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Geoelectrical and Microbial Assessment of the Agbarho Abattoir Effluent on Ground Water Quality in Agbarho Community, Delta State

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ABSTRACT

The effluence of Agbarho abattoir wastes and animals' dung on near surface groundwater quality was geoelectrically investigated using 2-Dimensional Electrical Resistivity by engaging Wenner array configuration using PASI-16GL Terrameter. Four traverses of lateral distance of 50m with 2.5m electrode spacing were gotten from the study area and the acquired data was processed and inverted using RES2DINV software so as to delineate the trend of migration of contaminants. Borehole-water samples were collected within the study area for both physiochemical and microbiological analyzes while the depth of aquifer (groundwater) was determined by employing Vertical Electrical Sounding (VES). The 2-Dimensional Inversion model for traverse 1 and 2 revealed a low resistivity value of 0.445Ωm and 2.53Ωm respectively and this occurred at the top soil. Also, the low resistivity value of 0.319Ωm in traverse 3 was indicated in the second layer at the lateral distance between 15m to 35m and at the depth of 6.22m. The model in traverse 4 revealed low resistivity value of 0.374Ωm from the top layer down to the fourth layer at the depth of 9.8m. These low resistivity values indicate high conductivity of bacterial and algae of the animal waste and this can be attributed to the presence of suspected contaminants plume of the abattoir. The depth of aquifer revealed by Vertical Electrical Sounding was 8.9m which is in third layer and the lithology was found to be as fine sand. All physiochemical results including pH value which is 5.1 (acidic in nature) fell below the permissible limit of World Health Organization (WHO). The microbial result showed the total coliform count value as 70 cfu/ml which is not in-line with WHO standard. In conclusion, the study showed that the contaminant exists and pose threat to groundwater in the study area.

Keywords: Wenner-array, Agbarho abattoir, contaminant, Aquifer, 2 Dimensional

Introduction

An Abattoir is a place (either private or government own) that has been approved by the controlling agency or government for the hygienic slaughtering of different categories of animals and processing of meat products for the safe consumption by the public. Abattoir industry is one of the important and major sectors of the livestock industry providing and supplying domestic meat to

over 150 million people and employment opportunities for both females and males in Nigeria (Alonge, 1991). According to history, public abattoir had been traced to some countries like France and Rome in the 15th and 16th centuries, and these slaughter houses has public facilities provided by the Government. Nowadays, in most countries of the world, slaughtering of animals for

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community and people consumption is inevitable. Hence, the production of meat from animals is considered as one of the potential food for the people's needs. Edwards (1979) observed that abattoirs may be situated in urban, rural and nominated industrial sites, and the disposal of any kind of waste from these abattoirs should be properly monitored. However, to the best of our knowledge, most abattoir activities (like slaughtering of animals) in Nigeria and some other developing countries lack facilities for the treatment of waste from abattoir such as animal horns, feces, urine, etc.

Animal waste can be defined as the excreted materials from live animals and it also includes dung, hay, bones, wood shavings, blood, fat and other sources of organic debris. Wastes from any type of abattoir operations can be separated into 3 different parts which they are; solid, liquid and fats (this could be highly organic). The solid part consists of bones, condensed meat, hairs, hoof, and aborted fetuses. On the other hand, the liquid aspect consists of blood, guts contents, urine, and water, while fat waste consists of fat and oil. (Aina and Adedipe, 1991). Waste disposal of these animal waste products is one of the major problems that has always dominated the slaughter environment. A continuous release of animal waste from an unregulated abattoir into both surface and ground water could constitute an environmental and public health hazard. However, this same waste has some advantages in which it can be valuable for crops and if there is a proper heating treatment of the waste, it can become a non-hazardous product.

However, when the slaughter wastes are not properly managed, they become a major pollutant in environment of any country or cities and the excess wastes of these slaughtered animals may percolate into subsurface (World Bank 1998). Also, if proper practices of activities and management of slaughter house are not adhered to, the waste from the remains of animals can affect water, land or air qualities and it can also affect the

quality of subsurface water in that area. According to WHO (2010), water is for human survival and it plays a vital role by reducing the global burden of disease and improving the health, welfare and productivity of population, but this natural resource has been contaminated and polluted in different ways and one of the ways is the unsafe disposal of wastes from abattoir.

The quality of the subsurface water can be deteriorated as a result of both vertical and horizontal spread of bacteria, trace heavy metals, salts, organic solids, viruses and other microorganisms into the subsurface. Kanu and Achi (2011) said that most of developing countries have problem of improper management of vast amount of wastes generated and the unsafe disposal of these generated waste by various abattoirs has been the most challenging issue to the environment such as water bodies especially fresh water reservoirs. Atuanya *et al.*, (2012) studied the effluent of private and government abattoirs and their environmental effects on Ikpoba River in Edo state. The result showed significant variations in the bacteriological and physico-chemical qualities of surface water. The research examined by Chukwu (2010) revealed the impact of Enugu abattoir on both environment and Nyaba water basin, the result showed that the stream has not been contaminated. Chukwu (2010) examined the impact of Enugu urban environment on the water quality of streams in the Nyaba catchment system. The generated variables were subjected to PCA to find out the strongest factors that affect water quality of streams in Nyaba basin. From the research of (Olaseni *et al.*, 2018) conducted around a leachate that leaks from septic tank in UNIBEN staff quarters, he found out from microbial/physiochemical analysis and 2-Dimensional Electrical Resistivity survey that there was a strong evidence of contamination of shallow water zone in the investigated area.

In this research, we attempt to evaluate the quality of the subsurface water in Agbarho Abattoir and its environment with the aim of establishing the extent

to which the abattoir wastes or contaminants would have influenced the groundwater using 2-Dimensional Electrical Resistivity. Also, this study seeks to ascertain the possible treats to the environment in the study area by comparing any significant differences in the concentration of physiochemical and microbial analysis of the water samples collected within the abattoir area and international standards.

The Agbarho slaughter house was established by government more than 30 years ago and the number of animals slaughtered depends on the nature of the market per day. However, more than a thousand of cows have been slaughtered since inception. The continuous deposition of dungs, animal blood and animals' wastes at the back of the Agbarho slaughter house from the inception prompted the geoelectrical investigation and microbial/physiochemical assessment of the effluent of the animal wastes that is periodically discharge to the subsurface ground-water in Agbarho community. The microbial and physiochemical analysis of groundwater samples collected from the borehole located in the area of study is necessary because of the cases of water borne diseases such as diarrhea, dysentery and typhoid. Figures 1 and 2 below show some parts of Agbarho-Abattoir with the personnel acquiring data around the hip of animal dung in the study area.



Fig 1: Picture of Agbarho Abattoir (Slaughter House)



Fig 2a, b: (a) showing the personnel with one of the hips of animal dung/waste (b) showing personnel acquiring data around the study area

Materials and Methods

Study Area

Agbarho town is one of the major and populated towns in Delta state, South-Nigeria, her population has an estimate of value 145,000. The town lies between latitude N05° 35' 01.5" and longitude E05° 52' 02.0" and 8m above sea level (Chudi, 1994). According to history, Agbarho slaughter house has been in existence more than 30 years ago. The number of animals slaughtered depends on the nature of the market solely; and it supplies about 65% of meat to the town residence and other communities.

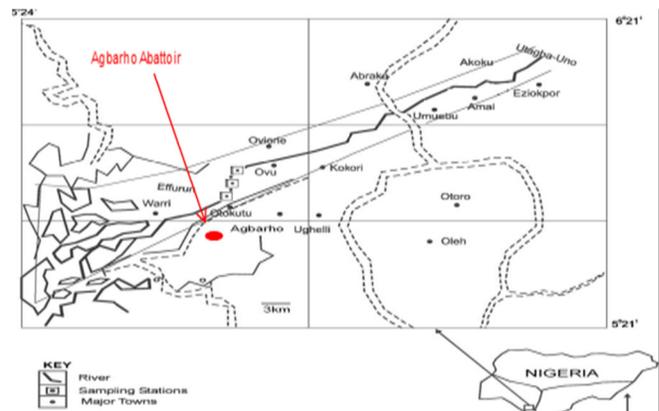


Fig 3: Geological Map of Agbarho and its environs showing the study area (Google map) modified

Theoretical Background

Ohm’s law is the fundamental law used in resistivity surveys and this law governs the flow of current in the subsurface and its equation in vector form for a current that flows in a continuous medium is given in equation 1 (Loke, 2000).

$$J = \sigma E \tag{1}$$

Where σ is the conductivity of the medium, J is the current density and E is the electric field intensity.

Practically, in geophysical surveys, electric field potential measured the medium resistivity ρ , which is equals to the reciprocal of the conductivity i.e. $\rho=1/\sigma$ (Loke, 2000).

However, equation 2 shows the relationship between the electric potential and the field intensity

$$E = \nabla\phi \tag{2}$$

Combining equations 1 and 2, we get equ 3 below

$$J = \sigma\nabla\phi \tag{3}$$

In almost all surveys, the current sources are taken as point sources and the first case is to have a homogeneous subsurface and a single point current source on the ground surface. In this case, current flows radially away from the source and also perpendicular to the equipotential surface of the earth, and the potential difference varies inversely with distance from the current source.

The potential in this case is given in equation 4 (Loke, 2000).

$$\phi = \frac{\rho I}{2\pi r} \tag{4}$$

Where r is the distance of a point in the medium from the electrode.

Two current electrodes are used during resistivity surveys (a positive and negative current source) and at the mid-point between the two electrodes; the potential values have a symmetrical pattern about the vertical plane and is given in equ 5.

$$\phi = \frac{\rho I}{2\pi} \left[\frac{1}{rc_1} - \frac{1}{rc_2} \right] \tag{5}$$

Where rc_1 and rc_2 are distances of the point from the 1st and 2nd current electrodes.

As shown in fig 4, the resistivity measurements are made by injecting current into the ground through the two current electrodes (C1 and C2) and measuring the resulting voltage difference at two potential electrodes (P1 and P2) (Loke, 2000).

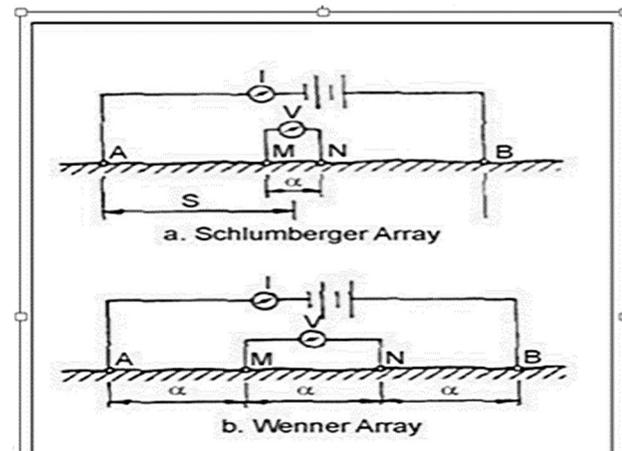


Fig 4: Electrode array configurations for resistivity measurements (Loke, 2000).

Figure 4 above shows a typical arrangement of 4 electrodes array over a homogenous half space and the potential difference between two points is measured and given in equation 6.

$$\phi = \frac{\rho I}{2\pi} \left[\frac{1}{rc_{1p1}} - \frac{1}{rc_{2p1}} - \frac{1}{rc_{1p2}} + \frac{1}{rc_{2p2}} \right] \tag{6}$$

However, the actual field surveys are invariably conducted over an inhomogenous medium where the subsurface resistivity has a 3-D distribution (Loke, 2000).

From the current (I) and potential values, an apparent resistivity (ρ_a) value is calculated.

$$\rho_a = K \frac{\Delta\phi}{I} \tag{7}$$

$$\text{Where; } K = \frac{2\pi}{\frac{1}{rc_{1p1}} - \frac{1}{rc_{2p1}} - \frac{1}{rc_{1p2}} + \frac{1}{rc_{2p2}}} \tag{8}$$

where K is known as a geometric factor that depends on the arrangement of the four electrodes and the resistivity measuring instruments is given as a resistance value in equation 9

$$\text{Page | 3743} \quad R = \frac{\Delta\phi}{I} \quad (9)$$

Therefore, in practice the apparent resistivity value can be calculated using equation 10

$$\rho_a = k R \quad (10)$$

$$\phi = \frac{\rho I}{2\pi r} \phi = \frac{\rho I}{2\pi} \left[\frac{1}{rc1p1} - \frac{1}{rc2p1} - \frac{1}{rc1p2} + \frac{1}{rc2p2} \right] \rho_a = k \frac{\Delta\phi}{I} \rho_a$$

The calculated resistivity value in equation 10 is not the true resistivity of the subsurface, but an “apparent” value that is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement (Loke, 2000).

The relationship between the “apparent” resistivity and the “true” resistivity is a complex relationship. To determine the true subsurface resistivity from the apparent resistivity values is what is called “inversion” (Loke, 2000). In this research one of the geophysical software called RES2D INVERSION was used for the inversion processes.

Source of Data

A 2-Dimensional Resistivity data was acquired at Agbarho Abattoir using PASI 16GL digital terameter with the Wenner array configuration and the co-ordinates and elevation of all the traverse points were also obtained to be N05°35' 01.5"; E085°51' 02.0", and N05°35' 02.8" and E05" 51" 04.7", 5m and 8m above Sea Level respectively.

The aquifer depth and probably geoelectric section of the investigated area was determined by carrying out Vertical electrical sounding (VES) using Schlumberger configuration. During the acquisition

of data on the field, four profile lines were acquired with 15 electrodes separated by 2.5m interval with a maximum spread of 50 m.

Processing of Acquired Data

RES2DINV version 6.2 inversion software was used as iteration software for inverting and processing the data acquired; the software was used in order to ascertain the areas of anomalies (concentrations) and also to delineate the extent of leachate plume. The VES was plotted on bi log graph and resistivity model curve which is also known as master curve and later processed with WINRES software, so as to delineate the number of layers, geo-electric section and aquifer zone.

Collection of Water Samples

Conductivity meter was used for the physiochemical and microbial parameters of the water sample collected from the borehole that is less than 5m to the study area, while pH meter, was used to determine pH of the water sample. The physiochemical parameters include Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Total Suspended Solids (TSS), Dissolved Oxygen (DO), Sulphate, Nitrate, etc. Also, the parameters of the microbial analyses include the following; coliform test, pigmentation and cell form.

Results

Map of Vertical Electrical Sounding

Vertical Electrical Sounding method using Schlumberger array configuration was conducted in the study area so as to determine the geoelectrical section and depth of aquifer level around the abattoir. This is necessary for us to know if the spread of contaminant plume displayed by the inversion model of RES2D software (figures 6 to 9) has reached the aquifer level.

Figure 5 below displayed a map that revealed the depth of aquifer at 8.9m and thickness of the layer is 5.1m. Table 1 showed the summary of the VES

of the area and it was revealed that the aquifer zone of the study area (Agbarho Abattoir) is in third layer and the lithology is found to be fine sand.

Table 1: Summary of the VES showing Thickness, Depth and Lithology of the Study Area

S/N	Layers	Thickness (m)	Depth (m)	Curve type	Probable lithology
VES	I	0.7	0.7	P1<p2>p3>p4 KQ	Top soil
	II	3.1	3.8		Sand
	III	5.1	8.9		Fine sand
	IV	--	--		Clay

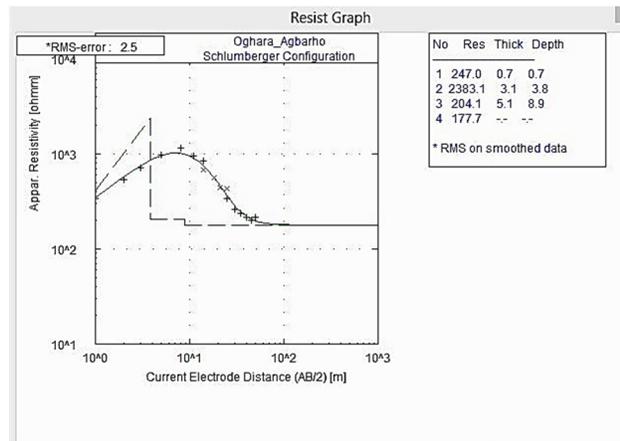


Figure 5: VES Curves showing the Depth and Lithology session of the study area

2-D Electrical Resistivity

Figures 6 to 9 are the maps or subsurface imaging generated using RES2D Inversion software, these maps are the four traverses that were conducted around the study area in Agbarho abattoir with a maximum lateral spread of 50m and they are displayed as cross sections of the true resistivity distribution of the subsurface with depth along each of the sections. On each map, the lateral distance is represented by the horizontal scale while the depth to the subsurface in meters is represented by the vertical scale. Also, the legend at the bottom of each map shows the resistivity value of all the colors in the resistivity structure.

The figure 6 displayed traverse one of the study area and the inversion model of this traverse showed low resistivity value of 0.445 Ω m (i.e. bluish region) at the top layer down to the depth of 3m to the subsurface. Traverse two showed high conductivity region which is equal to low resistivity value of 2.53 Ω m on the Inverse model resistivity section at the depth of 3.19 m. This low resistivity region in traverse 2 (fig 7) also occurred at the top soil of the lateral distance between 10m to 27.5m.

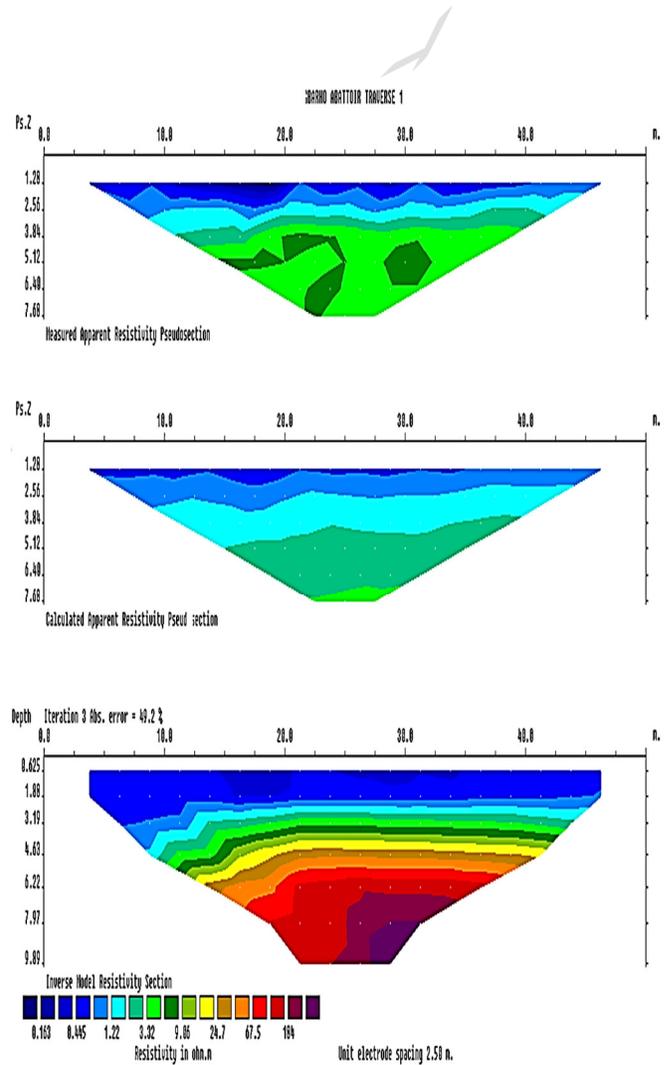


Fig 6: The Interpreted Apparent Resistivity, Pseudo-section and True Resistivity 2-D structure for Traverse 1

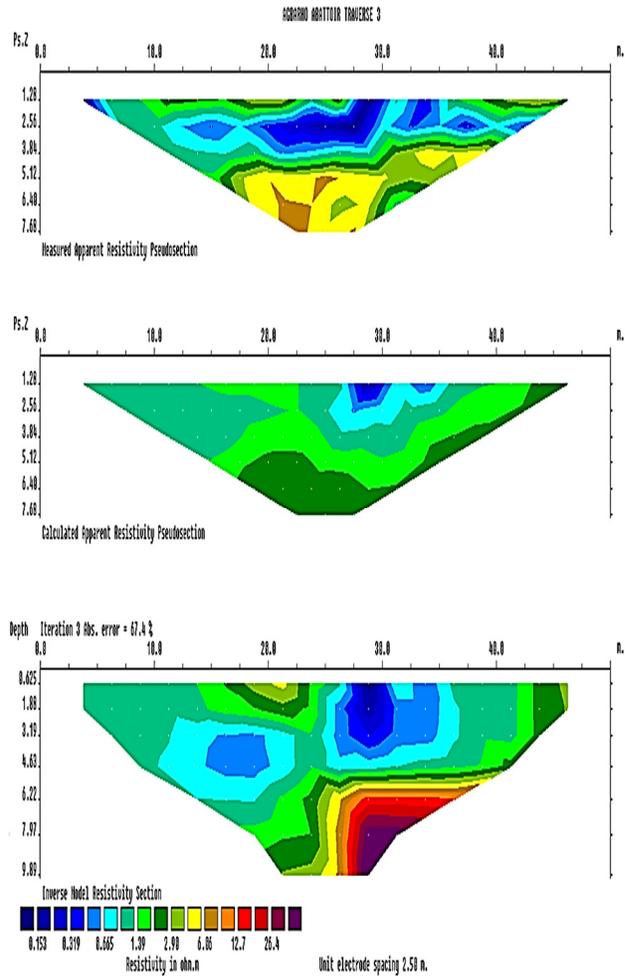
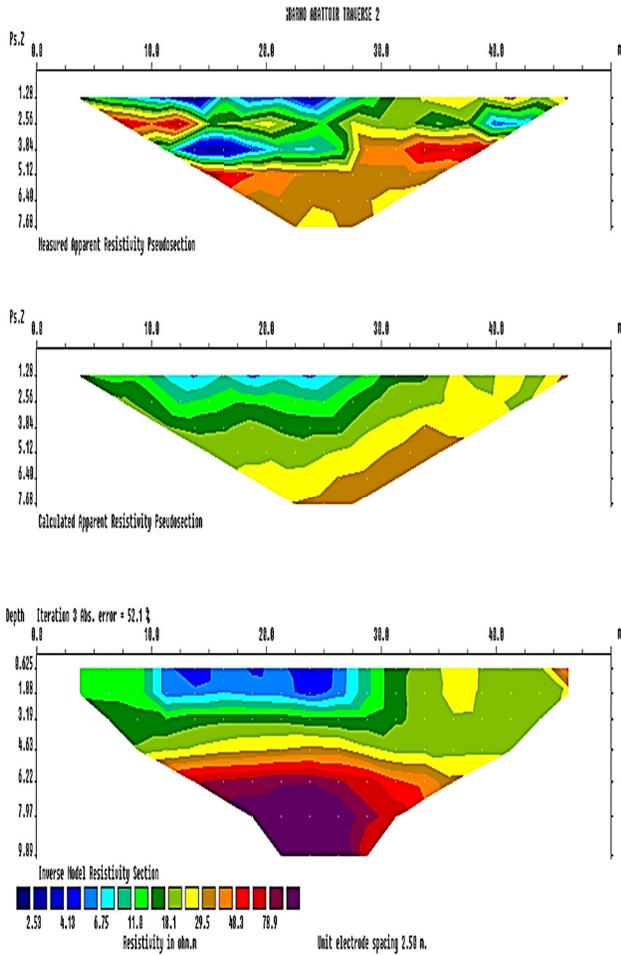


Fig 7: The Interpreted Apparent Resistivity, Pseudo-section and True Resistivity 2-D structure for Traverse 2

Fig 8: The Interpreted Apparent Resistivity Pseudo-section and True Resistivity 2-D structure for Traverse 3

The low resistivity value of $0.319 \Omega \text{ m}$ in the image of the Inverse Model of Traverse three in figure 8 below was indicated in the second layer of the study area at the lateral distance between 15m to 35m at the depth of 6.22m to the subsurface. Also, traverse four of the model of 2-Dimensional resistivity revealed a region of low resistivity value of $0.374 \Omega \text{ m}$, according to the model in figure 9, this low resistivity section means that the region is highly conductive and it occurred from the top soil to the fourth layer (according to VES in figure 5) at the depth of 9.8m.

However, all these low resistivity values indicate high conductivity of contaminants plume that discharged from the waste in abattoir and this plume contains bacteria, algae and other micro-organism of the animal waste. This is because the presence of these bacteria and any micro-organism in any fluid increases the fluid's conductivity and they are indicator organisms that has lower resistivity values as indicated as bluish color in the color (resistivity) chart. The presence of these indicative organism in water is the evidence of any polluted water.

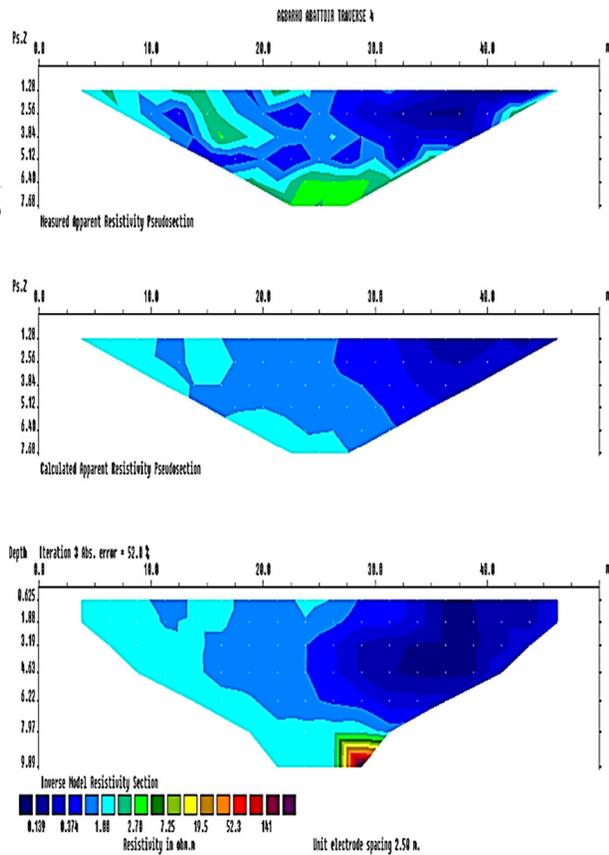


Fig 9: The Interpreted Apparent Resistivity Pseudosection and True Resistivity 2-D structure for Traverse 4

Analysis of Groundwater Samples Collected

Tables 2 and 3 show the results of all the physiochemical parameters and microbial analysis of water samples collected from the borehole that is less than 5m to the acquisition area.

It was observed from the table 2 that the pH value of the groundwater sample is 5.1 which fall below World Health Organization standard value which is between 6.5 and 8.5. This means that the subsurface water in the study area which is Agbarho abattoir is acidic and is not fit for direct domestic use. Also, Electrical Conductivity in the table is 61 $\mu\text{S}/\text{cm}$ which is below the World Health Organization permissible limit and this shows that the water in the study area is conductive. However, it can be observed that other physiochemical parameters fall

below recommended standard by WHO (WHO, 2017)

Table 2: Physiochemical Results of the Groundwater Samples from the Agbarho Abattoir

S/N	PARAMETERS	UNIT	SAMPLE RESULT	WHO STANDARD
1	pH		5.1	6.5 – 8.5
2	Electrical Conductivity (EC)	$\mu\text{S}/\text{cm}$	61	500
3	Total Dissolved Solids (TDS)	Mg/L	31	250
4	Turbidity	NTU	2.0	5.0
5	Total Suspended Solids (TSS)	mg/l	<1.00	N/A
6	Sulphate	mg/l	1.9	250
7	Nitrate	mg/l	15.8	50
8	Dissolved Oxygen (DO)	mg/l	10.2	92
9	Alkalinity	mg/l	6.1	92

Table 3: Microbiological Characteristics of the Bacterial Isolates of water Samples from Abattoir

S/N	Microbial Characteristics	Isolates / Results
1	Coliform Test	Negative 70 cfu/ml
2	Pigmentation	Yellow
3	Cell Form	Circular
4	Suspected Organism	Escherichia coli

Table 3 shows all the results of microbiological analysis of water sample and the table shows that the coliform count of the water sample analyzed is 70 cfu/ml. This coliform result shows that the water is contaminated with coliform bacteria and consequently not safe for domestic use. The other

microbiological results of the water sample in table 3 are as follows; pigmentation color is yellow; this means that the water is polluted with bacteria called *Staphylococcus aureus* and *Flavobacterium sp* (Usman *et al.*) and its cell form is circular. According to (WHO, 2017) *Escherichia coli* is present in very high numbers in human and animal faeces. Since the research is based on animal waste investigation and faeces is included, However, the suspected organism in the water sample analyzed is *Escherichia coli*. According to World Health Organization standard, all the results in table 3 are not in line with the guidelines for drinking water quality (WHO, 2017).

Conclusion

The inversion model in 2-Dimensional Resistivity method revealed that study area has a very low resistivity values that indicate high conductivity of bacterial and other micro-organism of the animal waste and this can be attributed to the presence of suspected contaminants plume. The model also showed that the contaminants occur at the depth of 9.8m as shown in figure 9 of traverse 4. Whereas, the Vertical Electrical Sounding (VES) method indicated aquifer at the depth of 8.9m, and this can be found in the third layer with the lithology of fine sand. Also, the values/results of the physiochemical and microbiological analysis of the borehole-water collected within the study area are not in line with the water quality standard as recommended by World Health Organization. It can be observed that contaminants plume exists in all traverses acquired around the abattoir, and these contaminants can be found down to the depth of 9.8m which is deeper than the depth of aquifer which is 8.9m.

The results of the Inverse model of 2-D Geoelectrical investigations, Vertical Electrical Sounding method and physiochemical/microbial analysis revealed that the contaminants exist and pose a threat to the subsurface water in Agbarho abattoir.

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