

# A Comparative Investigation of Groundwater Contamination in Typical Dumpsites and Cemetery Using Ert and Physicochemical Analysis of Water in Benin Metropolis, Nigeria

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**How to cite this paper:** Idehen, O. (2020). A Comparative Investigation of Groundwater Contamination in Typical Dumpsites and Cemetery Using Ert and Physicochemical Analysis of Water in Benin Metropolis, Nigeria. *Journal of Geoscience and Environment Protection*, 8, 72-85.

<https://doi.org/10.4236/gep.2020.81005>

**Received:** June 29, 2019

**Accepted:** January 13, 2020

**Published:** January 16, 2020

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## Abstract

This paper investigated the comparative analysis of groundwater contamination in Third Cemetery and Costain Dumpsite in Benin Metropolis, South South of Nigeria, using Electrical Resistivity Tomography (ERT) and Physicochemical analysis of water. The implications of land utilization for burial of dead human bodies in the form of cemeteries, many cases associated with coffin and caskets used for interment of remains and the location of refuse dump have received no consideration in Nigeria. Interment of bodies in cemeteries and dumping of refuse in dumpsites remain widespread practice and the only alternative endpoint to dead bodies and disposal of wastes in Nigeria. In Nigeria, this practice had not been perceived as having a significant potential contaminant effect in the environment and especially the groundwater component as search of literature attracted no such study to the country. In Benin City and Nigeria in general, the major cemeteries and dumpsites are located close to human residential areas and virtually all the populace within this locality depends on groundwater as the primary water source for various domestic purposes. Res2Dinv was employed in both sites as the geophysical method. The investigation of cemeteries is always difficult and challenging task in geoforensic prospective. Most researchers assess the impact of interment on the environment by comparing study results from cemeteries with data from reference sites. This study is based on this premise. The 2-D Geological Models showed that both Third Cemetery and Costain Dumpsite contained leachate plumes of various degrees as indicated by the low resistivity values, which infiltrated into the groundwater. The values of Water Quality Index (WQI) of groundwater samples in Third Cemetery and Costain

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Dumpsite were found to be 13.40 and 21.58 respectively which indicated that the quality of water at both Third Cemetery and Costain Dumpsite were good for drinking and other domestic purposes though with some degrees of contamination.

### Keywords

Dumpsite, Cemetery, Contamination, 2-D Geoelectric Model, Physicochemical Groundwater

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## 1. Introduction

Groundwater is an important freshwater resource in both the urban and rural areas of Nigeria (Adekunle et al., 2007). It is a valuable resource often considered for industry, commerce, agriculture, and domestic uses (most importantly for drinking). Various literatures have established a close relationship between land use and groundwater quality (Edet, 1993; Ikem et al., 2002; Majolagbe et al., 2011). Based on land use, sources of groundwater contamination include leachate from municipal refuse dumpsite, industrial discharge (liquid waste), domestic waste, salt water intrusion, application of agricultural chemicals, oil spillage and pipeline vandalisation and geological formations (Majolagbe et al., 2011). The issues of necroleachate represent a matter of concern because groundwater can be contaminated by such as they are laden with bacteria, viruses, nitrogen (N), phosphorus (P) (Neckel et al., 2016), and heavy metals and other toxic substances resulting from the decay of coffin material (Spongberg & Becks, 2000; Jonker & Olivier, 2012). These may be transported from the graves through seepage and percolate into surrounding soils and from there they may leach into groundwater and become a potential health risk to the residents depending on the contaminated water for various uses. The risk of contamination is influenced by soil nature and infiltration rate, types of burials, and the effect of rainfall on the groundwater level (Üçisik & Rushbrook, 1998). Ucisik and Rushbrook (1998) also expressed that existing cemeteries in Benin City were sited without due consideration for the local environment and population dynamics. In some part of Benin City residential buildings exist as close as 5 m to the cemetery in some cases, and an example is the sitting of Third Cemetery at New Benin district.

The identification of individual graves through geophysical techniques is relatively problematic and thus in the prospection of cemeteries and graves, there are no rules or specific guidelines. The success of such a survey depends on the conservation of the graves, the various artifacts that may accompany a burial, the depth and dimensions of the burial, the environmental noise, the geology, etc. (Idehen, 2018). Studies on the impact of cemeteries and dumpsites on the quality of groundwater in unsaturated and saturated zones are usually conducted within or at some distance from the cemeteries and dumpsites (Schrap, 1972; Zy-

chowski et al., 2000). Over 40% of cemeteries in South Africa contaminate water resources (Fisher & Croukamp, 1993).

## 2. Study Area (Third Cemetery and Costain Dumpsite)

This study was conducted in Benin City located in South-South geopolitical zone of Nigeria. Benin City is the capital of Edo State, bounded by latitudes  $06^{\circ}06'N$ ,  $06^{\circ}30'N$  and longitudes  $005^{\circ}30'E$ ,  $005^{\circ}45'E$  and an area of about 500 square kilometers (Idehen, 2019). The city is located within the rain forest ecological zone with annual mean temperature of  $27.5^{\circ}C$  (Ikhuoria, 1987) and an annual mean rain fall of about 2095 mm (Ikhile & Olorode, 2011).

### 2.1. Third Cemetery

Three cemeteries namely First, Second and Third cemeteries are located within this city. The Third cemetery which has existed for over 50 years was considered for this study because of its proximity to human residents. The cemetery which is the biggest among the cemeteries in Benin City covers an area of about 5.167 ha (Ibhadode et al., 2017; Idehen, 2019). Water sample was collected in the periphery of the cemetery (Site 1) used for the physicochemical analysis of water.

Site, S1, from New Benin Police Station that was carved out of the cemetery (S2 -  $N06^{\circ}21.357 E005^{\circ}37.721$ ).

Geological siting of Benin City is underlain by sedimentary formation described by Short and Stauble (1967) (Figure 1).

### 2.2. Costain Dumpsite

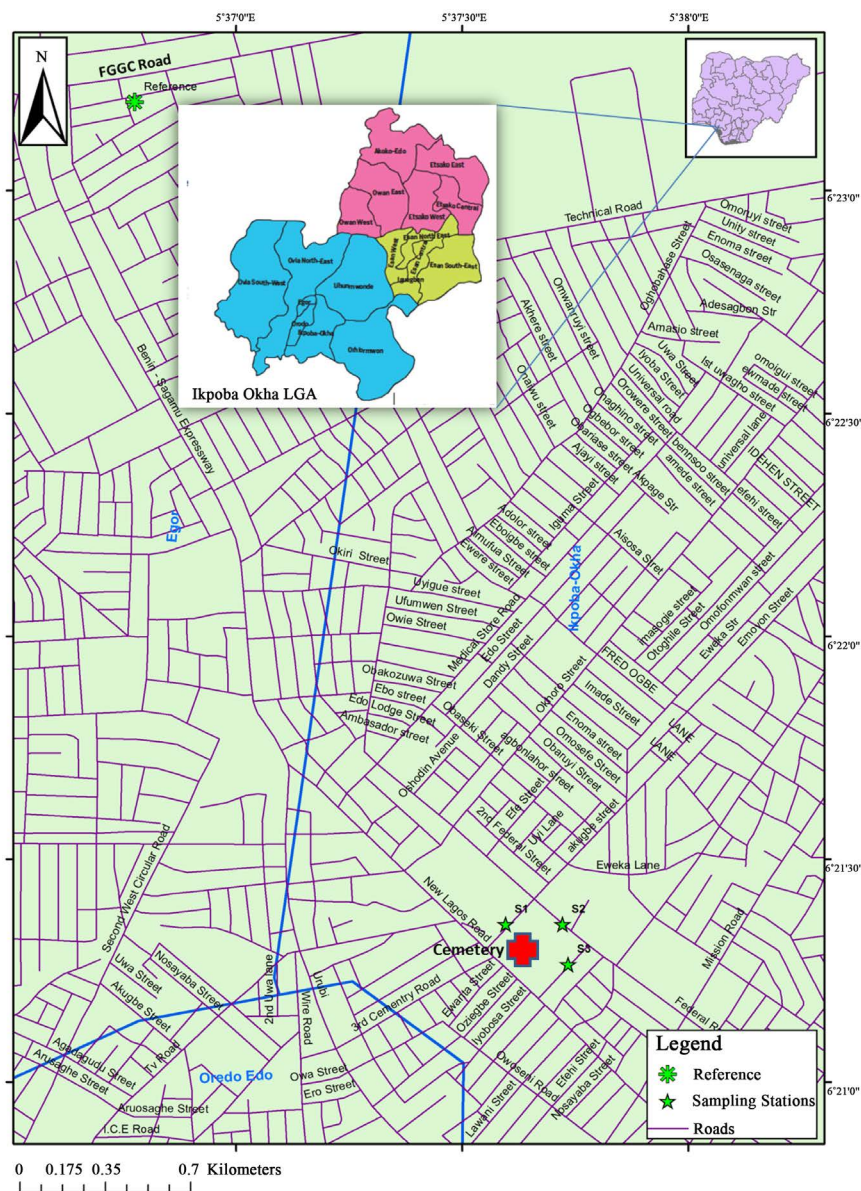
This dumpsite was located at the end of Costain Road, Off Upper Mission Road, adjacent to New Benin Market about 2 km from Third Cemetery. It terminates at a valley that cuts across Ikpoba Slope. The GPS of this dumpsite gave the following:  $N 06^{\circ}20'56''$  South of Benin,  $E 005^{\circ}38'15''$  +/- 12 ft, Elevation 211 ft, Odometer 68.56 m (Idehen, 2018).

## 3. Materials and Methods

Electrical resistivity imaging data was acquired using Pasi Earth Resistivity Meter. The data coverage was made over an area defined by rectangular loop measuring 30 m by 200 m. The electrical resistivity data was collected in seven equidistant lines as 2-D data set using Wenner-Schlumberger Array at 5 m interval in both periods. The first survey, the inter-electrode spacing in each line was 10 m while in the second survey was 5 m. The resistance values read from the measuring instrument was then transformed to apparent resistivity using the geometrical factor each sequence of measurement. Wenner-Schlumberger spread was used.

### 3.1. Field and Laboratory Analyses

In order to characterize the physicochemical parameters of the water and further ascertain the suitability of these groundwater resources located near the



**Figure 1.** Map of study area (third cemetery and costain dumpsite).

cemetery and the dumpsite, equal replicate of water samples were collected from borehole located at the peripheral of the cemetery and dumpsite. At each of the boreholes, the discharge pipe of the boreholes was swabbed with cotton wool soaked in 70% ethanol and water samples were collected after flushing for 4 to 5 minutes. Sample for determination of other parameters other than in situ parameters, heavy metals component was collected with 1 litre plastic bottles. Sample for heavy metal determination was collected in acid washed polyethylene bottles. All samples collected were labeled properly and stored in iced coolers ( $0^{\circ}\text{C} - 4^{\circ}\text{C}$ ). The samples were immediately taken to the laboratory and analyses were done within 24 hours of sample collection. In situ parameters including; electrical conductivity (EC), hydrogen ion concentration (pH) and total dissolved solids (TDS) were determined with the aid of Extech meter probes (Exstik II). In the laboratory, the

analysis of other parameters including total suspended solids (TSS), calcium, magnesium, sulphate, nitrate, phosphate, chloride, calcium carbonate ( $\text{CaCO}_3$ ), sodium, potassium, lead, copper, chromium, iron, zinc, manganese, cadmium, nickel, mercury, dissolved oxygen (DO), biochemical oxygen demand ( $\text{BOD}_5$ ), chemical oxygen demand (COD) were done using standard methods adopted from APHA (1998); (Radojevic & Bashkin, 1999, Idehen, & Ezenwa, 2019).

### 3.2. The Wenner-Schlumberger Array

This array is the hybrid between the Wenner array and the Schlumberger array arising out of the recent work with electrical imaging surveys. This array is moderately sensitive to both horizontal structure and vertical structures (Loke, 2014) (Figure 2)

$$K = a n \pi (n + 1) \quad (1)$$

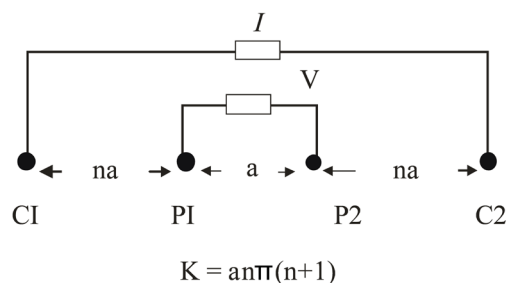
$$\rho = KR \quad (2)$$

That is apparent resistivity equals geometric factor times resistance.

$$C_1 \leftarrow na \rightarrow P_1 \leftarrow a \rightarrow P_2 \leftarrow na \rightarrow C_2 \quad \{K = a n \pi (n + 1)\}$$

### 3.3. Field Data Processing and Interpretation in Costain Dumpsite

Res2Dinv software was used to process the data with Geoelectric images consisting of four graphs in each figure. The upper modeled (measured apparent resistivity pseudosection) with the raw apparent resistivity. The second graph represents model of the computer generated apparent resistivity data (calculated apparent resistivity pseudosection). These two graphs are termed pseudo section. The third graph (inverse model resistivity section) is produced with the inverted apparent resistivity data, which is the true subsurface resistivity. The third graph is what is used to deduce the geological make-up of the surveyed depth range. The model resistivity (true subsurface resistivity) data was exported to surfer window and then the resistivity pictures were transformed to geological ones. Sand image was used to show the background subsurface sediment imaged (the fourth graph-geology section), while red colour shade was used to define the area suspected to be contaminated by leachate plumes (less than 100 Ohm-m), assuming clay is absent in the sediment, dominantly sand.



**Figure 2.** Wenner-Schlumberger Array (Anthony Ravindran & Mohd. Abdul Kadar Prabhu, 2012).

## 4. Results (Table 1)

### 4.1. Physicochemical Analysis of Water in Costain Dumpsite

The groundwater sample at Costain was slightly acidic and the pH was 6.200. According to Omoboriowo et al. (2012), acidity is probably caused by the presence of organic matter in the soils. Moreover, free CO<sub>2</sub> from the atmosphere can also enter the groundwater system as rainwater percolates underground and reduce the pH of the water.

Conductivity is the ability to conduct electricity, heat or sound. Pure water is a bad conductor of electricity. Conductivity increases as the concentrations of ions in water sample increases. The conductivity value at Costain was 99.900 µS/cm. This value was far below the stipulated value of 1000 µS/cm by NIS (2007). Conductivity also is a product of dissolved solids in water. The value of total dissolved solids at Costain was 53.000 mg/l compared with NIS (2007) stipulated value of 500 mg/l.

Also the concentrations of calcium and magnesium did not differ significantly ( $p > 0.05$ ). The concentration of calcium was greater than that of magnesium. Similar trend was observed by Omofonmwan and Esegbe (2009). The concentrations of magnesium did not compare favourably with the NIS (2007) stipulated value of 0.2 mg/l; measure has to be adopted to reduce the concentration of magnesium in order to avoid the incidence of stomach irritation.

**Table 1.** Summary of selected physicochemical analysis of groundwater in a typical dumpsite and a typical cemetery.

<i>Parameters</i>	<i>Costain dumpsite</i>	<i>Third cemetery</i>	<i>Reference site</i>	<i>Nis (2007)</i>
pH	6.200	4.960	6.800	6.50 - 8.50
Conductivity (EC)	99.900	118.000	12.000	1000.000
Total Dissolved Solid (TDS)	53.000	59.000	6.300	500.000
Calcium	2.400	3.840	2.400	NA
Magnesium	1.900	1.150	3.000	0.200
Sulphate	5.000	0.170	0.430	100.000
Nitrate	3.130	0.290	0.080	50.000
Phosphate	0.090	0.640	0.240	NA
Chloride	21.300	44.520	18.400	250.000
Lead	0.005	0.010	0.000	0.010
Chromium	0.004	0.010	0.010	0.050
Zinc	0.040	0.020	0.020	0.300
Iron	0.060	0.040	0.080	0.300
Cadmium	0.000	0.000	0.000	0.000
Mercury	0.000	0.000	0.000	0.000

**NA:** Not Available; **NSDWQ:** Nigerian Standard for Drinking Water Quality (NIS, 2007). All parameters except **pH** and **EC** were measured in *mg/l*; **EC** was measured in *µS/cm* and **pH** in *moles/liter*.

The anions analyzed among the sites include chloride, sulphate, nitrate and phosphate. Furthermore the concentrations of chloride (21.300), sulphate (5.000) and nitrate (3.130) at the site were far below NIS (2007) stipulated values of 250 mg/l, 100 mg/l and 50 mg/l respectively.

Cadmium, iron, lead, chromium and zinc were among the heavy metals analyzed in this study. Heavy metals are toxic and poisonous in relatively higher concentrations. Two factors contribute to the deleterious effects of heavy metals as environmental pollutants. Firstly, they cannot be destroyed through biological degradation as in the case of most organic pollutants. Secondly, they are easily assimilated and can be bioaccumulated in the protoplasm of living organisms (Egborge, 1994). The concentrations of the heavy metals individually did not differ significantly ( $p > 0.05$ ) the site, the concentrations of all the heavy metals except lead compared favourably with NIS (2007) stipulated values. Concentration of cadmium likewise chromium was undetectable in the groundwater sample obtained from site. Concentrations of zinc and iron were slightly lower at Costain. The concentration of lead was less than the NIS (2007) stipulated value of 0.01 mg/l. Lead is the most common environmental contaminant found in soils. Unlike other metals, lead has no biological role, and is potentially toxic to even microorganisms (Sobolev & Begonia, 2008). Its excessive accumulation in living organisms is always detrimental. Furthermore, lead exposure can cause seizures, mental retardation, and behavioural disorders in human beings (Adelekan & Abegunde, 2011). The Water Quality Index (WQI) values computed for groundwater sample obtained from the Costain environ was 21.58.

Most of the ions in water and other matrix of the environment become pollutant at certain concentration; furthermore the adverse effects of some of these ions including ions of heavy metals which can be accumulated (Egborge, 1994) are of serious health concern. The accumulation of heavy metal in the human body could result to malfunctioning of organs (Jarup, 2003). Cr has been identified as carcinogenic agents, Cd as nephrotoxic agent and Pb as neurotoxic and enzyme inhibitor (Ernest, 2010). The concentration of nitrate is of concern because of its toxicity. Nitrate concentrations greater than 10 mg. NO<sub>3</sub> in drinking water have been known to cause methaemoglobinemia in infants, a disease characterized by cyanosis, a bluish colouration of the skin, the so-called "blue-baby" syndrome. Infants up to three months old are especially prone to this disease (Radojevic & Bashkin, 1999). According to Ramakrishniah et al. (2009) the quality of groundwater at Costain peripheral was evaluated as being excellent and good for human consumption (Idehen, 2018).

#### 4.2. Physicochemical Analysis of Water in Third Cemetery

The groundwater was slightly acidic at Third Cemetery (4.960) except at the Reference Site; electrical conductivity (EC), total dissolved and total suspended solids, nutrients including nitrate and phosphate, the alkali metals, heavy metals (excluding iron values which were high in the reference sites and cadmium and

mercury which were not detectable in the water sample) values were low in the water sample obtained from Site. Generally chloride was the dominant anion on the site water sample, while the least of the same group were sulphate and nitrate for cemetery peripheral sites and reference site respectively.

The Water Quality Index (WQI) varied significantly ( $p < 0.05$ ) while considering the parameters used in the computation. The values obtained while including all the parameters in the computation was 13.40

The common parameters influenced by decomposing activities in cemeteries include pH, EC, Cl, NO<sub>3</sub>, SO<sub>4</sub>, P, Na, K, Ca and Fe (Üçisik & Rushbrook 1998; Young et al., 2002; Sawyer et al., 2003; Tredoux et al., 2004; Idehen & Ezenwa, 2018). With the exception of pH, SO<sub>4</sub> and Fe the other parameters including Cl, NO<sub>3</sub>, Na, and K were generally higher in the groundwater samples obtained from the cemetery peripheral when compared to the Reference Site. Furthermore, Tredoux et al., (2004) suggested the inclusion of Mn, Cd, Cr, Cu, Ni, Pb and Zn at high risk sites; these heavy metals especially Pb, Mn, Cu, Ni and Zn were the most influencing parameters relating to the cemetery. These changes together with other variations discussed above can be seen as clear indications of the impact of the decomposing activities in the cemetery upon the quality of the water in aquifer underlain the area.

## 5. Discussion of Geophysical Tomography in Third Cemetery

The acquired two-dimensional electrical resistivity data covered section of the surface laterite, fine sand just below it, very coarse sand and section of medium sand. The sandy formation is porous and highly permeable, and hence the flow leachate through it is rapid. The clay layer at depth of 46 m (152 ft) underlain the well sorted coarse sand impede further downward migration of leachate plume and hence the coarse sand is most likely saturated with water forming the unconfined aquifer. The water table likely occurs between the very coarse sand and medium sand. As leachate plume is detected in the medium sand, water in the well sorted coarse sand will be contaminated. Laboratory analysis (at the Elite Environmental Consultants and Laboratories Ltd.) of the water sample taken from borehole in the vicinity (NEW BENIN POLICE STATION ) show high Electrical Conductivity (EC). These abnormal values probably due to leachate plumes released into the shallow aquifer serving as the regional water supply source. If this shallow aquifer is polluted, there is high probability that the nearby deep confined, coarse sand aquifer at depth of 60 m (200 ft) is at risk (if the protection capacity of the underlain clay is not satisfactory). The repeated resistivity survey revealed displacement of the detected plumes over a time. The geoelectric models obtained for the survey displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source) (Idehen, 2018).

**2-D Geoelectric Models of Typical Cemetery and Typical Dumpsites (Figures 3-8) (Idehen, 2019).**



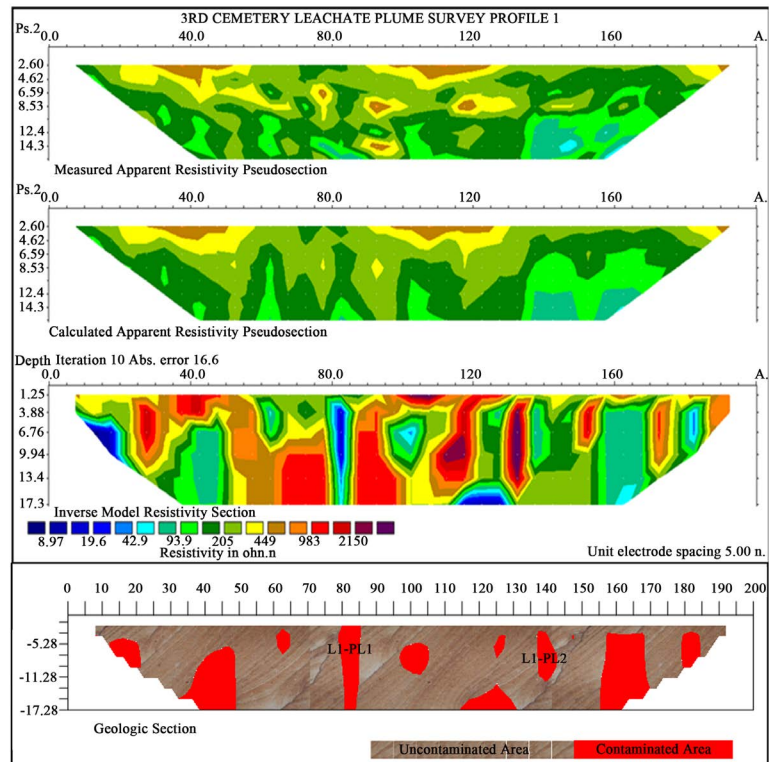


Figure 3. 2-D geoelectric model of third cemetery survey profile 1.

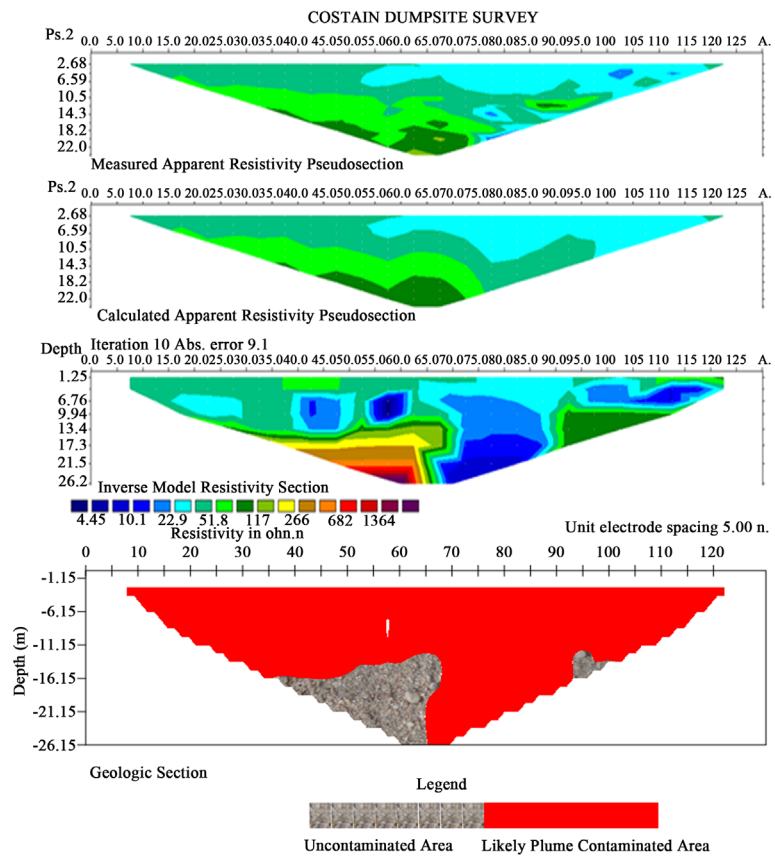


Figure 4. 2-D geoelectric models of costain dumpsite survey profile.

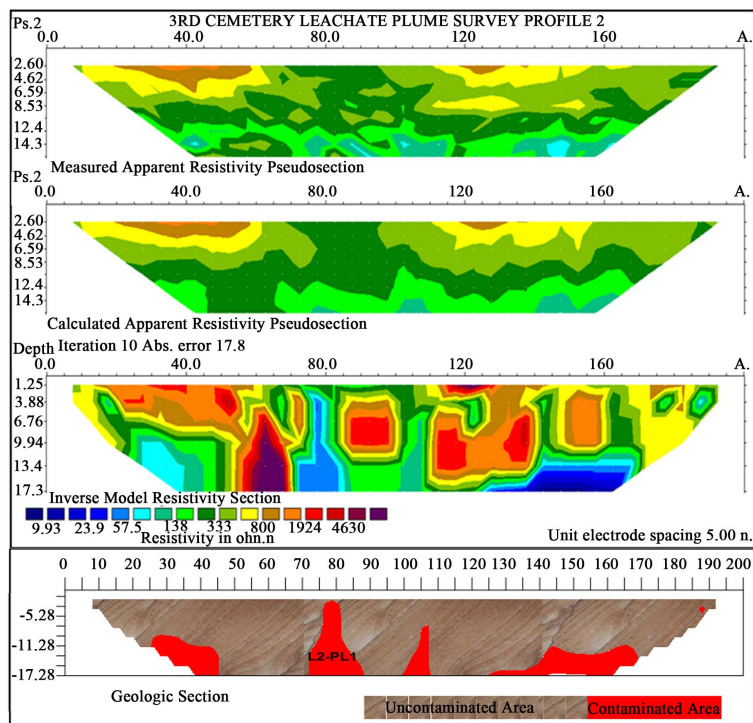


Figure 5. 2-D geoelectric model of third cemetery survey profile 2.

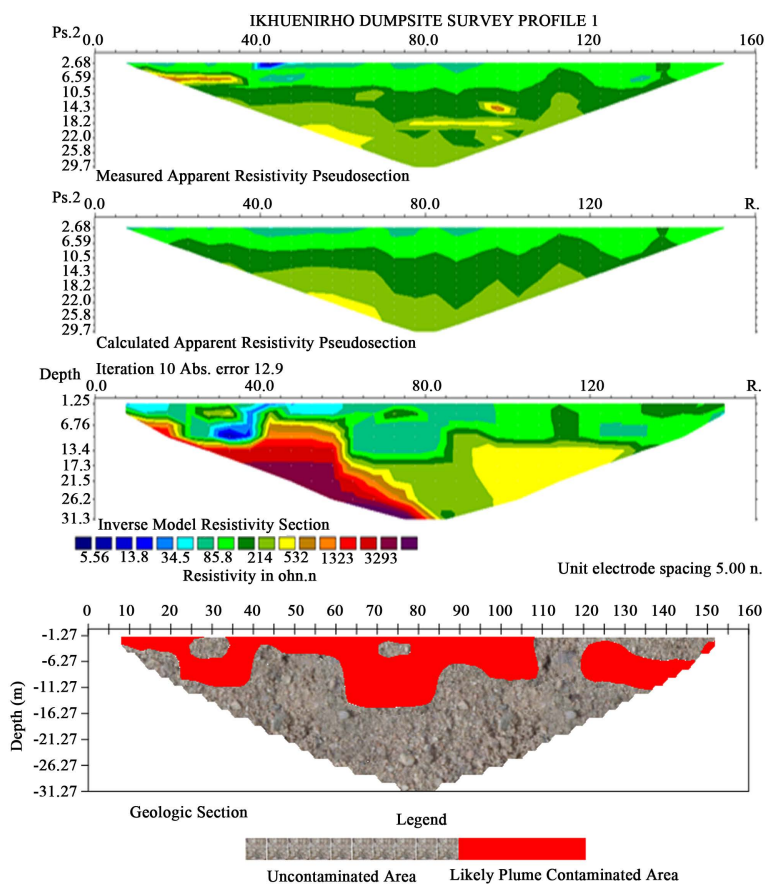


Figure 6. 2-D geoelectric models of ikhuenirho dumpsite survey profile.

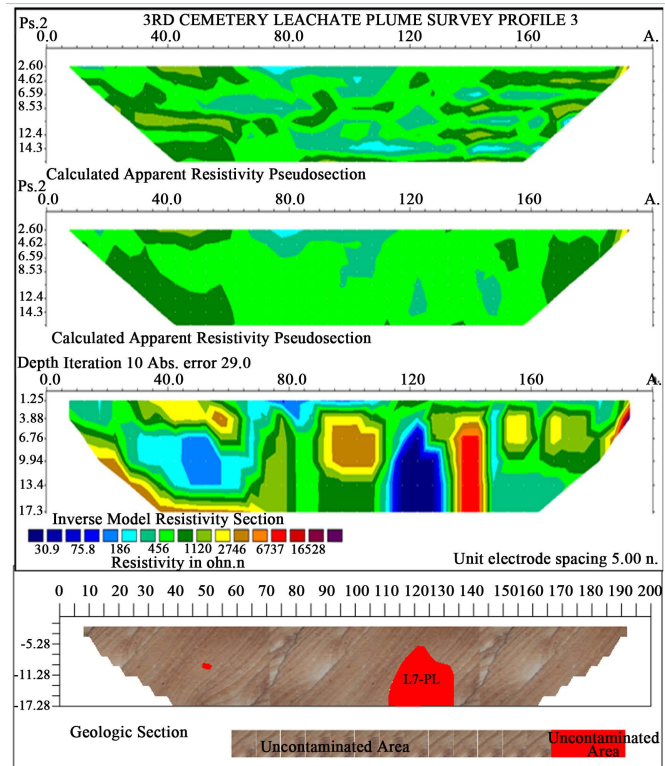


Figure 7. 2-D geoelectric models of third cemetery survey profile 3.

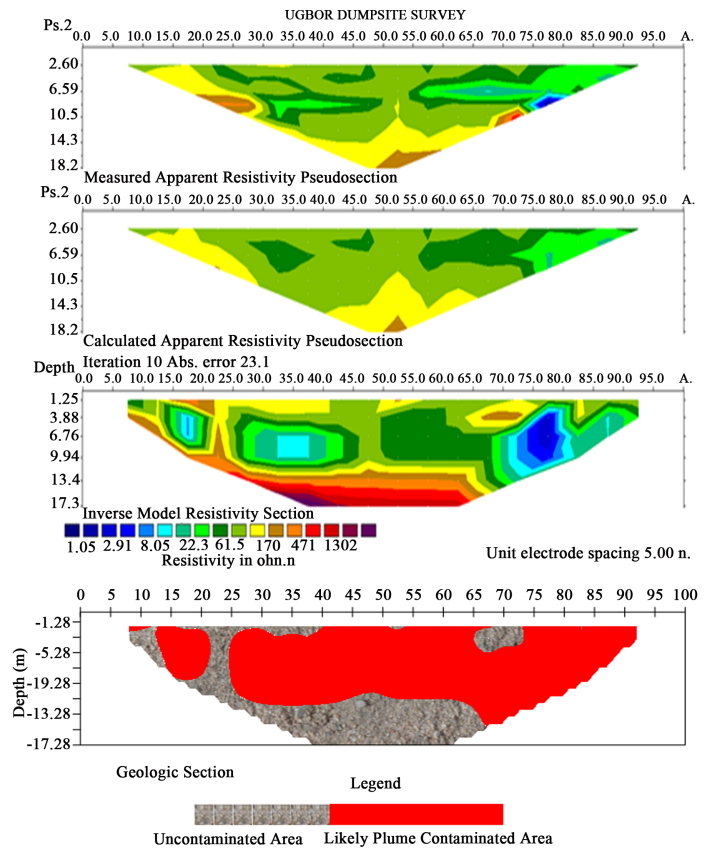


Figure 8. 2-D geoelectric models of ugbor dumpsite survey profile.

## 6. Conclusion

### Comparative Analysis (Third Cemetery and Costain Dumpsite)

From **Table 1** the pH values at both Third Cemetery and Costain Dumpsite were lower than the value at the Reference Site. The value at Third Cemetery being the lowest (4.960) showed that the water at the Cemetery is more acidic due to the infiltration from the burial loads.

The Electrical Conductivity (EC) values in Third Cemetery and Costain Dumpsite (118.000 and 99.900) respectively, are higher than the value at Reference Site. This implies that the resistivity values are also lower, which depicts the presence of leachate plumes in the above mentioned sites.

The values of Total Dissolved Solid (TDS) and Calcium in Third Cemetery were higher than that of Costain Dumpsite. Magnesium, Sulphate and Nitrate were found to be of higher values in Costain Dumpsite than Third Cemetery. Phosphate, Chlorides, Lead and Chromium have higher values in Third Cemetery than Costain Dumpsite. Zinc and Iron had higher values in Costain Dumpsite than Third Cemetery due to the different solid wastes and other refuse dump deposited at the Dumpsite. The 2-D Geological Models showed that both Third Cemetery and Costain Dumpsite contained leachate plumes of various degrees as indicated by the low resistivity values obtained at both sites which infiltrated into the groundwater. The geoelectric formation of both sites showed that laterite, clayed sand, sand and clay exist. The values of Water Quality Index (WQI) of groundwater samples in Third Cemetery and Costain Dumpsite were found to be 13.40 and 21.58 respectively which indicated that the quality of water at both Third Cemetery and Costain Dumpsite is good for drinking and other domestic purposes (less than 100, Ramakrishniah et al., 2009) though with some degrees of contamination.

### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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