

Full Length Research Paper

Geoelectrical investigation and hydrochemical analysis of groundwater in a waste dump environment, Isolo, Lagos

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Geoelectrical and hydrochemical analysis of groundwater in a waste dump environment was carried out to investigate the effect of the infiltrations of leachates and other sources of pollution from waste dump on groundwater. This was done by engaging the vertical electrical sounding method and laboratory water sample analysis. An Abem SAS 3000 terrameter was used to acquire the geophysical data from the vicinity of a major dumpsite called Oke Afa refuse dumpsite at Isolo, Lagos. The WINRESIST (version1.0) software was adopted in the interpretation of the survey data. Groundwater samples from boreholes were collected from the vicinity of the dumpsite with the aim of assessing the physiochemical impacts of the waste dumps on the quality of groundwater. Levels of various physiochemical parameters investigated include total dissolved solids (TDS), alkalinity, pH, electrical conductivity (EC), and hardness using standard analytical methods. Traces of metals like Fe, Cu, Zn, Mg and Na were equally determined using flame atomic absorption spectrophotometer (Unicam model 911). Many of the parameters determined following the specification of the World Health Organisation (WHO), groundwater samples in the area were found to be inadmissible for human consumption. This raises the question of toxicities of these elements, hence it is a threat to man. This shows that the groundwater is polluted because of the high conductivity of the water samples. This was confirmed by the water analysis from the study area in the laboratory.

Key words: Geoelectrical investigation, hydrochemical analysis, major dumpsite, groundwater.

INTRODUCTION

The deterioration of water quality in a waste dumps environment due to the infiltration of leachates and other sources of groundwater pollution into fresh water aquifer is a major concern. With the aim of providing information on the hydrogeologic system of the aquifers, the subsurface lithology, and delineating the groundwater bearing strata, vertical electrical sounding (VES) was carried out, engaging the Schlumberger electrode array configuration. This study also carried out the hydrochemical analysis of the water sample from boreholes in the vicinity of Oke Alfa waste dumpsite at Isolo, Lagos, Nigeria.

Nigeria covers an area of about two hundred thousand (200,000) square kilometers (Roa and Roa, 1987). The average annual rainfall is about 1,200 mm. This amount recharges a sedimentary formation which yields about 30,000 L/h of water (Guter, 1981). Nigeria is enclosed with an abundant surface and groundwater resources, but the later is about 10 times the former (Moore, 1991). The federal government of Nigeria, the various state government and non-governmental agencies are actively involved in water resources development and utilization.

Groundwater is of major importance to civilization since it is the largest reserve of potable water in regions where humans live. The health and well being of the population depends on abundance and adequate supply of these natural resources. Water forms an indispensable resource in economic activities like commerce, tourism and

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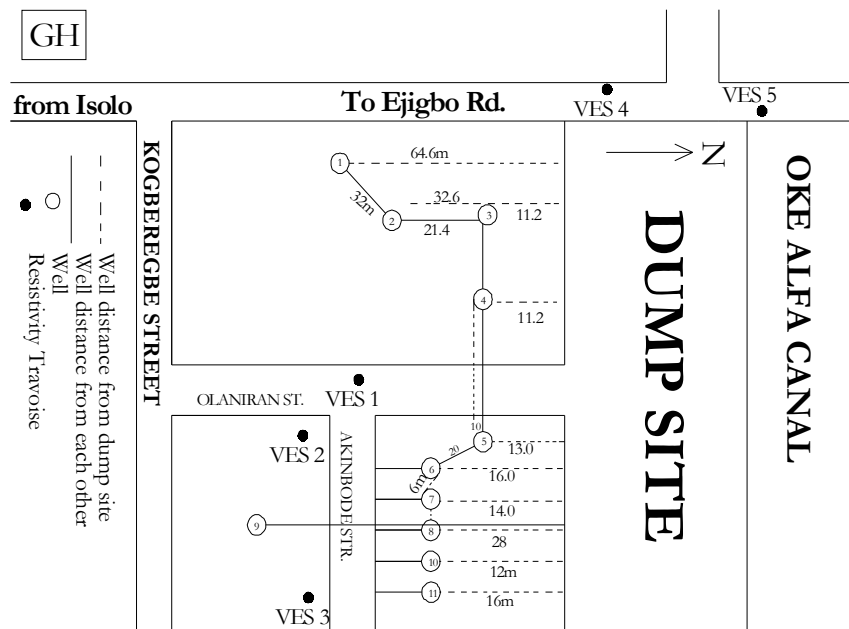


Figure 1. Field acquisition map.

industry, and also for uses in domestic activities and agriculture. The result of some studies in Nigeria showed that water resources in many parts of the country especially the southern part are more than adequate to meet any demand and only need development. A complete appraisal of available water resources is often best accomplished when aspects of water quality are included. This is because in a planned water quality supply system, quality constraints and requirements dictate the source of water allocated to various stages (Egereonu and Ibe, 2003).

Groundwater is less contaminated than surface water. Pollution of this major water supply has become an increasing concern in industrialized and industrializing nations due to contamination by toxic substances (Guter, 1981, Adeoti et al., 2010). Waste metal dumps and other waste materials which are either surface or buried are known to produce leachates that penetrate the aquifer and contaminate the groundwater (Becker, 2001). However, some geological factor accentuates considerably the penetration of these metallic contaminants (Speeding, 1997; Egereonu, 2004). The quality of any groundwater is primarily dependant on the elemental availability of metals in the soil and rocks through which it penetrates.

In general, it is difficult to correct groundwater pollution, depending on the level and type of groundwater pollutants. Some of the pollutants can be removed or reduced by natural processes. As groundwater flows through the zone of aeration, some contaminants are removed or reduced by natural means such as certain heavy metals may be taken up by plants, bacteria can

degrade or change a variety of organic compounds, other pollution reduction mechanisms include absorption (chemical and physical bonding to soil particles), filtration and chemical reactions. Some pollutants such as phosphates may be removed before they reach groundwater, others such as synthetic organic solvents are resistant to breakdown. The soil's ability to attenuate (reduce) pollution depends partly on its characteristics and partly on the volume and type of contaminants involved. Very small quantities may never reach groundwater, very large quantities may reach groundwater without any reduction and some pollutants resist degradation (Egereonu, 2004; Alile et al., 2009).

Geology of the study area

Isolo town lies between latitude $60^{\circ} 32'N$ and $60^{\circ} 33'N$ with longitude $30^{\circ} 20'E$. It houses about three and half-decades old Oke-Afa dump site, which was recently closed down for commercial dumping due to expiration of age (30 years). The dump site is still been managed by Lagos State waste management authority (LAWMA) in Nigeria. It is bounded by Oke -Afa Canal (Figure 1).

The geology of Nigeria shows the various units of the geological succession range in age from the Precambrian to Quaternary. The Precambrian are partly overlain by cretaceous sediments, which are approximately 120 million years old. More recent sediments overlie the cretaceous sediments in some areas, but lie directly on the Precambrian in others (Kogbe, 1974).

During the transgressive phase which followed closely to the cretaceous a thick sequence of tertiary sandstones



Figure 2. A section of the dumpsite of the study area.

was deposited in a belt. These sediments belong to the Paleocene and Eocene and are represented by the Ewekoro formation. (Kogbe, 1974). These are overlain by a thick succession of sands and clays which contain lignite. In addition, the first major marine transgression occurred during the maestrichtian when sediments constituting the Abeokuta formation were deposited. The formation consists mainly of ill-sorted ferruginous grit, siltstone with shale-clay layers (Kogbe, 1974). The sediments are partly marine, partly brackish water and partly freshwater in origin. The formation thickens westwards and continues to Dahomey. The subsurface geology is made up of Benin formation (Miocene to recent) and the recent littoral alluvial deposit.

Hydrology

The water bearing strata consists of shale, sand, gravel or a mixture of the two textural variations from fine through medium to coarse sand and gravels. They occur as poorly to well sorted. The unconsolidated nature of the soils greatly aid infiltration. Water percolation is generally high but flooding is totally absent probably owing to the soil's physical property and the general topography. The presence of aquifers is generally responsible for water recharge in the area, where it approximates a pinch of the water table as a result of the North-South facie changes (Kogbe, 1974). Water flow occurs within the upper part of the saturated zone, where all the openings are filled with water. The water table is an unconfined aquifer which rises in wet seasons and falls in dry seasons as water drains out of the saturated zone into the river.

Landfills have been identified as one of the major threats to groundwater. In these refuse dumpsites solids

wastes gradually releases its initial interstitial water and some of its decomposition by-products enter the aquifer, through the waste deposit. These wastes generate pollutants which are toxic to the human health. Therefore knowing the quality status of groundwater is important. This helps in determining the suitability of water for various purposes (Subramani et al., 2005).

Waste dump

The pollution of groundwater is a case of major concern mainly because of the health implications on humans. Wastes dumped undergo some bacteria and chemical actions along with the effect of sunlight and rainfall. They are known to have found their way into the groundwater aquifer, and if not checked may result into extensive contamination of the groundwater. Most industrial effluents contain non-biodegradable toxic and hazardous wastes. These wastes pose high health risk on sea creatures on which most rural populations especially those in the riverine areas depend on for their livelihood. These problem call for scientific investigation in order to improve the quality of both the surface water and groundwater in the study area to meet the rapid needs of ever-growing populations, urban development, as well as agricultural irrigation (Meju, 2000; Egereonu, 2007) (Figure 2).

Surface and groundwater can be contaminated because groundwater movement is usually slow. Hence polluted water may go undetected for a long time. Most contamination is discovered only after drinking water has been affected and people become ill. By this time, the volume of polluted water may be very large, and even if the source of contamination is removed, the problem is not solved. It is worthy of note that once the source of

groundwater contamination has been identified and eliminated, the most common practice is simply to abandon the water supply and allow the pollutants to be flushed away gradually. This is the least costly and easiest solution but the aquifer must remain unused for many years. To accelerate this process, polluted water is sometimes pumped out and treated. Following removal of the contaminated water, the aquifer is allowed to recharge naturally or, in some cases, the treated water or other fresh water is pumped back. This process is costly, time-consuming, and it may be risky because there is no way to be certain that all of the contamination has been removed. Clearly, the most effective solution to groundwater contamination is prevention (Lutgens and Tarbuck, 1998).

METHODOLOGY

The equipments used to carry out this survey include a Abem terrameter SAS 3000, four steel electrodes (two electrodes used as the potential electrodes and the other two electrodes for the current electrodes), four cable reels (two cable reels used for the potential and the other two cable reels for the current) with metal clips attached to the wires, measuring tapes, power source (battery) and hammers. A global positioning system (GPS) was used to take the coordinates as well as the elevation of the area being surveyed, and this as necessary so that the exact position of each Ves point could be located in the future when the need arises.

Electrodes were driven into the ground using the hammers, and were connected to the terrameter using connecting cables and metal clips. The electrodes are expanded, the electrode spacing increasing the distance between the current electrodes or that between the potential electrodes, but only at a time, during the course of measurement (Alile et al., 2008; Zhdanov and Keller, 1994). The potential electrodes are assumed to be an infinitesimal distance apart.

For every measurement taken, the terrameter took three readings since a cycle of three was used and the last reading was recorded and this was indicated by a beep. A voltage of 12.6 V was supplied to the terrameter during the survey. The terrameter provides the resistance, voltage and current which are indicated by R, V, I respectively. When the values, that is, the resistance, current and voltage are given the resistivity is calculated by multiplying the resistance by the geometric factor (K), that is, $(R \times K)$, K can be calculated by;

$$K = \frac{\left[\left(\frac{AB}{2} \right)^2 - \left(\frac{MN}{2} \right)^2 \right] \times 3.142}{\left(\frac{MN}{2} \right) \times 2}$$

$$= \frac{L^2}{2a}$$

Where, AB is the distance of the current and MN is the distance of the potential.

Ten (10) Water samples were collected from boreholes near Oke-Afa dumpsites in Isolo and stored in 5 liters plastic containers.

The plastic containers were thoroughly washed with detergent

and rinsed thoroughly with distilled water and finally with deionised water and labelled. For the metallic ion determination, 100 cm³ of each water sample was pre-concentrated by heating in a vacuum until the sample was reduced to 25 cm³. This was acidified with few drops of 2M HNO₃ for stability of the ions and then preserved in plastic bottles for atomic absorption. The metallic ions in the samples were determined using the atomic absorption spectrophotometer, Unicam model 911. Stock solutions from which working standards were prepared and standard calibration graphs for the elements were prepared following procedures and standard methods for examination of water and wastewater (Franson, 1975).

pH and electrical conductivity

A Philip analog pH meter was used to monitor the pH of all water samples, while the electrical conduction was determined using the Wissen schaftlich-Technische conductivity meter of the werkstätten-D8120 Weitehm model. Both pH and electrical conductivity were determined at the site of collection of water samples.

Temperature

This was determined at the site of collection of the water samples using the mercury-in-glass thermometer.

Total dissolved solids

This was done by the evaporation method. Evaporating dish was weighed and later 100 cm³ of the water sample was introduced into the weighed dish and dried in an oven operated at 103°C for proper drying for 1 h. After drying it was transferred to a desiccators and left to cool. The dish was finally weighed with its content. The difference in weight gives the weight of the total dissolved solids of the sample.

Alkalinity and chloride determination

Alkalinity was determined by the titrimetric method while the chloride was determined by the titrimetric method using silver nitrate as the titrant.

Nitrate, phosphate and sulphate

Nitrate determination was done using the Hach Corporation Nitrover 5 method which was adapted from the cadmium reduction method using powder pillows (IITA, 1970). Phosphate determination was done by Hach Corporation phosphate 3 phosphate methods. Sulphate determination was done using the Hach Corporation sulfaver 4 methods adapted from standard methods for the examination of water wastewater.

DATA INTERPRETATION AND RESULTS

The acquired apparent resistivity data set which include the water table depth were presented in the form of tables. A geophysical software known as WINRESIST version 1.0 (1988, 2004) have been used for that purpose. The result from the graph drawn by the software shows the thickness, depth and resistivity. In the graph,

Table 1. Ves 1.

Current electrode separation (m)	Potential electrode separation (m)	Geometric factor (K)	Apparent resistivity (ρ_a)
AB/2	MN/2	$K = L^2/2a$	
1	0.25	6.28	84.34
2	0.25	25.12	64.31
3	0.25	56.54	66.15
4	0.25	100.54	68.37
6	0.50	226.2	56.55
6	0.50	113.1	85.96
9	0.050	254.47	96.70
12	0.050	452.4	81.43
15	1.0	706.86	113.1
15	1.0	353.46	95.43
20	1.0	628.32	91.92
25	1.0	981.75	90.32
32	1.0	1608.5	123.85
40	1.0	2513.28	150.8
40	2.5	1005.31	231.22
50	2.5	1570.8	267.04

the apparent resistivity values (ohms) were plotted against current electrode spacing (AB/2) (m) by the software. An iteration process was then commenced until a good fit was obtained; there is always a root mean square error value and usually a root mean square error value of below 5% is considered satisfactory (Loke and Barker, 1996; Oldenburg, 1978).

Interpretation of geoelectric section

From the ves, four to five layers were delineated in all the locations. The first topsoil layer, in all the locations maintained a resistivity range of 11-20 Ω m which indicated a layer composed of clay, sandy clay and sand (Figure 8).

Ves 1

The pollution level in this area is not pronounced in the third layer, this area has a relatively high resistivity. Clean water is likely to be obtained at the depth of 15 m and above, the lower layer has a resistivity of 878 Ω m which indicate a clean horizon compose sandy clay which act a seal to the per collation of leachate to the subsurface (Table 1).

Ves 2

This zone is a polluted zone with a resistivity of 11 Ω m in the first layer; 33 Ω m in the second layer which is 2.7 m

deep and 16.8 Ω m in the third at a depth of 16.5 m sinking any borehole in this area would definitely encounter polluted water (Table 2).

Ves 3

This has five layers unlike the others. Here, the third layer is polluted and is almost impossible to obtain potable water in this area when compared with hydro- chemical results. Resistivity is seen to be reducing with depth here with an abrupt increase in the fifth layer. The fifth layer is not polluted this is because the resistivity of this layer is quite high, portable water would most likely be found here, However wells dug at depths between 4 to 5 m would be polluted (Table 3).

Ves 4

There is high level of pollution up to the third layer as indicated by the low resistivity 1.3 Ω m and depth 5.0 m. The fourth layer is a clean zone not polluted as indicated by the resistivity. To obtain good quality fresh water in this area, deep borehole will be required (Table 4).

Ves 5

There is high level of pollution up to the third layer as well indicated by the low resistivity 1.4 Ω m and depth 6.7 m. The fourth layer is a clean zone not polluted as indicated by the resistivity. To obtain good quality fresh water in

Table 2. Ves 2.

Electrode separation (m)	Potential electrode separation (m)	Geometric factor (K)	Apparent resistivity (ρ_a)
AB/2	MN/2	$K = L^2/2a$	
1	0.25	6.28	18.59
2	0.25	25.12	27.38
3	0.25	56.54	30.53
4	0.25	100.54	23.12
6	0.50	226.2	27.14
6	0.50	113.1	25.79
9	0.050	254.47	26.21
12	0.050	452.4	16.74
15	1.0	706.86	21.21
15	1.0	353.46	18.02
20	1.0	628.32	20.11
25	1.0	981.75	24.54
32	1.0	1608.5	33.78
40	1.0	2513.28	37.70
40	2.5	1005.31	30.16
50	2.5	1570.8	31.42
65	2.5	2654.65	31.85
80	2.5	4021.24	44.23

this area, deep borehole would also be required (Table 5).

Interpretation of hydrochemical results

A total of 10 water samples were taken in 5 L transparent bottles and sent for analysis. The closest borehole to the dumpsite was just 11.2 m (Bh3), 12.0 m (Bh10), and the next 12.2 m (Bh4), from the analyzed results all samples have a high level of contamination (Table 6). The traverse is about 65 m.

The geology of the area is sandy with clay intercalations. The water table is about 3M close to the surface which is quite surficial and explains why it is easily /grossly polluted. This thickness just represents the top soil, which is only loose and hence provides for easy seepage of leachate to the subsurface and the first aquifer. The only depth to clean water is at depths ≥ 16 m and at a distance of 60 to 65 m from the dumpsite. From the table above such locations are Bh1 and Bh9 respectively.

pH

The pH sample ranges between 5.5 to 6.8, which indicates acidity. With high content of carbon dioxide in all samples, carbonic acid is likely to be formed which results in the low pH of the water samples. Other parameters that have a direct effect on the pH include

total dissolved solids (TDS), Biochemical oxygen demand (BOD) and total suspended solids (TSS). These parameters help to determine the pollution level in water. From the hydrochemical results displayed in our table all these parameters do not meet recommended value which implies a high level of pollution.

Iron content

All the water samples except that from borehole 1 and 10 failed the recommended limit.

Calcium

All samples exhibit low level of calcium below the standard.

Magnesium

Low level of magnesium is due to the high acidity already prevalent, hence the precipitation of magnesium was observed.

Nitrate

The nitrate content of all samples fall within the WHO range. The presence could be due to the high microbial content observed.

Table 3. Ves 3.

Electrode separation (m)	Potential electrode separation (m)	Geometric factor (K)	Apparent resistivity (ρ_a)
AB/2	MN/2	$K = L^2/2a$	
1	0.25	6.28	150
2	0.25	25.12	70.1
3	0.25	56.54	43.54
4	0.25	100.54	30.16
6	0.50	226.2	38.45
6	0.50	113.1	26.35
9	0.050	254.47	19.34
12	0.050	452.4	9.5
15	1.0	706.86	12.70
15	1.0	353.46	16.26
20	1.0	628.32	19.48
25	1.0	981.75	16.69
32	1.0	1608.5	4.66
40	1.0	2513.28	0.05
40	2.5	1005.31	5.03
50	2.5	1570.8	15.71
65	2.5	2654.65	23.90
80	2.5	4021.24	32.17

Phosphate

All samples have high content of phosphate, hence fell below standards.

Sulphate

The sulphate content is well above the standards set by WHO.

Salinity

All the water samples except Bh1 maintained a high level of salinity, indicated by the presence of potassium, sodium and chlorine.

Bacteriological quality

All the well samples show high coliform count greater than 10 MPN except for borehole 1 with about 5 MPN. Three major organisms were isolated with solid media culture of the water samples and include *Klebsiella* sp found in well 5, *Clostrida* sp in well 4 and *Bacillus* sp found in well 3. These are normal soil flora found in contaminated food items. The domestic implication is that it could lead to skin infection, domestic cholera and dysentery.

DISCUSSION OF RESULTS

Figures 3 to 7 showed the plot of apparent resistivity against current electrode spacing. The cross sections showed the plot of the data obtained on the field, while the smooth curve showed the iterated data. The iteration gotten gives the true resistivity from the apparent resistivity of each layer; hence, these graphs showed the true resistivities, thickness, and depths for each Ves location.

Table 7 is the hydrochemical values of the parameters of the groundwater samples. For water to be potable, the concentrations of the substances must not exceed the level set by the World Health Organization (WHO, 1984). The pH of groundwater in Isolo has a range of 5.5 to 6.8. The electrical conductivity is dependent on the amount of dissolved materials. The electrical conductivity (EC) in the study area has range of 107-348 which is very high when compared with the WHO standard. Values of phosphate, nitrate and sulphate in Isolo were not within the WHO limit for potable water from boreholes 1 to10.

Iron has a lot of corrosive property which it imparts to surface water as iron (III) hydroxide can cause harm to humans if it exceeds the WHO permissible limit. The Isolo water from boreholes has high Iron content exceeding the WHO permissible limit of 0.1to1.0 mg/L thereby rendering it unfit for drinking.

Hardness of natural water varies widely depending upon the geology of the catchments and type of aquifer in the case of groundwater. The hardness of the study area

Table 4. Ves 4

Electrode separation (m)	Potential electrode separation (m)	Geometric factor (K)	Apparent resistivity (ρ_a)
AB/2	MN/2	$K = L^2/2a$	
1	0.25	6.28	13.82
2	0.25	25.12	13.31
3	0.25	56.54	16.40
4	0.25	100.54	11.06
6	0.50	226.2	4.52
6	0.50	113.1	6.22
9	0.050	254.47	2.8
12	0.050	452.4	3.17
15	1.0	706.86	4.88
15	1.0	353.46	4.24
20	1.0	628.32	5.65
25	1.0	981.75	8.25
32	1.0	1608.5	9.65
40	1.0	2513.28	15.83
40	2.5	1005.31	19.5
50	2.5	1570.8	23.1
65	2.5	2654.65	34.75
80	2.5	4021.24	28.15
100	5.0	6283.2	40.54
100	5.0	3141.6	87.96

Table 5. Ves 5.

Current electrode separation (m)	Potential electrode separation (m)	Geometric factor (K)	Apparent resistivity (ρ_a)
AB/2	MN/2	$K = L^2/2a$	
1	0.25	6.28	28.99
2	0.25	25.12	22.86
3	0.25	56.54	16.11
4	0.25	100.54	8.65
6	0.50	226.2	4.07
6	0.50	113.1	5.42
9	0.050	254.47	2.21
12	0.050	452.4	3.60
15	1.0	706.86	3.04
15	1.0	353.46	3.00
20	1.0	628.32	4.90
25	1.0	981.75	7.26
32	1.0	1608.5	5.79
40	1.0	2513.28	6.03
40	2.5	1005.31	8.04
50	2.5	1570.8	12.57
65	2.5	2654.65	18.58
80	2.5	4021.24	28.15
100	5.0	6283.2	31.42
100	5.0	3141.6	74.14

is within the permissible limit. Natural water is usually made up of carbonates and sulphates of calcium and

magnesium which are responsible for hardness of water. The level of total dissolved solids increases the hardness

Table 6. Well numbers and distance from the dumpsite.

Well nos	Distance(m)
1	64.6
2	32.6
3	11.2
4	12.2
5	13.0
6	16.0
7	14.0
8	28.0
9	64.0
10	12.0

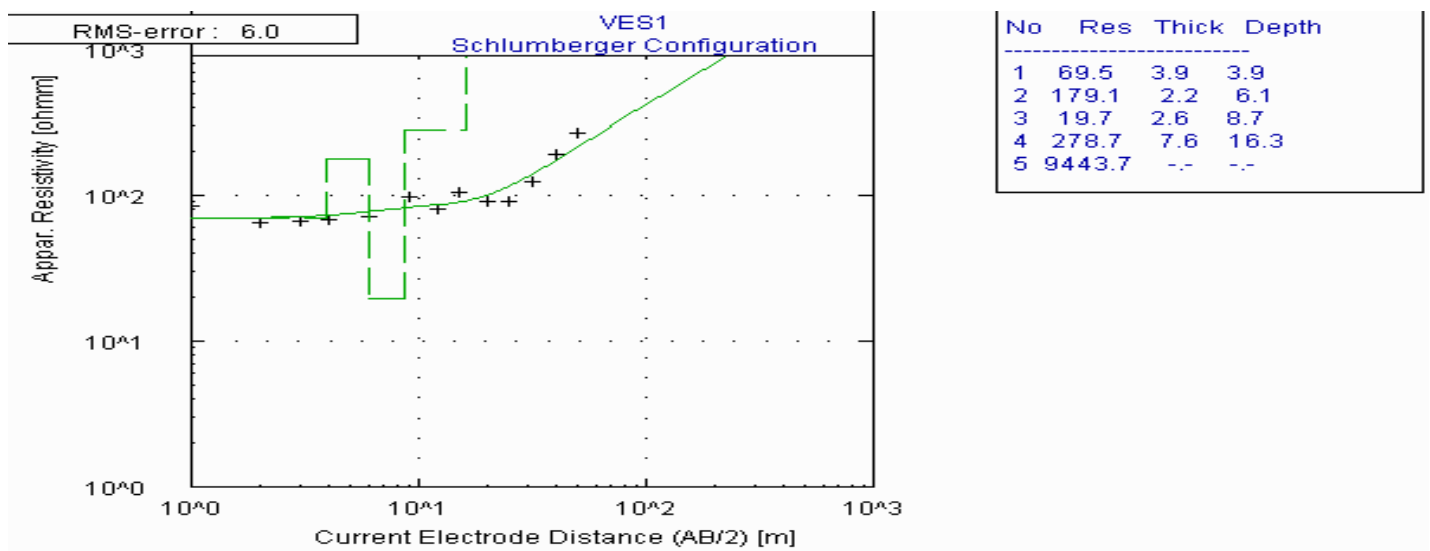


Figure 3. Ves1 curve.

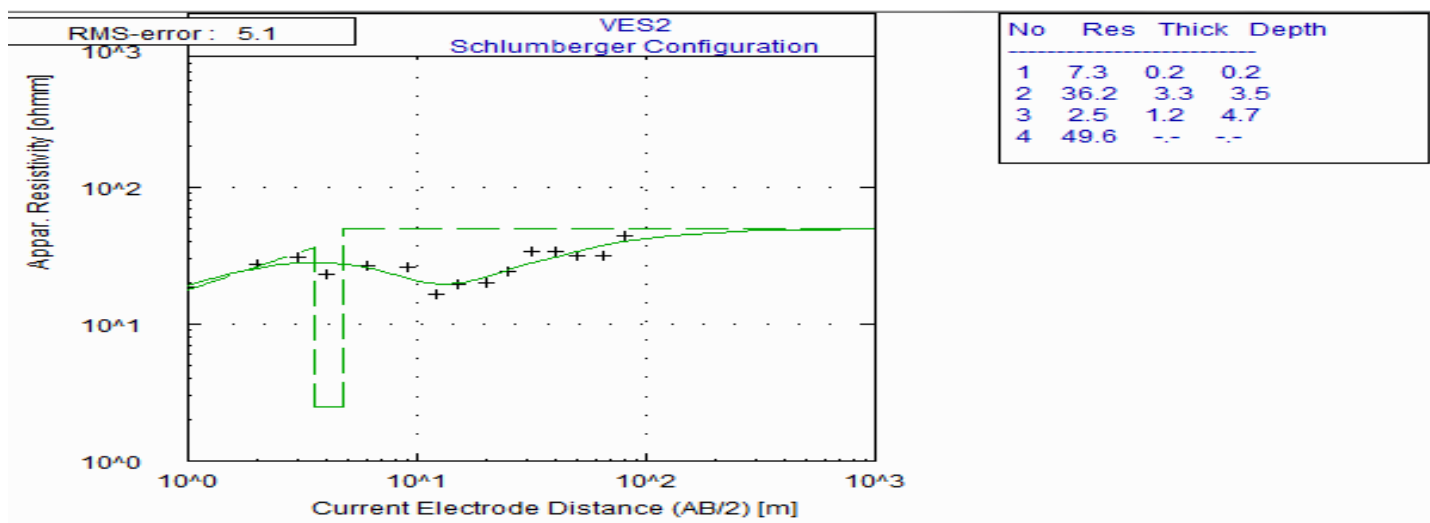


Figure 4. Ves 2 curve.

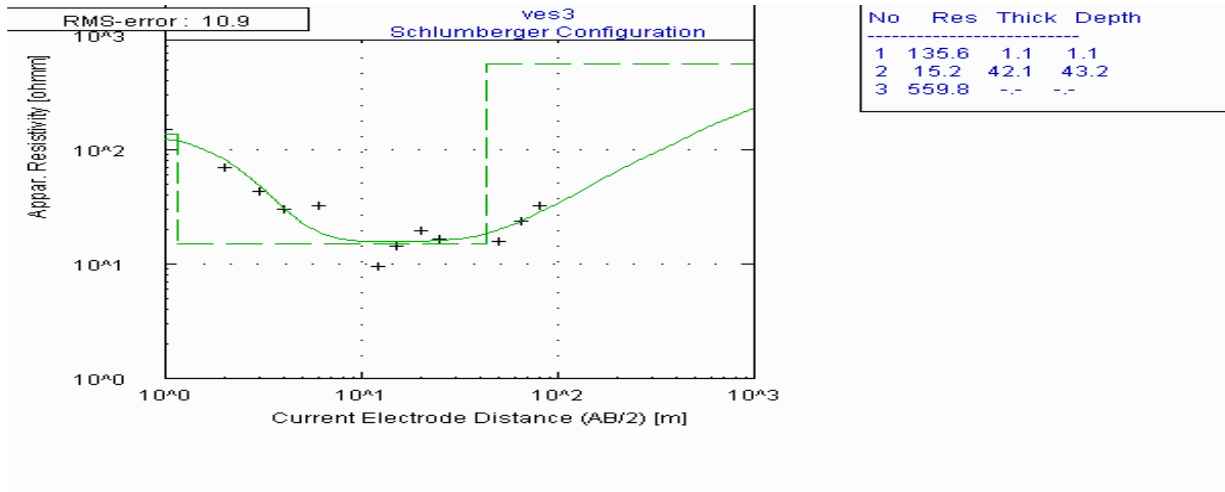


Figure 5. Ves 3 curve.

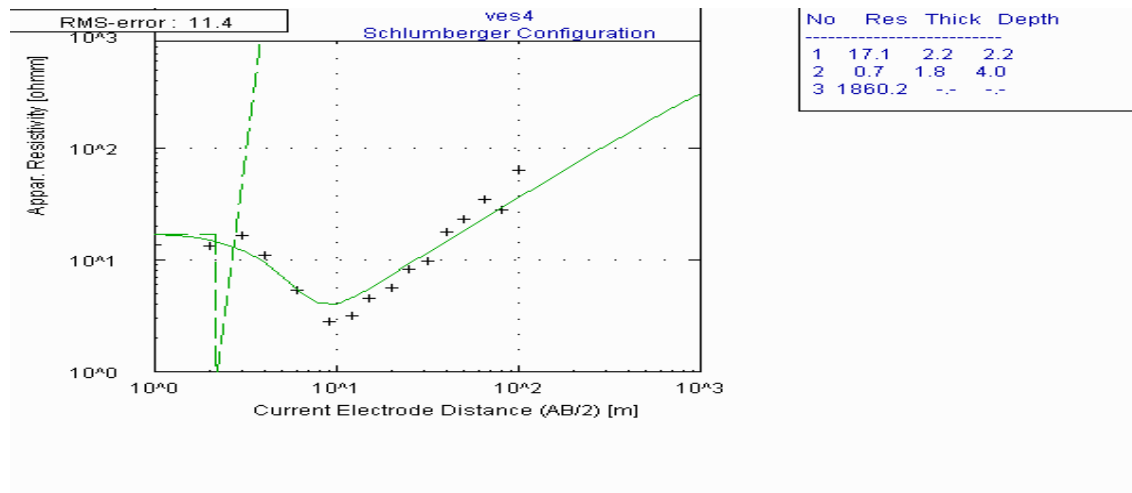


Figure 6. Ves 4 curve.

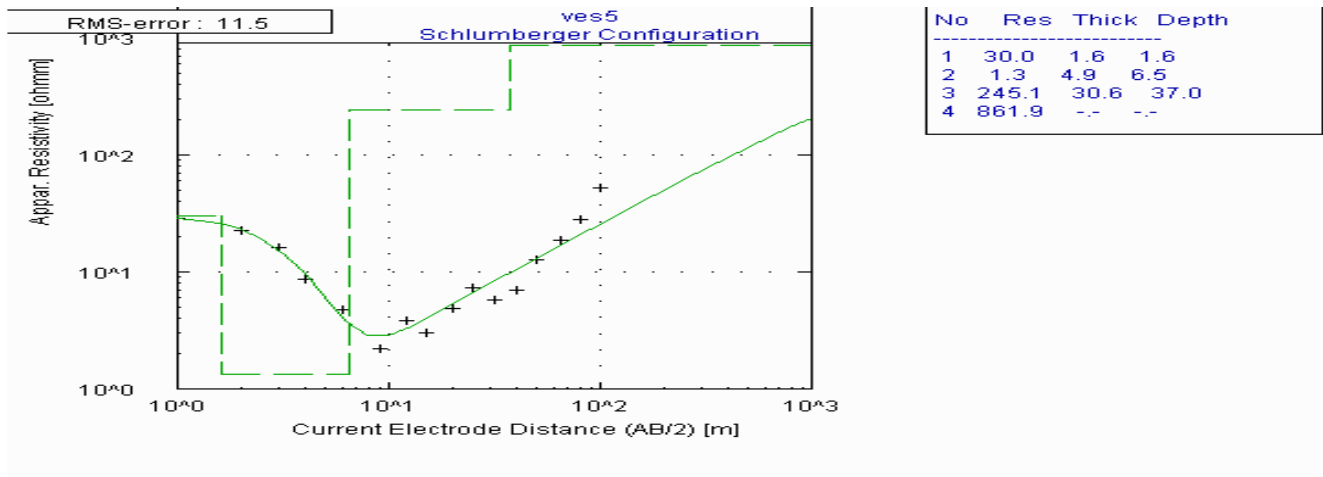


Figure 7. Ves 5 curve.

Table 7. Hydrochemical values.

parameter	WHO limit (ppm)	Bh1	Bh2	Bh3	Bh4	Bh5	Bh6	Bh7	Bh8	Bh9	Bh10	Remarks
PH	7 – 8.5	5.5	5.7	6.0	6.1	5.8	6.5	5.2	6.3	6.8	6.6	Acidic
Conductivity (μS/cm)	100	157	348	123	107	127	322	216	140	207	180	High
Total Alkalinity (ppm)	200	0	0	0	0	0	0	0	0	0	0	None
Total hardness (ppm)	30 -200	17.2	14.9	18.8	22.0	10.2	11.9	16.8	20.2	31.4	28.9	Within (WHO) limit
Total suspended solid (ppm)	-	5	10	15	12	11	9	13	19	6	10	
Iron (mg/L)	0.1 -1.0	>1.0	1.25	1.11	1.15	1.15	1.12	1.25	35	26	0.70	High, except for Bh1 and 10
Calcium (mg/L)	75 -200	<75	23	13	50	45	33	28	30	19	36	Not within limit
Magnesium (mg/L)	50 -150	<50	25	20	32	27	43	29	35	25	30	Not within limit
Phosphate (mg/L)	0-0.03	>0.03	0.26	0.34	0.11	1.02	0.09	0.15	0.49	0.14	0.43	High
Nitrite (mg/L)	5-30	30	23	27	22.2	19	28	31.5	12	33	20	High
Sulphate (ppm)	0.05	>0.05	0.06	0.12	0.29	0.17	0.15	0.34	1.11	0.04	0.07	High

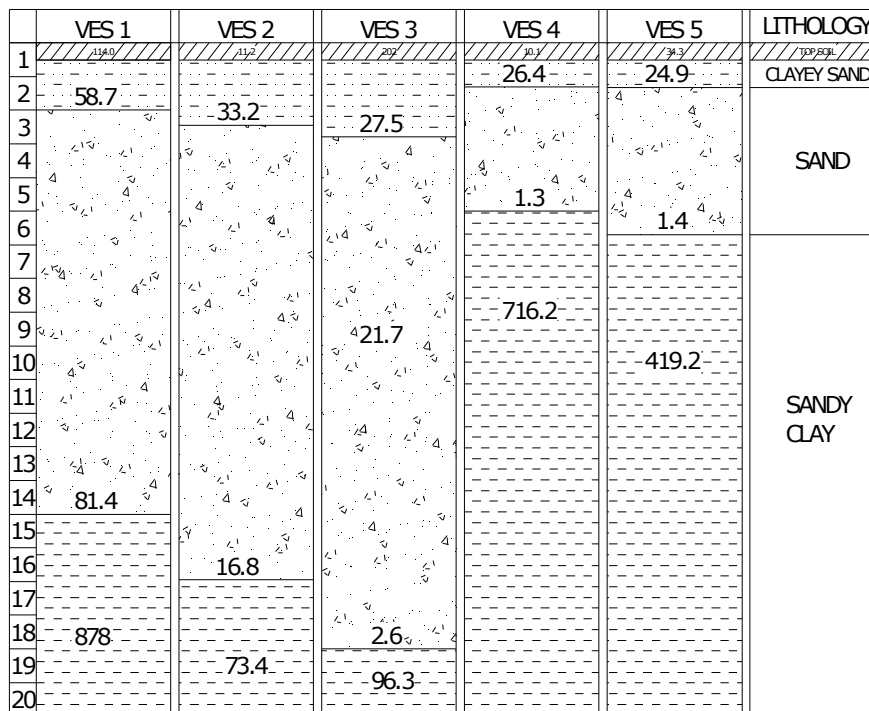


Figure 8. Geoelectric section.

of water.

Conclusion

The physiochemical analysis of groundwater samples from Isolo was carried out in line with the World Health Organization (WHO) water quality. Many of the parameters determined within the WHO, groundwater samples were found to be inadmissible for human consumption. The area traversed is an unconsolidated subsurface layer with a mixture of sand and clay in variable sequence with moderate to high porosity which allows the percolation of leachate from above. The water holding capacity of the topsoil is low and the water table is sufficient.

Serious environmental problems are associated with dumping and accumulation of refuse in an unauthorized location. In both dry and raining season, leachate from this dumpsite percolates through the subsurface and pollutes groundwater which is the major source of drinking water. The direction of the subsurface water flow is from west to east of the dumpsite, hence the depth of penetration increases to the east of the site. The presence of toxic chemicals like zinc, lead and Iron, pose a lot of health risk to users. The well water is therefore not recommended for domestic use. Wells three and four should be closed down to reduce risks.

It is therefore recommended that before a dump base is sited, a proper geophysical survey should be carried out to determine the soil porosity, layer thickness, depth to water table and lithology. Consequently, sanitary landfill is also recommended.

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