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Delineation of Groundwater Contamination Using Electrical Method at Dump Site in Awka Urban Locality, Anambra State, Nigeria

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Abstract

A resistivity survey was carried out to study the level of groundwater pollution in the dumpsite at Awka Urban Anambra State. Depth, thickness, resistivity, and sediment at which contamination of groundwater occurred were also established. From the analysis, the dump site has four layers, contaminated topsoil, subsoil, rock fragment, and bedrock while the control side has four layers also which are, topsoil, subsoil, rock fragment, and bedrock. The effect of leachates can be seen at the dump site, the first layer (contaminated topsoil) with low resistivity values and this effect tend to affect some distance at the second layer (subsoil). The control site has no effect of leachate which shows high resistivity values at its first and second layer compare to that of the dump site. The iso-resistivity maps also reveal the variation between the dump site and control site, at the 5 m and 10 m plot of the iso-resistivity maps, the dump site (profile A to D), shows low resistivity values compare to the control site (profile E and F). At the 12 m depth, the resistivity values at the dump site and control site tend to be at a similar range, which explains that the effect of leachate disappears at 12 m depth. At 20 m depth, the resistivity values at the control site (Western side of the map) is lower than that of the dump site which could explain the effect of water-bearing materials or weathering of the rocks at that depth.

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INTRODUCTION

General Introduction

About four percent of the earth's water is present in the subsurface as groundwater (Deming, 2002). Because groundwater is a renewable resource, it constitutes a reliable source of water, especially in arid and semi-arid regions where surface water is scarce, seasonal and much of the terrain is hard rock.

Water carries pollutants through the invisible and visible landscape. On the local scale, water-soluble components used in agriculture, industrial refuse, dry waste deposits, etc., may be caught by the water and produce groundwater pollution, which will remain undetected until the polluted water passes through a local well. Similarly, refuse disposed of in the discharge area may be leachate by the water, and ultimately transferred to the river. Effect of pollution may show up further downstream where the river water is being used for some vulnerable purpose like irrigation (Ekeocha, Ikoro, & Okonkwo., 2013).

Refuse (domestic and industrial solid waste) has been from human activities and are not free floating. Poor management of solid waste materials has resulted in many disastrous effects such as aesthetics, environmental hazards, and pollution. Groundwater pollution may also occur due to the potential contamination of leachate from waste. Various methods by which solid waste can be disposed of are open dumps, sanitary landfill, incineration on-site disposal, swine feeding and compositing (Ekeocha et al., 2013).

Groundwater Quality can be defined as the state of physical, chemical and biological water quality. Colour, Temperature, turbidity, and, taste make up the list of physical parameters. Naturally, groundwater contains ions that dissolve slowly from minerals in soils, rocks, and sediments as the water travels along its flow path. Many organization such as the World Health Organization (WHO), have established standards (guideline values) for drinking water and other water parameters.

The Nnamdi Azikiwe University, Awka is a campus in the municipal of Awka town. The community's development is imminent, as the university's presence in this area will necessarily bring the population in the area in the foreseeable future. The geophysical investigation of the area provides useful information on groundwater contamination level. Vertical Electric Sounding (VES) has been the most important geophysical method of water prospecting in sedimentary formation areas. It was therefore chosen to solve the most groundwater problems in different parts of the world because it has been proven to be an economic, quick and efficient way to resolve them (Udensi et al., 2005). The thickness of the overburden can also be estimated using VES method as presented in this work (Udensi, Ojo, & Ajakaiye, 1986).

Aims and Objectives of the study

The aim of this study is to use the electrical resistivity method to detect the possible contamination of groundwater by leachate around Government approved dumpsite in Awka Municipality Anambra State. The research is designed to achieve the following objectives:To determine the resistivity of groundwater in the study area; To determine the depth to the aquifer of the study area; To determine the depth at which the groundwater is contaminated; To determine the potential for leachate intrusion into and consequent contamination of groundwater

Study Area

Awka is the capital of Anambra State, Nigeria, with a population of an estimated 301,657 as of the 2006 census of Nigeria (Gazette, 15 May 2007). Located in the heart of the densely populated heartland of Igbo (in southeast Nigeria), the city is located 9.1 kilometres (123.7 mi), by road, directly north of Port Harcourt (Globalfeed.com., 2006) (Fig. 1).

The study area is located in Awka-South Local Government Area, between latitude $6^0 11^1$N and $6^0 15^1$N, and longitude $7^0 04^1$E and $7^0 09^1$E. It lies below 300 meters above sea level in a valley on the Mamu River plains. Two ridges or cuestas, both in a north-south direction form the area's main topographical features. At Agulu just outside the Capital Territory, the ridges reach the highest point. Approximately six kilometres east of this, the small cuesta peaks at Ifite–Awka about 150 meters above sea level.

Geology of the Study Area

The study area is located within the Anambra Basin, the first region where intensive oil exploration was conducted in Nigeria. Nigeria's sedimentary basin includes; Chad / Borno (North - East Nigeria) Sokoto Basin (northwest Nigeria), Benue Trough and Bida Basin, Anambra Basin, Dahomey (Benin Basin), and Niger Delta Basin. These entire basins are made up of different lithologies, formed at different times and have different mechanisms responsible for their formation (Obaje, 2009). All basins consist of one or more mineral resources (industrial, metallic and fossil fuel energy) being exploited for national development.

The Anambra Basin is a Cretan/Tertiary Basin, the structural link between the Cretan Benue Trough and the Delta Basin of the Tertiary Niger (Lucas & Ishiekwene, 2000). It is bordered by the Abakaliki anticlinorium to the east, the rock basement and the Benue hinge line to the north and northwest respectively (Fig. 2). The basin originated as a fault-controlled depression within the African shield basement complex. It's an internal fracture basin structurally. The Benue Trough and its echelon equivalent, the Abakaliki Trough, have experienced maximum sedimentation in the depression. During Coniacian-Santonian times, however, there was a structural reversal of the Abakaliki Trough. This move led to two depression on the anticlinorium flanks; the narrow syncline of Afikpo to the south-east and the far wider Anambra basin to the north-west (Grant, 1971; Lucas & Ishiekwene, 2000; Murat, 1970). The stratigraphic history of this region is marked by three sedimentary phases in which the sedimentary axis was changing (H. O. Aboh & I. B. Osazuwa, 2000). These three phases consisted of: the phase Abakaliki-Benue (Aptian to Santonian), the phase Anambra-Benin (Campanian to Mid Eocene), and the Niger Delta phase (Late Eocene-Pliocene).The area of study lies within Nigeria's tropical rainforest belt, but the current vegetation is mostly shrubs, grasses, and perennial trees as a result of the settlement and other human activities (Ekeocha et al., 2013) and fertile tropical valley. In places like the Ime Oka shrine, a few examples of the original rain forest remain are still available. Wooded savannah grassland predominates mainly to the city's north and east. South of the town on the Awka-Orlu Uplands slopes are some examples of soil erosion and gullies. The rainy season starts from April to October with a mean annual rainfall of about 2000mm. The dry season extends from November to March, in between this period haematin occurs and it is characterized by high temperature and dusty atmosphere.

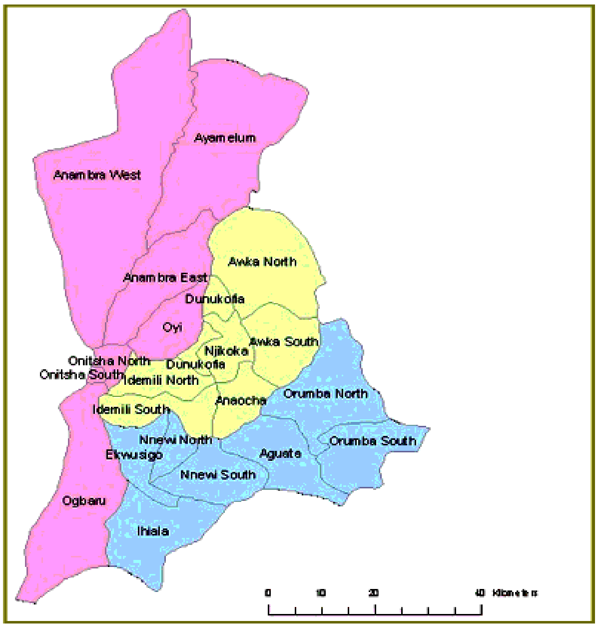

Figure 1. Map of Anambra showing the study area.

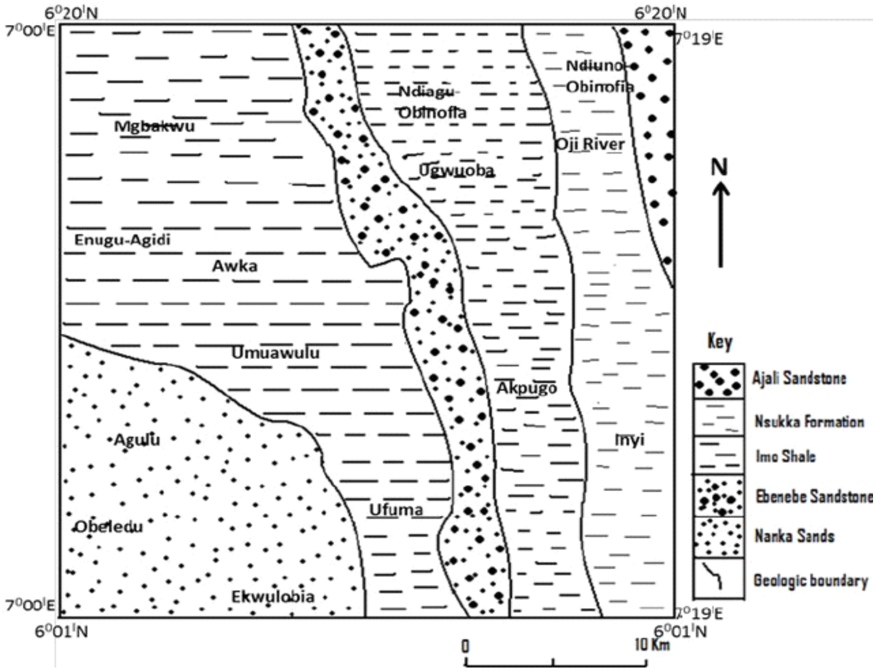

Figure 2. Geology Map showing the Study Area (Anakwuba, Nwokeabia, Chinwuko, & Onyekwelu, 2014).

DETAILS EXPERIMENTAL

Materials and Procedures

Vertical Electrical Sounding is also known as electrical drilling or 'expanding probe'. It is used mainly in the study of horizontal or near horizontal interfaces (Ehirm, Ebeniro, & Olanegan, 2009). Because of the fraction of total current that flows at depth varies with the current electrode separation, the field procedure is to use a fixed centre with an expanding spread and the whole spread is progressively expanded about a fixed central point. This causes the current lines to penetrate to an ever-greater depth depending on the vertical distribution of conductivity.

The goal is to observe the variation of resistivity with depth. This technique is best adapted to determine depth and resistivity for flat-lying layered rock structure such as sedimentary beds, or the depth to the water table. It is also used in geotechnical surveys to determine overburden thickness and also in hydrogeology to define horizontal zones of porous strata.

The geo-electrical method used in the survey is Vertical Electrical Sounding (VES), VES was conducted using the Schlumberger configuration and Horizontal spread covering the entire area. The array of the Schlumberger consists of four collinear electrodes (Fig. 3). The two outer electrodes are current (source) electrodes, and the two inner electrodes are the potential (receiver) electrodes (Hassan, 2018). The potential electrodes are installed with a small separation in the centre of the electrode array, typically less than one - fifth of the spacing between the current electrodes. During the survey, the current electrodes are increased to greater separation while the potential electrodes remain in the same position until too small to measure the observed voltage (I, 2013). The advantages of the Schlumberger array are that for each sounding fewer electrodes need to be moved and the cable length for the potential electrodes is shorter. Schlumberger soundings generally have better resolution, greater sampling depth, and less time - consuming field deployment than the Wenner array. The difficulties are that long current electrode cables are required, the recording instrument needs to be very sensitive, and the array can be difficult or confusing to coordinate among the field crew (Zonge, Figgins, & Hughes, 1985).

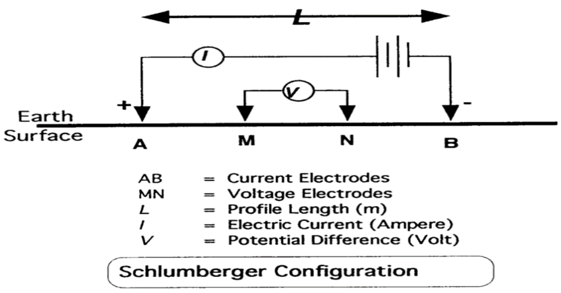

Figure 3. Shows the detailed Schlumberger Configuration Arrays.

A total of 36 VES soundings points performed in the field (fig. 4), with a spread of 100 m (AB/2). The resistivity on the subsurface was recorded using an ABEM Terrameter SAS 300c and the Ohmega campus digital resistivity meters. VES procedures in the field were employed (Aboh, 1996). The Schlumberger configuration, (O. H. Aboh & I. D. Osazuwa, 2000) shows how to use the Schlumberger array to determine the apparent resistivity using the equation below,

$$\rho = \frac{2\pi \Delta V}{I}\left(\frac{L^2 - a^2}{a}\right)$$

Where:

ρ = Apparent resistivity

L = distance between their mid points

ΔV = Potential difference

I = current

α = the spacing of the electrodes in each pair

The resistivity curves were then interpreted using computer interpretation program for Schlumberger sounding data modified after (Zohdy & D. B. Jackson, 1989). The VES curves were generated from the partial curve matching technique and were refined by computer iteration Window-Based Application software to get subsurface information. The electrical profiling curves were also interpreted qualitatively with the mapped surface geology.

RESULTS AND DISCUSSION

Data Analysis

The apparent resistivity in ohm-metre determined using equation above from the data collected from the thirty – six vertical electrical soundings was further analysed in plotting of iso-resistivity at 5 m, 10 m, 15 m and 20 m for the thirty-six point using Surfer8.

Table 1. Range of Resistivity values for various rock types In Sedimentary Formation used in driving The Geologic Sections. Compiled by (Ekeocha et al., 2013).

Rock Type	Range of Resistivity (M)
Granite	$300 - 10^5$
Top Soil	1 – 100
Gravel	100 – 1500
Alluvium and sand	10 – 800
Quartzite (various)	$10 - 2 \times 10^8$
Gnesis	$10^5 - 10^7$
Schist	$10 - 10^4$
Sub Soil	$10 - 5 \times 10^3$
Rock Fragments	$1 - 30 \times 10^4$
Bed Rock	$> 10^6$

Analysis of the Iso Resistivity Contour Map at 5m Depth

The contour map in Figure 4 at 5m depth with a contour interval of 10 **Ω**m shows variation in resistivity values. At dump side (profile A to D), shows resistivity values ranging from 0-40 **Ω**m with progressive variation in resistivity values towards the control side (profile E and F). The contact boundary between the dump site and control site revealed parallel contour lines with resistivity values ranging from 50- 100 **Ω**m. The control side shows resistivity values ranging from 150- 180 **Ω**m. The low resistivity values at profile A to D indicate the effect of the leachate on the resistivity values while the high resistivity values profile E and F indicate the absence of leachate.

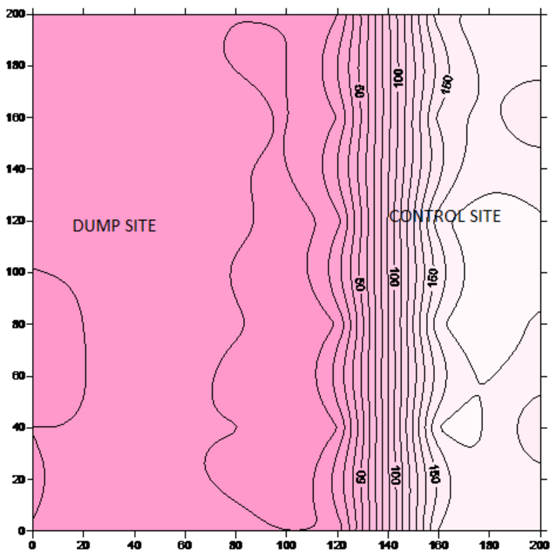

Figure 4. Iso Resistivity Contour Map at 5m Depth

Analysis of the Iso resistivity Contour Map at 10m Depth

Similarly, Figure 5 at 10m depth with a contour interval of 10 **Ω**m shows variation in resistivity values. At dump side (profile A to D), shows resistivity values ranging from 40-260 **Ω**m, the resistivity values increases with depth due to a decrease in the effect of leachate. The contact boundaries between the dump site and control site also exhibit discontinuity in contour lines, with resistivity values ranging from 150-390 **Ω**m. The control side shows resistivity values ranging from 400-500 **Ω**m. The south-western part of the contour map still exhibits low resistivity values which indicate the effect of leachate or weathered rock.

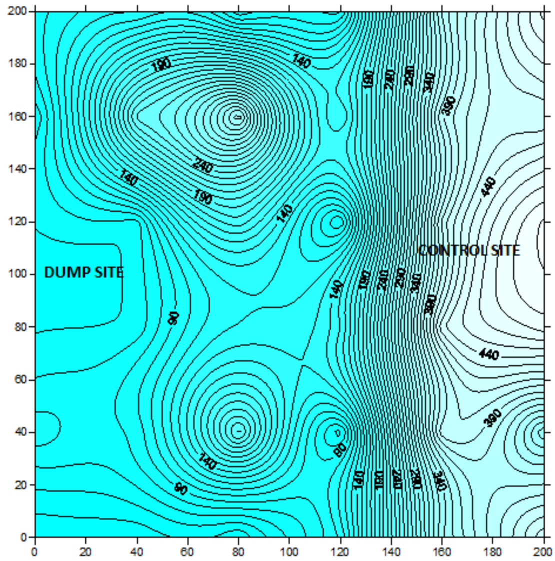

Figure 5. Iso-Resistivity Contour map at 10m depth

Analysis of the Iso Resistivity Contour Map at 12m Depth

The map at Figure 6 shows the contour at 12m depth, which trends are normalized and low resistivity values at both the dump site and control site, which reveals that there is no effect of leachate plumes at 12 m depth.

The resistivity values at both sides are similar; this explains that, the effect of leachate stop at the depth of 12 m

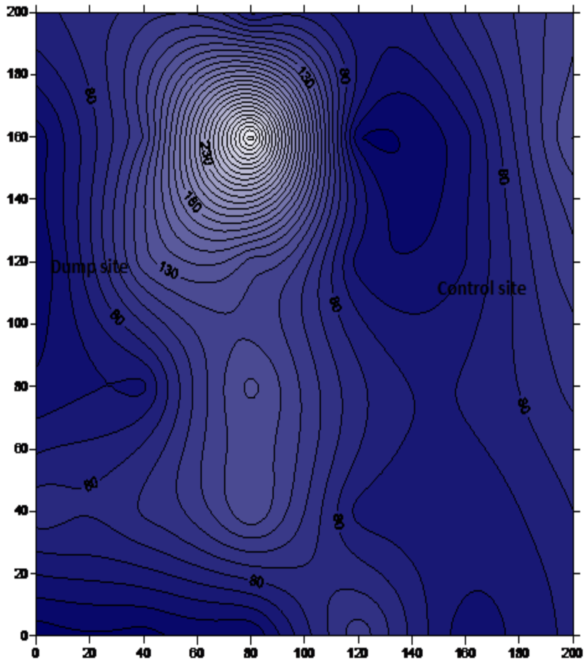

Figure 6. Iso-Resistivity Contour Map at 12m Depth

Analysis of the Iso Resistivity Contour Map at 20m Depth

The iso-resistivity contour map in Figure 7 shows that the trend at 20 m depth with a contour interval of 20 m to be flowing normally. The trends here clearly look the same all through, this explains the total disappearance of the leachates plumes at the refuse dump side (NE and SE). From the map we can say both sides of the study area, dump site and control site have the same trend of contour. No sign of leachate plumes at the depth of 20 m.

Towards the lower part of the contour map (SE), shows that the side is viable for good water potential.

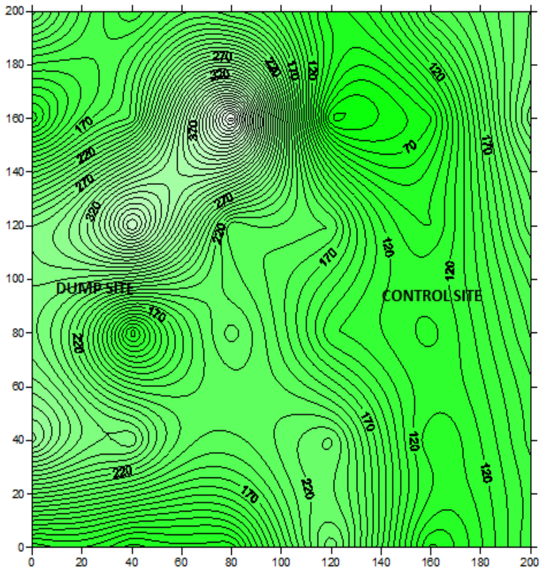

Figure 7. Iso-Resistivity Contour Map at 20m Depth

Comparison of the two Site and their Geo-electric and Geologic Sections

Looking at the two geo-electric sections we can state that the dump site has three subsurface and the control site with four subsurface, the refuse dump at the top of the dump site with lower apparent resistivity affect the subsoil following it and it tends to reduce it apparent resistivity also. While for the control site the first layer which is the topsoil has a high apparent resistivity compare to the first layer of the dump site. Comparing the rock fragments of the two sites it shows that the effect of leachate disappear, which explain that the leachate effect stop at a depth around 12 m. Deduction from the iso-resistivity map also shows that the effect of leachate at the dump site gives rise to the low resistivity values at 5 m and 10 m respectively compare to the high resistivity at the control. At the 12m depth iso-resistivity map, the effect of leachate disappears.

DISCUSSION

From the analysis, the dump site has four layers, contaminated topsoil, subsoil, soil fragments, and bedrock while the control side has four layers also which are, topsoil, subsoil, soil fragments, and bedrock. The effect of leachates can be seen at the dump site, the first layer (contaminated topsoil) with low resistivity values and this effect tend to affect some distance at the second layer (subsoil). The control site has no effect of leachate which shows high resistivity values at its first and second layer compare to that of the dump site.

The iso-resistivity maps also reveal the variation between the dump site and control site, at the 5 m and 10 m plot of the iso-resistivity maps, the dump site (profile A to D), shows low resistivity values compare to the control site (profile E and F). At the 12 m depth, the resistivity values at the dump site and control site tend to be at a similar range, which explain that the effect of leachate disappears at 12 m depth. At 20 m depth, the resistivity values at the control site (Western part) is lower than that of the dump site which could explains the effect of water-bearing materials or weathering of the rocks at that depth.

The effect of leachate on the dump site extends to about around 11 m depth, this means the subsoil is affected which also suggest that the groundwater at the dump site is affected also. After all the analysis and discussion, we can clearly say that the dump site is affected by leachate with variation to depth and the control site has no effect of leachate.

CONCLUSIONS

The study attempts to analyse the direct current (DC) resistivity data collected over the refuse dumpsite in Awka-Nibo ring road. Thus the following findings were obtained from the study:

This work had been able to contribute to the efforts of groundwater protection, and that Vertical Electrical Sounding effectively detected the leachate plume.

Four geologic sections were delineated; the topmost layers consist of thick clayey soil. This formation is followed in succession by subsoil zone, rock fragments, and bedrock. Qualitative interpretation of the data collected on the control site has revealed that the sub/rock fragments zones constitute the main aquifer unit from the vertical electrical sounding results; the depth of water table in the study area varies between 5.3m and 13.2m. This is due to variations in the thickness of the subsoil zone and intensity of weathering.

The second layer for all the vertical electrical sounding points collected on the dumpsite show low resistivity values (9.5**Ω**m–20.3**Ω**m) which could be attributed to contamination of the groundwater as a result of leachate accumulation or presence of in-situ weathered clay material.

From these findings the ground water at the dump site is contaminated, because from the observation that leachate plume emanates from the dumpsite and migrates along down towards the second layer. The movement of the leachate stop around the 12m depth; this is possibly controlled by subsurface geology.

From this result, we can conclude that leachate plumes contamination affects the groundwater to the depth of 12m.

RECOMMENDATION

It has become of particular importance to assess the status of working and abandoned dumpsites and especially in areas where dumping sites do not fulfill the minimum environmental standards in terms of site selection, design, and management, in such areas, wastes are disposed inadequately and randomly in an abandoned area without any application of wastes separation techniques or the use of liners, resulting in the percolation of leachate to the groundwater.

Based on the limitation and findings of this study, it is recommended that:

Another geophysical method such as induced polarisation could be used to survey the study area to confirm the findings of this study, and the results of both techniques could later be verified using boreholes and hydrochemical analysis.

Effective remediation measures must be put in place to reduce the further environmental hazard from the refuse dumpsites.

Also, the populace should be sensitized on the danger of drinking leachate contaminated groundwater.

Finally, the government should further enforce an existing ban on refuse dumping to prevent illegal local disposal of wastes.

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