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Investigation of Leachate Migration from Dumpsite and Its Effect on Surrounding Groundwater: A Case Study of Kuje Dumpsite, Fct, Abuja, Nigeria

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ABSTRACT
Groundwater contamination is one of the major problems caused by open dumpsitein an environment which directly results into health hazards for the people livingaround the area. Inthis study, geophysical and physicochemical methods werecarried out to investigategroundwaterpollutionat a dumpsite in Kuje, FCT,Abuja. From the result of geophysical method, high conductivity of 0.143 Ω-1m andlow resistivity of <7 Ωm, shows the presence and migration of leachate from thedumpsite. Also, physico-chemical analysis of hand dug well and borehole watersampleswerecarriedoutforheavymetalcomponentsuchaszinc,copper,manganese and iron. The concentrations of heavy metal were high with values of0.1352, 1.7, 0.36 and 0.32530 respectively for hand dug well, 0.28, 1.65, 0.28 and0.1387 respectively for borehole water sample, which is above WHO safe limits of5,0.05,0.2and0.03respectively(exceptforzincvaluewhichislowerthantheWHOsafe limit). The geophysical and physicochemical results indicate that the refuse atthe dumpsite consistofempty cans and rusted ironwhich causegroundwaterpollution. Hence there is a need for proper regulation of the dumpsite to improvewaterquality,environmentalandhealthstandardoftheinhabitants ofthiscommunity.

Keywords: Contamination, Dumpsite, Geophysical, Groundwater, Investigation, Physio-Chemical

I. INTRODUCTION

The study area, Kuje, is located in Abuja's Federal Capital Territory's southern region. The study region is located between longitude 07⁰ 14' 24"E and 07⁰ 14' 41"E and latitude 08⁰ 53' 24"N and 08⁰ 53' 47"N.

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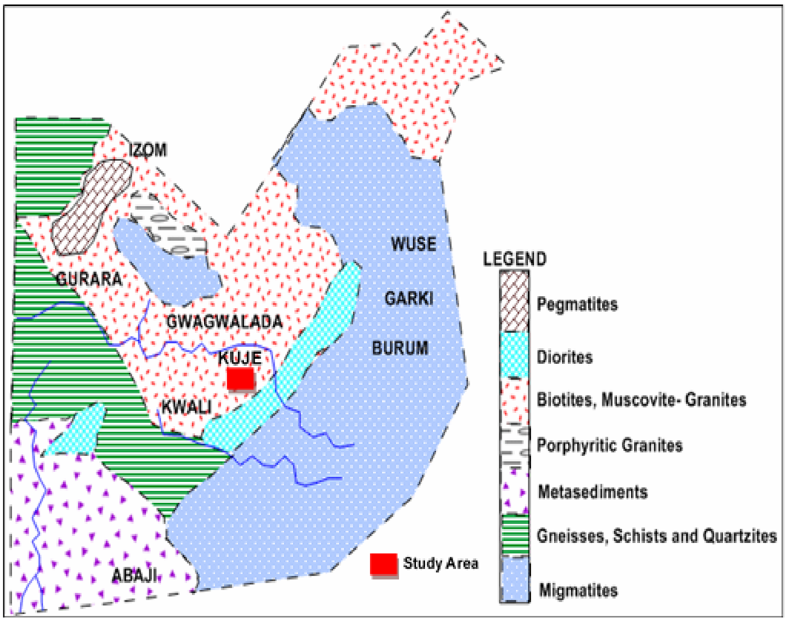

Geological map of FCT showing the study area (modified after Obaje, 2009)

Wastes are items that are undesired. Any item that is thrown away after its initial use or that is useless, broken, or otherwise unusable is considered waste. Solid waste generation is a regular result of necessary human activities. Despite the level of global industrialization and technological advancement that exists today, the intensity of human activity has led to an increase in solid waste globally. According to Abu and Al-Kofahi (2001), landfills have long been used as the final resting place for all waste types. The term "landfill" refers to a facility for the engineered disposal of garbage that uses specialized pollution control techniques to reduce any potential effects. Typically, open landfills are either above ground or located within of pits or quarries.

One of the most important problems with landfill design, operation, and long-term maintenance is leachate management, which happens when water percolates through the waste put in a landfill. Landfills are sources of groundwater and soil pollution because of the leachate that trash migration produces (Misra and Mani, 1991). The simultaneous interaction of physical, chemical, and biological processes results in the overall breakdown of the wastes. Chemically laden leachates, which are one of the results of all these mechanisms and accumulate at the bottom of the dump, are made up of a variety of organic and inorganic compounds. Liners are installed at the base of contemporary landfills to prevent leachate from migrating there. The migration of leachate into an aquifer is, however, acknowledged to be prevented by such liners, although with time, these liners degrade and finally fail to do so (Kirlna, 2002). Leachate generation at a landfill is influenced by a number of variables, including the climate, site topography, potential landfill cover material, vegetation cover, and type of garbage in the dump. These variables may also indirectly affect the risk of severe water resource impacts. The climate at the site significantly influences the rate of leachate generation, all other factors being equal. Areas near dumpsites have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site (Lokmanet al, 2014). The degree of threat is strongly influenced by the composition of the wastes in the landfill and the volume of leachates generated, as well as the location of the landfill from water bodies; groundwater and surface water (Chrestensen, 2001).

These leachates are a major cause of aquifer contamination because they result from the dumping of home and commercial solid wastes. In studying the leachate effects, it is expected that in areas of high concentrations of leachate, there will be a corresponding very high value of conductivity and a very low value of resistivity (Onyekuru et al, 2018). Since resistivity is the inverse of conductivity, electrical resistivity method is a popular tool for ground water exploration, it is also

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used in determining groundwater quality, i.e. whether the water is saline, fresh or contaminated.

Annual waste generation is increasing exponentially with rapid population growth, urbanization and industrial development.Thedumping ofnon-segregatedsolidwastetolandfill sitesisthemost prevalent waste disposal practice in Nigeria andeveninsome developedcountries(Ferronatoetal., 2019).Theimpropermanagementoflandfillsandgener ation oftoxicleachatetherebyexertsignificantimpactsons urrounding freshwater and groundwater (Ferronatoetal.2019).

Leachateistheaqueouseffluentgeneratedfromsolid wasteowingtotheirphysical,chemical,andbi ologicalalterationinlandfills(Zhao2018) and is considered as a chemical soup of dissolved organicmatter(DOM),xenobioticorganiccompounds ,differentanionsandcations,andheavymetals(Christ ensen2001).Among the several elements that make up landfill leachate, heavy metals are non-biodegradable, capable of lowering the quality of surface and groundwater, and hazardous to biological systems even at low concentrations.Heavymetalsarealso persistent,bio-accumulative,andtoxic(Mahmuduletal.,2022).Conve rsely, the DOM which constitute a large portion of leachate, has potential to bind with heavy metal, and consequently plays asignificantroleinthebio-availabilityofthosemetalsinthe aquatic environments (Baun and Christensen 2004; Parvinetal., 2021). Theprincipalconcernaboutmunicipallandfillisfocuse d on the pollution potential due to mobilization of the generated leachate through the subsoil into the surface and groundwater.Further,duringthewetseason,water containing leachate from landfillsite drains into the nearby lowlands and surface water bodies and pollutes the local environments.Hence,thistoxicaqueouseffluentfroml andfillsitecancausepotentialriskto surface and groundwater (Christensen 2001)and areeventually foundtoposesathreat foraquatic biota, plant and public health. Iswa, (2013) reported that in most of the developing countries, improperlymanagedopenlandfillsitesaremorecomm only practicedthancontrolledandengineeredlandfills. Residents, especiallytheurbanandsemiurbanresidentsinthoseco untries areaffectedseverelybythisuncontrolledmanagemen tof waste via waterandfood contamination by toxic leachate.

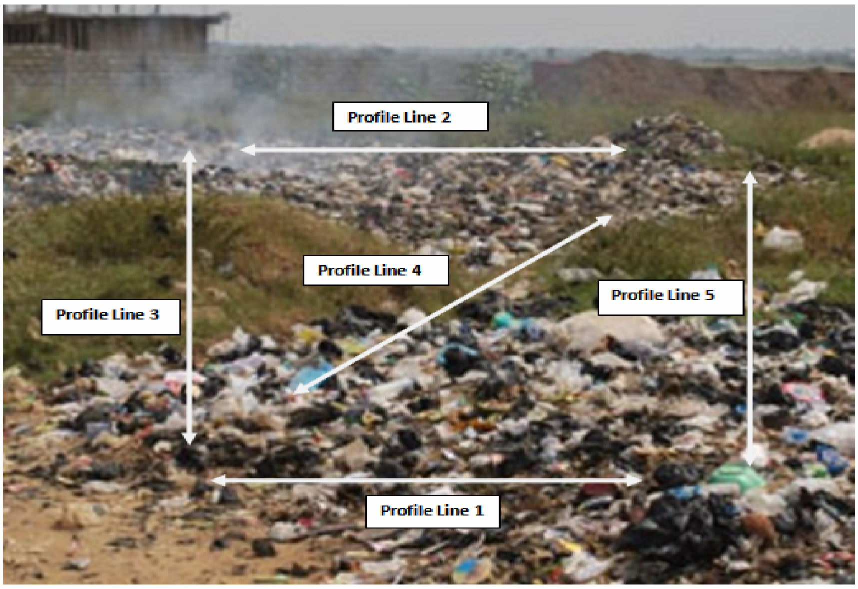
Kuje Area Council is dominated by farmers who specialize in agriculture and livestock breeding based on the information gathered within the community. However, the economic activities of the people are basically fresh meats and other farm products. Thus, solid, liquid and gaseous wastes are dumped or discharged into the dumpsite which could affect soil and groundwater. The sighting of borehole as the only source of good water in this area has become a serious challenge. This challenge is worsened by the fact that there are inadequately trained waste disposal personnel and equipment, poor waste collection, sorting and disposal without regards to the local geology and hydrogeology of the study area, as a result of the imminent impact of solid waste on the environment, it is necessary to investigate the potential for the contamination of groundwater around the dumpsites.The aim of this study is to investigate leachate migration from dumpsite and its effect on surrounding groundwater in the study area to determinedepth and thickness of thegeo-electric layers, to detectandmapcontaminatedzones, todeterminethelevelandextentofcontaminationtothe aquiferbyleachatefrom the dumpsites and to compare the difference in the quality of sampled water with WHO and NSDWQ water quality standards.

II. MATERIALS

The materials used for the research include Tarrameter (SAS 300), Global Positioning System (GPS), and Measuring tape, Hammers, Connecting Cables, Electrodes, Extra-large Umbrella., RES2DINV and IPI2win Software

III. METHOD

The vertical electric sounding (VES) method of electrical resistivity was employed using the Schlumberger electrode configuration. The current electrode spacing AB/2 varied from 1.5 to 150 m was used with the aim of probing a depth of at least 1/3 of AB. Tarrameter (SAS 300) was used in the data acquisition. In this configuration, the electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes were displaced outwards while the potential electrodes in general, were left at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outward otherwise the potential difference becomes too small to be measured with sufficient accuracy. The current electrodes been shifted to new position for most readings while potential electrodes are kept constant for up to three or four readings, during the field work, taking a sounding, the Tarrameter(SAS 300) performs automatic recording of both voltage and current, stacks the results, computes the resistance in real time and digitally displays it. Other instruments used includes; metal electrodes, measuring tape, hammer (used in hammering the electrodes into the ground), and connecting cables. The field data obtained was subjected to analysis and interpretation by computer iterations using RES2DINV and IPI2win software. Thevaluesobtainedwerefirstmanually plottedagainsttheir respectivecurrent-electrode spacingvalues()onalog-loggraph,partiallycurve-matchedandthen electronically iterated using RES2DINV and IPI2win computeriterationprogram to obtain thegeo-electric layers which showvertical variationin resistivityvalues withdepth.



Study Area showing the Profile lines.

IV.

V. RESULTS

The measurement of resistance and their corresponding apparent resistivity value for VES 1, VES 10, and VES 20 at the Dumpsite and VES 30 at the control site are presented in figure 1, 2, 3, 4, and 5 respectively.

Interpretation of VES data for dumpsite

The apparent resistivity values obtained from the field measurements were plotted against half current electrode spacing on a log-log graph sheet. The resulting data were iterated to the lowest

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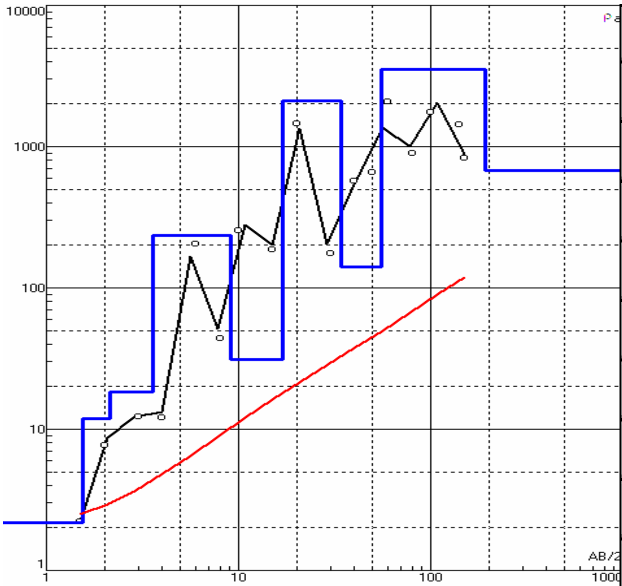
root mean square (RMS) percentage error with the aid of the IPI2Win software (which uses raw data sounding interpretation method). An important step in the interpretation of resistive sounds survey data is to classify the apparent resistivity curves into types. In this research, the curves from the sites were predominantly type –H. This classification is made on the basis of the curves which depends on the number layers in the subsurface and the thickness of each layer. The uses of IPI2Win software which produce graphical representation of data grant the basis of making qualitative statement and observation of the study area. Figure 1, 2, 3, 4, and 5 shows the graph of apparent resistive plot against half current electrode spacing for VES 1, VES 5, VES 10, VES 20, and VES 30 (Control) and the corresponding depth of each layer in the dumpsite.



N	ρ	h	d	Alt
12	2427	2.9	20.7	-20.69
13	2427	3.59	24.3	-24.27
14	162	20.1	44.3	-44.33
15	2972	8.96	53.3	-53.29
16	2972	13.4	66.7	-66.73
17	780	8.63	75.4	-75.36
18	780	12.9	88.3	-88.3
19	2749	98	186	-186.3
20	869			

Fig 1: Graph of apparent resistivity plotted against half current electrode spacing for VES 1 dumpsite.

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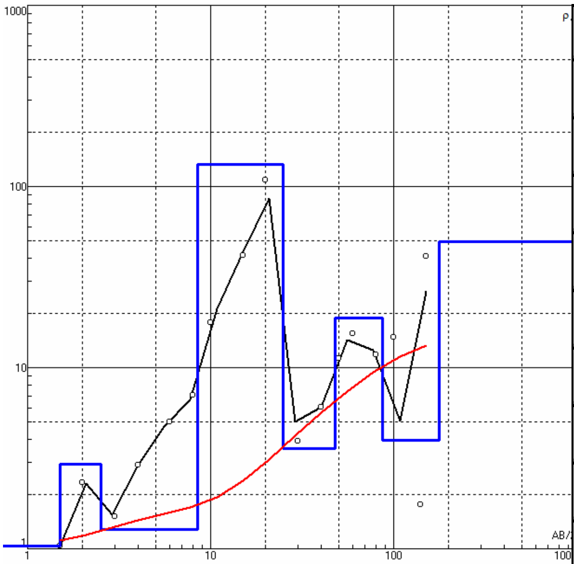
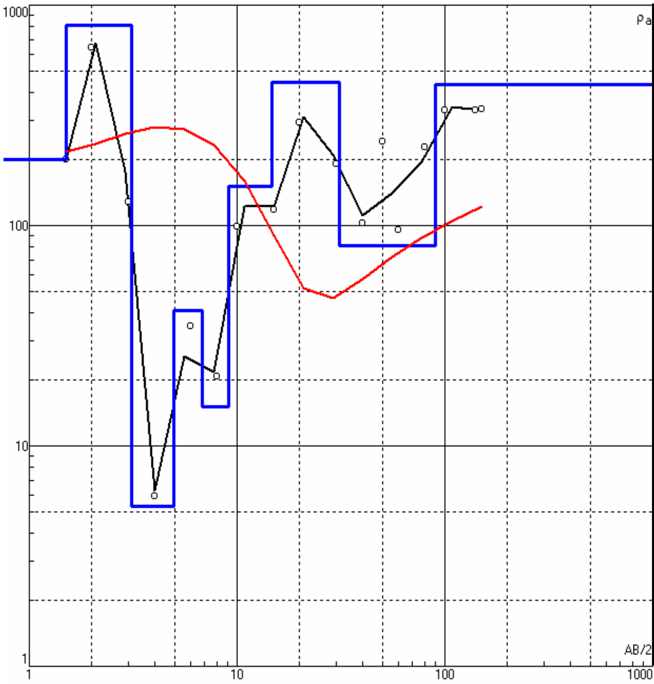


N	ρ	h	d	Alt
6	1.28	4.03	8.49	-8.491
7	132	5.89	14.4	-14.38
8	132	10.5	24.9	-24.89
9	3.58	9.2	34.1	-34.09
10	3.58	13.8	47.9	-47.89
11	18.8	39	86.9	-86.92
12	3.97	90.4	177	-177.3
13	49.6			

Fig 2: Graph of apparent resistivity plotted against half current electrode spacing for VES 5 dumpsite.



N	ρ	h	d	Alt
6	41.1	1.84	6.8	-6.8
7	15.1	1.01	7.81	-7.809
8	15.1	0.435	8.24	-8.244
9	15.1	0.863	9.11	-9.107
10	151	5.6	14.7	-14.71
11	446	11.1	25.8	-25.77
12	81	64.2	90	-90.02
13	436			

Fig 3: Graph of apparent resistivity plotted against half current electrode spacing for VES 10 dumpsite.

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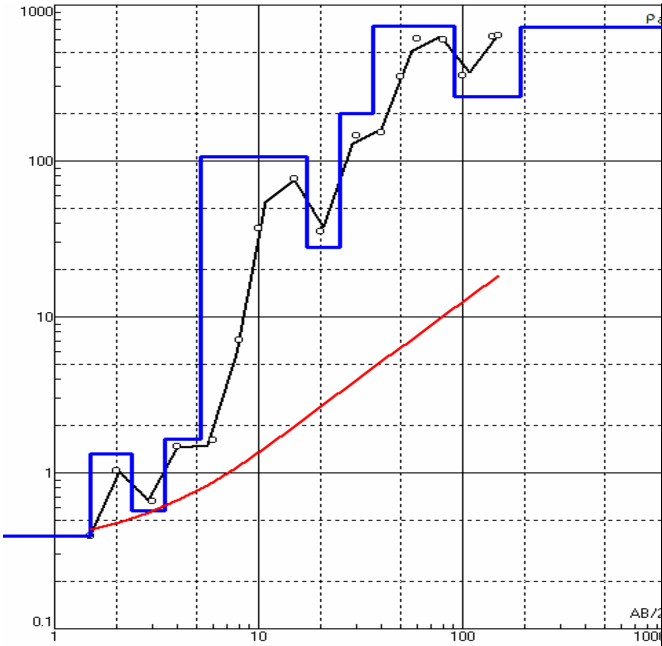
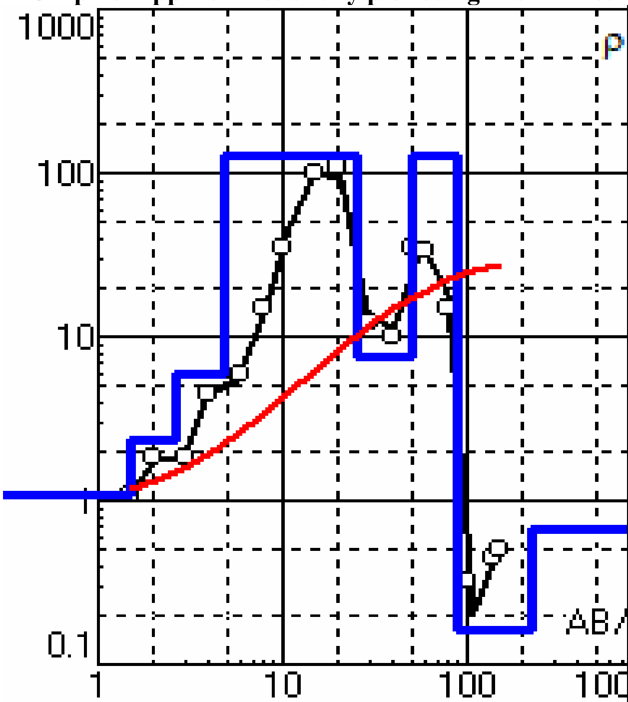


N	ρ	h	d	Alt
4	0.571	0.649	3.47	-3.472
5	1.65	1.73	5.2	-5.203
6	106	12	17.2	-17.24
7	27.9	3.12	20.4	-20.36
8	27.9	4.68	25	-25.04
9	201	11.3	36.4	-36.38
10	733	54.7	91.1	-91.09
11	258	101	192	-192.2
12	721			

Fig 4: Graph of apparent resistivity plotted against half current electrode spacing for VES20 dumpsite.



N	ρ	h	d	Alt
1	1.08	1.5	1.5	-1.5
2	2.34	1.14	2.64	-2.637
3	5.89	2.25	4.89	-4.889
4	126	20.5	25.4	-25.43
5	7.56	25	50.4	-50.43
6	126	37.9	88.3	-88.3
7	0.165	132	221	-220.7
8	0.667			

Fig 5: Graph of apparent resistivity plotted against half current electrode spacing for VES 30 dumpsite.

Result of the 2-D Inversion for Profile line 1

Figure6showstheresistivity inversionresults(iteration3,5.25%totalaverage RMSerror)for profile1.Thus, indicatingthat, there is goodfitbetweenthemeasuredand calculatedapparentresistivity datawasachieved.TheApparentresistivity (Ωm)isplottedagainst pseudo-depth(m). The Profileis located attheSouthernend inside the dumpsiteand itis150mlong,andrunsin theWesttoEastdirection.Lowresistivity zones(<7Ωm)wereisolatednearthe surfacewithdepthbetween 10.5m to15.4mwhichindicatescontaminationofthe topsoil.Inthisprofilethedepthtothebedrockisshallow, about26m andextends from x=26m to140m alongtheprofile.Colourvariationsinthebasementrock are indication ofcontactsbetweendifferent rockswhichcanbeinterpretedas fractures.TheOrangecolourindicatetheweathered basementwithresistivity value (<34Ωm).

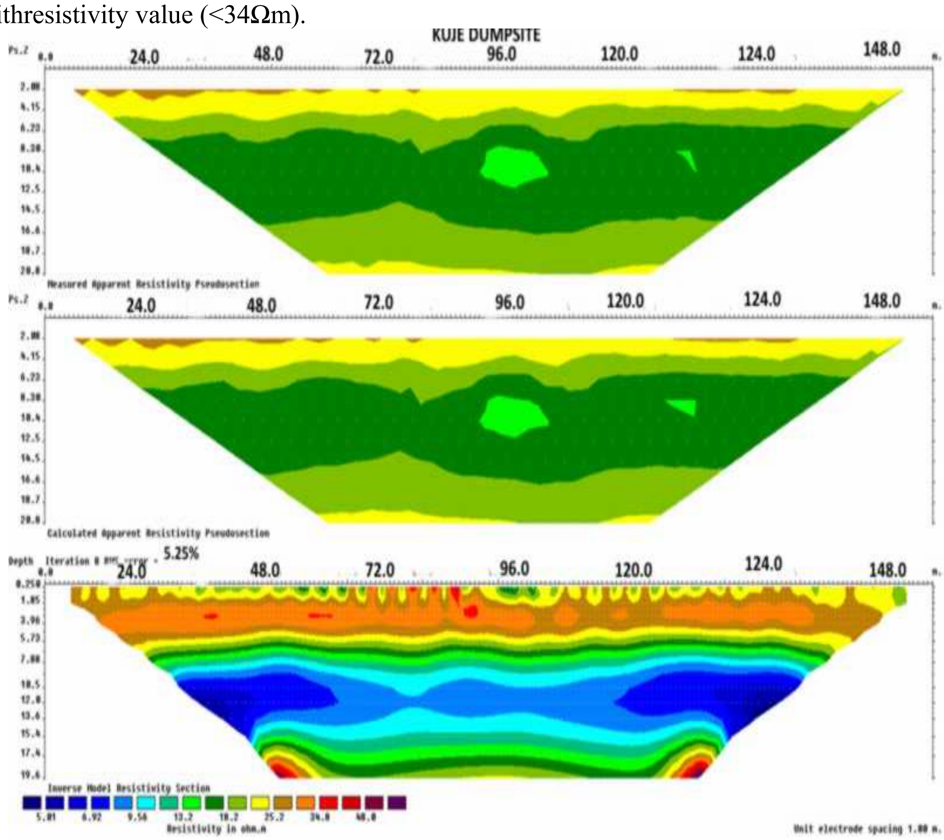


Figure6:Result of2D inversionoftheSchlumberger-arraydataalong profile line1

Result of the 2-D Inversion for Profile line 2

Figure7showstheresistivity inversionresults(iteration3,1.72%totalaverage RMSerror)forprofilel i n e 2.Thus,indicatingthat,goodfitbetweenthemeasured andcalculatedapparentresistivitydatawereachieved. TheApparentresistivity (Ωm)is plottedagainst pseudo-depth(m). ThisProfile is located a t a b o u t 100mawayfromprofile1insidethedumpsite.ThisProf ile runsintheWest-Southdirectionanditis150m long. Thematerialsinthisprofile areveryresistiveasshownbytheirresistivityvalues.Th elowresistivity(<27Ωm)zone,indicatesthepresenceo fleachatesfromthesurfacetoadepthof 8m, which could be interpretedastopsoilcontamination. The depthtothe bedrockisalsoshallow, whichisabout 74m. The redandorangecolour isthe fresh basementas shownwithresistivityvalues(>65Ωm).

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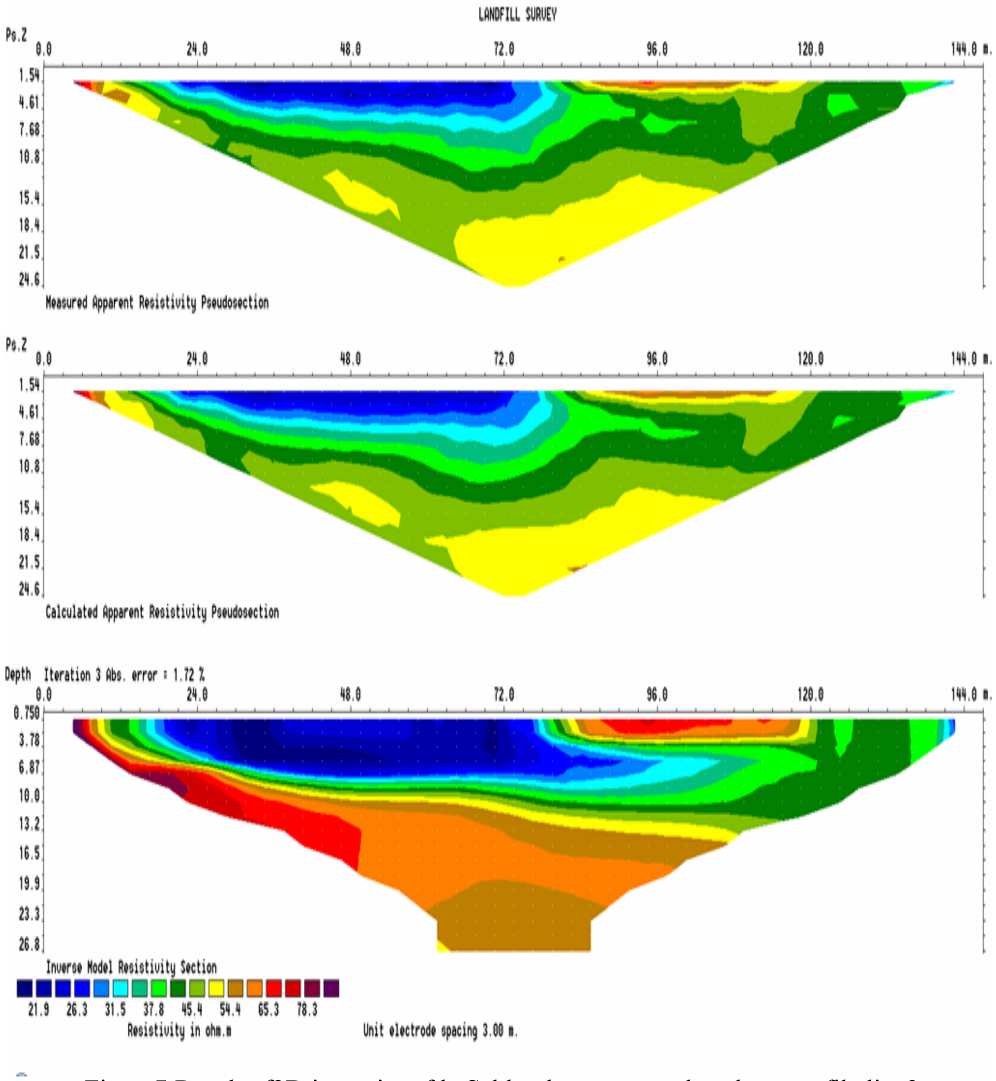

Figure7:Result of2D inversionoftheSchlumberger-arraydataalong profile line2

Result of the 2-D Inversion for Profile line 3

Figure8showstheresistivity inversionresults(iteration7,5.1%totalaverage RMSerror)forprofile line3.Thus,indicatingthat,goodfitbetweenthemeasured andcalculatedapparentresistivitydatawereachieved. ThisProfileislocatedat theWestern endof the dumpsiteand runsin the North-South direction oflength 150m. Materials here, are lessresistiveas shownbythe resistivityvalues(< 25Ωm)ofblueandpurplecolour.Thelowresistivityend (<25Ωm)could beattributedtocontamination ofthe groundwaterasaresultof invasionoftheleachatefrom x=50m to75m at1.84mdepth and x= 124.0m at 2.38m depth.Themigrationofthe leachatecould be asaresultoffractures(contacts betweenrocks of different materials) orunconsolidatedmaterials(sandorgravel).

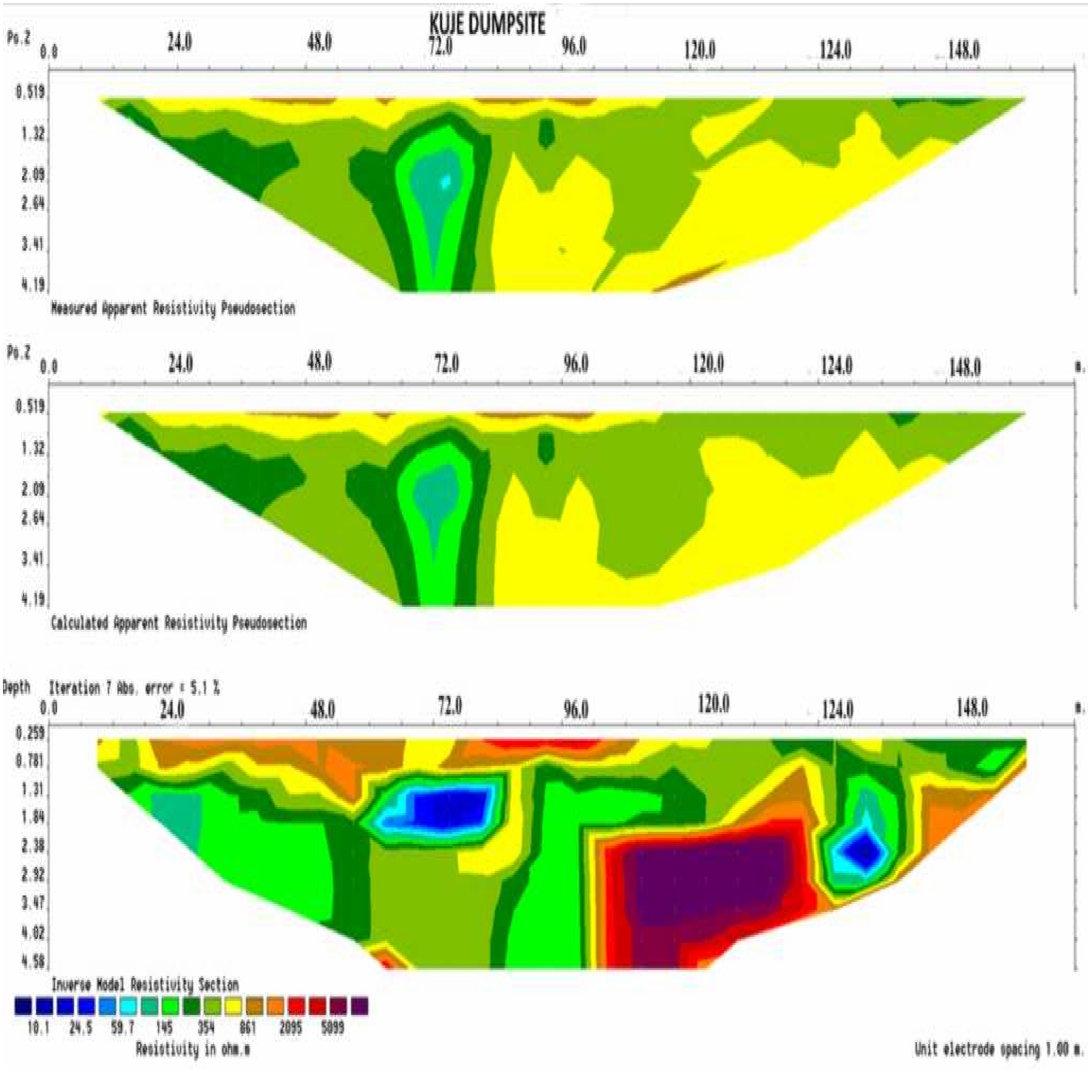

Figure8:Result of2D inversionoftheSchlumberger-arraydataalong profileline 3

Result of the 2-D Inversion for Profile line 4

Figure9showstheresistivity inversionresults(iteration3,6%totalaverage RMSerror)forprofile line 4.Thus,indicatingthat,goodfitbetweenthemeasured andcalculatedapparentresistivitydatawereachieved. Changingfrom deepbluetolight bluealso reflectsthechangesintheconcentrationofthe leachatesasitseepsdown dueto filtrationbythesediments from x= 72m to 148m and at a depth of 24.9m. ThisProfile islocated in the middle ofthe dumpsite.Lowresistivity zones(< 6.98Ωm)areevident in thisprofile, indicating contamination of the topsoil and undergroundwater.Thelighttodeepbluecolouralongthe profileindicates varyingdegreeofconcentrationoftheleachate.Thisprofiledisplaysmaterials thatareunconsolidated(sand, gravelandfracturedrocks).Thereismigrationof theleachatewhichisbelievedtobedueto fracturesorunconsolidatedsubsurface material.

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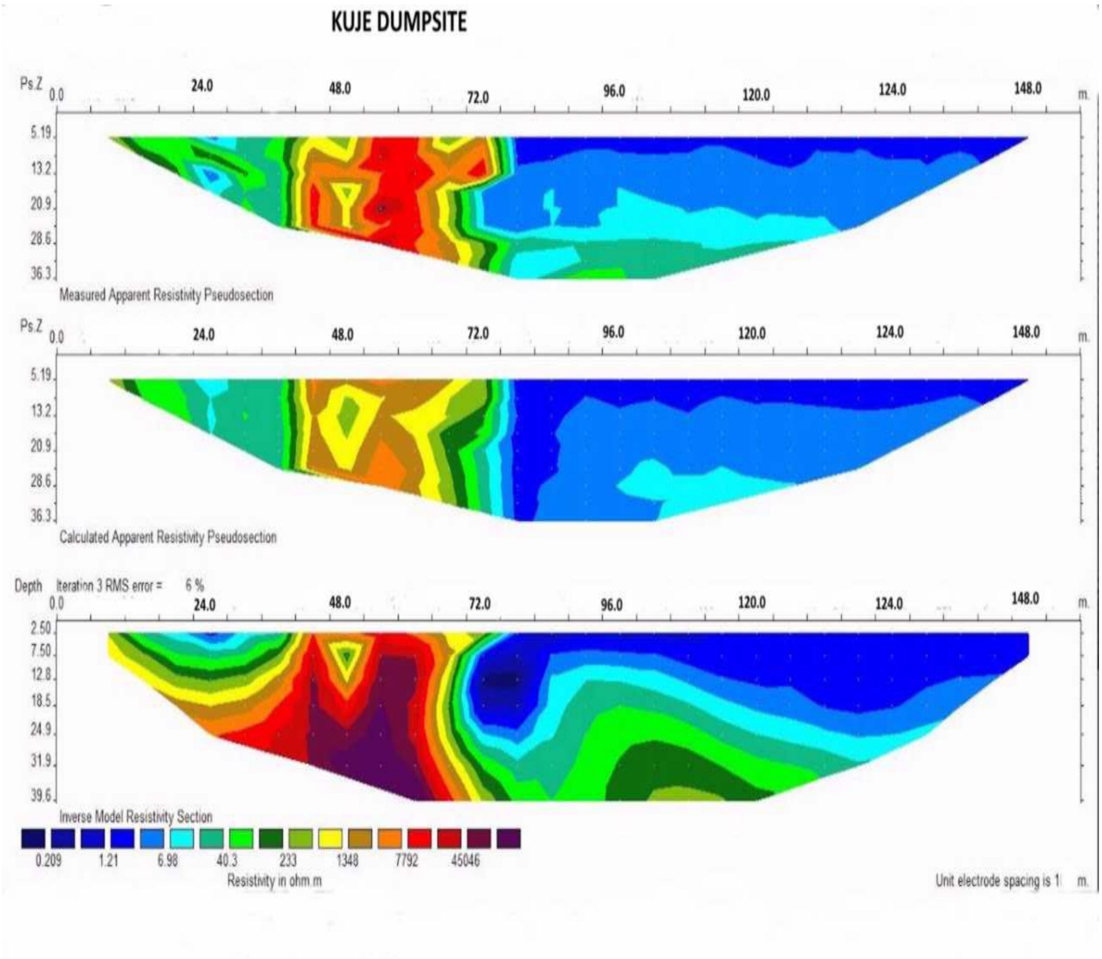

Figure9:Result of2D inversionoftheSchlumberger-arraydataalong profile line 4

Result of the 2-D Inversion for Profile line5

Figure10showstheresistivity inversionresults(iteration3,5.1%totalaverage RMSerror)forprofilel i n e 5.Thus,indicatingthat,goodfitbetweenthemeasured andcalculatedapparentresistivity datawereachieved. ThisProfileislocatedat 100m outsidethe dumpsite andruns in the North-Southdirection.ThisProfileis100m longandisperpendiculartoProfiles1 and 2.Thereis evidence of contamination of the topsoil as shown by low resistivity value (<21.7Ωm)whichoccurbetweenx=50m tox=64mandfrom the groundsurfaceto adepthof 2m.Thereisprobably the presence ofClay whichisimpedingthe downwardmovementoftheleachates.This profileshowsapartially weatheredbasementasindicatedby thelowresistivity value (<84.2Ωm).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 10 Oct. 2024, pp: 610-626 www.ijaem.net ISSN: 2395-5252

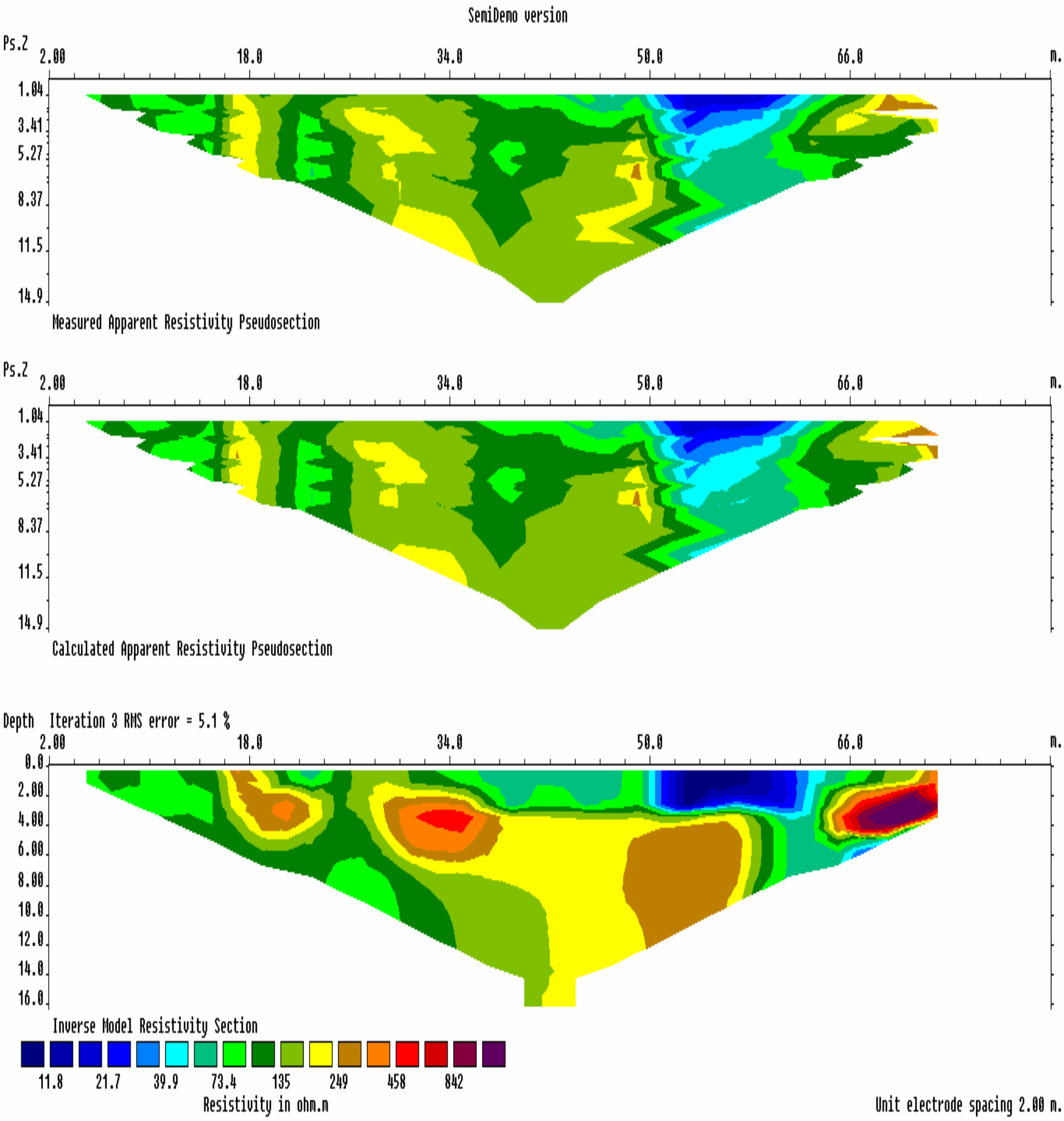

Figure4.10:Result of2D inversionoftheSchlumberger-arraydataalong profile

5Physiochemical Analysis of Water Samples

Physiochemical analysis were carried out at Sheda Science and Technology Complex (SHETSCO) on water samples obtained from the well (SAMPLE A) and borehole (SAMPLEB)on and around the dumpsite for some selected parameters in order to ascertain the extent of contamination as presented in Table 2

Table 2 shows the physicochemical analysis result of the two major source of water in the study area which are hand dug well and bore hole. It shows the concentration of major ions present in the water samples and their percentage compliance with World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ).

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Volume 6, Issue 10 Oct. 2024, pp: 610-626 www.ijaem.net ISSN: 2395-5252

PHYSIOCHEMICAL ANALYSIS OF WATER SAMPLES

S/N	PARAMETERS	STANDARD WHO/NSDWQ	SAMPLE A	SAMPLE B
1	PH	7.0 – 8.0	6.90	6.89
2	TDS (mg/l)	500	1054	353.1
3	CONDUCTIVITY (µS/cm)	1000	2152	720.2
4	Fe^{2+} (mg/l)	0.03	0.3253	0.1387
5	Zn^{2+} (mg/l)	5	0.1352	0.0874
6	Mg^{2+} (mg/l)	0.2	0.36	0.28
7	Cu^{2+} (mg/l)	0.05	1.7	1.65
8	HARDNESS	100	771.68	1002.4

The PH value for both water samples lie within the permissible limit. The total dissolved solids (TDS) concentrations for hand dug well is 1054mg/l and 353.1mg/l for borehole. Hand dug water sample lies above the 500mg/l specified by WHO and NSDWQ while bore hole lies below the limit. Conductivity values of hand dug well is 2152µS/cm while borehole is 720.2µS/cm contrary to the standard limit of WHO and NSDWQ (1000µS/cm).

The result for total hardness for the hand dug well was given as 771.68 while that of bore hole was given as 1002.4. based on Sawyer and McCarthy (1967) classification for total hardness, 10% falls under ‘moderate’ class, 60% fall under ‘hard” class while 30% fall under ‘very hard’. For the two samples. Total hardness values were higher.

The two water samples were also tested for heavy metal such as iron, zinc, magnesium and copper. The result of the two water samples does not agree with WHO standard limit except for the value of iron in hand dug well water and that of magnesium in bore hole which approximately agreed with the standard limit of WHO.The presence of high amount of those elements in the water samples are caused by the deposit of materials like metals irons etc on the dumpsite. Iron rusts and other materials decompose when come in contact with water when it rains. of theleachatewhichisbelievedtobedueto fracturesorunconsolidatedsubsurface material.In conclusion, the effectsof leachateongroundwater repositorieswereassessedusingvertical electricalsounding(VES). Theresults ofgeoelectricalsurvey revealedthatthestudyareaismadeupofthreetofour geoelectriclayersandthefourthlayerharbouringmostoftheaquiferouszoneswhichisdelineated asbeingmoreconductiveandlessresistivethantheover lying layersasaresultofseepageof leachate loadedcontaminantsintothe layers. The results of the Physiochemical analysis revealed that almost all the analyzed parameters are not within the permissible limit ofdrinkingwater quality based on World Health Organization (WHO) standard and Nigeria Standard for Drinking Water Quality (NSDWQ)asshowninTable 4.2.

Itcouldalsobeinferred thatgroundwaterquality improveswithincreaseindepthanddistancefromthedumpsite.Theresultfromthisstudyhasthrownmorelighttotheunderstandingoftheimpactofleachate onaquiferrepositoriesaroundthis dumpsite. Ithereforesuggestthatsoilanalysisshouldbecarriedout toassesstheeffectof leachate onsoil. Deeperdrillingandconstantmonitoring ofboreholesisalsorecommended.The Governmentshouldalsoconsiderthecontrolofleachate generation,itstreatmentandsubsequent recycling ofwastes.Thisisnecessary,sincemostaquifersinthestudyareaareassociatedwith leachate contamination.The continuous percolation ofleachateinto the subsurfaceconstitute health hazardandcautionshouldbe takentopreventspreadofwaterborne diseases.Technical data and details on the state of the study area's subsurface have been made available by this research. These include the depth to groundwater and aquifer system, lithology, corrosivity of the topsoil, and the level of contamination at the dumpsite. It also showed the effects of a number of toxins coming from the dumpsites on the groundwater there as well as in the neighborhood.

We wish to express our deepest gratitude to the University of Abuja, and in particular, the Department of Physics, for their unwavering support and guidance throughout this project. Also like to extend our sincere appreciation to SHESTCO (Sheda Science and Technology Complex), where all laboratory tests were carried out. The exceptional facilities and support from the staff played a vital role in the success of this research.

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