FUPRE Journal of Scientific and Industrial Research
Vol.2, (2), 2018
ISSN: 2579-184 (Print) ISSN: 2578-1129 (Online)

2-D Electrical Resistivity Survey and Physiochemical/ Microbial Analysis of Groundwater around the Central Septic Tank within Female Hostels, University of Benin, Ugbowo Campus, Benin City, Nigeria

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Abstract

Two dimensional (2-D) Electrical Resistivity survey was employed to investigate the presence of contaminants plume around central septic tank within Female Hostels in University of Benin, Ugbowo Campus, Benin City. The investigation was carried out by using the Wenner alpha configuration using the PASI resistivity meter. RES2D Inversion software was used for interpretation of the three traverses that were covered so as to delineate the plume and probable trend of migration of leachate in the study area. Both physiochemical and microbial analyses were carried out on borehole-water collected within the study area. The 2-D inversion model for traverse 1 revealed that the zone with low resistivity of 90Ωm was indicated in the topsoil at the lateral distance of 95m to 100m at a depth of 6m to the subsurface. In the second and third layers of traverses 2 and 3 with lateral distance of 40 to 95m is suspected to be leachate saturation that leaked from the septic tank. The study also revealed that other physiochemical analysis of the heavy metals lie within standard value except pH value of 5.55 which is below WHO standard indicating that the site is acidic, but the result of microbial analysis gave a value 2.8×10^6ml which is above the standard specification for drinking water. Therefore, the study showed that leachate exists and pose a threat to groundwater in the study location.

Keywords: **Wenner-alpha, leachate, borehole-water, heavy-metals.**

1.0 **Introduction**

Availability of quality water resources has always been the primary concern of societies in any region, even in areas of more abundant rainfall, the problem of obtaining an adequate supply of quality water has become more acute due to ever increasing population and industrialization (Alile, et al 2009). As a result of this, surface water cannot be dependable throughout the year, hence, the need to look for other alternatives to supplement surface water (Alile, et al., 2012). This makes the world to depend on the largest available source of quality water which lies underground and this is generally referred to as Groundwater (Alile, et al., 2013). Man use water for various purposes but unfortunately, quality and potable water is not available because most water supply sources are contaminated to the point where odour and taste make it unacceptable for drinking (Freeze and Cherry, 1979).In order to analyze groundwater contamination, attention should be focused on soil characteristics, site geology, hydrogeology, hydrology and nature of the contamination (Altmanand Parizek, 1995).The consequences of groundwater contamination can result in poor drinking water quality, loss of adequate and quality water supply, high costs in cleanup and potential health problems. In terms of water supply, in some instances, groundwater contamination is so severe that the water supply must be abandoned as a source of drinking water (Baker and Mooty, 1993). In other cases, the groundwater can be cleaned up and used again, if the contamination is not too severe. Drinking contaminated water can result in illnesses in man, such as hepatitis, cholera, blue baby syndrome (an illness affecting infants), kidney, and liver problems. These can be caused by drinking water that is high in nitrates and Benzene. Preventing contaminants from reaching the groundwater is the best way to reduce the health risks associated with poor drinking water quality (Robertson et al., 1991).

This study was carried out around central septic tank within Female Hostels environs in University of Benin, Benin City, Nigeria.The aim of the study is to map leachate and contaminant plume around septic tanks using2-D Electrical Resistivity imaging.

1.1 Study Area

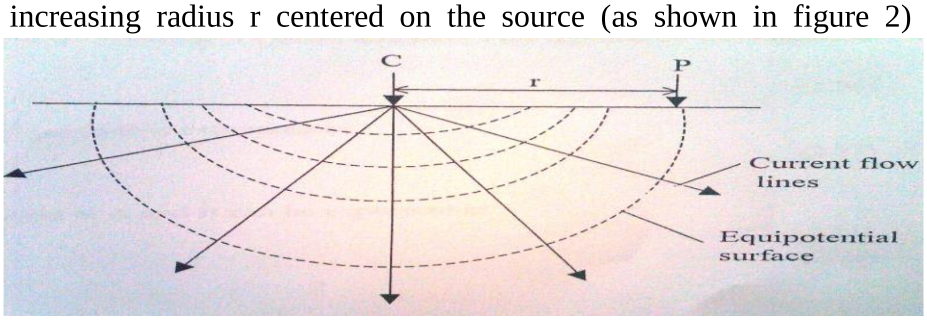
This research work was conducted around a large septic tank within Female Hostels environs in University of Benin, Benin City (see figure 1) and the area is basically a sedimentary area located in South South geo-political zone of Nigeria. It is bounded by latitudes 06^{o} 06$^{'}$ N and 06^{o} 30$^{'}$ N and longitudes 005^{o} 30$^{'}$ E and 005^{o} 45$^{'}$ E covering an area of about 500 square kilometers. The sampling sites were identified as Females' Hostel with coordinates 06^{o} 23.937$^{'}$N, 005^{o} 37.250$^{'}$E and elevation of 335ft (100.5 m).

Figure 1: Aerial view showing the location of the Central Septic Tank of all the 3 hostels (modified Google Earth). The three hostels are Hall 1, Hall 2 and Hall 3.

1.2 Mathematical Theory

The fundamental equation for resistivity survey is derived from Ohm's law (Kearey et al., 2002), According to Ohm's law, when a current I flows through a conducting body, it sets up a potential difference V between the ends of the body and they are related in equation 1 as $I = \frac{V}{R}$ (1)

Where **V** = Potential difference (Volts), **I** = Current Supplied (Amperes) and **R** = Resistance offered by the medium (Ohms).Considering a homogeneous Earth of resistivity ρ; a single current electrode placed on the surface of the Earth will produce a radial flow of current I away from the electrode so that the current distribution is uniform over hemispherical shells of increasing radius r centered on the source (as shown in figure 2)



Where
C: Current electrode
P: Potential electrode

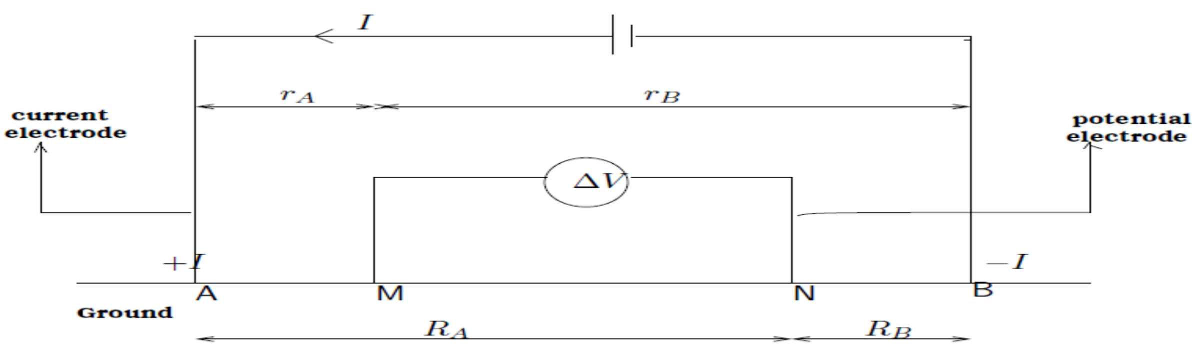
$$V = \frac{I\rho}{2\pi r} \qquad (2)$$

The Equation 2 defines the potential at point P due to current at point C. That is, equation 2 defines the potential equation of a 2-electrode array system. (one current and one potential).

In this research, four electrodes (2 current and 2 potential) were used in electrical resistivity survey based on the figure 3.

Figure 3: Generalized diagram for any four electrodes array (Kearey et al., 2002),

Let $r_A, r_B, R_A, R_B = r_1, r_2, r_3, r_4$



The potential (V) at M due to current A is defined by the equation

$$V_M^A = \frac{I\rho}{2\pi r_1} \qquad (3)$$

Potential (V) at M due to current at B is expressed in equation 4

$$V_M^B = -\frac{I\rho}{2\pi r_2} \qquad (4)$$

Potential (V) at M due to current at A and B can be expressed in equation 5

$$V_M^{A,B} = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \qquad (5)$$

Potential (V) at N due to current at A is expressed in equation 6

$$V_N^A = \frac{I\rho}{2\pi r_3} \qquad (6)$$

Potential (V) at N due to current at B is expressed in equation 7

$$V_N^B = -\frac{I\rho}{2\pi r_4} \qquad (7)$$

Potential (V) at N due to current at A and B can be expressed in equation 8

$$V_N^{A,B} = \frac{I\rho}{2\pi}\left(\frac{1}{r_3} - \frac{1}{r_4}\right) \qquad (8)$$

What is measured in resistivity survey is the potential difference between M and N which is defined in equation 9

$$V_M^{A,B} - V_N^{A,B} = \Delta V = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \qquad (9)$$

If equation 9 is rearranged:

$$\rho = 2\pi \frac{\Delta V}{I}\left[\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}\right] \qquad (10)$$

But $\frac{\Delta V}{I} = R$ (Resistance)

Hence, $\rho = 2\pi R\left[\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}\right]$ (11)

Equation 11 is the true resistivity equation for a homogenous and isotropic earth. The earth is however not homogenous, so what is measured is an apparent resistivity (ρ_a) defined as:

$$\rho_a = 2\pi R\left[\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}\right] \qquad (12)$$

Equation 12 is the required equation for the generalized resistivity for any four electrode array system and it is expressed simply as

$\rho_a = RK$ where K is geometric factor of the electrode array (13)

Where K expressed as $2\pi\left[\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}\right]$ (14)

The calculated apparent *resistivity* is expressed in ohm-m and it depends on the geometry of the electrodes (Kearey et al., 2002).

2.0 Materials and Methods

2.1 Data Acquisition

The 2-D data with three profiles lines were acquired with 36 electrodes along three traverses with a maximum spread of 160 m lateral distance each using Wenner Alpha array configuration with a PASI 16GL digital resistivity meter (Terrameter). The data acquired points were separated by 5 m intervals.

2.2 Data Processing

The data acquired on the field was processed and inverted using RES2D INVERSION software, maps in figures 4 to 6 were generated.

2.3 Collection of Water Samples

The water samples were collected from the borehole that is close (less than 10 m) to the central septic tank in the study area. It was collected using plastic bottles and the bottles were already rinsed with water to be sampled before sample collection and stored in a cool environment before taking them to the laboratory. The site location has the latitudes of 06^{o} $23.937^{'}$, longitude of 005^{o} $37.250^{'}$ and elevation of 335ft.

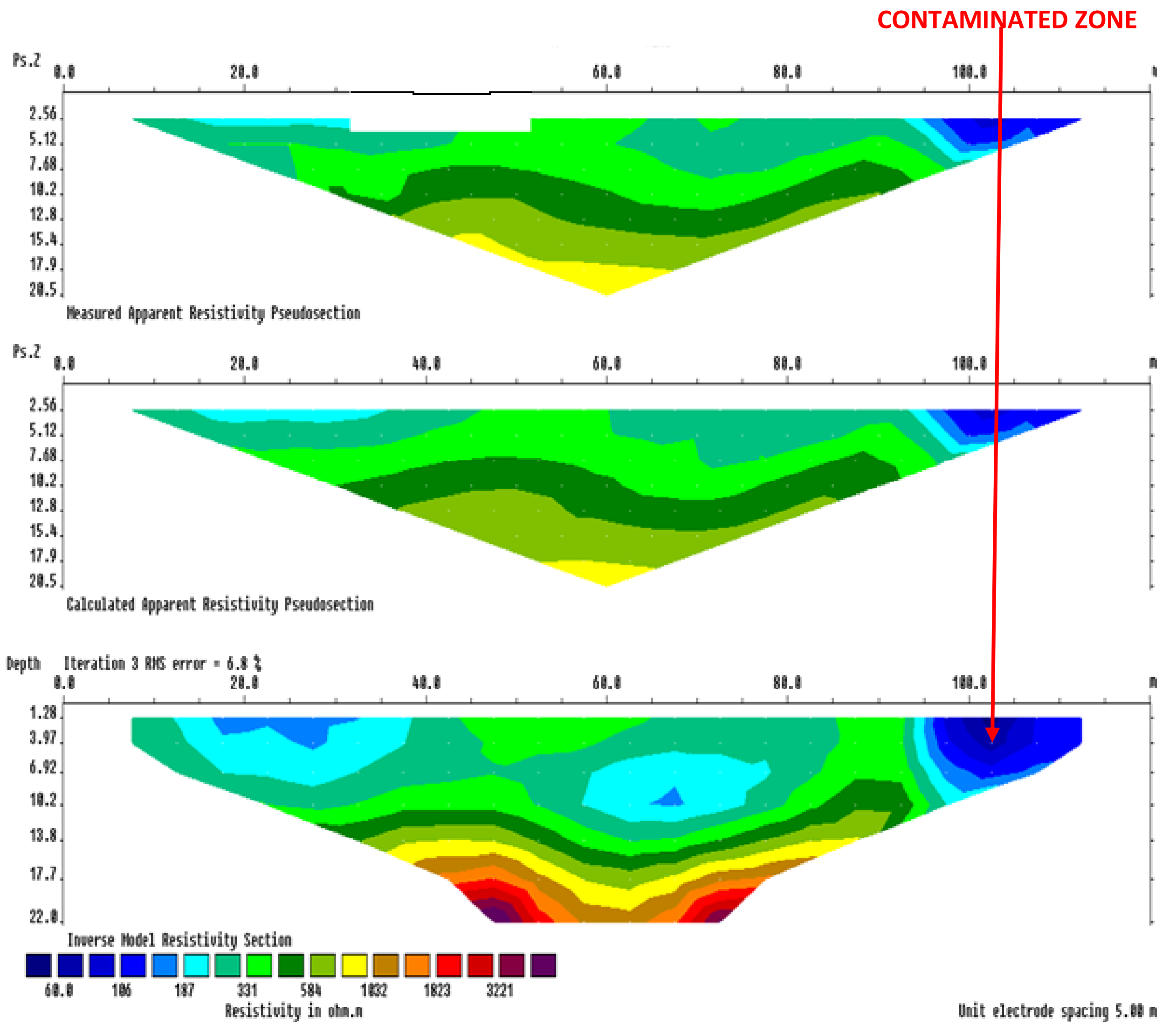
The following parameters were determined from the Physiochemical analysis of the water sample collected using pH meter and conductivity meter, the parameters are pH, heavy metals, Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), electrical conductivity (EC), hardness of water etc. The microbial and biochemical characteristics of the following were also analyzed: pigmentation, cell form, texture, coliform test ,and catalase ,coagulate.

3.0 Results and Discussion

3.1 Results for 2-D Electrical Resistivity

2-D resistivity sections obtain from this study are shown in figures 4 to 6 and they are displayed as cross sections of the true resistivity distribution of the subsurface with depth along each of the sections.

Among the sections generated for each single inversion include; the observed apparent resistivity pseudo-section, the calculated apparent resistivity pseudo-section and the inverted model resistivity section which is the interpretation model. For each figure, the observed apparent resistivity pseudo-section is the topmost, the calculated pseudo-section is placed immediately below it and the inverted (interpretation) model is at the bottom. The inverted (interpretation) model shows the distribution of resistivity within the subsurface. The colour scale bar attached below the sections is used as colour coding to interpret the distribution of resistivity in each of the 2-D resistivity sections.



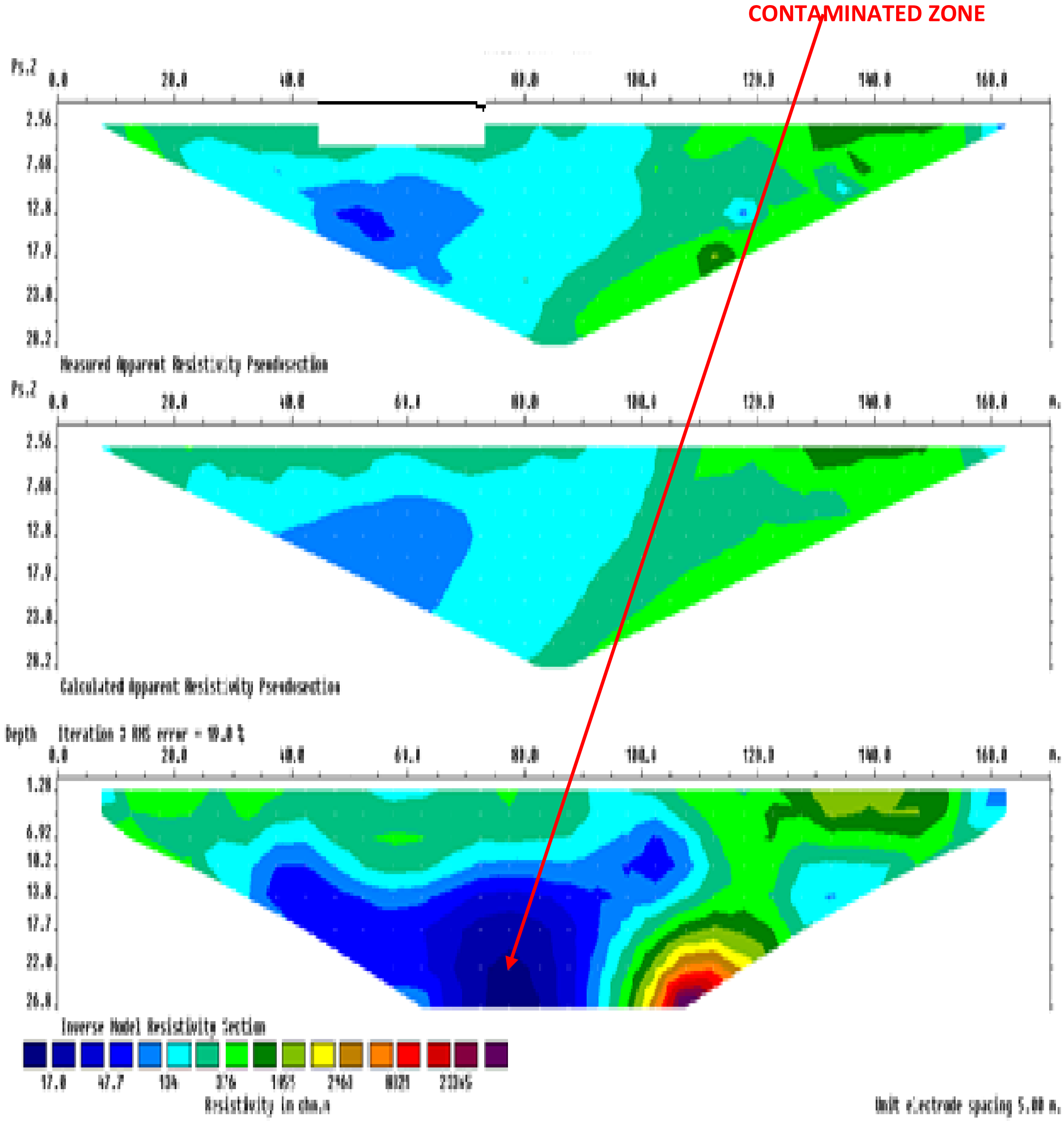


Figure 5: 2-D Electrical Resistivity Image of Traverse 2

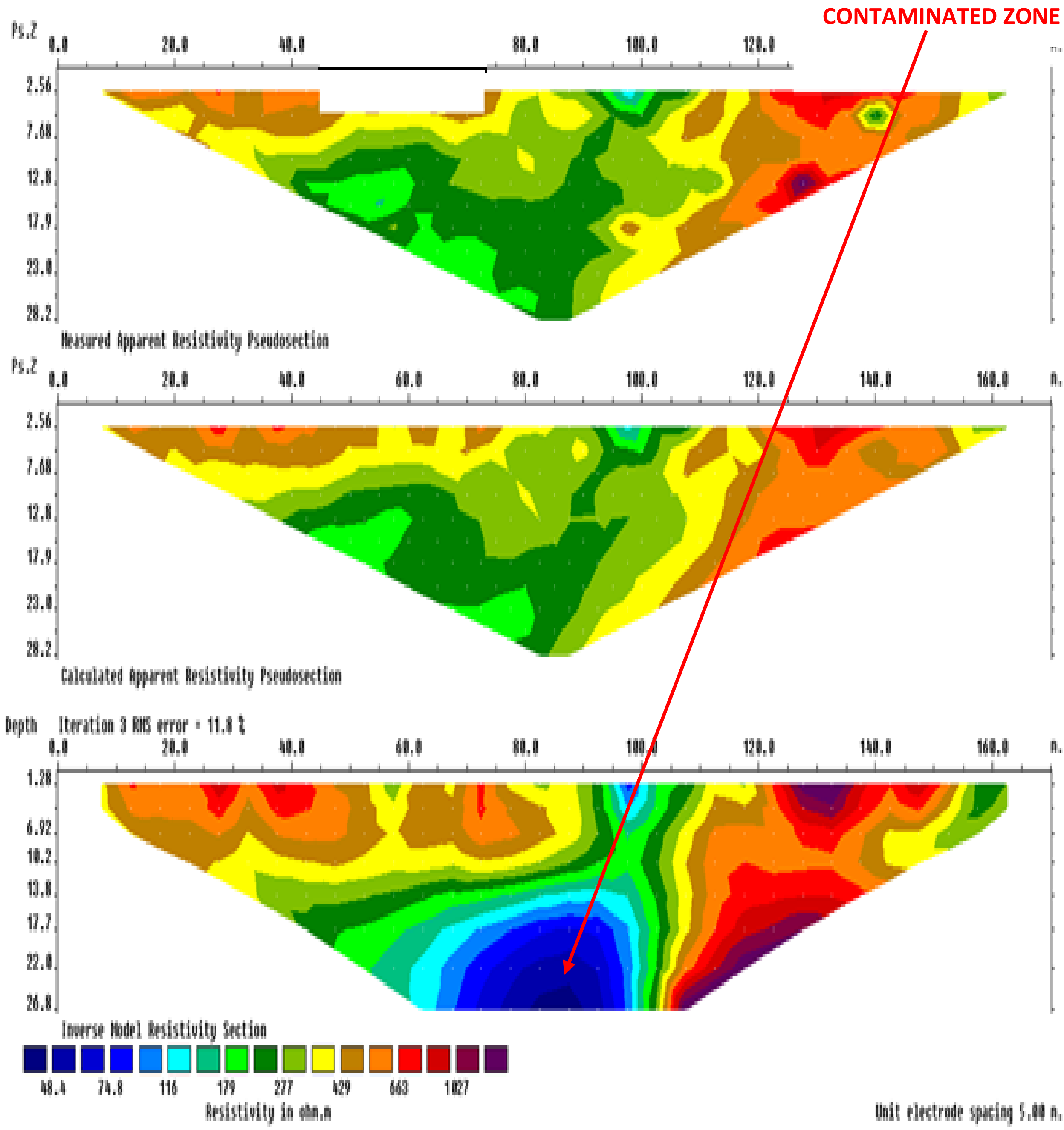


Figure 6: 2-D Electrical Resistivity Image of Traverse 3

3.2 Results for Physiochemical/ Microbial Analysis

Table 1 shows the physiochemical parameters that were analyzed from the water samples collected while table 2 display the results of microbial, biochemical and morphological characteristics of bacterial isolates of the sample water.

Table 1: Physiochemical Characteristics of the Groundwater Samples from Investigated Sites

S/N	PARAMETERS	UNIT	STANDARD VALUES	FEMALES HOSTELS
1.	Ph		WHO 6.5-8.5	5.50
2.	EC	μs/cm	WHO 1000	14
3.	TDS	mg/l	ASTMD 1868	7
4.	CALCIUM	mg/l	ASTMD 1126-96B	2.56
5.	MAGNESIUM	mg/l	ASTMD1126-96B	1.15
6.	ALKALINITY	mg/l	ASTMD 1067-92	6.10
7.	CHLORIDE	mg/l	API-RP-45	4.06
8.	SODIUM	mg/l	ASTMD 2791-93	2.80
9.	POTASSIUM	mg/l	ASTMD 2791-93	3.64
10.	LEAD	mg/l	ASTMD 3559-96	ND
11.	CHROMIUM	mg/l	ASTMD 1687	<0.005
12.	COPPER	mg/l	ASTMD 1688	0.02
13.	ZINC	mg/l	ASTMD 1691-95	0.03
14.	IRON	mg/l	ASTMD 1068	0.05
15.	MANGANESE	mg/l	ASTMD 858	<0.005
16.	CADMIUM	mg/l	ASTMD 3557-95	ND
17.	NICKEL	mg/l	ASTMD 1886	ND
18.	DO	mg/l	ASTMD 888-92	10.20
19.	BOD	mg/l	ASTMD 507	3.6

Table 2. Biochemical and Morphological Characteristics of Bacterial Isolates

MICROBIAL CHARACTERISTICS	ISOLATES
Pigmentation	Yellow
Cell Form	Circular
Colony Margin	Entire
Elevation	Raised
Texture	Smooth
BIOCHEMICAL CHARACTERISTICS	RESULTS
Catalase	Positive
Coagulase	Positive
Coliform Test	Negative
CULTURAL CHARACTERISTICS	Cocci
SUSPECTED ORGANISM	Escherichia Coli

3.3 Discussion of the Results

3.3.1.Discussion of Images Generated

The resistivity inverse models are displayed as cross sections of the true resistivity distribution of the subsurface with depth along each of the profiles. In all the figures the resistivity images show some zones of low resistivity within the subsurface of the traverses and these areas are very conductive zones.

As revealed by the inversion model, there is a less indication of contaminants zone in traverse1 along lateral distance of 95m to 120m with low resistivity values of 90 ohm-m at the depth of 8m to the subsurface. However traverse two showed a strong indication of low resistivity value that is less than 90 Ωm on the second and third layers with lateral distance of 35m to 95m at depth of 7m to the subsurface, which is suspected to be leachate from the septic tank. Also, at the depth of 15m beneath the surface, a strong indication of low resistivity value that is less than 90 Ωm was delineated in traverse three which is within the third geological region at the lateral distance of 65m to 95m.These low resistivity zones, could have occurred due to infiltration of leachate from the septic tank (as shown by the arrows in figures 4 to 6).However, there is a suspected ground water contamination in the study area.

3.3.2 Discussion of Result of Water Analysis

3.3.2.1 Observations from Physiochemical Analysis

In this study, it was observed that low pH values of 5.50 were obtained from water samples tested in study area and these value was below World Health Organisation (WHO, 1993) standard value which is between 6.5 and 8.5. This is an indication that the groundwater in the study area is acidic and is not good for human consumption. The acidic nature of the water tested shows the presence of organic matters and it can be favourably to the growth of iron bacteria. However, sodium carbonate can be applied as a purifier for acidic groundwater. With the exception of pH, other parameters analysed in Table 1 compared favourably with WHO, United State Environmental Protection Agency (USEPA) and American Society for Testing and Materials (ASTMD) standard for drinking quality water (USEPA1990, WHO 1993, ASTM 1998).

3.3.2.2 Observations from Microbial Reports

From Table 2, it is observed that the presence of Escherichia Coli in the tested water could be as result of direct contamination of storage tanks or underground seepage. Also there is presence of coliform at a count of 2.8×10^5 ml. The microbial analysis also revealed that the total aerobic plate count of 3.1×10^6ml is too high and above the standard specification of drinking water.

4.0 Conclusion

The 2-Dimensional resistivity imaging and the physiochemical/microbial analysis of ground water has been successfully carried out with a view to determining the extent of contamination of the subsurface. The Second and third layers of traverses 2 and 3 with lateral distance of 35-95m show a vertical migration of plume, which is suspected to be leachate that leak from the septic tank. All heavy metals analysis lie within standard value except pH value of 5.5 which is below WHO standard. The results of the analysis of both the pH value of 5.5 and microbial analysis of total aerobic plate count of 3.1×10^6, were the standard specification of World Health Organization indicating that the groundwater pollution. The presence of Escherichia Coli and coliform at a count of 2.8×10^5 in the water collected from the borehole showed that the study area needed to be treated for domestic consumption. The observed contamination could be as result of direct contaminants that leak from the septic system or underground seepage.

References

Utom, A. U; Odoh, B. I. andOkoro A. U. (2012):Estimation of Aquifer Transmissivity Using Dar Zarrouk Parameters Derived from Surface Resistivity Measurements: A Case History from Parts of Enugu Town (Nigeria*). Journal of Water Resource and Protection*,4: 993-1000.

Alile, O, M., S.I. Jegede and R.E. Emekeme (2009). Subsurface Probe and Hydrochemical Analysis for the Purpose of Siting Waste Landfill. African Journal of Environmental Science and Technology, 4(1): 472-476.

Alile O.M., Oranusi S., Adetola O.O. and J.O. Airen (2012). Surbsurface Geophysical Investigation and Physiochemical/Microbial Analysis of Groundwater Contaminant in Ota, Southwestern Nigeria. *Geosciences*. 2(6): 179-184.

Alile, O.M., Aigbogun, C.O., Osuoji, O.U., Ikponmwen M.O. and D.O Okojie (2013).Geoelectrical Subsurface Imaging for the Mapping of Leachate and Contaminant Plume Around Large Septic System, Ota, Southwestern Nigeria. *Australian Journal of Basic and Applied Sciences.* 7(2): 297-305.

Altman, *S*. J. and R.R. *Parizek*, (1995). Dilution of Nonpoint-Source Nitrate in Groundwater: Journal of Environmental Quality 24 (4): 707-718.

ASTM (1998). Standard E1943-98: Standard Guide for Remediation of Groundwater by Natural Attenuation at Petroleum Release Sites, Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA.

Baker, R.M and W.S. Mooty (1993). Use of water in Alabama, Geological Survey of Alabama Information Series 59E, p49.

Freeze, R.A. and J.A. Cherry (1979). Groundwater: Englewood Cliffs, NJ, Prentice-Hall, 604 pp 23-39.

Kearey P., Brooks, M. and I. Hill (2002). *An Introduction to Geophysical Exploration second edition.* Blackwell Science Ltd, USA. 125.

Robertson, W. D., Cherry, J.A, and E. A. Sudicky (1991). Ground-water contamination from two small septic systems on sand aquifers. Ground Water 29: 82-92.

USEPA (1990) United State Environmental Protection Agency: A groundwater Protection Strategy for the Environmental Protection Agency, pp11.

World Health Organisation (WHO), (1993). Guidelines for Drinking Water Quality (Second Edition), Geneva, 1:1134.