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IMPACT ASSESSMENT OF SOLID WASTE ON GROUNDWATER: A CASE STUDY OF AARADA DUMPSITE, NIGERIA

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ABSTRACT

A research on the impact of waste disposal site on groundwater resources was conducted around Aarada refuse dumpsite, Ogbomosho, Oyo State, Nigeria using electrical resistivity (Vertical Electrical Sounding) and hydro-physicochemical methods. World Health Organization (WHO) standard was used as yard stick for the hydro-physicochemical method. A total of seven VES were carried out with electrode spacing ranging between 80 to 130m. The hydro-physicochemical analysis was conducted at the peak of the dry season on nine water samples taken from nine different hand-dug wells in the research area. The result obtained from the interpreted VES data revealed leachate plumes at the subsurface in the study area. The outcome of the hydro-physicochemical method revealed hazardously high values of Fe^{2+}, Pb^{2+}, Zn^{2+}, Cu^{2+} and NO_3^-.

Keywords: groundwater, leachate plume, resistivity, contaminants, health hazard, VES.

INTRODUCTION

Dumpsite is a piece of land where waste materials are dumped. To the best of our knowledge, depositions of refuse in residential areas have been part and parcel of people in the developing countries including Nigeria. Though the three arms of government (Federal, State and Local government) are trying hard to put an end to this act in Nigeria, it seems our people are adamant to corrections. This is one of the reasons why periodic researches should be carried out at these unauthorized dumpsites in order to keep the populace informed about the risk in living close to dumpsites. In other hand, it is imperative to keep government informed about the results of researches carried out in these dumpsites and let them know the risk in allowing the citizen to continue living in unhealthy environment. World Health Organization defined solid wastes as useless and unwanted materials arising from human activities that are not free floating (WHO, 1971) and estimated that about a quarter of the diseases affecting mankind today are due to prolonged exposure to environmental pollution. Solid wastes can be categorized into hazardous wastes (toxic chemicals, radioactive materials, flammable and explosive wastes) and non-hazardous wastes (agriculture, commercial and industrial wastes that are not lethal by nature or contain toxic materials). It is obvious that, waste disposal is a vital part of man's daily activities and are also potential sources of pollution to the environment. Over the decades the hazardous effects of environmental pollution on the health of the populace has been alarming. Poor management of solid wastes greatly affects the environment thereby resulting to public health hazards such as periodic epidemics and communicable diseases (Fasunwon, 2010). The research area like many cities/towns in developing countries lack proper waste disposal and management practices. Improper management of solid waste is the major causes of environmental pollution and degradation in many cities worldwide. This study focuses on the impact of the dumpsite on groundwater resources because of the increasing lack of potable and safe drinking water in the study area.

Groundwater contamination in a dumpsite facility occurs mainly due to the contaminants potential of leachate from the waste body. These leachates are solution or suspensions of stabilize, essentially organic or inorganic complexes of biodegradation of components of solid wastes flowing out from the refuse dumps, saturated with rainwater flowing through them (Kassenga and Mbluligwe, 2009). Leachate from municipal solid waste deposits is generally associated with high ion concentrations and hence very low resistivities. This makes geo-electrical techniques most adequate for mapping the extent of leachate contamination around landfills (Bernstone and Dahlin, 1999). Landfill related geo-electrical surveys have been carried out by numerous researchers in the study of leachate contamination of soil and groundwater. Bernstone and Dahlin (1999), Christopher and Jones (1999), Keller and Frischescht (1999), Powers *et al*. (1999), and Rosqvist *et al*. (2003), using geophysical methods, to estimate the depth to groundwater, identify and delineate the extent of contaminant leachate plume and migration paths below surface around landfills.

The main objective of this work is to investigate leachate generation and migration paths and the impact of this on human health and the environment of Aarada dumsite. This involves an assessment of the soil and groundwater contamination on and around the landfill through the integrated use of vertical electrical soundings and hydro-physicochemical analysis methods.

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HYDROGEOLOGIC AND GEOLOGICAL SETTINGS

The study area is located in Ogbomoso South Local Government Area, southwestern Nigeria between latitude 8˚06′70″ to 8˚06′98.7 north and longitude 4˚14′28.2″E to 4˚14′56.9″ east. According to MacDonald and Davies (2000) who classified the hydrogeology of Sub-Saharan Africa into four provinces, these are: Precambrian basement rocks, volcanic rocks, unconsolidated sediments and consolidated sedimentary rocks. These four provinces are well represented in Nigeria (Figure-1a). The study area is located on the Precambrian basement rocks of Southwestern Nigeria which comprise of crystalline and metamorphic rocks over 550 million years old (MacDonald and Davies, 2000). 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 (Sunmonu et al., 2012). Locally, Ogbomoso is within the Migmatite-Gneiss-Quartzite Complex (Rahaman, 1988). This rock group consist of the banded gneiss, granite gneiss, migmatite gneiss, Porphyroblastic gneiss, and the quartzites (figure-1b). The gneisses are of granitic origin. The banded variety occurs as a ring that encompasses the quartzites in the central part of Ogbomoso. The quartzites occur as elongated ridges trending NW-SE and are mostly schistose. Schistose quartzites with micaceous minerals alternating with quartzofeldsparthic ones are common in the southern part of the town. The Granite gneisses dominate the North-Eastern part of Ogbomoso. The North-Western part is dominated by the Porphyroblastic gneiss, while migmatite gneisses are found in the Southern part of Ogbomoso Township. The different varieties of the Migmatitic gneisses contain mineral assemblage of Quartz + Feldspar + Biotite ± Hornblende ± Mica. There are evidences of tectonism in the area, expressed as folds, fractures, joints, e.t.c. these structural features are likely targets during groundwater exploration.

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.

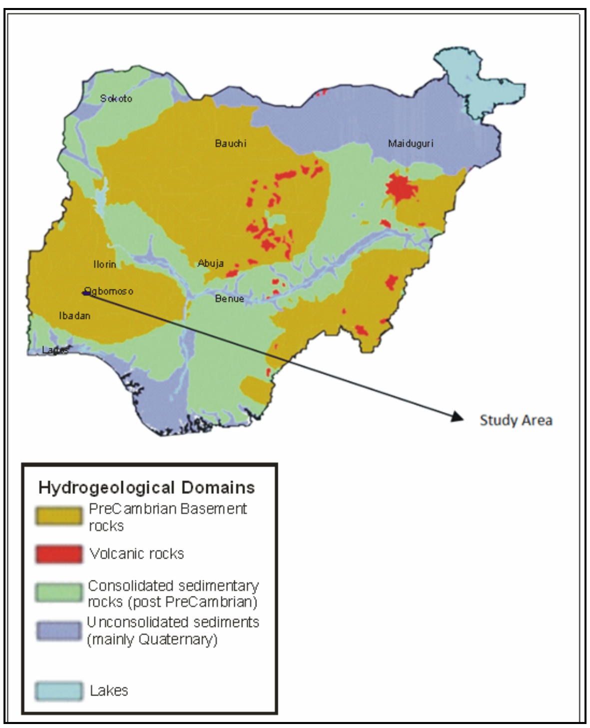

Figure-1a. The hydrogeological domains of Nigeria.

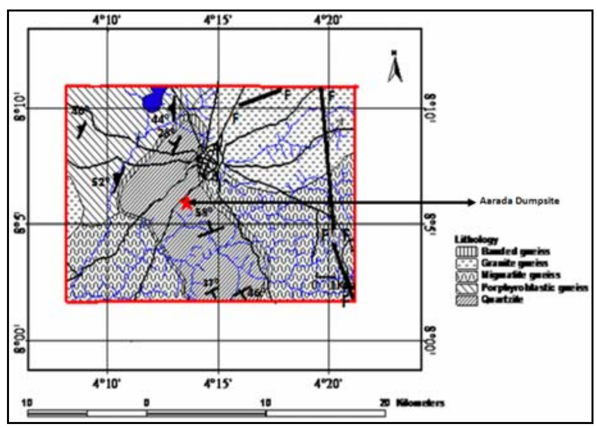

Figure-1b. Geologic Map of Ogbomoso (modified after Afolabi et al., 2011).

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MATERIALS AND METHOD

The VES was carried out using Schlumberger electrical array (Zohdy *et al*., 1974). 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 (Figure-2). 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, 2004). The partial curve matching technique carried out on the seven VES revealed a 3 layered model with H type curve (resistive-conductive-resistive) (Figure-3 - Figure-9).

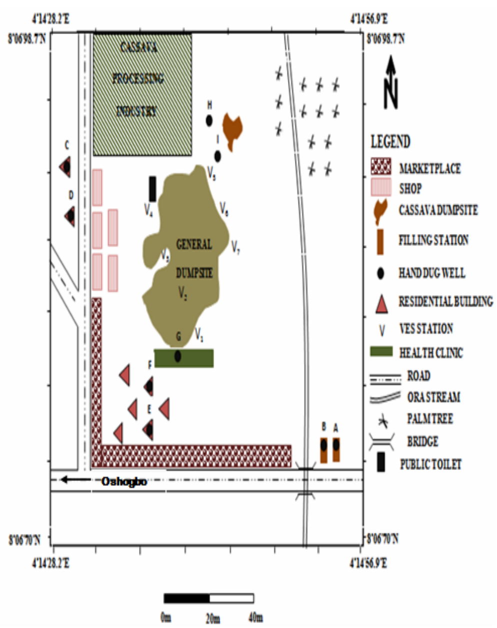

Figure-2. Base map of the study area.

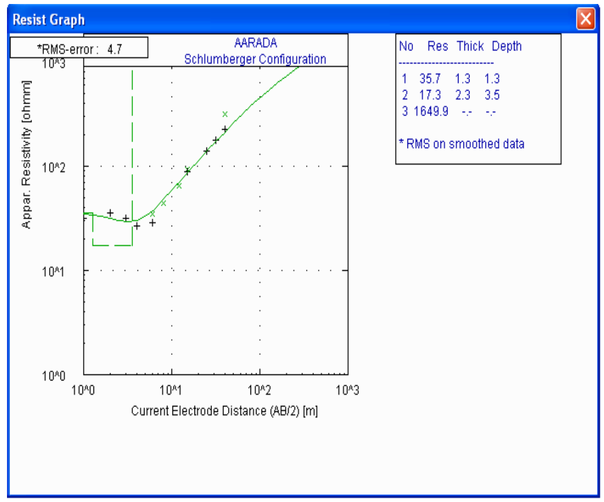

Figure-3. Modeled curve for VES-1.

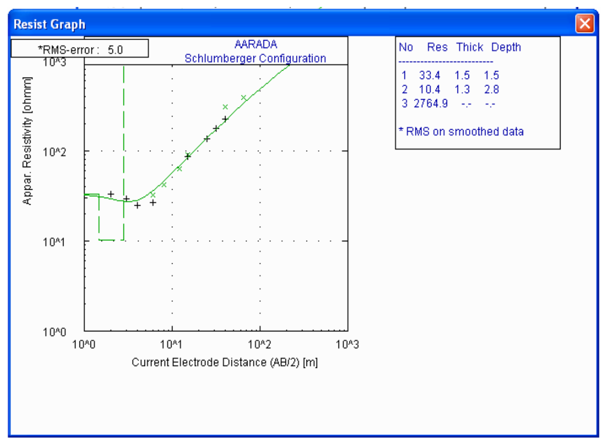

Figure-4. Modeled curve for VES-2.

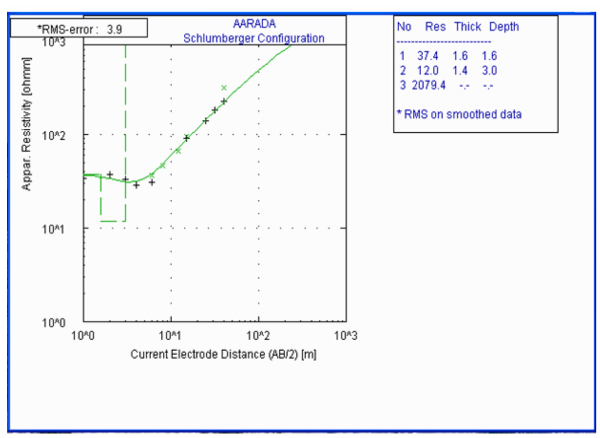

Figure-5. Modeled curve for VES-3.

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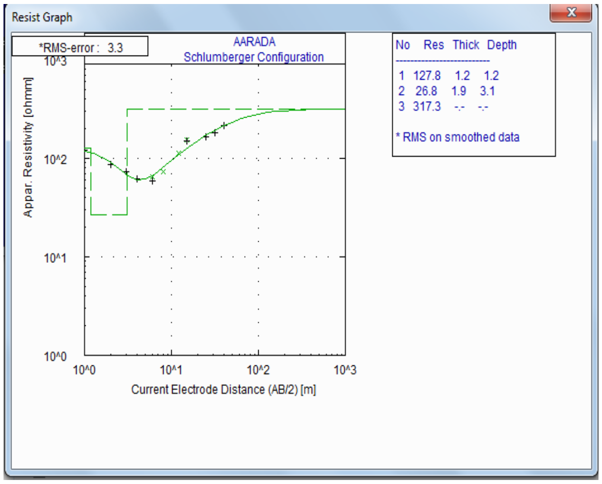

Figure-6. Modeled curve for VES-4.

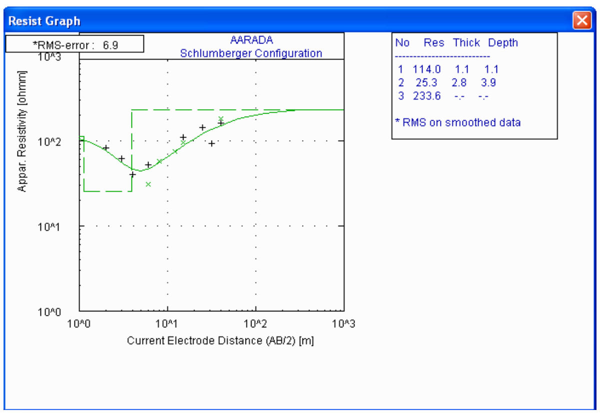

Figure-7. Modeled curve for VES-5.

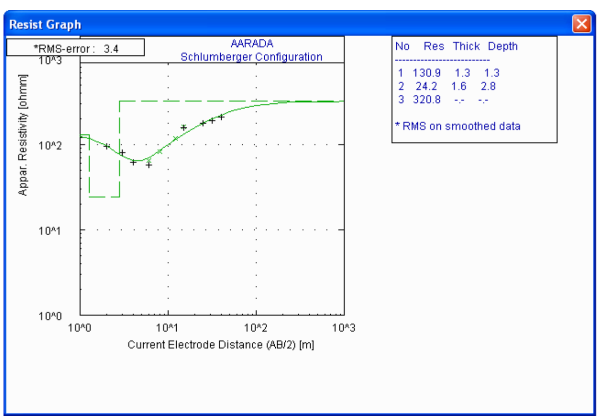

Figure-8. Modeled curve for VES-6.

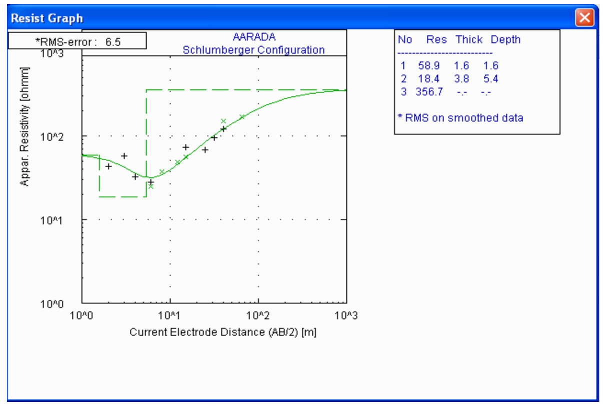

Figure-9. Modeled curve for VES-7.

RESULT AND DISCUSSIONS

The results generated from the VES data interpretation are presented in Figures 10 and 11 as geoelectric sections. The partial curve matching technique carried out on the field data revealed a 3 layered model with H type curve ($\rho_1 > \rho_2 < \rho_3$) 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 130.9Ωm with a relative thickness of 1.1 to 1.6m. The second layer has resistivity values varying from 10.4 to 26.8Ωm 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 encouraging the seepages 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 10.4Ωm. 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.

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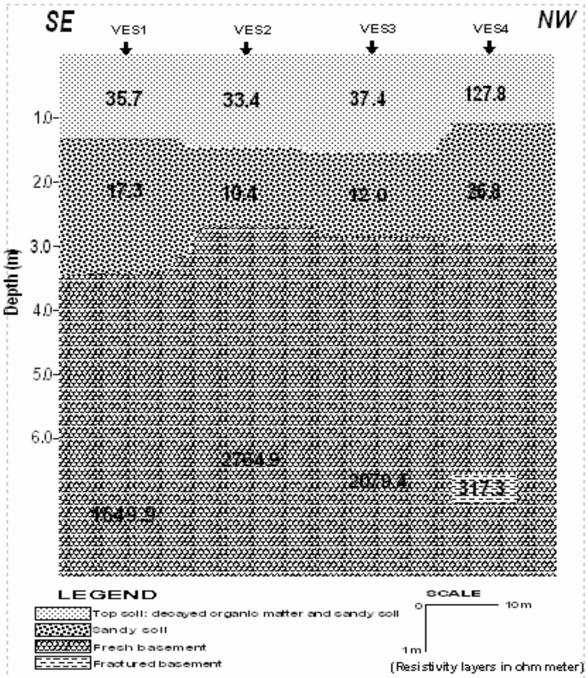

Figure-10. Geoelectric section beneath VES 1, 2, 3 and 4.

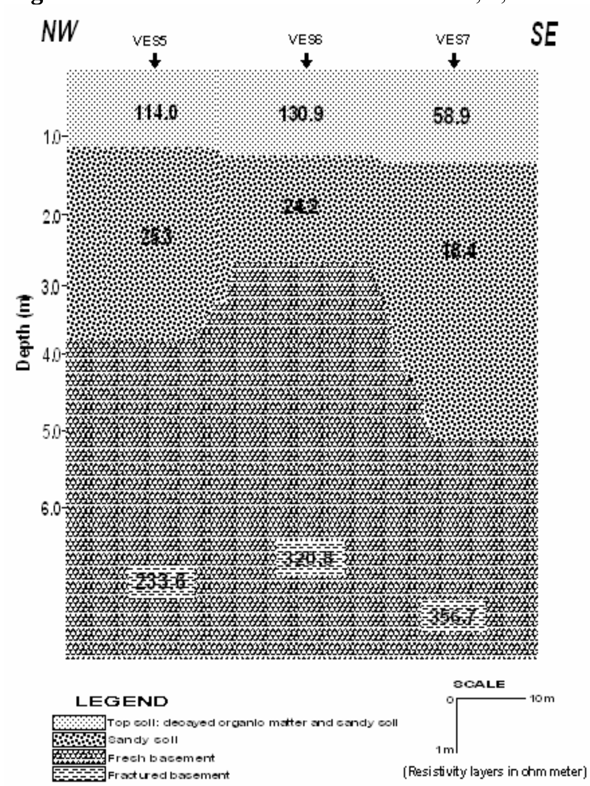

Figure-11. Geoelectric section beneath VES 5, 6 and 7.

HYDRO-PHYSICOCHEMICAL ANALYSIS

The various parameters tested for in the sampled wells show different concentration: from mild to highly hazardous level as presented in Table-1. The World Health Organization (WHO) guidelines were used for assessing the groundwater quality in the research area (Table-2). The result of the assessment revealed that most of the hand dug wells (especially those close to the refuse dump) in Aarada area are fairly acidic, shows anomalously high concentration of TDS, NO_3^-, Cl^- and coliform counts which simply indicates that their usage for domestic purposes without administering necessary treatment in advance will provoke serious health hazard. The depths of the sampled wells and their various distances from the waste disposal site are also presented in Table-1. The hydro-physicochemical analysis conducted showed that wells A, B, C, D and E are in good conditions; the concentration of various parameters tested are within the WHO standard while wells F, G, H and I have high concentration of NO_3^- and total bacteria counts which are attributed to anthropogenic activities. The high concentration of total dissolved solids in most of the samples may be an indication of gradual weathering of the basement rocks.

Waterborne diseases are the most predominant in the study area. 55% of the patients on admission list suffer from typhoid fever; cholera about 25%; gastroenteritis 15% while other disease type 5%. This analysis was made after personal communication with the medical doctors from the health clinic situated within the refuse dumpsite facility. Polluted water is a favourable environment where coliforms group of bacteria (pathogens of most waterborne diseases) breed. The elevated concentration in coliform counts of wells H and I indicates that they are highly polluted with feacal wastes and the domestic usage of these contaminated hand dug wells expose the local community to high risk of infection. However, wells A, B, C, D and E show non-detectable coliform counts which is a reflection of more hygienic environment.

Table-1. Result of the hydro-physicochemical analysis of hand dug well samples carried out during dry season.

Parameters	Well A	Well B	Well C	Well D	Well E	Well F	Well G	Well H	Well I
Depth of wells (m)	5	4.5	4.0	5	4.5	3.5	4	4.3	4.1
Distance of wells from the dumpsite (m)	25	19	15	13	11	7	6	5	3
Colour	Clear, colourless	Clear, colourless	Clear, colourless	Clear, colourless	Light brown	Clear, colourless	Light brown	Light brown	Clear, colourless
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	7.1	7.2	7.3	7.4	7.8	7.6	7.9
Temperature (°C)	26.1	26.1	26.4	27.2	26.9	27.9	28.2	27.5	28.9
Fe^{2+} (mg/L)	0.5	0.5	0.75	0.5	1.5	2.5	4.7	2.4	4.2
Pb^{2+} (mg/L)	0.0	0.001	0.002	0.004	0.005	0.007	0.7	0.009	0.75
Cu^{2+} (mg/L)	0.55	0.52	0.57	0.67	0.5	0.75	0.87	0.8	0.90
Zn^{2+} (mg/L)	1.45	1.3	1.4	1.61	2.20	2.1	2.5	2.0	2.5
K^{+} (mg/L)	10.5	14.5	20.0	16.0	27.5	27.0	70.5	30.5	75.3
Na^{+} (mg/L)	9.45	12.0	15.5	21.85	27.76	20.2	39.5	25.8	45.87
Mg^{2+} (mg/L)	11.54	5.9	12.4	6.6	10.8	17.5	23.0	19.87	24.0
Cl^{-} (mg/L)	5.34	12.5	15.0	25.5	25.67	33.7	60.65	35.85	55.75
SO_4^{2-} (mg/L)	1.75	1.5	1.88	0.75	3.97	4.5	9.75	4.05	10.5
NO_3^{-} (mg/L)	3.56	8.66	12.63	17.75	20.97	51.54	69.95	65.85	70.98
HCO_3^{-} (mg/L)	5.7	5.7	6.0	7.2	9.5	14.8	56.95	14.25	55.97
CN^{-} (mg/L)	0.31	0.25	0.3	0.2	0.35	0.42	0.26	2.45	2.36
Total solids (mg/L)	1490	1440	1490	1470	1560	1680	1780	1690	1790
Total dissolved solids (mg/L)	500	700	840	700	845	740	815	805	900
Suspended solids (mg/L)	1253	1180	1170	1290	1300	1395	1275	1355	1450
DO (mg/L)	77.19	41.65	50.89	66.56	47.87	89.65	101.51	93.73	55.6
BOD (mg/L)	0.01	2.5	2.0	3.5	3.89	4.21	4.20	4.5	5.75
COD (mg/L)	0.22	2.0	2.5	2.25	3.75	3.70	4.0	4.77	5.14
Total hardness (mg/L)	51.12	48.75	22.11	55.76	67.76	51.7	69.54	71.89	71.65
Turbidity (mg/L)	0.0	0.0	0.0	0.0	0.0	0.15	0.25	0.37	0.39
Conductivity (µS)	600	607	607	785	876	1110	1254	1236	1333
THBC (cfu/ml)	4	43	57	69	77	87	570	99	700
THFC (cfu/ml)	Nil	Nil	Nil	Nil	Nil	Nil	3.42	Nil	4.23
Total coliform (cfu/ml)	Nil	Nil	Nil	Nil	Nil	Nil	1.24	0.04	3.1
Feacal coliform (cfu/ml)	Nil	Nil	Nil	Nil	Nil	Nil	1.12	Nil	2.56

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Table-2. Summary of the results of the method employed and WHO standards of 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

Vertical Electrical Sounding method was used to investigate the contamination level and extent in the study area. The analysis of the VES survey revealed that leachate spread out in all direction originating from the part of the 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 for the mean time 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 in order to build on the results from this research because no one can predict the time that the groundwater in the study area will be contaminated. This will enhance continuous consumption of good water quality for some years before the contaminants reach the water table. 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

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compounded. This research work enlightens the residence in and around the dumpsite the danger that lies ahead if they should continue to depend on the existing hand-dug well in the study area. In order to obtain contaminant-free groundwater, government should assist these people to drill boreholes in strategic locations that will surpass the present contamination level. If the government seems that it is waste of money to assist these people, it is suggested that these people should be evacuated from Aarada dumpsite environment and be moved to a new site or enforce law that will ensure they stop dumping refuse in the study area in order to protect their life. However, this integrated approach has been able to reveal the physical properties of a waste disposal site and description of its characteristics.

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