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Investigation Of Leachate Percolation to Groundwater Depth Around Choba Campus, University of Port Harcourt.

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ABSTRACT
Investigation of Leachate Percolation to Groundwater Depth Around Choba Campus, University of Port Harcourt. This study investigates the extent of leachate percolation and its impact on groundwater quality within and around the Choba Campus of the University of Port Harcourt, Rivers State, Nigeria. The rapid population growth and unregulated waste disposal practices in the area have raised concerns over potential contamination of shallow aquifers. To assess the subsurface impact of leachate migration, the study employed a non-invasive geophysical technique—Apparent Diffusion Magnetic Technology (ADMT)—to delineate resistivity anomalies indicative of contamination. Two geophysical survey lines were established across suspected waste disposal zones. Results from the 2D resistivity tomograms and geoelectric sections revealed low-resistivity zones (<100 Ωm) extending to depths of 25–30 meters, consistent with known leachate plumes. These anomalies suggest active percolation of leachate from surface waste deposits into the vadose and phreatic zones, facilitated by the high permeability of the underlying Benin Formation sediments. The vertical and lateral spread of these low-resistivity zones confirms the vulnerability of the aquifer system to pollution, with possible implications for the quality of water extracted from boreholes and hand-dug wells in the area. The study underscores the urgent need for improved waste management practices, groundwater monitoring, and environmental regulation enforcement to prevent further degradation. It also demonstrates the effectiveness of integrating geophysical methods in environmental assessment and provides a replicable model for evaluating leachate migration in similar urban settings. Ultimately, the research contributes to the sustainable management of groundwater resources within the Niger Delta region.
Keywords: *leachate, groundwater, percolation, investigation, campus, geophysical, resistivity, ADMT.*

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I. Introduction

Environmental pollution arising from improper waste disposal and the consequent contamination of groundwater resources has emerged as a critical concern in both developed and developing countries. In urban and semi-urban regions such as Choba in Rivers State, Nigeria, the exponential increase in population and the expansion of academic institutions such as the University of Port Harcourt have led to increased waste generation. A substantial portion of this waste, particularly solid waste, is disposed of in open dumpsites or poorly engineered landfills, which in turn become significant sources of leachate. Leachate is the liquid that percolates through a solid waste deposit, drawing out dissolved and suspended materials from it. When this leachate infiltrates into the subsurface, it may eventually reach and contaminate the groundwater, thereby posing environmental and health hazards (Alam&Ahmaruzzaman, 2021).

Groundwater serves as a major source of potable water for domestic, agricultural, and industrial uses in Nigeria, including the University of Port Harcourt and its environs. As the most abundant and readily available fresh water source, the contamination of groundwater systems by leachate from solid waste is particularly alarming due to the difficulty of remediation once pollution occurs (Foster & Chilton, 2003). Around Choba campus, waste is often disposed without adequate lining or leachate collection systems, which increases the risk of infiltration into the unsaturated zone and the eventual contamination of underlying aquifers.

The University of Port Harcourt’s Choba campus, located within the Niger Delta sedimentary basin, sits atop a geologically complex region consisting predominantly of unconsolidated sands, clayey layers, and interbedded silts. These lithologies facilitate vertical and lateral migration of contaminants, especially in areas where the vadose zone (unsaturated zone) is thin or has high permeability (Ibe&Egereonu, 2003). The relatively shallow water table in many parts of the Choba region further exacerbates the vulnerability of the aquifer systems to contamination from surface sources such as dumpsites and leachate ponds. Several boreholes and hand-dug wells scattered across the campus and surrounding community depend on this groundwater for everyday water needs. Given the absence of stringent waste disposal regulations and the visible signs of indiscriminate dumping, concerns about potential contamination are legitimate.

The importance of groundwater monitoring in this region cannot be overstated. The infiltration of leachate into groundwater not only alters its physico-chemical characteristics but can introduce toxic substances such as heavy metals (e.g., lead, cadmium), organic pollutants, and pathogens that pose severe health risks (Obi & George, 2011). Leachate is known to be rich in ammoniacal nitrogen, chemical oxygen demand (COD), biological oxygen demand (BOD), and various dissolved solids, all of which can degrade water quality and violate World Health Organization (WHO) and Nigerian water quality standards for drinking water (WHO, 2017; SON, 2007).

Previous studies in similar environmental settings have revealed that leachate migration from open dumpsites can extend several meters below ground surface depending on the permeability of the soil and the volume of waste deposited (Mor et al., 2006). Geophysical methods, particularly Electrical Resistivity Tomography (ERT), have proven to be reliable and non-invasive tools for investigating subsurface contamination and tracing leachate plumes (Adelusi et al., 2013). These methods enable researchers to determine the resistivity variations in subsurface materials, thereby identifying zones of possible leachate infiltration which typically exhibit lower resistivity values due to increased ionic concentration in the soil water.

The increasing concerns surrounding groundwater contamination due to leachate infiltration from open waste dumpsites and poorly engineered landfills have driven numerous research efforts in environmental geoscience. Solid waste disposal methods in many urban and peri-urban areas of Nigeria remain inadequate, often lacking basic engineering design such as liners and leachate collection systems. These deficiencies allow leachate to percolate through the soil profile, dissolving and transporting organic and inorganic pollutants into the groundwater system (Mor et al., 2006). The vulnerability of groundwater to such contamination is heightened in areas characterized by porous and permeable subsurface materials, as is typical in the Niger Delta region, including Choba.

Conceptually, the movement of leachate into groundwater systems is driven by gravitational flow and governed by principles of unsaturated flow and Darcy's Law. The soil acts as a medium through which the leachate, containing various solutes, migrates vertically and sometimes laterally, depending on the hydraulic gradient, porosity, and permeability of the underlying geological formations (Freeze & Cherry, 1979). This process is further complicated by the heterogeneity of subsurface materials, which creates preferential pathways that enhance or inhibit leachate transport. The geological setting around the University of Port Harcourt consists mainly of sand, silt, and clay sequences, each exhibiting different hydraulic conductivities, with sandy layers promoting faster contaminant transport (Ibe&Egereonu, 2003).

The theoretical framework underpinning studies of contaminant transport in groundwater is built on the advection-dispersion equation, which models how solutes migrate within a flowing fluid. Advection moves the contaminant with the bulk flow of groundwater, while dispersion causes spreading due to velocity differences within the pore spaces (Bear, 1979). Furthermore, soil-leachate interactions including adsorption, ion exchange, and chemical precipitation can retard or transform contaminants as they migrate. These geochemical and physical factors are critical in understanding how far and how fast leachate can reach an aquifer and affect its quality.

Empirical studies conducted in similar geological and environmental settings have demonstrated that leachate from dumpsites significantly alters the physicochemical composition of groundwater. A study by Akinbile (2012) in Akure, Nigeria, revealed that leachate percolation elevated concentrations of nitrate, iron, and total dissolved solids in surrounding wells beyond the permissible WHO limits. This aligns with findings by Obi and George (2011) in Port Harcourt, who detected elevated levels of ammonia, heavy metals, and microbial contaminants in water sources near waste disposal sites. These studies confirm that dumpsites, especially those lacking impermeable liners, pose a significant risk to groundwater integrity.

Advanced geophysical techniques, particularly electrical resistivity tomography (ERT), have gained prominence in recent years as a non-invasive method of investigating subsurface contamination. ERT detects variations in subsurface resistivity, which can be linked to differences in moisture content, salinity, and the presence of contaminants (Soupios et al., 2007). Low resistivity zones are typically indicative of leachate-affected areas due to their high ionic concentration. Adelusi et al. (2013) employed 2D resistivity imaging to map the extent of leachate intrusion in southwestern Nigeria, successfully identifying contamination plumes extending several meters beneath the surface.

Leachate composition is variable and depends on the nature of the waste, climatic conditions, and the age of the landfill. Generally, it contains high concentrations of organic matter (measured by BOD and COD), ammonium, chloride, iron, zinc, lead, and other hazardous substances (Christensen et al., 2001). In tropical climates such as Nigeria, high rainfall facilitates greater leachate generation and more extensive percolation, especially in the absence of drainage or containment structures. Consequently, regions like Choba, with high rainfall and shallow water tables, are more prone to groundwater contamination.

The development of resistivity surveying techniques has been very rapid in the last three decades. The advent of automated data acquisition systems, inversion codes, and easy access to powerful and fast computers has tremendously increased the practical applicability of the geophysical method. The lithological characterization approach through geoelectrical resistivity imaging is increasingly being used in environmental, engineering and hydrological investigations as well as geothermal and mineral prospecting, where detailed knowledge of the subsurface is sought (Oghonyon and Njoku, 2024).

In several Nigerian studies, the observed chemical signatures in groundwater near dumpsites reflect the progressive interaction between percolating leachate and aquifer materials. For instance, Ehirim and Ebeniro (2010) demonstrated using electrical resistivity profiling that subsurface layers within 10–20 m of a refuse site in Rivers State had significantly lower resistivity values, consistent with leachate presence. Their findings were validated with borehole water analysis, confirming elevated conductivity and trace metal concentrations. This convergence of geophysical and hydrochemical evidence forms a reliable basis for leachate tracking and risk assessment.

On a global scale, studies have reinforced the local findings in Nigeria. Mor et al. (2006) reported similar groundwater contamination from a municipal landfill in India, showing spatial distribution of pollutants and correlation with resistivity anomalies. Their approach highlighted the effectiveness of combining ERT with hydrochemical sampling in leachate investigation. In Malaysia, Yusof et al. (2009) found strong correlations between proximity to a landfill and deteriorating groundwater quality, with wells within 500 m of the landfill consistently showing unacceptable water quality parameters.

Geology of The Area

The Choba Campus of the University of Port Harcourt is located within the Niger Delta Basin as seen in Figure 1 below, one of the most prominent sedimentary basins in Africa, which plays a significant role both geologically and economically due to its rich hydrocarbon reserves. The Niger Delta Basin is a Tertiary to Recent sedimentary basin that evolved from the late Cretaceous into the Paleocene and continues to accumulate sediments to this day (Doust&Omatsola, 1990). The region is underlain by a thick sequence of unconsolidated to semi-consolidated sediments, which were deposited primarily through fluvial, deltaic, and shallow marine processes.

Geologically, the study area is underlain by the Benin Formation, which represents the youngest and most superficial stratigraphic unit in the Niger Delta sequence. The Benin Formation, also known as the Coastal Plain Sands, is of Miocene to Recent age and attains a thickness of over 2,000 meters in some locations (Reyment, 1965). It is predominantly composed of coarse- to medium-grained sands, gravels, and occasional thin layers of clay and shale. These sediments are loosely consolidated and exhibit high porosity and permeability, which support active groundwater flow but also increase the vulnerability of the aquifer to surface contamination.

The Benin Formation is overlain in some places by a thin cover of recent alluvium, particularly in floodplains and low-lying areas, consisting of clayey silts, peaty soils, and organic-rich sediments deposited by recent fluvial activity. These surficial materials can act as temporary barriers or conduits for percolating water depending on their composition and degree of compaction.

Stratigraphically, the Niger Delta Basin consists of three major lithostratigraphic units:

1. Akata Formation (Paleocene – Recent): Composed primarily of marine shales with some interbedded sandstones and turbidites. It is the deepest unit and acts mainly as a source rock.
2. Agbada Formation (Eocene – Recent): Represents the transitional zone between the marine Akata and the continental Benin formations. It consists of alternations of sandstone and shale beds and serves as the primary reservoir rock in hydrocarbon exploration.
3. Benin Formation (Miocene – Recent): The uppermost unit, consisting mainly of thick, clean, freshwater-bearing sands with intercalated clays and lignite. This is the formation that directly underlies the Choba area (Short &Stauble, 1967).

In the Choba region, the Benin Formation is largely homogeneous in composition, dominated by thick, lateritic, and ferruginous sandy sequences that are highly permeable. This makes it a prolific aquifer system but also implies that contaminants such as leachate can migrate rapidly through the subsurface in the absence of adequate natural attenuation layers like compact clay or shale (Edet&Okereke, 2001). The lack of confining layers in some parts of the formation exacerbates the risk of direct vertical infiltration from surface dumpsites to groundwater.

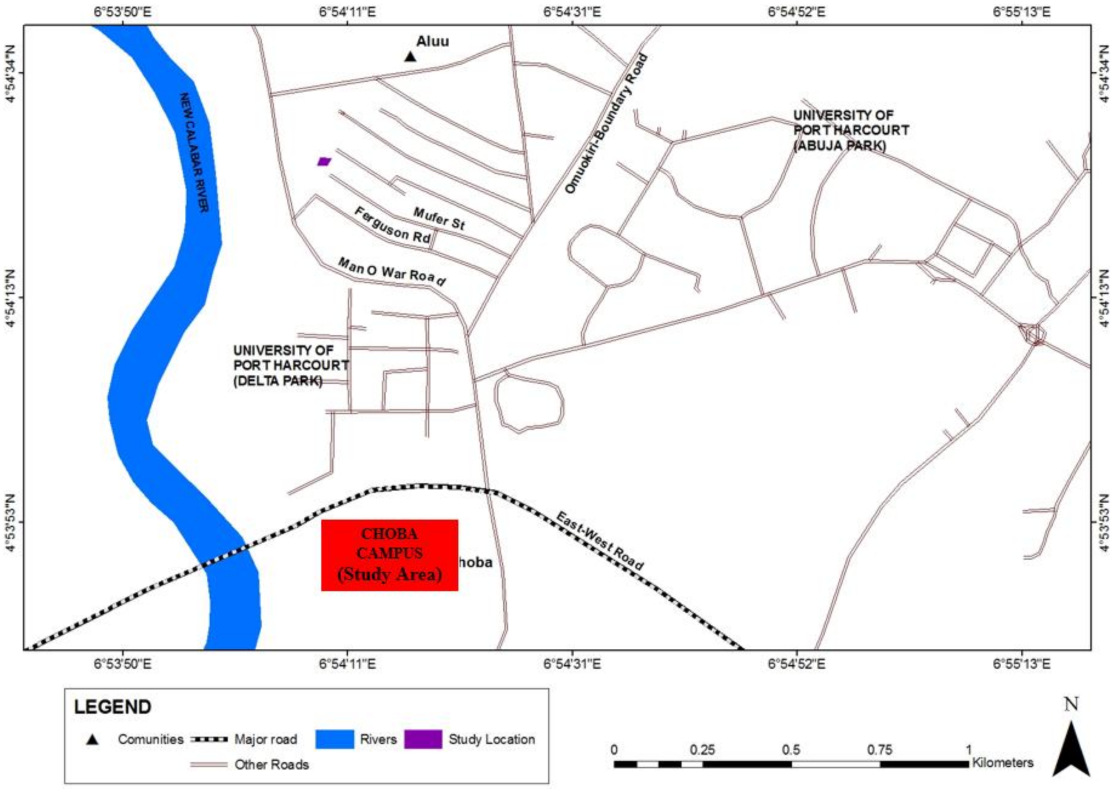


Figure 1: The geologic Map of the Study

II. Methodology

This study employs a non-invasive geophysical technique—the Digital Resistivity Method using Apparent Diffusion Magnetic Technology (ADMT)—to investigate the extent of leachate percolation and its interaction with the groundwater system around the Choba Campus of the University of Port Harcourt. The method is complemented by field reconnaissance and geospatial referencing to enhance interpretation and ensure accurate mapping of subsurface features.

At the heart of the system lies a mobile instrument, likely from the ADMT series (Figure 2). This innovative tool boasts Bluetooth connectivity to a dedicated mobile app. This eliminates the need for lengthy cables, allowing field personnel to seamlessly input, process, and visualize data in real-time. Gone are the days of cumbersome data management back in the lab – results are readily available on-site. Data acquisition itself is revolutionized through the use of wireless sensor probes. Gone are the days of trailing long cables across the survey area. Instead, personnel can walk and stop at designated points to collect measurements, enhancing efficiency and significantly reducing the manpower required for the survey. This methodology offers several key advantages. First, the mobile app facilitates the creation of 2D and 3D maps immediately after data collection. This allows researchers to visualize subsurface features and potential freshwater zones with minimal delay. Second, the operation is remarkably

simple. Field personnel can efficiently complete the survey by simply walking and stopping at measurement points, eliminating the need for complex setup procedures. Third, the use of wireless technology contributes significantly to time and resource savings. A single person can conduct the entire survey, eliminating the need for a dedicated data management team. Finally, the equipment boasts strong anti-interference capabilities and incorporates field source correction and proprietary data processing techniques. This ensures the accuracy of the collected data, forming a reliable foundation for identifying freshwater resources (Oghonyon *et al,* 2024)

III. Results

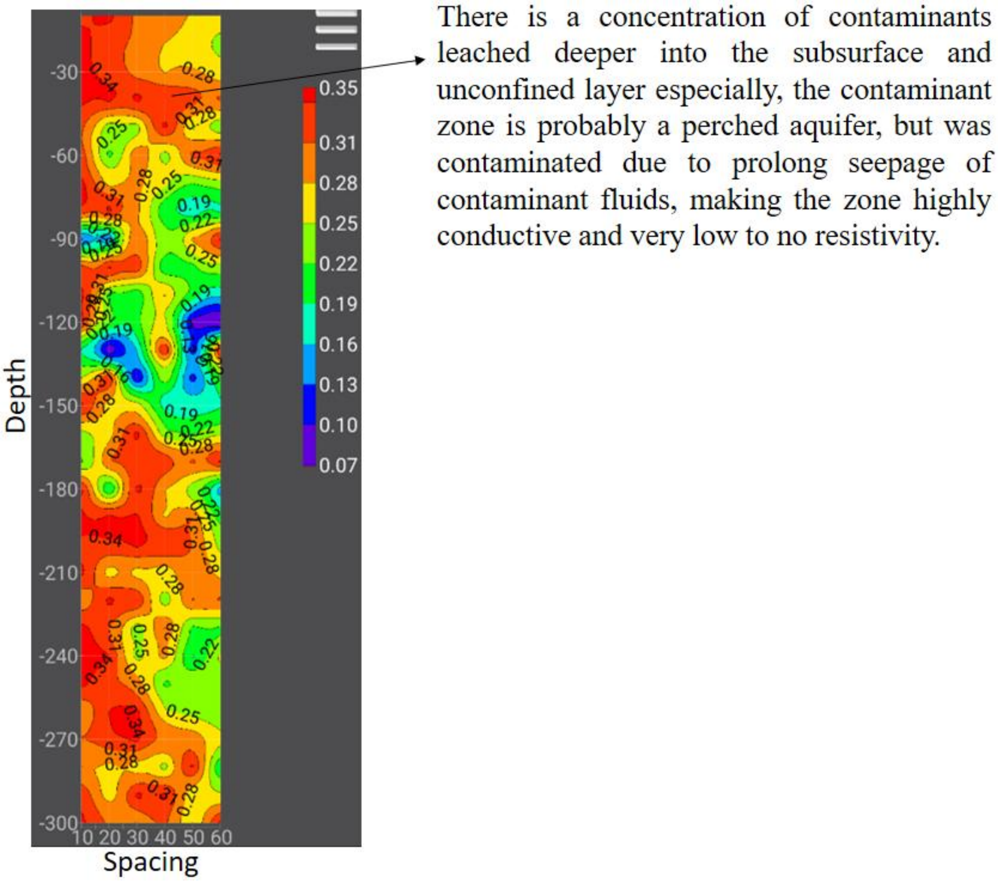


Figure 2: The 2D Tomogram of the study area line 1

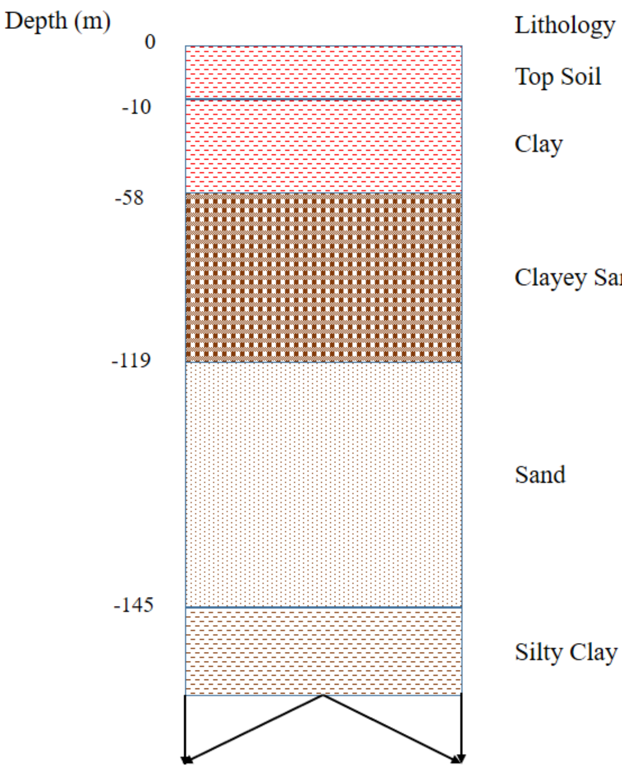
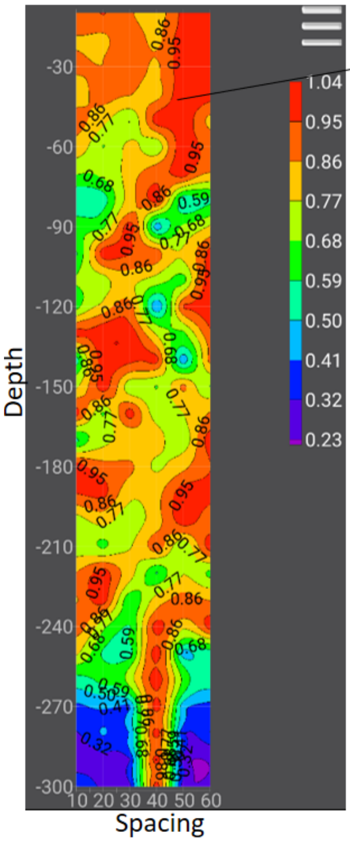


Figure 3: The Geoelectric Section of The 2D Tomogram for Line 1.



There is a concentration of contaminants leached deeper into the subsurface and unconfined layer especially, the contaminant zone is probably a perched aquifer, but was contaminated due to prolong seepage of contaminant fluids, making the zone highly conductive and very low to no resistivity.

Figure 4: The 2D Tomogram of the study area line 2

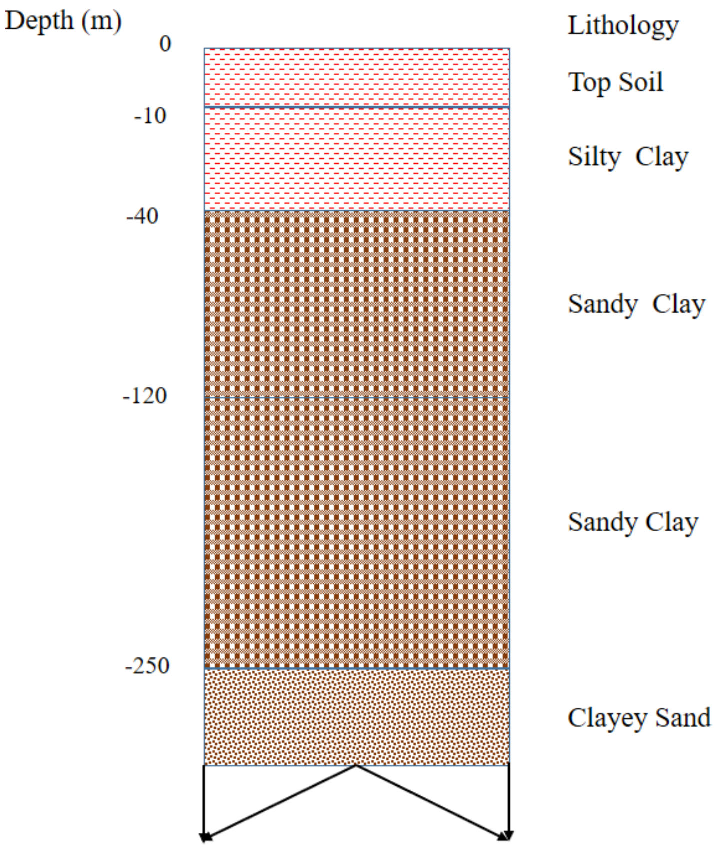


Figure 5: The Geoelectric Section of The 2D Tomogram Line 2

IV. Discussion

The ADMT digital resistivity method provided a fast, reliable, and non-invasive means of investigating subsurface conditions within the Choba Campus. Its application in this study helped to delineate potential leachate plumes and identify groundwater contamination risks, contributing valuable geophysical data for environmental monitoring and water resource protection in the area.

The geophysical investigation employed Apparent Diffusion Magnetic Technology (ADMT), a digital resistivity technique, to evaluate subsurface contamination due to leachate migration around the Choba Campus. Two survey lines were established, and their resulting 2D tomograms and geoelectric sections were critically analyzed to interpret resistivity anomalies indicative of leachate infiltration.

Figure 2 and Figure 3 reveal the resistivity distribution along Line 1. The 2D tomogram displayed a clear vertical resistivity profile, ranging from low (<100 Ωm) to high (>500 Ωm) zones.

Notably: Shallow Depths (0–10 m): The uppermost layers show variable resistivity values. In several segments, notably between 20–40 meters along the profile, resistivity values dropped significantly (<60 Ωm), suggesting zones of high moisture content and possible leachate saturation. Intermediate Depths (10–40 m): A prominent low-resistivity anomaly persists vertically to depths of ~25–30 meters. These zones are most likely leachate plumes due to their ionic enrichment and moisture content, consistent with documented resistivity ranges for leachate-impacted soils (Ehirim&Ebeniro, 2010).

Lateral Variation: The anomaly appears to migrate slightly laterally, suggesting both vertical percolation and horizontal spreading of contaminants within permeable sandy strata.

Figures 4 and 5 represent the 2D tomogram and geoelectric section for Line 2: Upper Layer (0–5 m): Similar to Line 1, the shallow layer consists of mixed resistivity values, though more extensive low-resistivity zones (<80Ωm) were observed from 0–50 meters along the line. This strongly suggests a widespread contamination plume close to the surface, likely influenced by surface runoff or shallow seepage.

Middle to Deep Sections (5–30 m): The most critical observation is the continuity of low-resistivity zones extending deeper into the aquifer zone. This confirms that leachate has percolated beyond the unsaturated zone, reaching the shallow water-bearing formations.

Interpretive Synthesis: The geoelectric section suggests that the contamination is not superficial but multi-layered, affecting both the vadose zone and phreatic zone, especially in sandy units known for their high permeability, the results from both lines, when integrated, painted a concerning picture of active leachate migration.

Depth of Penetration: Contamination plumes are not restricted to shallow depths; the vertical continuity down to ~30 m highlights the high vulnerability of the aquifer, attributed to the unconsolidated and permeable Benin Formation sediments.

The irregular spread of low resistivity indicates the heterogeneity of the subsurface geology. Preferential flow paths possibly through sandy lenses have facilitated deeper and wider plume migration. Given that shallow aquifers within this zone provide domestic water, the intrusion of leachate into the saturated zone poses a serious public health risk. The potential presence of dissolved organics, nitrates, and heavy metals—although not analyzed chemically in this study—can be inferred based on standard leachate behavior (Akinbile, 2012; Alam&Ahmaruzzaman, 2021).

The results align with the observed urban pressures on Choba, where open dumping, high rainfall, and a shallow water table collectively exacerbate pollution risk. The low-lying topography also limits runoff efficiency, increasing infiltration.

The geophysical evidence confirms that leachate from surface waste deposits has significantly infiltrated the subsurface, affecting both shallow and intermediate aquifer levels around the Choba Campus. The study successfully delineates contamination zones through ERT-based resistivity anomalies. These findings highlight the urgent need for groundwater monitoring, pollution control, and waste management reforms within and around the University of Port Harcourt. The study also reinforces the value of integrating geophysical surveys in environmental assessments, particularly in urbanized and geologically vulnerable regions like the Niger Delta.

Conclusion

The geophysical survey using ADMT successfully revealed the presence and extent of leachate percolation within the subsurface of the Choba Campus. Two 2D resistivity profiles (Lines 1 and 2) demonstrated significant low resistivity anomalies (<100Ωm) at various depths, strongly suggesting zones impacted by leachate contamination.

In Line 1, contamination was observed to reach depths of 25-30m, indicating downward percolation into shallow aquifers. In Line 2, a more extensive horizontal spread of low resistivity zones suggested both vertical infiltration and lateral plume migration, following permeable sandy pathways. These patterns reflect the high vulnerability of the Benin Formation aquifer, which underlies the study area and is known for its high porosity and permeability.

The findings confirm that surface waste leachate has breached the unsaturated zone and contaminated the groundwater system, especially in areas with visible dumpsites and inadequate waste containment. This poses a serious environmental and public health risk, particularly given the area's reliance on groundwater for domestic use.

The results emphasize he urgent need for groundwater protection, proper landfill management, and continuous environmental monitoring in and around the University of Port Harcourt.

In Conclusion, the geophysical evidence confirms that leachate from surface waste deposits has significantly infiltrated the subsurface, affecting both shallow and intermediate aquifer levels around the Choba campus. The study successfully delineates contamination zones through ER-based resistivity anomalies. These findings highlight the urgent need for groundwater monitoring, pollution control, and waste management reforms within and around the University of Port Harcourt. The study also reinforces the value of integrating geophysical surveys in environmental assessments, particularly in urbanized and geologically vulnerable regions like the Niger Delta.

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