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The field work covered a time – lapse of six months (June 2017 to December 2017). Three sites at the peripheral of the cemetery and a reference site were used as water sample sources. Groundwater samples were collected and analyzed. The electrical resistivity data collected in parallel equidistant lines was processed to obtain geoelectric models using Res2dinv and the second survey data was also merged and inverted as a single 3-D data set using Res3dinv software and Voxler 4.0 to give 3-D block model and volumetric analysis of the leachate plume. Multivariate analysis involving Principle Component Analysis, Cluster Analysis and computation of Water Quality Index, was also carried out to identify the major contaminants and their levels of contamination.

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Health concern about possible impact of the cemeteries in Nigeria on the water supply has prompted this research. The research engaged Vertical Electrical Sounding (VES), 2-Dimensional and 3-Dimensional imaging (tomography) to investigate the presence and migration of leachate plumes in the cemetery, hydro physicochemical analysis of water samples (for multivariate analysis) and computation of time- lapse to detect the time rate of migration in both the vertical and horizontal directions.

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The study showed that the status of the groundwater at the vicinity of the cemetery is fit for drinking and other domestic purposes though with some degree of contaminations. The main parameters constituting the contaminants include pH, EC, Cl, NO_3, SO_4 and Na, which are mostly influenced by the on-site activities in the cemetery. The leachate plumes in the cemetery migrate vertically and horizontally at different rates. The research also showed that repeated ERT surveys can track movement of leachate plume emanating from decomposed dead bodies over time in active cemetery.

Keywords: groundwater, contamination, cemetery, hydro-physicochemical, geophysical.

I. INTRODUCTION

The investigation of cemeteries is always difficult and challenging task in geoforensic prospective. 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.

Geoforensic, which simply means Forensic Geology, is defined as the gathering and analysis of geological evidence of a crime. It is the study of evidence relating to minerals, oil, petroleum, and other materials found in the earth, used to answer questions raised by the legal system (Murray and Tedrow 1975). However, the implications of land utilization for burial of dead human bodies in the form of cemeteries and many cases associated with coffin and caskets used for interment of remains has received no consideration in Nigeria. Interment of bodies in cemeteries remains a widespread practice and the only alternative endpoint to dead bodies 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 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 Idehen, O and Ezenwa,I. M (2019). According to DOC (2016), cemetery sites/graveyards have the potential to result in impact on the local water environment and in particular, the groundwater underlying such sites.

Toxic chemicals that may be released into groundwater include substances that were used in embalming and burial practices as well as varnishes, sealers and preservatives and metal component of ornaments used on wooden coffins (Jonker and Olivier, 2012). Wood preservatives and paints used in coffin construction contain compounds such as copper, naphthalene and ammoniac or chromated copper arsenate (Spongberg and Becks, 2000). Paints contain lead, mercury, cadmium, and chromium; arsenic is used as a pigment, wood preservative and anti-fouling ingredient while barium is used as a pigment and a corrosion inhibitor (Katz and Salem, 2005; Huang *et al*., 2010; Jonker and Olivier, 2012).

This underpins the importance of carrying out studies aimed at investigating the impact and attendant risks that cemeteries present to the populace living close to them. This project has been carried out to provide information on whether the cemetery located at Third Cemetery, Benin City, impacts the groundwater resources in aquifer within that zone.

Studies on the impact of cemeteries on the quality of groundwater in unsaturated and saturated zones are usually conducted within or at some distance from the cemeteries (Schraps, 1972; Zychowski *et al*., 2000b). Over 40% of cemeteries in South Africa contaminate water resources (Fisher and Croukamp, 1993). Local authorities seem oblivious of the problem. Both legal regulation and the determination to act in a way which would limit the threat are lacking (Alfoldi and Croukamp, 1988). Most researchers assess the impact of interment on the environment by comparing study results from cemeteries with data from reference sites. This type of assessment is satisfactory despite some possible errors (Zychowski, 2012).

Groundwater has for many decades served as a source of drinking water and it is still relevant for same purpose till date (Radajevic and Bashkin, 1999) despite the fact that different human activities have impaired its quality in some locality.

II. STUDY AREA

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° 06' N, 06° 30' N and longitudes 005° 30' E, 005° 45' E and an area of about 500 square kilometers. The city is located within the rain forest ecological zone with annual mean temperature of 27.5 °C (Ikhuoria, 1987, Idehen, 2019) and an annual mean rain fall of about 2095 mm (Ikhile and Olorode, 2011). Three cemeteries namely First, Second and Third cemeteries are located within this city. The Third cemetery which has existed for over 50 year 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). The burial load of this cemetery could not be calculated, because the record-keeping was not always adequate regarding the number of people buried. Also there is issue where a single grave is used for multiple burials. Three sampling sites were used for the collection of water samples.

III. METHODOLOGY

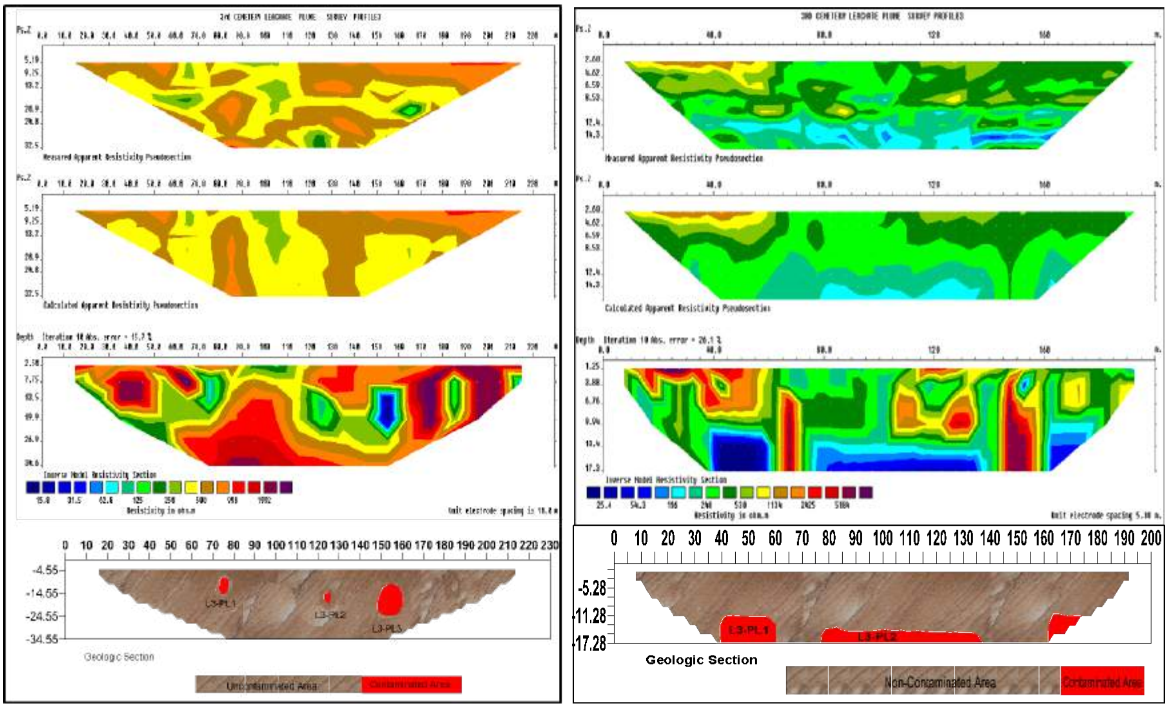
Electrical resistivity imaging data was acquired twice using Pasi Earth Resistivity Meter. The second data set was acquired six months after the first one. The data coverage was made over an area defined by rectangular loop measuring 30 m by 230 m in the first survey while in the second survey was 30 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 .Thus, first survey used to guide planning and execution of the second. The resistance values read from the measuring instrument was then transformed to apparent resistivity using the geometrical factor each sequence of measurement.

In order to characterize the physicochemical parameters of the water and further ascertain the suitability of these groundwater resources located near the cemetery, equal replicate of water samples were collected from borehole located at the peripheral of the cemetery.

Wenner -Schlumberger spread was used. In first survey, in each line location, electrodes numbered 0- 23 were placed into the ground at intervals of 10 m along the line, while in the second survey, electrodes numbered 0-40 at 5 m interval was planted into the ground. Each time measurement, was to be taken, array of four electrodes are selected manually and connected to the PASI earth resistivity meter via single core cable.

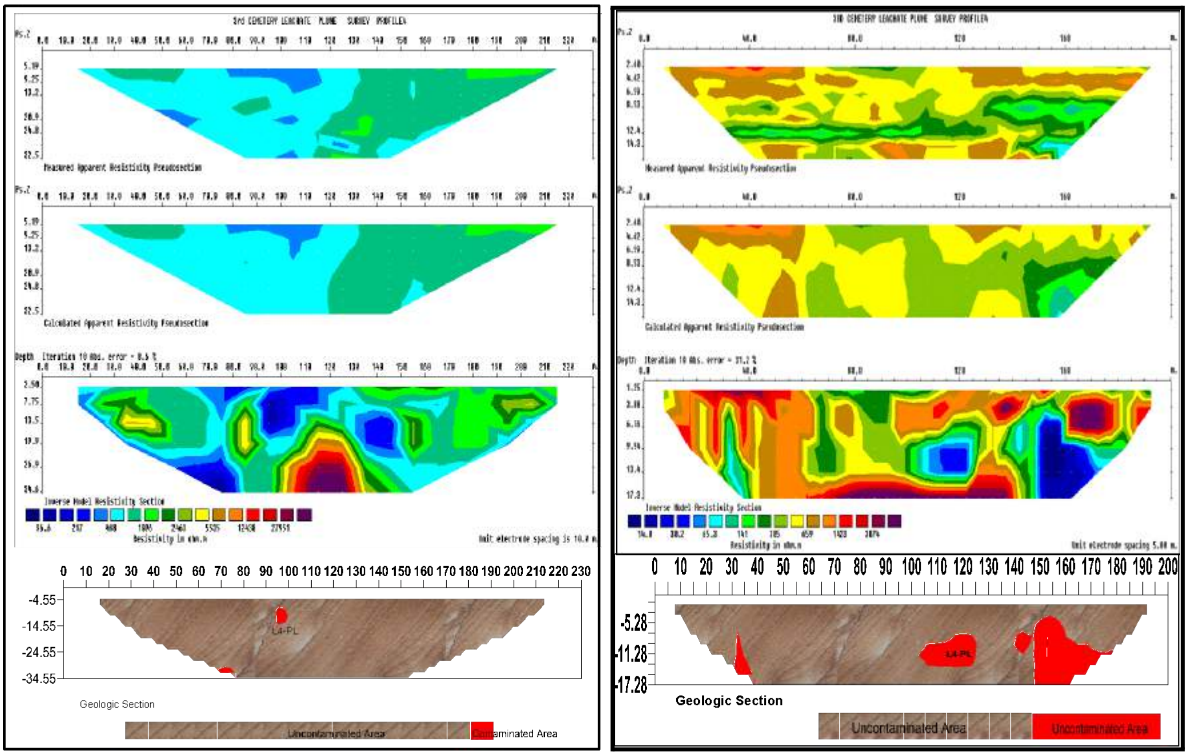
IV. RESULTS AND DISCUSSION

The geoelectric models obtained for the first and second surveys displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source). The leachate plumes presence in the sand bed are modeled and described as shown in the 2-D and 3-D displays (Fig. 1 to Fig. 3).



First Survey Profile3 (June, 2017) Second Survey Profile3 (Dec. 2017)

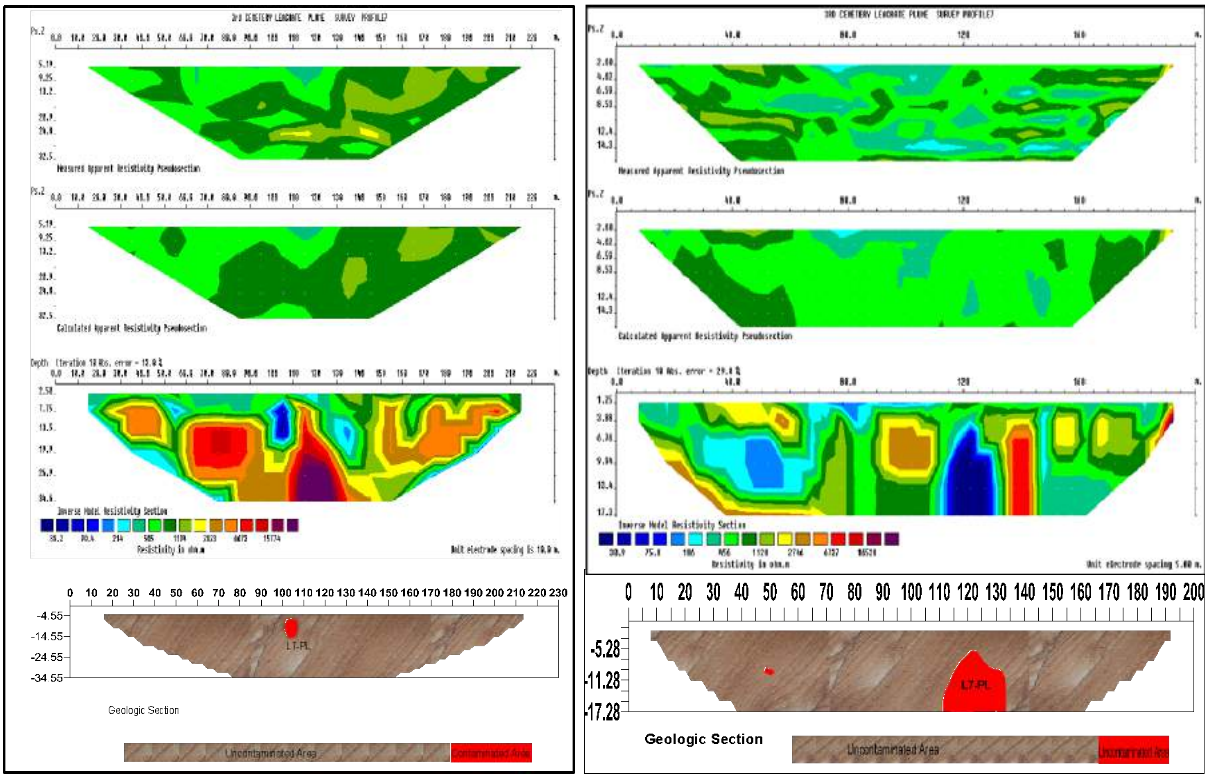
Fig. 1: 2: D Geoelectric Models of Profile3 in the First and Second Survey



First Survey Profile 4 (June, 2017)

Second Survey Profile 4(Dec. 2017)

Fig. 2: 2: D Geoelectric Models of Profile 4 in the First and Second Survey



First Survey Profile 7 (June, 2017)

Second Survey Profile 7 (Dec. 2017)

Fig. 3: 2: D Geoelectric Models of Profile 7 in the First and Second Survey

V. DISCUSSION

The field works were conducted in two sessions with a time interval of six (6) months. The first ERT survey was conducted in June 2017 (early period of rainy season) and the second ERT survey was conducted in December 2017 (early period of dry season) when the plumes must have been diluted with excess infiltrating water and move faster in the vertical and horizontal directions. The rate of migration depends on the permeability of the soil, incline topography, depressions created by decomposed corpses and collapsed burial materials. All these aid infiltration into the subsurface.

The rate of migration in the horizontal direction is higher than the rate of migration in the vertical direction. The maximum rate of migration in the vertical direction is 4.1 cm/day while the maximum rate of migration in the horizontal direction is 32.8 cm/day. It is observed that horizontal migration is higher than the corresponding vertical migration. The plume flows vertically and outwardly into the ground, and the horizontal permeability of sediment is found to be higher than the vertical permeability except in vertical solution fractures (Djebbar *et al.*, 2004, Idehen, 2020).

VI. PHYSICOCHEMICAL ANALYSES OF WATER SAMPLES MULTIVARIATE STATISTICAL ANALYSIS

Exploratory data analysis was performed by linear display methods (principal component analysis, PCA) and unsupervised pattern recognition techniques (hierarchical cluster analysis, CA) on experimental data. Cluster analysis allows the grouping of obtained samples on the basis of their similarities in chemical composition. Cluster analysis uses all the variance or information contained in the original data set (Razmkhah et al., 2010).

Table.1: Summary Of Variations In The Physicochemical Variables

Variables	Site 1	Site 2	Site 3	Reference	CV	NSDQW
Ph	4.96	4.34	4.05	6.80	24.51	7.50
EC	118.00	82.00	160.00	12.00	67.43	1000.00
TDS	59.00	41.00	80.00	6.30	67.04	500.00
TSS	0.58	0.07	0.66	0.00	103.80	0.00
Calcium	3.84	3.20	4.48	2.40	25.56	NA
Magnesium	1.15	2.30	3.84	3.00	44.25	0.20
Sulphate	0.17	0.25	0.00	0.43	83.75	100.00
Nitrate	0.29	1.37	1.75	0.08	93.23	50.00
Phosphate	0.64	0.83	0.33	0.24	53.65	NA
Calcium carbonate	30.50	24.40	18.60	50.80	45.11	150.00
Chloride	44.52	23.78	36.40	18.40	38.57	250.00
Sodium	37.60	16.40	32.00	2.60	71.43	200.00
Potassium	48.88	21.32	41.60	3.38	71.43	NA
Lead	0.01	0.00	0.01	0.00	115.01	0.01
Chromium	0.01	0.01	0.01	0.01	0.00	0.05
Copper	0.02	0.01	0.03	0.01	81.65	1.00
Zinc	0.02	0.01	0.02	0.02	28.57	3.00
Iron	0.04	0.02	0.03	0.08	61.88	0.30

Manganese	0.03	0.01	0.02	0.01	81.65	0.20
Cadmium	0.00	0.00	0.00	0.00	0.00	0.00
Nickel	0.01	0.01	0.02	0.01	70.71	0.02
Mercury	0.00	0.00	0.00	0.00	0.00	0.00
DO	8.80	6.20	9.80	9.20	18.68	NA
BOD_5	2.60	1.80	3.40	0.60	56.88	NA
COD	12.46	10.32	14.77	12.10	14.74	NA

NSDWQ - Nigerian Standard for Drinking Water Quality (NIS, 2007).

All variables except pH and EC were measured in mg/l; EC was measured in µS/cm.

VII. VARIATIONS IN THE PHYSICOCHEMICAL PARAMETERS

Table.1 shows the variations in the physicochemical parameters characterized in the groundwater samples obtained from the various sites. The levels of homogeneity of the levels of the variables across the sites including the reference site are represented by the coefficient of variation (CV). TSS and lead had CV values > 100; EC, TDS, sulphate, nitrate, phosphate, sodium, potassium, copper, iron, manganese, nickel and BOD_5 recorded CV values > 50 while pH, calcium, magnesium, alkalinity, chloride, zinc, DO and COD had CV values < 50. The levels of chromium, cadmium and mercury were relatively the same across the sites including the reference site thus no variation was recorded (CV = 0).

The groundwater was slightly acidic at all sites except the reference; electrical conductivity (EC), total dissolved and total suspended solids, nutrients including nitrate and phosphate, the alkali metals, heavy metals (excluding iron values which was high in the reference sites and cadmium and mercury which were not detectable in the water samples) values were low in the water samples obtained from reference site (Idehen and Ezenwa,2019). Generally chloride was the dominant anion across all the sites samples were obtained while the least of the same group were sulphate and nitrate for cemetery peripheral sites and reference site respectively.

VIII. CONCLUSION

The geoelectric models obtained for the first and second surveys displayed leachate plumes starting from the laterite (the burial environment) down to the sandy formation (the regional water supply source). The leachate plumes presence in the sand bed are modeled and described as shown in the 2-D and 3-D displays. This study showed that parts of the cemetery had been contaminated. This was evident in the attendant low resistivity values. This contamination was also observed to have infiltrated into the aquifer in the cemetery. This could pose serious health risks to the inhabitants of the study area who depend largely on boreholes for their drinking water supply.

The acquired two-dimensional electrical resistivity data covered laterite, fine sand, very coarse sand, medium sand. The sandy formation is porous and highly permeable, and hence the flow leachate through it is rapid. The study clearly revealed that the status of the groundwater at the vicinity of Third Cemetery is fit or suitable for drinking and other domestic purposes though with some degree of contaminations. Under favourable hydrological and geological conditions, the plumes delineated from the Electrical Resistivity Imaging will slowly migrate into the groundwater.

Human experience has taught that people shall continue dying and they shall continue being buried, however, we could reduce the number of people whose death could be linked to consumption of polluted groundwater by paying attention to obvious risk to residents who live close to cemeteries. This should be considered more seriously since priority must be given to the living above the dead. Based on the data obtained in this study, we conclude that there are very clear variations between various indices of the groundwater around the cemetery at Benin City, Nigeria and the reference site. These variations could have been caused by decomposition process going on at the cemetery.

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