Geoelectric and Electrochemical Investigation of Piggery Waste Deposits and Their Environmental Impact at Bouesti Farm, Ikere Ekiti, Ekiti State, Southwestern, Nigeria

***O.V. Enuiyin[1], F.O. Ogunlana[1], A.O. Ogunlana[2], A.G. Usifo[3] and O.K. Adeoye[1]**

[1]Department of Physics, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Ekiti State, Nigeria

[2]Department of Mining Engineering, Federal University of Technology and Environmental Sciences, Iyin Ekiti, Ekiti State, Nigeria

[3]Department of Physical and Earth Sciences Crawford University, Igbesa, Ogun State

***Corresponding Author**

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ABSTRACT

This study investigates groundwater contamination resulting from untreated piggery waste disposal at BOUESTI Farm, Ikere-Ekiti, Southwestern Nigeria. The discharge of effluent into unlined pits promotes leachate generation and rapid infiltration into underlying aquifers, particularly within a hydrogeological setting characterized by intense tropical rainfall and permeable lateritic soils. Such conditions significantly increase aquifer vulnerability and threaten local potable water supplies.

An integrated approach combining Electrical Resistivity Tomography (ERT), Vertical Electrical Sounding (VES), and hydrochemical analysis was employed to delineate subsurface contamination and assess groundwater quality. The geophysical surveys identified extensive low-resistivity zones (<50 Ωm) extending laterally and vertically from the waste disposal area, indicative of conductive leachate migration pathways. Hydrochemical analyses of water samples from wells, boreholes, and waste pits revealed elevated Electrical Conductivity (EC), Total Dissolved Solids (TDS), and nitrate (NO_3^-) concentrations, with several values exceeding World Health Organization (WHO) permissible limits for drinking water. The detection of faecal coliform bacteria further confirmed significant microbial contamination.

The integrated findings demonstrate the presence of an active leachate plume and confirm that the groundwater system is both chemically and microbiologically compromised, rendering it unsuitable for human consumption. The study highlights the urgent need for engineered waste containment systems, leachate treatment infrastructure, and continuous groundwater monitoring to mitigate environmental degradation and protect public health.

Keywords: Groundwater contamination; Electrical Resistivity Tomography; Leachate plume; Nitrate pollution; Aquifer vulnerability.

INTRODUCTION

Background

Geophysical and Hydrochemical Assessment of Contaminants Distribution means using both geophysical techniques (such as electrical resistivity or electromagnetic surveys) and hydrochemical analysis (testing water for chemical and microbial contents) to detect, map, and understand how pollutants are spread in an environment. Geophysical methods help locate and outline zones in the soil or groundwater that may have been altered by contamination, while hydrcochemical methods identify the specific contaminants, their concentration and possible sources (Bernstone, C., & Dahlin, T. 1997).

Given the importance of maintaining a healthy and sustainable agricultural environment, it is crucial to assess the extent and distribution of contaminants around the piggery section of BOUESTI Farm. This study integrates geophysical and hydrochemical techniques to detect possible subsurface migration of contaminants from piggery waste into the surrounding soil and groundwater systems, analyze water samples for possible contamination such as ecoli test, total bacteria test, and sampling bottle. The findings of this study will help in identifying zones at risk of contamination, assessing the quality of groundwater around the farm, and providing scientific evidence to support appropriate waste management and environmental protection strategies test for anions and test for cations, and also recommend appropriate waste management strategies.

Environmental pollution resulting from agricultural activities has become a significant concern, particularly in areas where animal husbandry is practiced on a large scale. One such practice is pig farming, which produces large volumes of waste that, if not properly managed, can lead to serious environmental and public health hazards. These wastes contain high levels of organic matter, nutrients (especially nitrogen and phosphorus), pathogens, and potentially toxic substances that may leach into the soil and contaminate groundwater or be transported to surface water through runoff. Environmental monitoring of pig slurry ponds using geochemical (Ximena Capa-Camacho et al.2024).

Problem Statement

Despite the economic and research importance of piggery operations to the university, there has been limited scientific assessment of the environmental impact of its waste disposal practices. The increasing waste output from the piggery section of BOUESTI Farm poses a potential threat to the surrounding soil and groundwater resources. There is a growing concern that leachate from piggery waste may be infiltrating the soil and reaching the groundwater table, thereby endangering the quality of used for domestic, agricultural, and possibly drinking purposes by nearby communities. Geophysical methods, especially electrical resistivity techniques, are effective tools for detecting subsurface anomalies related to contaminant plumes in the soil and groundwater. Use of the geophysical approaches for studying the environmental impact assessment of the human burying techniques to the soil and groundwater. Application of geophysical techniques in detecting contamination plumes from agricultural waste. Kayode, et al demonstrated on how electrical resistivity surveys can identify leachate flow paths in near livestock farms in Nigeria (2005). Pollution of agricultural soil and shallow well water from animal waste on a teaching farm at Federal University of Technology, Akure. Akinbile, *et al;* showed heavy metal contamination and elevated chemical parameters including nitrates and TDS in soil and water samples close to animal waste dumpsites on farm land (2016).

Aim of the study

The aim of this study is to investigate the nature, extent, and environmental impact of contaminant distribution resulting from piggery waste on soil and groundwater systems around the BOUESTI farm, using integrated geophysical and hydrochemical methods, in order to support environmental protection, public health, and sustainable agricultural practices.

Objectives of the study

The objectives are:

1. to investigate possible subsurface migration of contaminants from piggery waste into the surrounding soil and groundwater systems.
2. to analyze the chemical composition of water samples around the piggery section.
3. contribute to environmental protection efforts and sustainable agricultural practices within and beyond the university community.

Research Questions

1. How does untreated piggery waste disposal influence groundwater quality and subsurface contamination around BOUESTI Farm, Ikere-Ekiti, Southwestern Nigeria?

2. What are the subsurface geoelectrical characteristics associated with leachate migration from the piggery waste disposal site?

3. To what extent can Electrical Resistivity Tomography (ERT) and Vertical Electrical Sounding (VES) delineate groundwater contamination zones around the study area?

Research Hypotheses

H_0: There is no significant correlation between subsurface resistivity values and groundwater quality parameters in the vicinity of the piggery waste disposal site.

H_1: There is a significant inverse correlation between subsurface resistivity values and groundwater quality parameters, indicating that zones of low resistivity correspond to areas affected by leachate contamination.

Significance of the study

1. Environmental Protection: The study provides critical data on how piggery waste affects soil and groundwater systems around the BOUESTI farm. By identifying areas at risk of contamination, it helps in developing strategies to prevent further environmental degradation.

2. Sustainable Agriculture: By highlighting the negative effects of poor piggery waste management, the study encourages the adoption of more sustainable and eco-friendly farming practices, ensuring long term productivity and resource conservation.

3. Academic and scientific contribution: The integration of geophysical and hydrochemical methods adds to the body of knowledge in environmental geoscience and hydrogeology. It also serves as a valuable reference for future research in similar agricultural or institutional settings

4. Policy and Decision Making: The finding of this research can be used by the university management, environmental agencies, and policymakers to improve waste disposal practices, enforce regulations, and ensure compliance with environmental standards.

LITERATURE REVIEW

Literature review

Geophysics involves the use of physical principles to study the Earth's subsurface without excavation. In environmental monitoring, geophysical methods such as Electrical Resistivity are valuable tools for detecting changes in subsurface properties caused by contamination. Electrical resistivity surveying measures how strongly the ground resists the flow of electric current. Contaminated zones, often with higher moisture and dissolved solids, tend to have lower resistivity values compared to uncontaminated soils. Groundwater is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences. Leachate migration from water sites or landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to groundwater resource if not adequately managed. The pH ranged from 5.7 to 6.8 indicating toxic pollution, turbidity values were between 1.6 and 6.6 NTU and temperature ranged from 26.5 to 27.50C. Concentrations of iron, nitrate, and calcium ranged from 0.9 to 1.4 mg L-1 and lead ranged from 1.1 to 1.2 mg L-1. The landfill was not directly responsible for the presence of Chromium in one of the wells but could be traced to an abattoir near the well. Bacteriological examinations revealed severe pollution in all the wells. Statistical analysis indicated significant differnces among all the parameters tested for in the samples at 95% level. The results showed that all but one of the boreholes was strongly polluted but require urgent certain levels of treatment before use (2011).

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Review of past work

Akinbile and Yusoff (2011) investigated piggery waste impact on groundwater in Akure, Southwest Nigeria. They found high nitrate levels exceeding WHO limits in wells near piggery units, indicating significant contamination. Kayode, Olayinka and Amidu (2005) applied electrical resistivity methods to detect leachate plumes around livestock farms. Their results showed low resistivity anomalies consistent with contamination pathways. Awomwso et al. (2010) assessed groundwater quality near livestock farms in Ogun State. Elevated TDS, EC and nitrate levels were recorded, suggesting infiltration of animal waste into the aquifer. Osunbitan, Babalola and Okunade (2008) studied slaughterhouse in Osun State and found that water sources nearby had contaminant concentration above WHO standards, showing that livestock related waste has a serious pollution potential. Essien et al. (2024) examined groundwater near slaughterhouses in Cross River State and found acidic pH, high conductivity, elevated heavy metals, making the water unsafe for drinking. Sangodoyin and Agbawhe (1992) reported contamination of shallow wells near abattoirs in Ibadan, with high concentrations of nitrates and coliform bacteria, especially during the wet season. Harkin (2024) in the USA found that improper manure management in pig farms led to nitrate contamination of groundwater, causing health concerns such as methemoglobinemia in infants. Hansen et al. (2001) in Denmark reported that areas with intensive pig farming had significantly elevated nitrate levels in groundwater, linked to high leaching from manure application on fields. Lal (2009) emphasized the need for sustainable livestock waste management globally to prevent soil and water degradation. Environmental impact of Leachate Pollution on Groundwater supplies in Akure, Nigeria. Akinbile and Yusoff investigated piggery waste impact on groundwater. Borehole locations were at radical distances of 50m, 80m, and 100m respectively away from the landfill. The parameters determined included; turbidity, tempture, pH, Dissolved oxygen (DO), total dissolved solids (TDS), Total hardness, Total Iron, Nitrate, Zinc and Lead using convectional equipment and standard laboratory procedures, most of these parameters indicated traceable pollution but were below the World Health Organization (WHO) and the Nigerian Standard for Drinking water quality (NSDWQ) limits for consumption. Appraisal of groundwater to risk contamination near an abandoned limestone quarry pit in Nkalagu, Nigeria, using enrichment factor and statistical approaches. Statistical index analysis using, contamination factor, metal pollution index, enrichment factor and ecological risk were successfully applied for the assessment of the impact of heavy metal contamination in groundwater resources within the study area. The samples were analyzed using the America Public Health Association standard (APHA) method. Results indicated that four component analysis; strong correlations were observed in the majority of the parameters. This Pearson's correlation matrix calculated shows weak correlations. Deduction from the pollution index of groundwater showed that values were <1, and were categorized into the following low, moderate and very high pollution zones. Ecological Risk Assessment results revealed that the ecological risk associated with Cd, Fe, As, Mn, Cu, Co, Ni, Zn and Pb are generally low. The contamination factor of this study reveals that the entire parameters had a low concentration of <1 in the entire study area except for HCO_3 which had a low concentration above 1(moderate contamination), and Fe (moderate contamination to considerable contamination). Pollution load index values imply that no pollution exists. Metal pollution index results in the entire groundwater sample in the study area below 0.3, which signifies that they are in class 1 and are said to be very pure. Hazard quotient order is Cd>Ni>Co>Mn>Zn>Fe. Hydrogeochemical characterization shows $HCO3^{-} + co_3$ and Na + K are the dominant ionic species: also, 80% of the groundwater resources in the study area are the geochemical zone of 4 with a hydrogeochemical trend of $HCO3^{-} + co_3 > SO_4 > Cl^{+} > Na^{+} + K^{+} > Mg^{+} > Ca^{+}$. Based on these results, pre-use treatment before use of the water resources is highly recommended. Hydrogeochemical processes regulating the spatial distribution of groundwater contamination, using pollution index of groundwater (PIG) and hierarchical cluster analysis (HCA). Analysis of water quality is one of the most fundamental aspects of groundwater studies, while the knowledge of geochemical processes that control the water chemistry is needed for groundwater management. Now a day's contamination of groundwater resources is s matter of serious concern (Subba Rao et al., 2019). Evaluation of groundwater quality is, thus, an essential aspect in understanding the role of rock-water interactions and/ or impacts of anthropogenic influences on the groundwater system (Li et al., 2016a; Subba Rao et al., 2027; Gorgij et al. 2019). Groundwater resource is a prime source of drinking water in the world, as it is generally good quality, difficult to contaminate and available throughout the year (Li and Qian, 2018a, b). However, with the rapid development of the urban economy, the gap between the water supply and its demand is widening day by day. About 75% of the world's total pollution faces tremendous water scarcity, while 660 million lack access to safe potable water (Mekonnen and Hoekstra, 2026), including India (Chaudhuri and

Roy, 2017). In many regions of the world, shortage of water and contamination of groundwater seriously restrict the economic development (Zhang rt al., 2014; Li et al., 2015). As contaminants and ions contained in soils dissolve thorough the recharge water and they reach finally the groundwater quality. Geochemistry of groundwater can be affected by natural processes, including chemical reaction between water and soil, and surface water-groundwater interactions as well as man-made activities. The chemical Variables from hierarchical cluster analysis (HCA) demonstrate three distinct clusters I, II and III, representing the salinity carbonate hardness and pollution processes. $Ca^{2+}>Na^{+}>Mg^{2+}>K^{+}$: $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}$ facies. The groundwater samples of Group III influenced by low pollution activity, which support the low pollution zone of pig (Li et al., 2016).

Research Gap

Despite growing concerns about groundwater contamination from livestock waste, there remains a paucity of integrated studies combining geophysical and hydrochemical techniques to delineate contaminant plumes and evaluate their impacts on groundwater quality within the basement complex terrain of Southwestern Nigeria. Furthermore, limited information exists on the extent of chemical and microbial contamination associated with piggery waste disposal practices in Ekiti State. This study addresses these gaps by integrating ERT, VES, and hydrochemical analyses to characterize leachate migration pathways, assess groundwater quality, and provide evidence-based recommendations for sustainable waste management and groundwater protection.

METHODOLOGY

Geophysical Method

Geophysical methods are scientific techniques used to measure and interpret variations in the physical properties of the Earth's surface in order to infer geological, structural, hydrological, or environmental conditions without direct excavation (Telford et al., 1990).

Geophysical techniques assess subsurface conditions without excavation, primarily by measuring physical properties such as electrical resistivity, conductivity, or induced polarization.

1. Electrical Resistivity Tomography (ERT): Measures how the ground resists an applied electrical current. Contaminated areas (e.g., with leachate) generally have lower resistivity due to higher moisture or dissolved solids. It uses surface electrodes to produce a 2D or 3D image of subsurface resistivity.

2. Induced Polarization (IP): Similar to ERT but measures how the ground temporarily stores (polarizes) electrical charge. Useful for distinguishing materials based on grain-surface chemistry.

3. Transient Electromagnetics (TDEM/ TEM): Generates transient electromagnetic pulses and measures the subsurface response. Effective for identifying conductive zones, such as saline contaminant plumes or aquifers.

Hydrochemical Methods

Hydrochemical method is the study of the chemical characteristics of groundwater to understand its evolution, sources of contamination, and suitability for intended uses (Freeze and Cherry 1979).

Techniques of Hydrochemical Methods

1. Water Quality Indices (WQI): Combine multiple parameters to produce an overall water quality score (e.g., for drinking or irrigation).

2. Graphical/Chemometric Tools: Tools like piper diagrams, Gibbs plots, Chadha plots help identify hydrochemical facies and interpret controlling processes like rock-water interactions or salinization.

How Geophysical and Hydrochemical Methods can assess contaminant distribution in a piggery section

Piggery farms produce large volumes of animal waste rich in organic matter, nitrogen, phosphorus and pathogenic microorganisms. If waste management is poor, leachates can infiltrate the soil and contaminate groundwater. Geophysical and Hydrochemical methods complement each other in detecting and monitoring such contamination.

Geophysical Assessment: Electrical resistivity methods can detect zones of high conductivity caused by leachates infiltrating into the subsurface. Contaminated zones usually have lower resistivity than clean groundwater zones due to the presence of dissolved salts and organic matter (Oladapo and Akintorinwa 2007).

Hydrochemical Assessment: Water samples collected from boreholes and shallow wells around the piggery can be tested for pH, EC, TDS, nitrates, ammonium, chlorides and microbial counts. Elevated levels of nitrates and ammonium indicate animal waste pollution (Owamah et al. 2013).

Electrical Resistivity Imaging

A 2D resistivity survey used the dipole-dipole configuration, with five spreads at 5m electrode spacing, achieving a depth of 25m. ERI combines horizontal profiling with vertical sounding –a proven method for detecting leachate movement into groundwater accumulation zone of subsurface.

Vertical Electrical Sounding

Three Vertical Electrical Sounding were deployed into two observable locations revealed by the dipole-dipole approach, while the third VES was located outside the delineated contaminated zone. Schlumberger configuration was adopted with the total spread of 200m. The data obtained were plotted on standard curves to obtained iteration parameters before using WinResist to process the field data. Field curves were generated from the process results which were used to produce geoelectric section. Ohmega Campus SAS 1000 Resistivity Meter instrument was used for data acquisition.

Hydrochemical Method

To ensure the integrity of the collected sample, a sterile 100 ml Bijou bottle was used during the sampling process. This careful approach ensures that the sample accurately reflects the borehole water quality. To preserve the quality and stability of the water sample until laboratory analysis, it was stored in a cooler with ice packs. This temperature-controlled environment was crucial for maintaining sample integrity during transport. Upon arrival at the laboratory, the sample was refrigerated at 4ºC to prepare it for detailed analysis. This rigorous methodology adheres to best practices in water quality assessment and underscores the commitment to safeguarding public health by delivering accurate and reliable result.

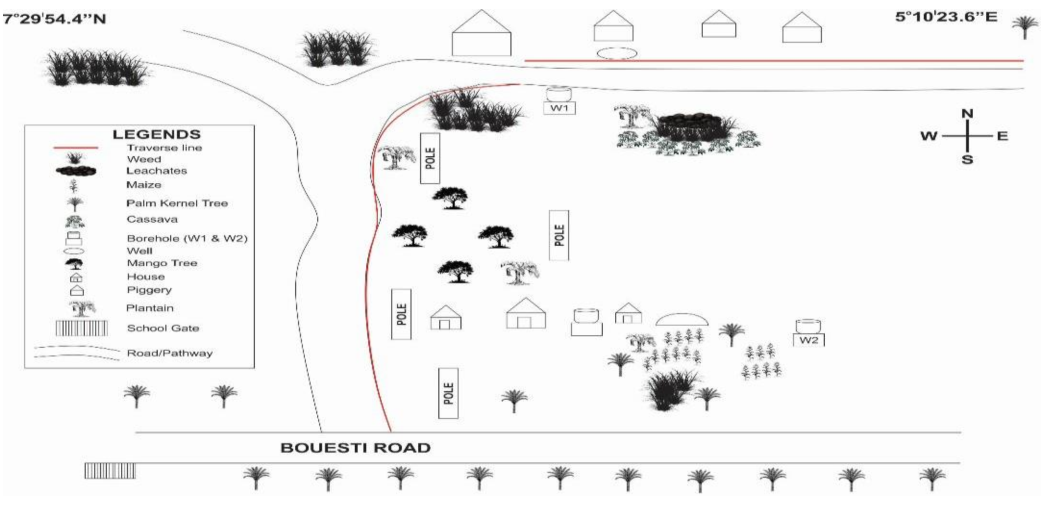

Figure 3.0: Base map of Bouesti farm showing piggery site of the study area

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RESULTS AND FINDINGS

Results Electrical Resistivity Imaging

The ERI pseudo-resistivity section shows extensive shallow low-resistivity zones between distances 20 to 40 m within a depth range of 0 to 7 m depth and a partly conductive anomaly between 50-60m extending beyond 10 m depth consistent within water-saturated zones containing leachate plumes and partly infiltrated zones (Figure 4.1)

Table 4.1

RESISTIVITY SOUNDING FIELD RECORD						
ELECTRODE ARRAY: DIPOLE-DIPOLE (n=5)						
DATE: 16/08/25						
INSTRUMENT: Omega Campus SAS 1000						
SITE DESCRIPTION: BOUESTI FARM, IKERE-EKITI						
a = 5m						
C_1	**C_2**	**p_1**	**p_2**	**G Factor**	**pa(T_1)**	**pa(T_2)**
1	2	3	4	94.2478	2.513	236.84
		4	5	376.9911	80.38	315.92
		5	6	942.4778	110.0	1036.73
		6	7	1884.956	1.594	3004.62
		7	8	3298.672	0.630	2078.16
2	3	4	5	94.2478	4.065	383.12
		5	6	376.9911	1.604	604.64
		6	7	942.4778	0.4181	394.05
		7	8	1884.956	0.07090	133.66
		8	9	3298.672	0.329	1085.26

RESISTIVITY SOUNDING FIELD RECORD
ELECTRODE ARRAY: DIPOLE-DIPOLE (n=5)
INSTRUMENT: Omega Campus SAS 1000
SITE DESCRIPTION: BOUESTI FARM, IKERE-EKITI
a = 5m

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3	4	5	6	94.2478	1.2830	120.92
		6	7	376.9911	0.06462	24.36
		7	8	942.4778	0.4402	415.35
		8	9	1884.956	0.007462	14.07
		9	10	3298.672	0.2635	869.2
4	5	6	7	94.2478	0.0252	2.38
		7	8	376.9911	0.8257	311.06
		8	9	942.4778	0.9491	894.51
		9	10	1884.956	0.02503	47.18
		10	11	3298.672	0.01872	61.75
5	6	7	8	94.2478	0.27700	2.61
		8	9	376.9911	0.01050	3.96
		9	10	942.4778	0.1019	96.04
		10	11	1884.956	2.443	403.95
		11	12	3298.672	0.3724	1228.43
6	7	8	9	94.2478	1.393	131.29
		9	10	376.9911	0.3402	128.25
		10	11	942.4778	0.1050	98.96
		11	12	1884.956	1.282	2416.51
		12	13	3298.672	0.07794	256.62
RESISTIVITY SOUNDING FIELD RECORD						
ELECTRODE ARRAY: DIPOLE-DIPOLE (n=5)						
INSTRUMENT: Omega Campus SAS 1000						
SITE DESCRIPTION: BOUESTI FARM, IKERE-EKITI						
a = 5m						
7	8	9	10	94.2478	1.4430	135.99
		10	11	376.9911	0.2269	85.54
		11	12	942.4778	0.08057	75.94

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		12	13	1884.956	0.06169	116.28
		13	14	3298.672	0.1201	396.17
8	9	10	11	94.2478	1.090	102.73
		11	12	376.9911	0.4079	153.77
		12	13	942.4778	0.1645	155.03
		13	14	1884.956	0.6704	1263.7
		14	15	3298.672	0.06512	214.81
9	10	11	12	94.2478	1.0500	104.14
		12	13	376.9911	0.3170	119.51
		13	14	942.4778	0.1231	116.02
		14	15	1884.956	0.0735	138.47
		15	16	3298.672	0.0908	299.42
10	11	12	13	94.2478	1.484	139.86
		13	14	376.9911	7.1990	2713.96
		14	15	942.4778	0.08709	87
		15	16	1884.956	0.03786	71.36
		16	17	3298.672	0.2070	82.83
RESISTIVITY SOUNDING FIELD RECORD						
ELECTRODE ARRAY: DIPOLE-DIPOLE (n=5)						
INSTRUMENT: Omega Campus SAS 1000						
SITE DESCRIPTION: BOUESTI FARM, IKERE-EKITI						
a = 5m						
11	12	13	14	94.2478	2.068	194.9
		14	15	376.9911	0.8608	324.41
		15	16	942.4778	0.3513	331.09
		16	17	1884.956	0.1221	230.15
		17	18	3298.672	0.1140	376.05
12	13	14	15	94.2478	3.571	336.56

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		15	16	376.9911	1.0390	391.69
		16	17	942.4778	5.502	1415.6
		17	18	1884.956	0.1898	357.76
		18	19	3298.672	0.921	3038.08
13	14	15	16	94.2478	1.373	129.4
		16	17	376.9911	0.5553	209.72
		17	18	942.4778	0.747	704.03
		18	19	1884.956	4.822	599.42
		19	20	3298.672	0.0516	170.15
14	15	16	17	94.2478	3.2100	302.54
		17	18	376.9911	1.2410	461.85
		18	19	942.4778	0.7865	741.26
		19	20	1884.956	0.07977	150.36
		20	21	3298.672	0.07621	253.04
RESISTIVITY SOUNDING FIELD RECORD						
ELECTRODE ARRAY: DIPOLE-DIPOLE (n=5)						
INSTRUMENT: Omega Campus SAS 1000						
SITE DESCRIPTION: BOUESTI FARM, IKERE-EKITI						
a = 5m						
15	16	17	18	94.2478	4.0080	95.01
		18	19	376.9911	36.67	1383.56
		19	20	942.4778	0.2787	262.67
		20	21	1884.956	0.1524	287.27
		21	22	3298.672		
16	17	18	19	94.2478	4.170	393.01
		19	20	376.9911	0.8007	301.86
		20	21	942.4778	0.3332	314.03
		21	22	1884.956		

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		22	23	3298.672		
17	18	19	20	94.2478	2.991	281.9
		20	21	376.9911	0.8693	327.79
		21	22	942.4778		
		22	23	1884.956		
		23	24	3298.672		
18	19	20	21	94.2478	3.130	294.99
		21	22	376.9911		
		22	23	942.4778		
		23	24	1884.956		
		24	25	3298.672		

Results of Vertical Electrical Sounding

Three field curves were obtained from the data which includes K-Curve, H-Curve and A-Curve which reveals Topsoil Polluted Zone, Partly Weathered Zone and Fresh Basement Zone; Clean Topsoil, Polluted Weathered Zone and Fresh Basement; and Topsoil, Weathered Zone and Fresh Basement for VES 1, VES 2 and VES 3 respectively. Figure 4.2(a-c). The geoelectric section shows four major formations delineated are Topsoil Leachate Polluted Zone. Topsoil, Weathered Basement, Weathered Basement Polluted Zone and Fresh Basement with resistivity ranging from 138, 367 – 1043, 439 – 599, 1789 – 16083 (Ωm); and basement thickness ranging from 0 — 8.2, 0.3 – 2.8, 0 – 13.3 (m) and infinity respectively.

Table 4.2

RESISTIVITY SOUNDING FIELD RECORD								
HALF ELECTRODE ARRAY – SCHLUMBERGER								
INSTRUMENT: Omega Campus SAS 1000								
DATE: 16/08/2025								
VES POINT 9, POINT 21								
AB/2	**MN/2**	**K**	**R_1**	**$KR_1(p_1)$**	**R_2**	**$KR_2(p_2)$**	**R_3**	**$KR_3(p_3)$**
1	0.5	6.28	0.2522	1.58	60.88	382.33	68.31	428.99
2	0.5	25.13	0.78	19.60	8.546	214.76	12.93	324.93
3	0.5	56.13	2.604	146.16	3.52	197.58	6.18	346.88
4	0.5	100.53	1.3552	136.24	2.002	201.26	4.38	440.32
6	0.5	226.19	0.6042	136.66	0.9994	226.05	2.168	490.38

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6	1.0	113.10	1.3186	149.13	2.058	232.76	4.301	486.44
8	1.0	201.06	0.7046	141.67	1.2358	248.47	2.318	466.06
12	1.0	452.39	0.4806	217.42	0.644	291.34	1.125	508.94
15	1.0	706.86	0.2928	206.97	0.418	295.47	0.917	648.19
15	2.0	353.43	0.384	135.72	0.880	311.02	1.829	646.42
25	2.0	981.75	0.24	235.62	0.3234	317.50	0.831	815.83
32	2.0	1608.50	0.1959	315.11	0.2176	350.01	0.482	775.30
40	2.0	2513.27	0.1689	424.49	0.1812	455.40	0.3571	897.49
40	4.0	1256.80	0.3286	412.98	0.3092	388.60	0.7135	896.73
65	4.0	3318.78	0.2258	749.38	0.4048	1343.44	0.5113	1696.89
100	4.0	7855.00	0.0956	750.94	0.0829	651.18	0.3192	2507.32

VES1

Nothing: 7.498447

Easting: 5.173232

Elevation: 424 yd a.s.I

VES2

Nothing: 7.498442

Easting: 5.173360

Elevation: 424 yd a.s.I

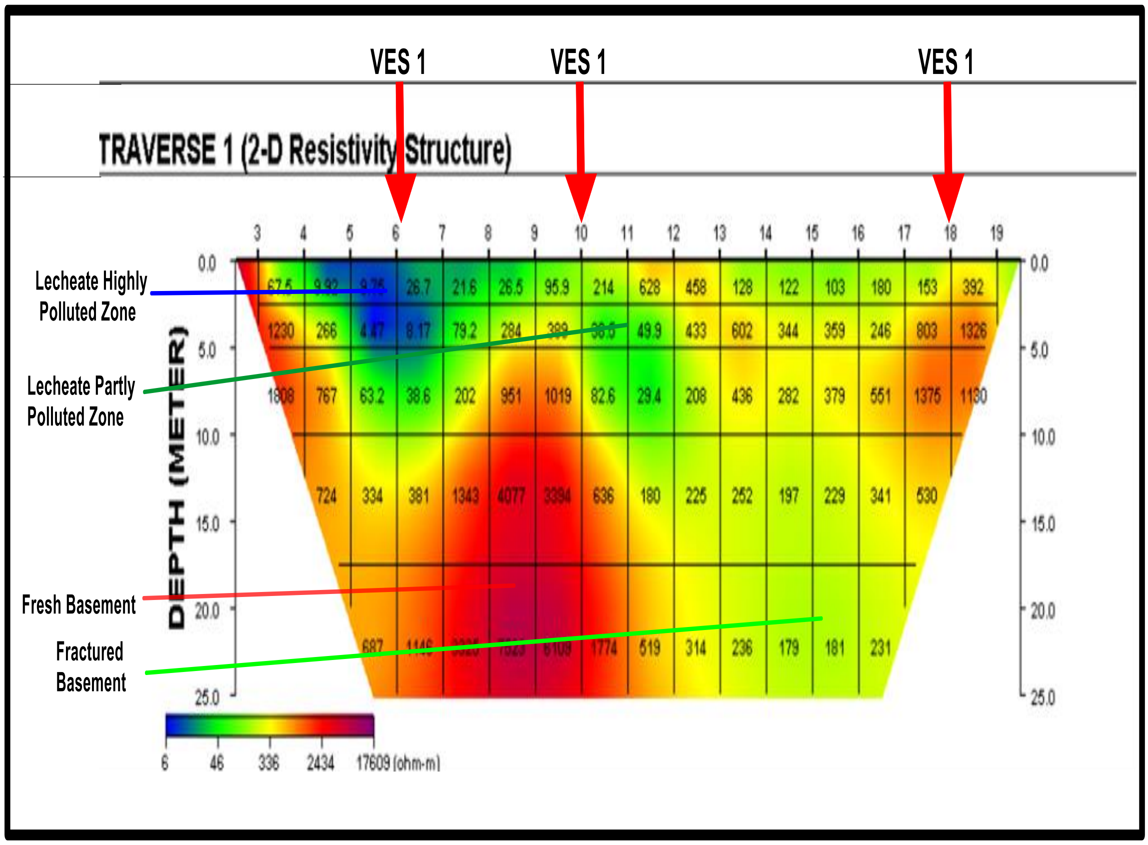

Figure 4.1 Geo-resistivity Pseudo-Structure of the Study Area

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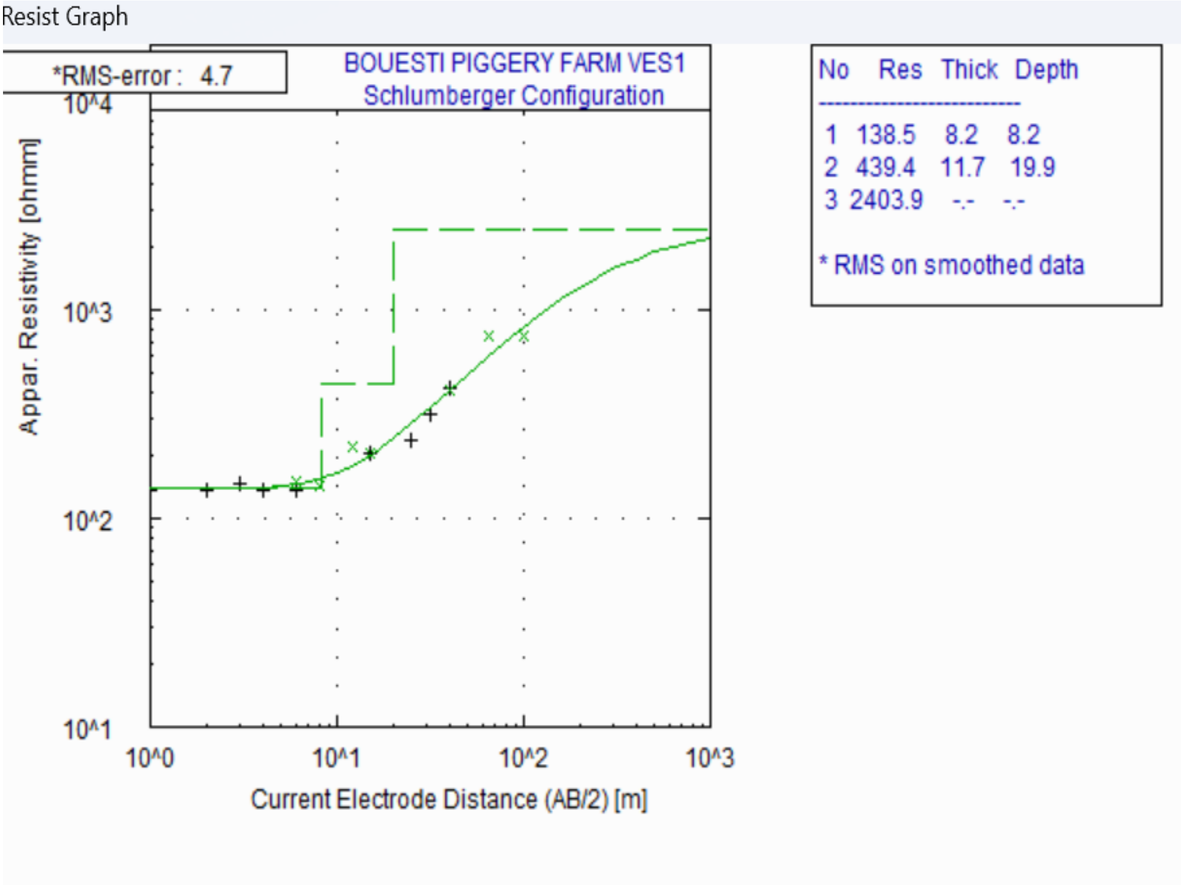

Figure: 4.2.0 The Field Curves Of The Study Area

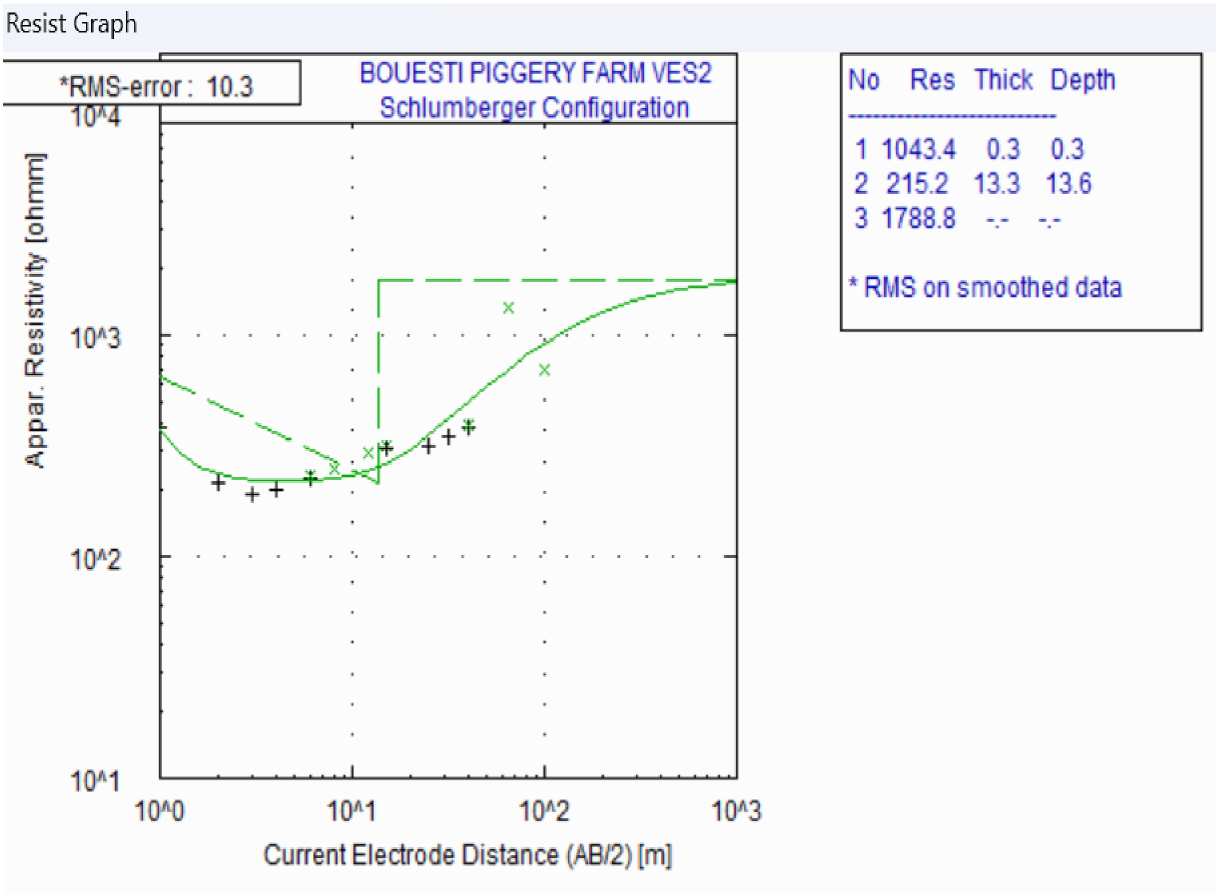

Figure: 4.2.1 The Field Curves Of The Study Area

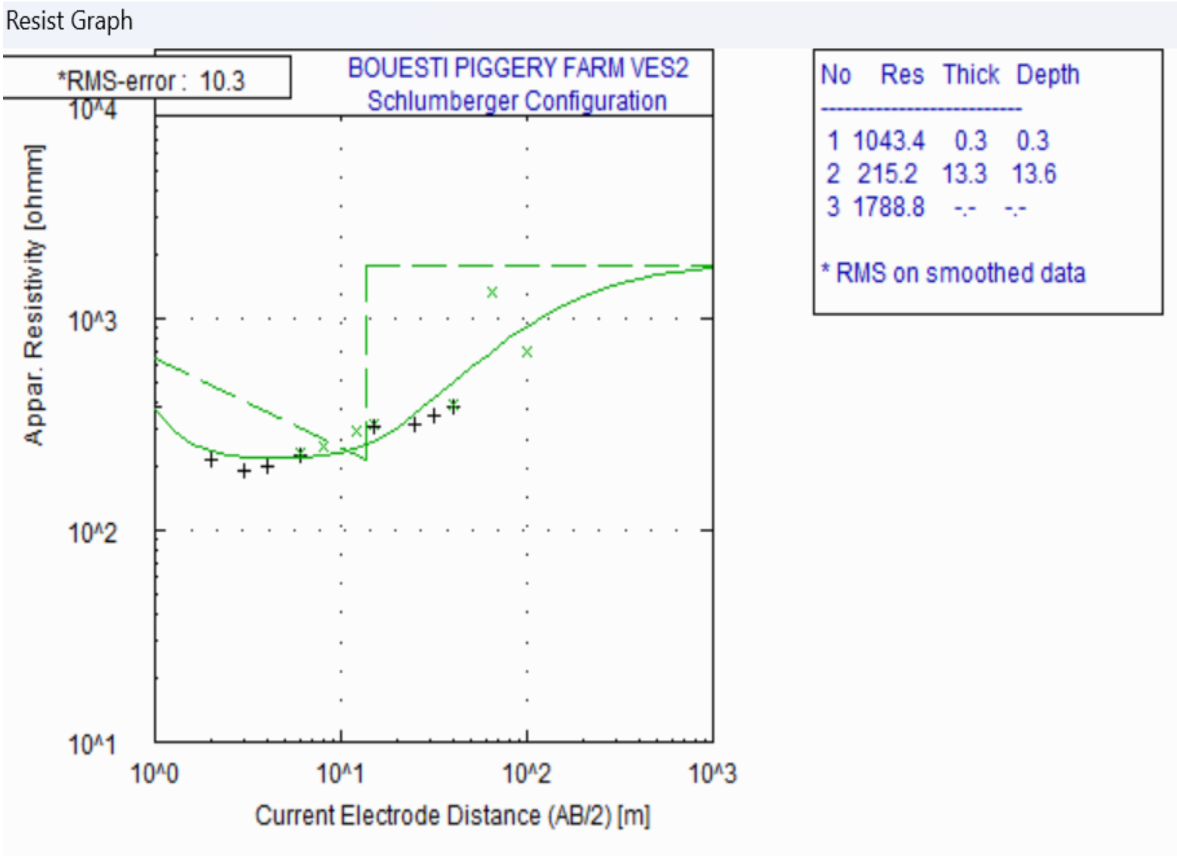

Figure: 4.2.2 The Field Curves Of The Study Area

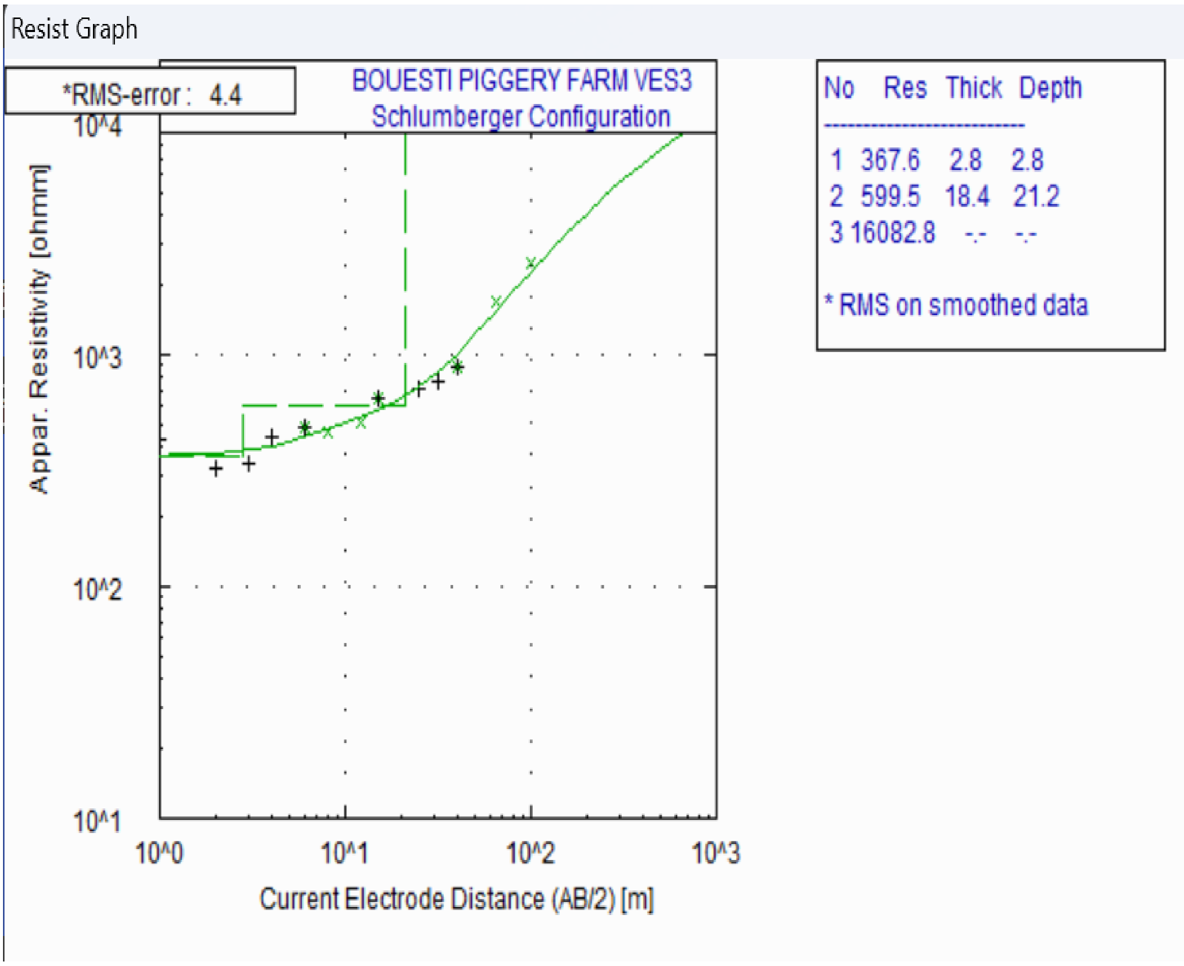

Figure: 4.2.3 The Field Curves Of The Study Area

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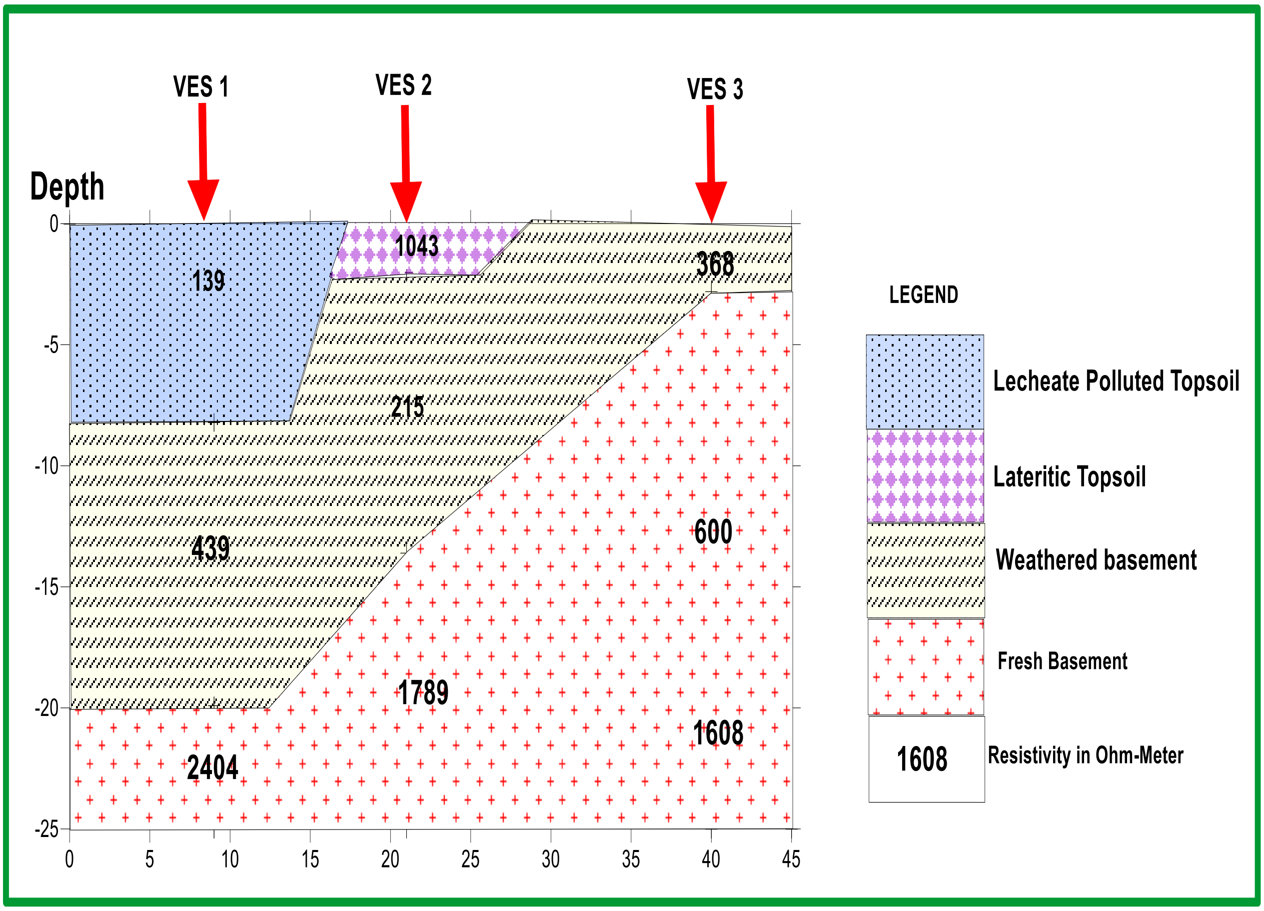

Figure 4.3 Geoelectric Section Of The Study Area

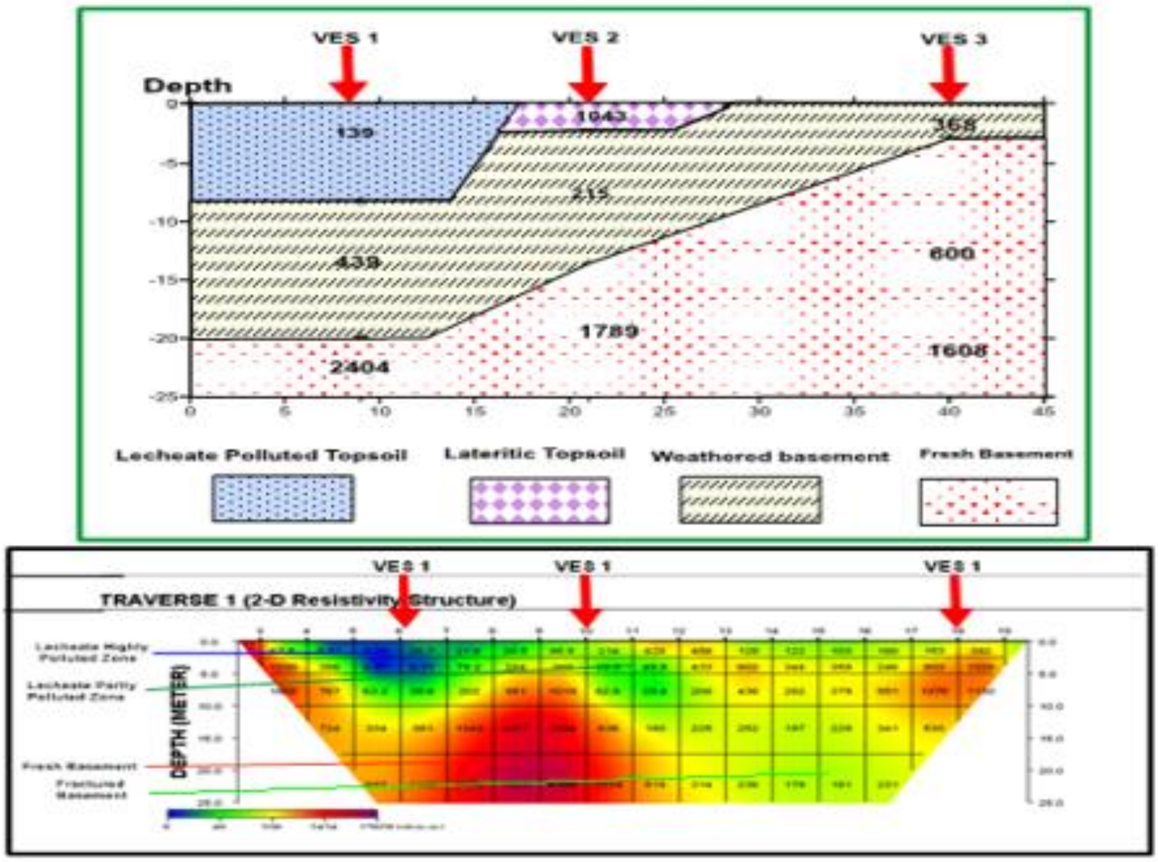

Figure 4.4 Result Of Integrated Method Of Geophysics

Water Analysis Of The Study Area

Water is fundamental for sustaining life, and ensuring a reliable supply of safe, adequate, and accessible drinking water is essential for every individual. Access to safe drinking water can lead to significant health benefits since contamination is a primary contributor to waterborne diseases, which pose a substantial burden on global health. Contaminated drinking water is linked to various illnesses that can severely impact both physical and public health. Therefore, implementing targeted interventions to improve water quality in communities, schools, and healthcare Facility is crucial for safeguarding public health and enhancing overall well-being.

In response to this need, a water quality assessment was conducted on the borehole water sample from the Piggery. Analyzing this sample is essential for understanding water quality at the farm in alignment with the guidelines established by the Nigerian Industrial Standards (NIS) and the World Health Organization (WHO). These organizations provide vital frameworks for determining maximum allowable limits for various contaminants in drinking water, which guided the selection of parameters for this study.

The results of the Water samples from a borehole located within the piggery section and a control point very far from the study area labelled as W2 and W1 are presented in Table 4.1 below.

Table 4.1: Result of Water analysis within the study area

Parameters	**Control Point (W2)**	**Piggery Area (W1)**	**WHO**
Bicarbonate mg $CaCO_3$ /L	16.20	14.14	—
Calcium mg/L	24.60	32.18	—
Magnesium (mg/L)	8.99	12.18	—
Nitrate (mg/L)	0.34	52	50mg/L
Sulphate (mg/L)	14.50	18.42	—
Chloride (mg/L)	11.80	14.20	—
Potassium (mg/L)	5.2	8.6	—
Sodium (mg/L)	12.6	18.5	—
Manganese (mg/L)	ND	0.03	0.4 mg/L
Cadmium (mg/L)	ND	ND	0.003 mg/L
Zinc (mg/L)	0.10	0.08	—
Iron (mg/L)	0.08	0.12	—
Lead (mg/L)	ND	ND	0.01 mg/L (10 µg/L)
Chromium (mg/L)	ND	ND	0.05 mg/L (50 µg/L)
Nickel (mg/L)	0.04	0.08	0.07 mg/L (70 µg/L)
MICROBIOLOGICAL			
E. Coli count (cfu/ml)	0	0	0 cfu/100 mL

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Total Bacteria Count (cfu/ml)	124	168	0 cfu/100 mL

DISCUSSION

The analysis of the Physico-chemical parameters from the surveyed project locations reveals a range of values that highlight key trends in water quality. The parameters analyzed include Appearance, Temperature, Turbidity, Conductivity, pH, Total Hardness, Alkalinity, Nitrate, Total dissolved solids, Total solids and Total suspended solids. Here is an analysis of the water sampling results, with definitions and implications for each parameter:

Appearance: The water is clear and colorless, which is ideal and aligns with NIS and WHO standards that require water to be visually free of color and turbidity.

Temperature (°C): The measured temperature of 28.3°C is within acceptable environmental temperature ranges, as WHO has no strict limit but recommends monitoring water sources for changes. This temperature does not suggest any harmful impact on water quality.

Turbidity (NTU): A turbidity of 3.0 NTU is within the NIS limit of 5 NTU and WHO guideline of ≤5 NTU. This low turbidity indicates a clear water source with minimal suspended particles.

Conductivity (µS/cm): At 98.8 µS/cm, the conductivity is well within the typical range for freshwater (WHO recommends ≤1500 µS/cm). This indicates a low level of dissolved salts and acceptable mineral content according to both NIS and WHO standards.

pH: The pH level of 6.03 is slightly acidic but remains within the WHO recommended range of 6.5–8.5. Although it is slightly below this range, it is still acceptable for natural water sources and does not pose a significant concern for health or safety.

Acidity (mg/L): The acidity of 6.80 mg/L is within acceptable levels, as neither NIS nor WHO provide strict limits on acidity but consider acceptable pH ranges. This level does not indicate a risk for water corrosivity.

Alkalinity (mg $CaCO_3$/L): With a value of 24.0 mg/L, the alkalinity is within safe limits, as it provides sufficient buffering capacity without exceeding WHO or NIS guidelines.

Total Dissolved Solids (TDS) (mg/L): A TDS of 68.4 mg/L is well within the NIS and WHO guideline of ≤500 mg/L. This low concentration suggests minimal dissolved minerals and high-water quality.

Total Solids (mg/L): The total solids content of 69.6 mg/L, including both dissolved and suspended solids, is below WHO's recommended levels, indicating minimal particulate matter.

Total Suspended Solids (TSS) (mg/L): At 1.20 mg/L, TSS is very low and well within NIS standards, which do not strictly limit TSS for drinking water, though WHO suggests minimal suspended particles for optimal water quality.

Total Hardness (mg/L): With a total hardness of 16.8 mg/L, the water is classified as soft, which is well below the WHO threshold of 100–300 mg/L. This level minimizes scaling and is within NIS guidelines.

Calcium Hardness (mg/L): The calcium hardness of 24.60 mg/L is below WHO limits, which typically allows up to 75 mg/L. This low value aligns well with standards, indicating safe and low calcium content.

Magnesium Hardness (mg/L): A magnesium hardness of 8.99 mg/L is safely below WHO's recommended limit of 50 mg/L, further supporting the classification of the water as soft.

Chloride (mg/L): The chloride concentration of 11.80 mg/L is well below the NIS and WHO maximum allowable limit of 250 mg/L, indicating minimal risk of corrosion and no salinity issues.

Nitrate (mg/L): Nitrate at 52mg/L is above the limit of NIS and WHO which is 50 mg/L, suggesting there is a contamination from fertilizers or organic waste of the piggery waste.

Sulphate (mg/L): The sulphate level of 12.60 mg/L is within both NIS and WHO limits of 250 mg/L, indicating no significant sulphate contamination.

In summary, each parameter analyzed aside Nitrate falls well within NIS and WHO standards and limits for safe water quality, suggesting that the water is safe for its intended use and demonstrates high-quality environmental compliance. The results reveal low levels of contamination, soft water, and minimal turbidity, indicating the Facility maintain good water quality management practices.

Heavy Metal Analysis of Water Sample

The analysis of the Heavy metals parameters from the water sample reveals a range of values that highlight key trends in water quality. The parameters analyzed include Manganese (Mn), Cadmium (Cd), Lead (Pb), Chromium (Cr), and Nickel (Ni).

Manganese (mg/L)

Manganese is a naturally occurring metal that, in excess, can impact water taste and color, and pose health risks. The level of 0.03 mg/L is within both NIS and WHO limits of 0.4 mg/L, indicating safe concentrations without risk of adverse effects.

Cadmium (mg/L)

Cadmium is a toxic heavy metal with strict safety thresholds due to its potential for causing kidney damage and other health issues. Its absence in the sample (BDL) is ideal, as both WHO and NIS standards limit cadmium to a maximum of 0.003 mg/L. The BDL result confirms compliance and safety.

Lead (mg/L)

Lead is a highly toxic metal, particularly harmful to the nervous system and overall human health. Its presence in drinking water is undesirable. The BDL result indicates an absence of lead, which aligns with WHO and NIS standards that set the maximum allowable concentration at 0.01 mg/L, confirming the water is safe from lead contamination.

Chromium (mg/L)

Chromium, especially in its hexavalent form, is toxic and poses serious health risks at elevated levels. Its absence (BDL) is in compliance with WHO and NIS guidelines, which allow a maximum of 0.05 mg/L, confirming there is no chromium-related risk.

Nickel (mg/L)

Nickel can cause skin irritation and other health effects at high levels. The result of 0.08 mg/L is well below the NIS and WHO limit of 0.07 mg/L, indicating nickel levels are within a safe range and pose no health concern.

The heavy metal analysis results for the water sampled demonstrate that each parameter is well within the NIS and WHO safety limits except Nickel which requires a great concern for groundwater within the study area. The levels of zinc, manganese, copper, and iron are all within safe ranges, and cadmium, lead, and chromium were below detection limits, indicating no contamination. This analysis confirms that the Facility' water sources are free from harmful heavy metal contamination and meet environmental and health safety standards.

Microbiological Analysis of Water Sample

The analysis of water microbiological sampling results offers important insights into microbial health and potential contamination issues within the water environment. Evaluated parameters include Total Coliforms and E. coli, each reflecting critical aspects of water microbiology and their implications for environmental safety. This discussion analyzes the results of each parameter and their significance in line with the Environmental Audit.

Total Coliform (cfu/ml):

Total coliform bacteria include various types of bacteria that are naturally present in the environment. While generally harmless, their presence in water is monitored as an indicator of potential fecal contamination. The result of 128 cfu/ml is above NIS and WHO guidelines, which generally allow minimal coliform presence in treated or natural water sources. This high count indicates that the water is largely polluted with coliform bacteria, suggesting significant contamination from the piggery waste.

E. Coli (cfu/ml)

Escherichia coli (E. coli) is a type of coliform bacteria specific to fecal contamination. Certain strains of E. coli can be pathogenic, making their presence a significant health concern. The result of 0 cfu/ml for E. coli is well within NIS and WHO guidelines, which recommend the absence of E. coli in potable water. This absence confirms that the water is free from fecal contamination and is safe for consumption.

In summary, the microbiological analysis of water sample demonstrates that Total Coliform Bacteria count is above NIS and WHO safety limits. The high total coliform levels indicate that the water is not microbiologically safe and free from contamination.

Summary

This research investigated the geophysical and hydrochemical characteristics of the soil–groundwater system around the piggery section of BOUESTI Farm, Ikere-Ekiti, to evaluate the nature and extent of contaminant distribution arising from piggery waste.

Geophysical Investigation

A 2-D Electrical Resistivity Imaging (ERI) survey and Vertical Electrical Sounding (VES) revealed low-resistivity anomalies (0–7 m depth and locally beyond 10 m), consistent with leachate plumes and water-saturated zones. Geoelectric sections delineated topsoil leachate-polluted zones, weathered basement, and fractured bedrock, indicating downward migration of contaminants through weak zones.

Hydrochemical Analysis

Physico-chemical parameters: Most were within WHO and Nigerian Industrial Standards (NIS) limits, except nitrate at 52 mg/L, slightly above the 50 mg/L WHO limit, suggesting infiltration of nitrogen-rich piggery effluent.

Heavy metals: Manganese, cadmium, lead, and chromium were below limits, but nickel (0.08 mg/L) marginally exceeded the 0.07 mg/L guideline, requiring attention.

Microbiological tests: E. coli was absent, but Total Coliform counts (168 cfu/mL in the piggery borehole) exceeded the recommended 0 cfu/100 mL, showing microbial influence from surface activities.

CONCLUSION

The integrated geophysical and hydrochemical assessment demonstrates that

Subsurface leachate migration is already occurring within the piggery section, as revealed by low-resistivity zones. Groundwater quality is generally good but exhibits early warning signs of contamination, notably elevated nitrate, slight nickel enrichment, and high total coliform levels. If unmanaged, these contaminants could threaten domestic and agricultural water use, with implications for public health, sustainable agriculture, and environmental integrity in the surrounding communities.

RECOMMENDATION

1. **Improved Waste Management:** Construct lined or concrete holding pits or anaerobic digesters for piggery effluent to prevent uncontrolled seepage. Regularly remove and properly compost solid manure before field application.

2. **Groundwater Protection Measures:** Establish a minimum buffer zone (≥30 m) between the piggery and any well or borehole. Periodically disinfect wells and seal abandoned boreholes to reduce microbial intrusion.

3. **Routine Monitoring:** Conduct biannual hydrochemical and microbiological tests on nearby wells. Repeat geophysical surveys every 2–3 years to track subsurface changes.

4. **Policy and Institutional Actions:** BOUESTI management should develop a farm-level environmental management plan aligned with Ekiti State and national water-quality regulations. Engage local environmental agencies for enforcement and technical support.

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