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EFFECTS OF REFUSE DUMPSITE ON GROUNDWATER QUALITY OF AARADA AREA, OGBOMOSO, SOUTHWESTERN NIGERIA.

[1]L.A. Sunmonu, [2]T.A. Adagunodo, [3]E.r. Olafisoye, & [4]O.P. Oladejo.
[1,2&3]Department of Pure and Applied Physics,
Ladoke Akintola University of Technology,
P.m.b. 4000, Ogbomoso, Oyo State, Nigeria.
[4]Department of Physics,
Emmanuel Alayande College of Education,
Oyo, Oyo State, NigeriA.

Abstract
In this 21st Century, it is saddened to see people living comfortably close to refuse dumpsite and at this same time developing hand-dug wells that will be using for their domestic activities near dumpsite without considering the hazards that surrounds their actions. Groundwater contamination both in rural and urban area is growing alarming in Nigeria today. Some people ignorantly believe infiltration must take place before the refuse been dumped on topsoil reached the water table in the subsurface without taking into consideration depth to the aquifer and flow of underground water. This has necessitated this research about investigation of effects of refuse dumpsite on groundwater quality of Aarada area, Ogbomoso, Southwestern Nigeria. A big dumpsite is located at the centre of Aarada in Ogbomoso where both domestic and commercial activities take place everyday without considering the effects of this dumpsite on their health. The study was conducted using Vertical Electrical Sounding techniques and hydro-physicochemical analysis. A total of seven electrical soundings were carried out with length ranging between 80 to 130m while the hydro-physicochemical analysis was conducted at the peak of the raining season on nine water samples taken from nine different hand-dug wells in the research environment. The results revealed that The surrounding soil and groundwater in the research area near the waste disposal site have actually been contaminated to depth exceeding 5m, which happens to be

within the first aquifer unit in the research area. These are leachate plumes from decayed organic matters, which found there way to the groundwater from the waste body. Anomalously high level of toxic substances such as Pb^{2+} and CN^{-} were observed in the sampled wells. The high concentration of NO_3^{-} detected was due to anthropogenic activities prevalent in the study area. These revelations are alarming considering their implications on the health of the people and the environment if not checked.It is therefore recommended that Oyo State Government should enforce law against dumping of refuse in that area, or if the place would continue to be used for dumpsite, Government should evacuate people living within the dumpsite in order not to be contacted with water borne diseases.

Keywords: *Vertical Electrical Sounding, Health Hazard, Solid Waste, Groundwater, Leachate Plume, Contaminants, Soil.*

Background to the study

Groundwater contamination is one of the main concerns of earth scientists and researchers from other related fields of science worldwide. Urban waste materials, mainly domestic garbage, are usually disposed of without the appropriate measures imposing a high risk to the underground water resources. The quality required of groundwater supply depends on its purpose (Diersing and Nancy, 2009). The basic purposes for which water is domestically required include drinking, bathing, cooking and general sanitation such as laundry, flushing of closets and other household chores, whereas for agricultural purposes it is essentially used for irrigation and livestock. Therefore an assured supply of water both qualitatively and quantitatively for these purposes greatly improves the social, economic and agricultural activities of the people. The health and productive life of the people in any society depend solely on potable and safe drinking water.

However, maintaining a good quality groundwater supply that is free from microbial and chemical pollution is far from reality in most of our cities and towns due to poor waste disposal and management practices. The major causes of waste generation are industrial development and increased urbanization in the municipality. The problem of inadequate trained waste disposal personnel and equipment, poor waste collection, inadequate solid waste disposing method, improper functioning septic tank systems and indiscriminate sitting of disposal sites without regards to the local geology and hydrogeology of the area contribute significantly in the contamination of soil and groundwater. Polluted groundwater has elevated microbial, ionic and volatile organic content, resulting to hazardous effects on public health and poor groundwater quality. As a result of the imminent dangerous impact of solid waste disposal site, it has become necessary to investigate the subsurface contaminant level of soil and groundwater around a municipal solid waste dumping site. The refuse dump site is located in Ogbomoso South Local Government Area, Ogbomoso, Southwestern Nigeria (Figure 1). It was delineated between latitude 8°06?70˝ and 8°06?98.7˝ north and between longitude 4°14?28.2˝E and 4°14?56.9˝ east. The waste disposal site receives municipal wastes, mainly domestic garbage, with hazardous and non hazardous constituents. These release large amount of leachate into the surrounding soil and groundwater.

Generally, electrical resistivity method provides economical and reliable means to identify and delineate leachate contaminant plumes from waste disposal site because there is elevation in the electrical conductivity of leachate to that of natural groundwater. The use of resistivity method as applied to waste dumping site studies are well documented by numerous researchers in the study of leachate contamination of soil and groundwater (Porsani et al., 2004; Karlik and Kaya, 2001; Mukhtar et al., 2000). The objective of this research work is to apply the electrical resistivity technique to detect and delineate leachate plume from uncontrolled solid waste dumpsite in Ogbomoso, Southwestern Nigeria. The hydro-physicochemical analysis of sampled water is to complement the results of the geophysical data and measure the degree of contaminants' accumulation.

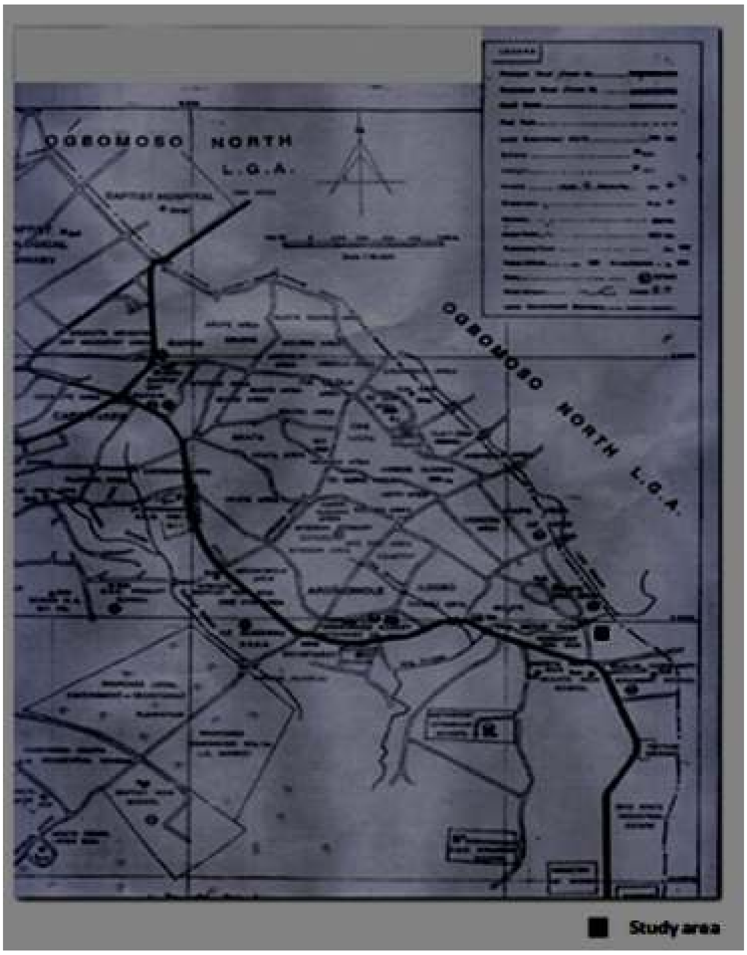

Figure 1: Map of Ogbomoso South L.G.A. Showing the Location of the Study Area.

Site Description and Geological Setting

The studied area lies within the crystalline Basement Complex of Nigeria (MacDonald and Davies, 2000). It lies within latitude 8°06?70′ and 8°06?98.7′ north and between longitude 4°14?28.2′E and 4°14?56.9′ east. The study area overlies the western upland region of the Nigeria highland plateaux with average altitude between 1000m and 1500m above mean sea level (Akinloye et al., 2002). The drainage type is intrinsically dendrites. Locally, Ogbomoso area experiences tropical rainfall which dominates most of southwestern part of Nigeria and the area has two distinct seasons, the wet season usually between March and October, and the dry season which falls between November and February every year. The annual rainfall for the study area is 1247mm, but the amount varies from 1016mm to 1524mm, and is almost entirely concentrated in the wet season. The study area falls within the guinea savannah belt of Nigeria but human activities such as exploitation are gradually changing the vegetation to that of Sudan savannah.

Regionally, the Study area lies within the South Western parts of the Basement rocks, which is part of the much larger Pan-Africa mobile belt that lies in between the West Africa Craton and Congo Craton, suspected to have been subjected only to a thermotectonic event (Alagbe, 2005).

In general, the southwestern Nigeria crystalline Basement can be grouped into three the Migmatite-Gneiss Complex, Metasedimentary and Metavolcanic Rocks, and the Pan-African Older Granite Series (Ajibade et al., 1988). Locally, the study area lies within Ogbomoso and is underlain by rocks of the Precambrian complex with Quartzite and Quartz-Schist and Undifferentiated Gneiss and Migmatite (Ajibade et al., 1988) (Figure 2). The rock groups in the area include quartzites and gneisses (Ajibade et al, 1988). Schistose quartzites with micaceous minerals alternating with quartzo-feldsparthic ones are also experienced in the area. The gneisses are the most dominant rock type. They occur as granite gneisses and banded gneisses with coarse to medium grained texture. Noticeable minerals include quartz, feldspar and biotite. Pegmatites are common as intrusive rocks occurring as joints and vein fillings (Rahaman, 1976; Ayantunji, 2005). They are coarse grained and weathered easily in to clay and sand-sized particles, which serve as water-bearing horizon of the regolith. Structural features exhibited by these rocks are foliation, faults, joints and microfolds which have implications on groundwater accumulation and movement (Ayantunji, 2005).

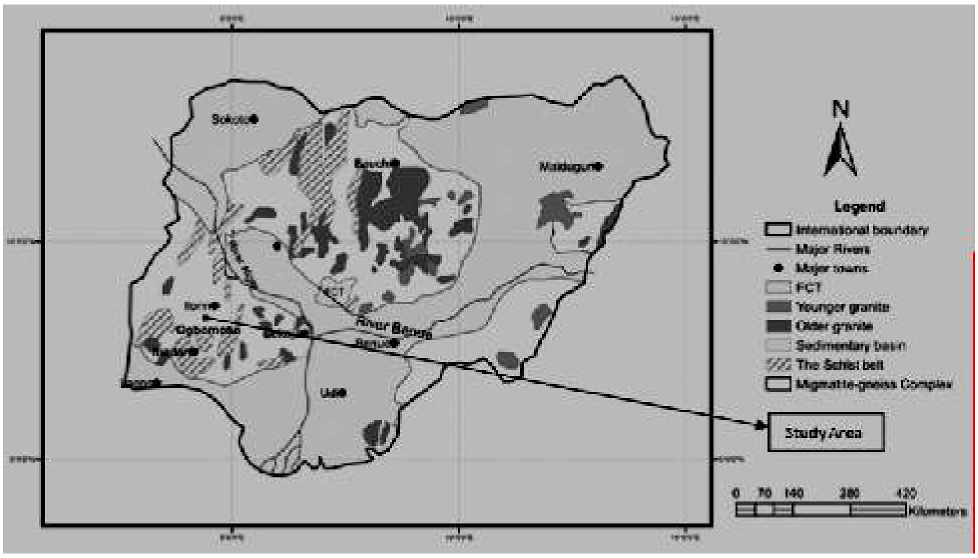

Figure 2: Geological map of Nigeria showing the study area. (Modified after Ajibade et al, 1988).

MATERIALS AND METHOD

The vertical electrical sounding was conducted using the schlumberger array which has a complex geometry with spacing between the current electrodes not equal to the spacing between the potential electrodes. The apparent resistivity values were then computed using the equation:

$$r_a = KR$$

Where K is the geometric factor of the electrode array and R is the resistance of the wire. The Campus Tiger resistivity meter was employed for resistance measurements. A total of seven electrical soundings were established, with maximum half-current electrode spacing (AB/2) of 65m. The field data was interpreted by applying partial curve matching technique (Koefoed, 1979) with the help of master curves (Orellana and Mooney, 1966) and sets of auxiliary charts (Zohdy, 1965; Keller and Frischnecht, 1966). From the preliminary interpretation, initial estimates of the resistivity and thickness of the various geoelectric layers at each VES locations were determined. These geoelectric parameters were then employed as starting models for the computer-aided iteration using Resist software (Vander Velpen, 1988). Hydro-physicochemical analysis however takes place in the month of July, 2011 from different nine wells in the study area. The location map of the study area is shown in Figure 3.

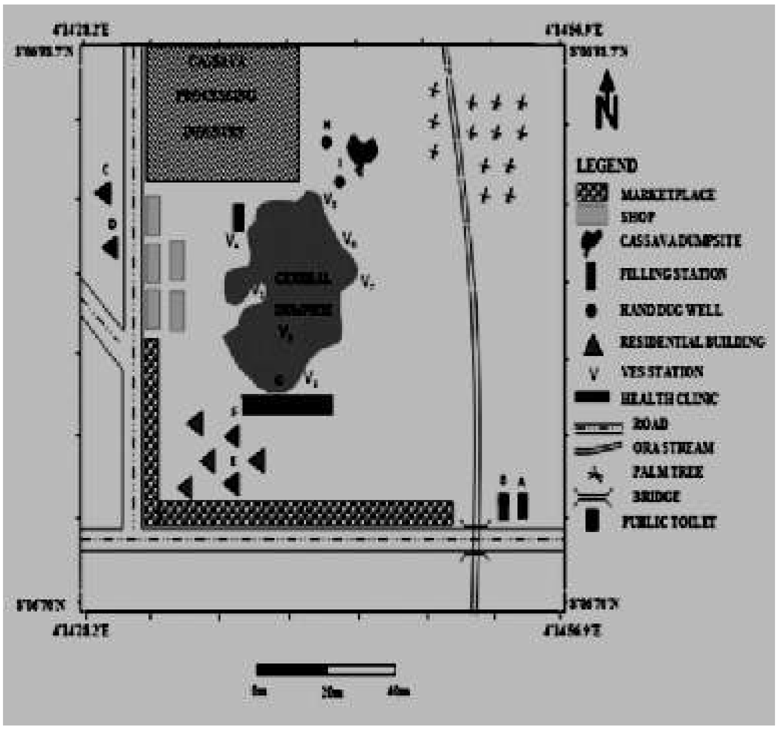

Figure 3: Location Map of the Study Area

Result and Discussion

VES Discussion

The VES curves are presented in Figure 4 to Figure 10. However, the results generated from the VES data interpretation are presented in Figure 11 and Figure 12 as geoelectric sections. The partial curve matching technique carried out on the field data revealed a 3 layered model with H type curve ($?_1>?_2<?_3$) for all the soundings. Electrical method primarily reflects variations in ground resistivity (Omosuyi et al., 2007). The electrical resistivity contrasts between lithological sequences (Dodds and Ivic, 1998; Lashkaripour, 2003) in the subsurface are often adequate to enable the delineation of geoelectric layers and identification of aquiferous or non-aquiferous layers (Schwarz, 1988). The VES interpretation reveals three geoelectric layers across the research area: the topsoil consisting of sand and decomposed organic matters; the weathered layer which is made up of sandy soil and the bedrock constituting the fractured or fresh basement. The geoelectric sections show subsurface variation in electrical resistivity along the profiles and attempt to correlate the geoelectric sequence across the profiles. In the first layer, the resistivity values ranged from 33.4 to 130.9? m with a relative thickness of 1.1 to 1.6m.

The second layer has resistivity values varying from 10.4 to 26.8? m with relative thickness of 1.3 to 3.8m. However, the low resistivity values depicted in this layer is due to pollution which resulted from the high porosity and permeability characteristics of the sandy soil permitting the seepage of the leachate plumes to a maximum depth of 5.4m at the subsurface. The region of this layer beneath VES2 conducted on the waste disposal site where there is older wastes deposit depicted low resistivity value of 10.4? m. It also reveals an elevation in the resistivity values in the order VES 1, 3, 5, 6, 7 and 4 which revealed that the leachate emanated from the region where there is older deposit of wastes and spreading out in all direction polluting the hand dug wells nearby in the process. This geoelectric layer also served as the first aquifer on the research site from which virtually all the hand dug wells in the area obtained their water. The third layer has resistivity values ranging from 233.6 to 356.7m which indicated the presence of fractured zones and resistivity values between 1649.9 and 2764.9m; reflective of fresh basement. The thickness of this geoelectric layer is to an infinite depth.

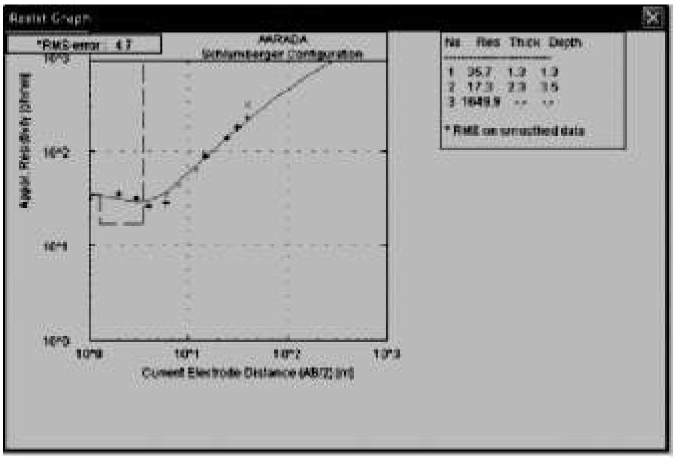

Figure 4: Modeled Curve Showing Ves 1.

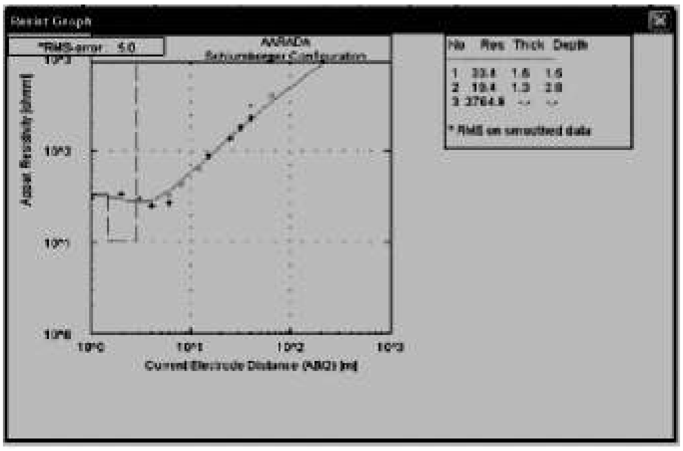

Figure 5: Modeled Curve Showing Ves 2.

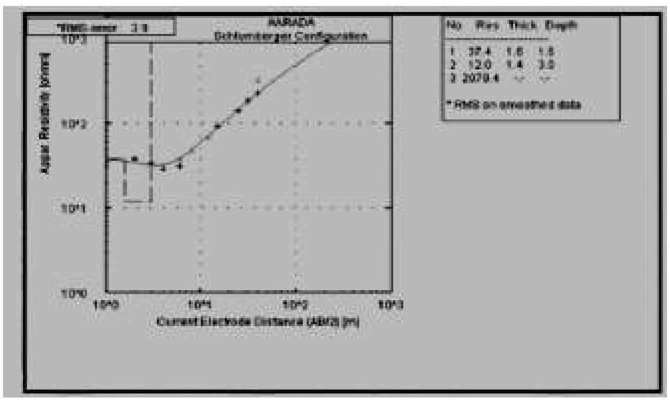

Figure 6: Modeled Curve Showing Ves 3.

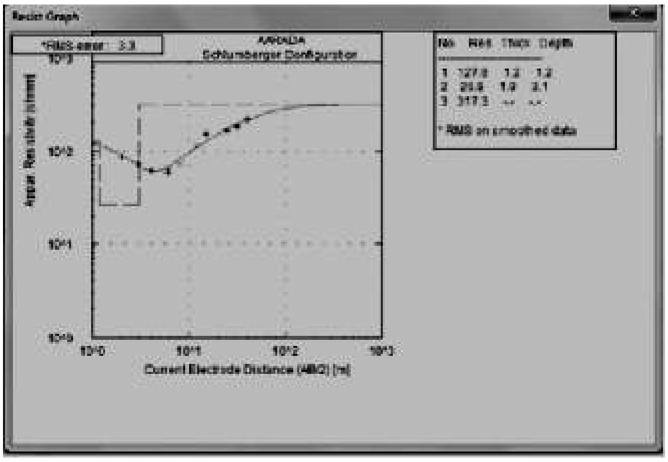

Figure 7: Modeled Curve Showing Ves 4.

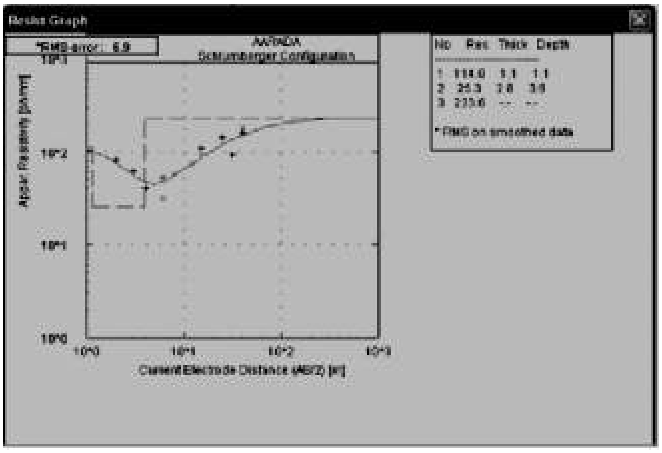

Figure 8: Modeled Curve Showing Ves 5.

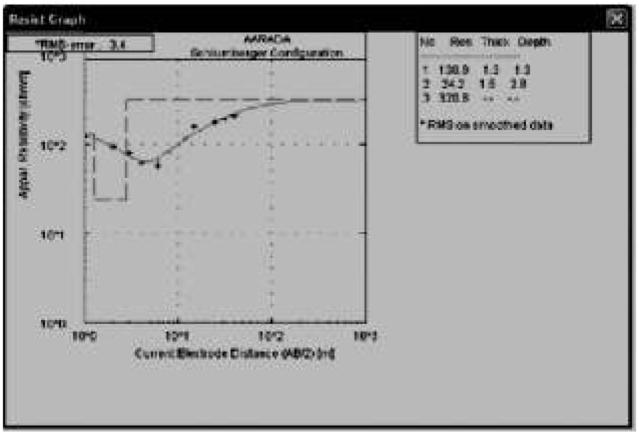

Figure 9: Modeled Curve Showing Ves 6.

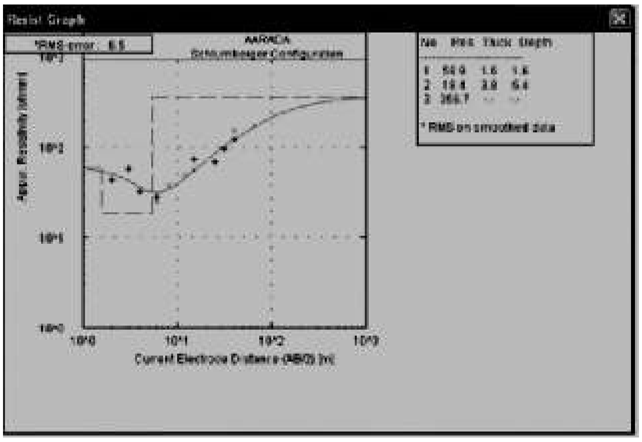

Figure 10: Modeled Curve Showing Ves 7.

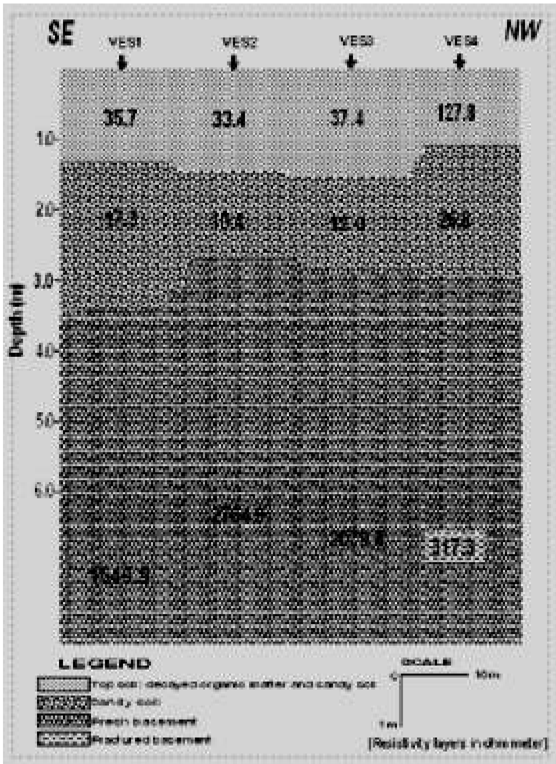

Figure 11: Geoelectric Section Beneath Ves 1 to VES 4.

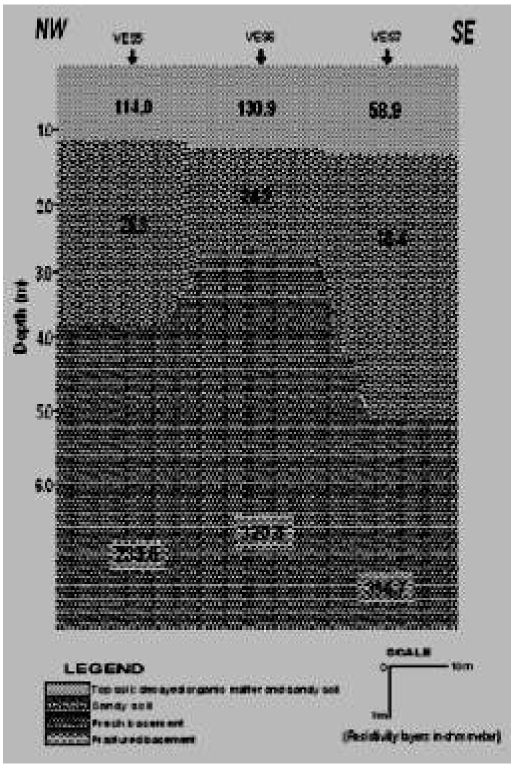

Figure 12: Geoelectric Section Beneath Ves 5 to VES 7.

Hydro-Physicochemical Analysis Discussion

The depth of the hand dug wells from which the nine samples were collected and their locations from the waste body are shown in Table 1. The result of the concentration of cations and anions as well as the total bacteria and coliform counts from the water samples are also presented in Table 1. The concentration of each ion is an indication of the potability of the water (Ehinola, 2002). The World Health Organization (WHO) standard for good quality drinking water serves as criteria for assessing the potability of the sampled hand dug wells in the research area. The analysis of the result obtained from the hydro-physicochemical method indicates that most of the hand dug wells (especially those nearest to the waste disposal site) in Aarada area are fairly acidic, shows elevated values in the concentration of TDS, NO_3^-, Cl^- and bacteria counts compared to the guidelines recommended by WHO. This reveals that the usage of these hand dug wells for domestic purposes without administering any form of treatment in advance poses a serious health hazard.

The concentration of various parameters tested in wells A, B, C, D and E falls within the WHO standard, which is an indication of good conditions of the wells. The poor conditions of wells F, G, H and I are attributed to anomalously high concentration of

NO_3^- which are caused by anthropogenic pollution and high total coliform counts in the water samples. The high concentration of total dissolved solids in most of the samples may be a reflection of gradual weathering of the basement rocks.

Health Hazard Implications

The disease type predominant in the research area is waterborne diseases like cholera which forms about 15%, typhoid about 50% and gastroenteritis 35%. This analysis was made after personal communication with the medical doctors from the health clinic situated within the refuse dumpsite facility. The pathogens of most of these waterborne diseases are the coliforms group of bacteria which are the most abundant microorganisms occurring in polluted water. The coliform counts in most of the samples (well H and I) show that they are highly polluted with faecal waste, hence, residents of this area are exposed to high risk of infection due to contaminated water used for domestic purposes. On the contrary, wells A, B, C, D and E located more than 10m away from the waste disposal area show non-detectable coliform count suggesting a more hygienic environment. However, even in a clean environment, it is not unusual to detect high coliform count in wells, as there might be ingress of effluents from improperly constructed or damaged sewage tanks. Davis and Dewiest (1966) observed that cementation of inner wall of wells provide a barrier against bacteriological contamination. Dournadeali and Tayback (1979) stated that the use of pipe to pump well water reduces microbial contamination risk (rather than using plastic draws which can easily introduce contaminants into the groundwater).

Table 1: Result of the Hydro-Physicochemical Analysis of Hand-Dug Well Samples Carried Out at the Peak of the Raining Season.

Parameters	Well A	Well B	Well C	Well D	Well E	Well F	Well G	Well H	Well I
Distance of wells from the dumpsite (m)	25	19	15	13	11	7	6	5	3
Depth of wells (m)	6	5.5	6.1	6.5	6.5	4.5	5.4	5.3	4.1
Colour	Clear, colourless	Clear, colourless	Clear, colourless	Clear, colourless	Clear, colourless	Clear, colourless	Light brown	Clear, colourless	Light brown
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Salty taste	Salty taste	Salty taste	Salty taste	Salty taste
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Undesirable odour	Undesirable odour	Odourless	Odourless
pH	6.9	6.9	7.3	7.5	7.5	7.7	7.9	8.3	8.0
Temperature (°C)	26.5	26.0	26.4	27.8	27.1	26.5	27..2	28.5	26.9
Fe^{2+} (mg/L)	0.75	1.5	1.85	1.65	2.1	3.1	2.81	3.51	2.72
Pb^{2+} (mg/L)	0.001	0.005	0.006	0.009	0.01	0.015	0.42	1.0	0.95
Cu^{2+} (mg/L)	0.65	0.5	1.57	1.57	2.89	2.05	0.31	2.15	0.98
Zn^{2+} (mg/L)	3.45	2.33	3.4	2.91	4.20	4.1	3.57	4.0	3.63
K^{+} (mg/L)	15.15	14.7	21.0	17.75	37.11	23.32	43.86	54.31	41.33
Na^{+} (mg/L)	13.45	18.23	27.31	31.15	57.27	40.32	53.97	59.98	55.76
Mg^{2+} (mg/L)	15.44	8.74	17.4	10.26	17.84	23.5	19.78	29.97	17.05
Cl^{-} (mg/L)	9.95	17.5	21.53	37.5	39.67	49.7	60.25	65.33	61.57
SO_4^{2-} (mg/L)	2.15	2.75	3.12	1.53	5.93	7.58	7.85	11.55	9.75
NO_3^{-} (mg/L)	5.77	14.96	19.39	23.75	31.65	87.97	90.50	97.98	93.24
HCO_3^{-} (mg/L)	6.87	5.3	5.7	7.89	10.5	15.13	23.75	37.93	26.42
CN^{-} (mg/L)	0.33	0.35	0.42	0.35	0.49	0.83	0.96	3.15	3.76
Total Solids (mg/L)	1500	1575	1575	1565	1670	1740	1963	1800	1950
Total Dissolved Solids (mg/L)	779	750	840	900	1145	1300	1315	1345	1296
Suspended Solids (mg/L)	1270	1220	1250	1395	1410	1427	1400	1510	1515
DO (mg/L)	89.77	60.41	67.58	71.42	60.91	100.5	150.14	135.95	69.72
BOD (mg/L)	0.07	3.9	3.1	3.95	4.72	5.40	5.49	5.95	6.27
COD (mg/L)	0.32	3.1	3.51	3.27	4.21	4.15	5.13	6.0	6.95
Total Hardness (mg/L)	63.72	59.73	35.52	67.83	78.57	65.75	81.35	89.79	90.65
Turbidity (mg/L)	0.0	0.0	0.7	1.1	1.21	0.97	1.3	1.35	1.47
Conductivity (µS)	805	795	800	845	943	1320	1470	1495	1550
THBC (cfu/ml)	7	55	47	74	89	100	835	270	890
THFC (cfu/ml)	Nil	Nil	Nil	Nil	Nil	3.78	4.76	3.97	6.43
Total coliform (cfu/ml)	Nil	Nil	Nil	Nil	Nil	0.97	2.13	1.15	5.0
Feacal coliform (cfu/ml)	Nil	Nil	Nil	Nil	Nil	Nil	3.3	Nil	3.78

Table 2: Summary of the Results of the Method Employed and W.H.O. Standards for Potable Drinking Water.

Parameters	Method Employed	WHO Standard
Colour	-	Clear, colourless
Taste	-	Unobjectionable to consumers
Odour	-	Unobjectionable to consumers
pH	pH meter (APHA 4500 – H)	6.8 – 8.5
Temperature (°C)	Thermometer	24.5 – 39.7
Fe^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.0
Pb^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.05
Cu^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	1.5
Zn^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3120 - B)	4.0
K^{+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - KB)	15
Na^{+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - NaB)	200
Mg^{2+} (mg/L)	Atomic absorption spectrophotometry (APHA 3500 - MgB)	150
Cl^{-} (mg/L)	Titrimetry (APHA 4500 - B)	600
SO_4^{2-} (mg/L)	Spectrophotometry (APHA 4500 SO_4B)	400
PO_4^{3-} (mg/L)	Spectrophotometry (APHA 4500 P)	250
NO_3^{-} (mg/L)	Spectrophotometry (APHA 4500 NO_3B)	50
CN^{-} (mg/L)	Titrimetry (APHA 4500 - B)	0.5
Total Dissolved Solids (mg/L)	Gravimetry (APHA 2540 - B)	1000
Suspended Solids (mg/L)	Spectrophotometry (APHA 2540 - D)	30
DO (mg/L)	Titrimetry (APHA - O)	-
BOD (mg/L)	Titrimetry (APHA 5210 - B)	10
COD (mg/L)	Titrimetry (APHA 5220 - B)	40
Total Hardness (mg/L)	Titrimetry (APHA 2340 - B)	500
Turbidity (mg/L)	Turbidimeter (APHA 2130 - B)	5.0
Conductivity (µS)	Conducting meter (APHA 2510 - B)	1500

Conclusions and Recommendation

The soil and groundwater contamination in the research area was investigated using vertical electrical sounding and hydro-physicochemical analysis method. The analysis of the resistivity sounding revealed that leachate spread out in all direction originating from the part of the refuse dumps with older wastes deposit polluting the nearby hand dug wells it comes in contact with to a distance less than 10m from the waste body. The geoelectric sections of the interpreted VES data delineated the leachate extent to a maximum depth of 5.4m in the subsurface. The analysis of the hydro-physicochemical result conducted on the hand dug wells F, G, H and I showed concentrations of organic and inorganic parameters tested exceeding World Health Organization's permissible limits. This is due to the fact that the depths of those wells terminated within the contaminated zone indicating a high degree of pollution.

However, the results obtained for the hand dug wells A, B, C, D and E depicted non-detectable contamination level. The good condition of these sampled wells is due to their various depth of penetration which is greater than 5.4m and their distance from the waste disposal area (more than 10m away). In addition, the close proximity of wells H and I to the cassava waste disposal site resulted to anomalously high CN^- concentration in their tested samples. In spite of these observations, good quality drinking water can still be obtained in the research area by drilling wells to greater depth of penetration. This will highly slow down the rate at which contamination plumes infiltrates the groundwater resources in the area. Also, the assessment of the research site and analysis of water samples from hand dug wells in the area should be carried out periodically. This will enhance continuous consumption of good water quality. Moreover, the result of the hydro-physicochemical analysis conducted on the hand-dug well located within the hospital situated less than 4m away from the waste disposal site shows high total coliform counts. It is therefore suggested that the hospital should be evacuated so that patients seeking health care delivery system in the clinic will not have their health problems compounded.

This research work enlightens the residence in and around the refuse dumpsite facility on how to obtain contaminant-free groundwater. This study also reveals the importance of using an integrated approach of geophysical techniques for acquiring the physical properties of a waste disposal site. The employment of different techniques allows the resolution of possible discrepancies and reveals the most accurate description of a waste disposal site's characteristics. Finally, to be on a safer side, Oyo State Government should enforce law against dumping of refuse in that area, or if the place would continue to be used for dumpsite, Government should evacuate people living within the dumpsite in order not to be contacted with water borne diseases.

References

Ajibade, A.C., Rahaman, M.A. & Ogezi, A.E.O. (1988). "The Precambrian of Nigeria, a Geochronological Survey." Publication of the Geological Survey of Nigeria.

Akinloye, M.K., Fadipe, D.O. & Adabanija, M.A. (2002). "A radiometric mapping of the Ladoke Akintola University Campus, Ogbomoso, Southwestern Nigeria." Science Focus 1, 55-61.

Alagbe, O.A. (2005). "Integration of Electrical Resistivity Techniques and Lineament analysis in Hydrogeological investigation of parts of Ogbomoso, South Western Nigeria." M. Tech Thesis, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Ayantunji, B.G. (2005). "Integrated use of electrical and electromagnetic (VLF) method in the delineation of the fault pattern of Odokoto, Ogbomoso, Southwestern Nigeria." M. Tech Thesis, Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

Davies, A.H. & Dewiest, T.K. (1966). "Hydrology." New York: John Wiley and Sons inc., 463p

Diersing, N. & Nancy, R. (May, 2009): "Water Quality: Frequently Asked Questions." *PDA*. NOAA. http://floridakeys.noaa.gov/pdfs/wqfaq.pdf. Retrieved 2009-08-24.

Dodds, A.R. & Ivic, D. (1988). "Integrated Geophysical Methods Used for Groundwater Studies in the Murray Basin, South Australia." Geotechnical and Environmental Studies. Geophysics, Vol. II. Soc. Explor Geophys.: Tulsa, OK. 303-310

Dournadaeli, V. & Tayback, M. (1979). "Progress in water technology." vol. II (i), 31-35

MacDonald, A.M. & Davies, J. (2000). "A brief review of groundwater for rural water supply in Sub-Saharan Africa." B.G.S. Technical Report. W.C./00/33.

Mukhtar, I. S., Abdullatif, P. & Hanafi, M . (2000). "Detection of groundwater pollution using resistivity imaging at Seri Petang landfill, Malaysia." Journal of Environmental Hydrology. 8: 1-8

Omosuyi, G.O., Adeyemo, A. & Adegoke, A.O. (2007). “Investigation of Groundwater Prospect using Electromagnetic and Geoelectric Sounding at Afunbiowo, near Akure, Southwestern Nigeria.”

Orellana, E. & Mooney, H.M. (1966). “Master Tables and Curves for Vertical Electrical Sounding over layered Structures.” Interciencis, Madrib.

Porsani, L., Filho, W.M., Ellis, V.R., Shimlis, J.D., Moura, H.P. (2004). “The use of GRR & VES in delineating a contamination plume in a landfill site: A case study in SE Brazil.” Journal of Applied Geophysics. l55: 199 209

Rahaman, M.A. (1976). “Review of Basement Geology of Southwestern Nigeria, Elizaberthan Publishing Company, Nigeria pp 41-58

Schwarz, S.D. (1988). “Application of Geophysical Methods to Groundwater exploration in the Tolt River Basin, Washington State.” Geotechnical and Environmental Studies. Geophysics, Vol. II. Soc. Explor Geophys.: Tulsa, OK. 213-217

Vander Velpen, B.P.A. (1988). “Resist Version 1.0.” M.Sc. Research Project. ITC: Delft, Netherlands.