement or lateritic clayey formation with thickness of 0.8 – 9.9 m and is characterised by resistivity value range of 100 – 670 Ωm. The third layer includes fractured and highly weathered zone where accumulation of leachate is more pronounced with thickness of 0.9 – 10.9 m and characterized by resistivity range of 4.5 – 96.6 Ωm. The fourth to fifth layer is the fresh basement/fractured basement with thickness ranging from 5 m to infinity and resistivity range of 40.8 to 7413.7 Ωm. Traverse 1 is 110 m length, VES 1, 2 and 3 were located on it (Fig. 4A). The geo-electric section shows that a sizeable portion of the highly weathered zone has been contaminated with the leachate from the waste dump materials. All the VES points reflected the occurrence of leachate accumulation with resistivity values ranging from 6 – 67 Ωm located within a depth range of 4 – 16 m. The traverse is not good for groundwater development considering the overwheming accumulation of the contaminants within the aquiferous zone.

Table 1 Data acquired from the VES Locations

AB/2	MN/2	k	KR_1	KR_2	KR_3	KR_4	KR_5	KR_6	KR_7
(m)	(m)		$(\rho 1)$	$(\rho 2)$	$(\rho 3)$	$(\rho 4)$	$(\rho 5)$	$(\rho 6)$	$(\rho 7)$
1	0.5	6.28	837	638	1023	610	101	956	894
2	0.5	25.13	786	509	928	507	112	845	745
3	0.5	56.13	645	503	879	235	115	766	6.89
4	0.5	100.53	359	453	723	158	113	639	323
6	0.5	226.19	233	301	601	135	85	543	415
6	1.0	113.10	231	299	599	133	83	541	413
8	1.0	201.06	258	115	511	115	75	256	326
12	1.0	452.39	405	82	321	117	92	267	303
15	1.0	706.86	425	102	223	112	98	301	329
15	2.0	353.43	423	100	221	160	96	299	337
25	2.0	981.75	20	111	152	116	152	822	556
32	2.0	1608.50	16	183	108	221	168	328	424
40	2.0	2513.27	35	204	110	328	201	289	283
40	4.0	1256.8	33	202	108	326	199	287	281
65	4.0	3318.78	48	314	129	401	242	275	221
100	4.0	7855.00	60	528	143		314	314	133
100	8.0	3927.50	58					312	131
150	8.0	8836.88						389	169

The study shows that the leachate has migrated from the dumpsite to the neighbourhood since the traverse is located outside the dumpsite as observed in the 2D-resistivity pseudosection. Traverse 2 is 70 m length, VES 4 and 5 were located on traverse 2 (Fig. 4 B). The geo-electric section shows that the leachate of the waste dump is migrating in E-W direction with higher thickness of about 10 m at the western part compared to 5m at the eastern part of the traverse line. The traverse is located within the dumpsite. The basement located within a depth range of 5 – 10 m act as sill to the permeation of the leachate into the fractured zone beneath the basement at VES 5. The two VES points also reflected the occurrence of leachate accumulation with resistivity values ranging from 28 – 101 Ωm located within a depth range of 4.5 – 10 m. VES 5 is good for groundwater development considering the occurrence of the fractured zone. The contaminant will be prevented from permeating the freshwater located within the fractured zone. The contaminated zone must be treated with artificial seal after drilling. The study shows that the leachate has migrated from the dumpsite to the neighbourhood since the traverse is located outside the dumpsite as observed in the 2D-resistivity pseudosection. Traverse 3 is 70 m length, VES 6 and 7 were located on traverse 3 (Fig.4C). The geo-electric section shows that an ample portion of the highly fractured zone has been contaminated with the leachate from the waste dump materials. The traverse is located very close to the dumpsite parallel to traverse 2. All the VES points reflected the occurrence of leachate accumulation with resistivity values ranging from 43 – 77 Ωm located within a depth range of 25 – 34 m and thicknesses 15 – 22 m. The traverse is not good for groundwater development considering the total accumulation of the contaminants within the aquiferous zone. The study shows that the leachate has migrated from the dumpsite to the neighbourhood since the traverse is located very close to the dumpsite as observed in the 2D-resistivity pseudosection. The figure shows that the leachate found another traceable part to penetrate the porous fractured zone of the geoelectric portion.

Conclusion

Geo-electric survey has been useful in the contamination assessment of Ilokun Waste Dump Ado-Ekiti, Ekiti State Nigeria. Results from the VES revealed occurrence of KQH, KH and QHA, H, KHK, QKHA, HKH curve types. Both the VES and 2-D imagery surveys delineated three to five geo-electric subsurface layers comprising of topsoil, lateritic soil, weathered layer and fractures/fresh basement. The 2-D resistivity structure shows that the topsoil and the weathered layer virtually merged with relatively low resistivity of <40Ωm. The weathered layer has relatively low resistivity arising from contamination due to leachate saturation. The 2-D resistivity structure for traverse 1 showed the lateral flow of leachate plum from about 25m to 100m and the leachate migrated into a hollow between 85m to 105m with the depth of about 25m. The geo-electric section on traverse 2 (within the dumpsite) indicated that the leachate from the waste was migrating in E-W direction with higher thickness of about 10 m at the western part compared to 5m at the eastern part of the traverse line. Traverse 3 revealed that the leachate plume has migrated to the depth above 25m. This study indicated that leachate from the waste dump has migrated into the subsurface and contaminated the surrounding soils/groundwater of the area.

Table 2 Summary of interpreted VES curves

VES	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH	CURVE TYPE	NO OF LAYERS	REMARK
1	443.9	4.2	4.2	QH	4	TOPSOIL(LATERIC SAND)
	455.3	1.6	5.7			TOPSOIL(LATERIC SAND)
	182.1	0.6	6.3			WEATHERED ZONE (CLAYED)
	4.5	10.9	17.2			HIGHLY POLUTED ZONE
	399.7	-	-			FRESH BASEMENT
2	594.9	0.9	0.9	H	3	TOPSOIL
	670.7	1.3	2.2			TOPSOIL
	49.1	8.4	10.6			HIGHLY POLUTED
	935.2	-	-			FRESH BASEMENT
		-	-			
3	1014.1	1.5	1.5	HK	5	TOPSOIL
	200.5	3.9	5.4			WEATHERED LAYER (SANDY CLAY)
	56.7	10.8	16.2			HIGHLY POLUTED ZONE (WEATHERED ZONE)
	1531.6	130.6	146.9			FRESH BASEMENT
	64167	-	-			FRACTURED ZONE
4	543.6	1.0	1.0	H	3	TOPSOIL
	100.6	9.9	10.9			WEATHERED LAYER &/PARTLY POLLUTED ZONE
	5736.6	-	-			FRESH BASEMENT
		-	-			
5	71.0	0.5	0.5	KHK	5	CLAYEY TOPSOIL
	269.8	0.8	1.4			WEATHERED ZONE
	25.6	3.5	4.9			HIGHLY POLLUTED (WEATHERED ZONE)
	1391.3	8.2	13.0			FRESH BASEMENT
	303.6	-	-			FRACTURED ZONE
6	931.1	1.4	1.4	AHKH	6	TOPSOIL
	185.0	1.8	3.1			WEATHERED ZONE(CLAYEY SOIL)
	97.6	0.9	4.0			HIGHLY POLLUTED ZONE
	808.3	6.4	10.4			FRESH BASEMENT
	77.4	15.5	25.9			FRACTURED BASEMENT
	7413.7	-	-			FRESH BASEMENT
7	846.5	1.5	1.5	HKH	5	TOPSOIL
	134.3	2.7	4.2			WEATHERED ZONE
	1391.0	5.0	9.3			FRESH BASEMENT
	42.8	23.0	32.2			FRACTURED/ HIGHLY POLLUTED ZONE
	603.9	-	-			FRESH BASEMENT

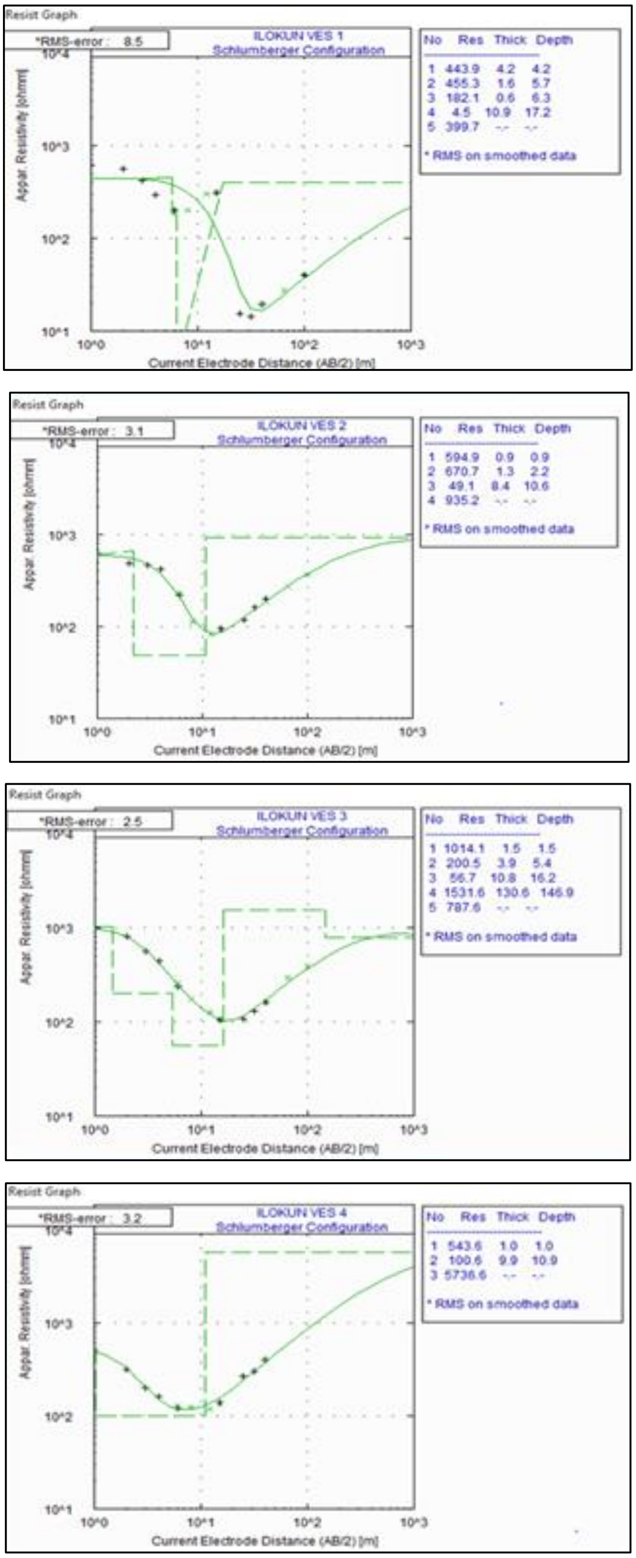
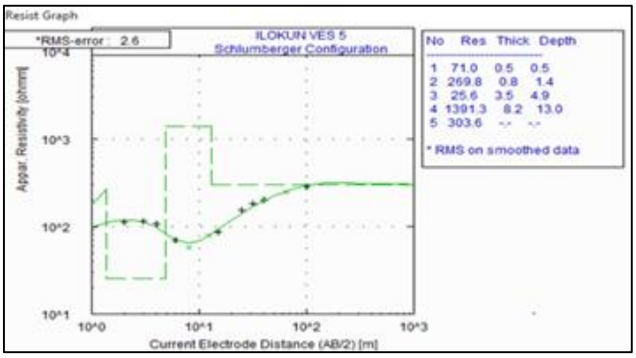


Fig. 3: Geoelectric Curves from the Study Area.



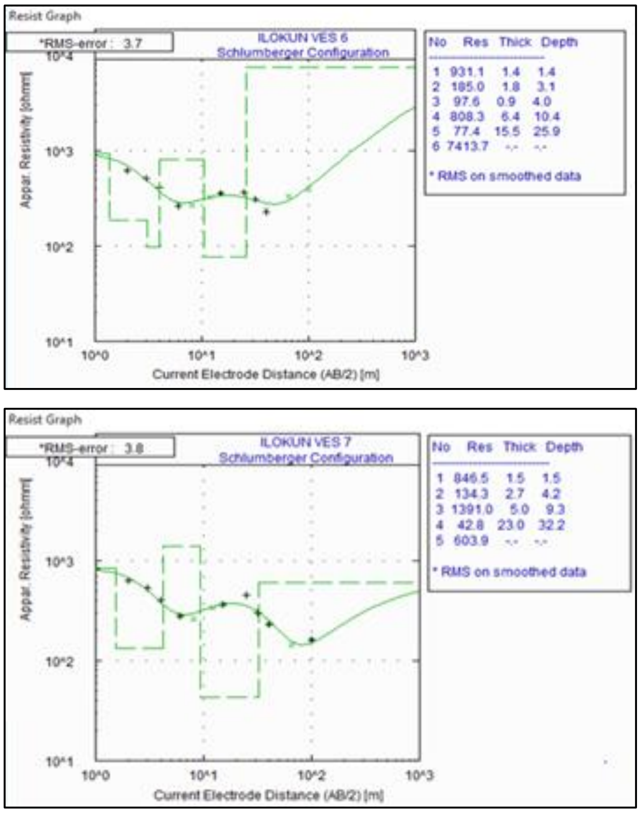
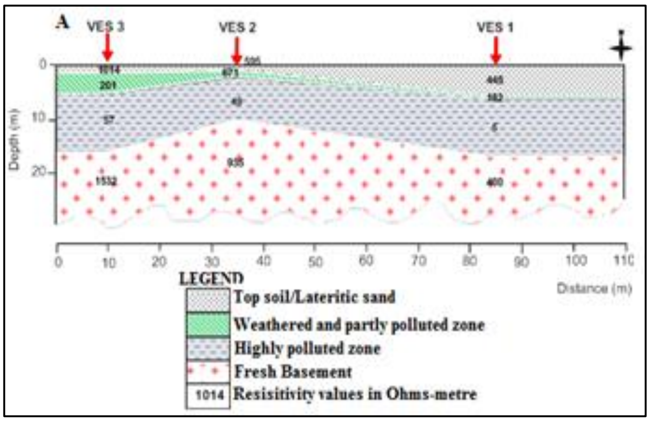
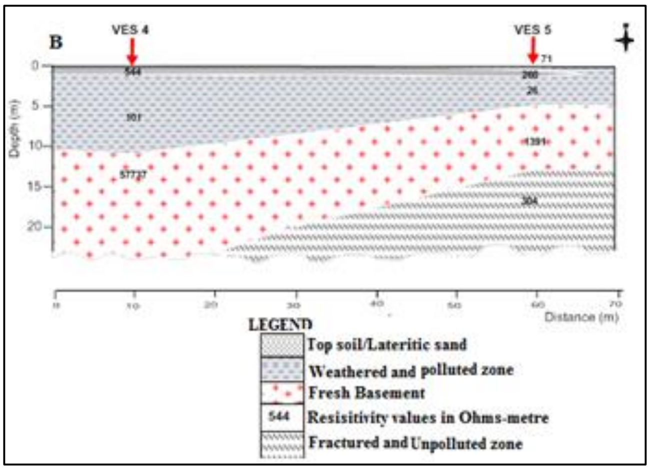


Fig. 4: Geoelectric Curves from the Study Area contd.





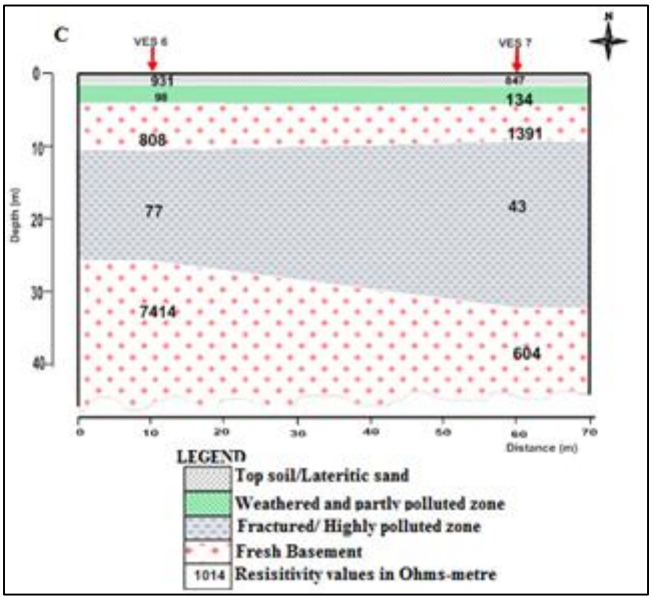


Fig. 4 Geo-electric Sections (A, B and C) across VES points in the study area.

Declaration of competing interest

There are no conflicts of interests with regards to this manuscript.

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