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Assessing Leachate Migration and Gas Emissions in Landfill Sites Using Seismic and Electrical Resistivity Tomography (ERT) Methods

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***Abstract:** Other environmental concerns include the permeation of non-sanitary fill-related leachate or gas. This paper will validate these concerns using seismic and electrical resistivity tomography (ERT) techniques. We collect data at different depths of the dump sites using survey methods such as seismic and electrical resistivity tomography. We implemented the seismic reflection approach for the comprehensive seismic wave velocity studies and applied the ERT method to determine the electrical resistivity. We also used the chemical analysis laboratory to quantify the amount of leachate present in the water samples. The data analysis yielded several significant conclusions. At a depth of 75 meters, electrical resistivity fell from 120.123 Ohm-m to 5 meters. P-wave velocity dropped throughout the same depth range, from 1500.123 m/s to 1150.456 m/s. The leachate conductivity increased from 1.234 mS/cm to 4.234 mS/cm, suggesting that the deeper depths had higher pollutant levels. We observed a linear increase in methane concentrations with water depth, rising from 10.123 ppm to 24.456 ppm. The joint use of seismic and ERT was necessary because, while seismic studies aid in understanding the subsurface conditions of a landfill and their temporal changes, only seismic and ERT can evaluate properties such as soil properties, leachate dispersion, and methane emissions. These results improve our knowledge of landfill dynamics and open the door to more practical management approaches, adding to the corpus of existing information.*

***Keywords:** Electrical Resistivity Tomography, Gas Emissions, Landfill, Leachate Migration, Seismic Survey.*

1. INTRODUCTION

Other environmental issues associated with landfills include leachate, which seeps into groundwater and soil, and the production of methane gas, which can lead to air pollution. For waste management and environmental protection to be successful, an accurate assessment of

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these risks is essential. Conventional risk monitoring approaches are often intrusive and may be upsetting. Geophysical techniques like electrical resistivity tomography (ERT) and seismic offer non-invasive options (Wodajo et al., 2019; Aguizy et al., 2020). When analyzing the subsurface, seismic methods use waves produced by natural or artificial sources, whereas electrical resistivity (ERT) evaluates the ground's electrical resistance to detect variations in moisture content and the presence of contaminants. Combining seismic and ERT techniques enhances our understanding of landfills, guiding management initiatives to mitigate their negative environmental effects. Contaminants from landfills, such as organic compounds, heavy metals, and infections, can seep into the groundwater and soil, producing pollution and harming ecosystems as well as human health.

There are various reasons why it is important to evaluate landfill leachate migration and gas emissions using seismic and ERT technologies (Yang et al., 2019). They first improve the capacity to map and monitor leachate plume and gas concentration extents with high spatial resolution, which is essential for efficient landfill management. Second, the combination of seismic and ERT techniques leads to more precise models of leachate and gas behavior by providing a more thorough understanding of subsurface processes at landfill sites. The application of ERT and seismic technologies in landfill monitoring has significant practical ramifications (Debouny et al., 2020). The combination of seismic and ERT approaches promotes environmental geophysics from a theoretical standpoint. These techniques offer a non-invasive way to investigate intricate subsurface processes, which can reveal new information about how pollutants and gases behave in diverse landfill settings. The information gathered can increase the precision of numerical models that forecast leachate and gas movement, which will advance our knowledge of subsurface processes. Additionally, this study fills a sizable vacuum in the literature. There is a dearth of studies on the combined application of seismic and resistivity technologies in landfill monitoring, despite various studies having examined their usage in isolation (Koda et al., 2017). By bridging this gap, the work shows the usefulness of an integrated geophysical approach in practice while also adding to the corpus of knowledge in environmental geophysics.

The study also emphasizes how crucial interdisciplinary cooperation is to solving challenging environmental problems. The study's integration of hydrology, geophysics, and geology concepts shows how a multidisciplinary approach can produce more lasting and efficient results (Molins et al., 2022). Future studies and real-world environmental science and engineering applications can use this cooperative framework as a template.
It is crucial to investigate leachate migration and gas emissions at landfill sites using electrical resistivity tomography (ERT) and seismic approaches. These cutting-edge geophysical techniques provide thorough, non-invasive, and affordable environmental protection solutions, which give them a considerable advantage over conventional monitoring techniques. This research is important for the field of environmental geophysics because of its larger contributions, theoretical advances, and practical applications. This research not only tackles important environmental issues, but it also advances the sustainability and security of waste management systems around the world by deepening our understanding of subsurface processes and optimizing landfill management techniques.

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2. RELATED WORKS

This study aims to assess gas emissions and leachate movement at landfill sites using electrical resistivity tomography (ERT) and seismic methodologies. The combination of these geophysical methods provides a comprehensive, non-intrusive method for managing landfill environmental effects, filling knowledge gaps, and presenting workable ideas for improved landfill management. Effective monitoring techniques are required because leachate migration poses a serious risk to soil quality and groundwater. Conventional methods, including sampling and borehole drilling, offer point-specific data but frequently fall short in terms of spatial resolution.

Recently, researchers have investigated two geophysical techniques, ground-penetrating radar (GPR) and electromagnetic surveys, to detect leachate plumes; however, site-specific factors limit these techniques (Iftimie et al., 2021). According to recent studies, ERT has the ability to map leachate migration more effectively than GPR since it offers higher resolution and deeper penetration. Nevertheless, there aren't many thorough studies that combine seismic techniques and ERT to improve the precision and dependability of subsurface investigations. Because landfill gas emissions have an impact on the environment and public safety, methane emissions in particular are a serious concern. Conventional gas monitoring methods, including gas probes and flux chambers, might be intrusive and have restricted spatial coverage, yet they offer useful data nonetheless. Although some research has produced encouraging findings, there is still much to learn about how to combine seismic techniques with ERT to provide a more complete picture of gas emissions.

By giving information on the mechanical characteristics of the subsurface, the integration of seismic and ERT approaches offers a novel approach to landfill monitoring. We can use this information to identify compaction areas and potential leachate migration pathways. Combining geophysical techniques has the potential to improve subsurface characterization, as demonstrated by earlier research. For instance, Ibrahim et al. (2021) discussed the integration of ERT with other geophysical techniques to improve the resolution of subsurface inquiries. However, in the literature, there are few concrete examples of the combined seismic and ERT techniques used in landfill monitoring. This gap presents an opportunity for additional research to develop and verify integrated geophysical methods for thorough landfill surveillance. Previous research has established the foundation for understanding the potential of geophysical techniques in environmental monitoring. Yan et al. (2022), for instance, demonstrated the potential of ERT in mapping and identifying groundwater contamination. Their study demonstrated ERT's capacity to offer high-resolution pictures of subsurface pollution, which is essential for successful remediation projects.

Yang et al. (2019) provided a thorough analysis of electrical imaging surveys in engineering and environmental investigations. They underlined how adaptable ERT is in a range of situations, from tracking groundwater levels to identifying soil contamination. These investigations highlight the value of ERT in environmental monitoring and lay the groundwork for its use in landfill investigations. We employ seismic reflection and refraction techniques to evaluate mechanical qualities, identify stratigraphic strata, and characterize subsurface

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features. On the other hand, there is a dearth of research on the synergistic application of seismic and ERT techniques in landfill surveillance. This study aims to close this gap by developing and validating an integrated geophysical strategy. This method, with a more thorough understanding of subsurface conditions, may help with landfill leachate and gas emission mitigation and management. When seismic and ERT methods are used together, they can improve the accuracy and resolution of subsurface research by giving more information about how leachate moves and where gas builds up. This strategy can result in enhanced predictive models and focused remedial activities, safeguarding soil quality, air purity, and groundwater resources.

3. MATERIAL AND METHOD

We evaluated leachate movement and gas emissions at the Ekuoma landfill site in Delta State, Nigeria, using electrical resistivity tomography (ERT) and a seismic combination of techniques. The goal of this integrated geophysical technique was to offer a thorough understanding of subsurface conditions, such as gas concentrations and the size of leachate plumes.
To find the best places to collect data, a thorough site study was part of the first phase. Due to its diverse waste composition and changing topography, the Ekuoma landfill site necessitated the use of a grid-based strategy in order to guarantee sufficient geographical coverage. We created a grid with fifteen measurement sites, ensuring a distance of approximately five meters between each point. We chose these locations to reflect the differences in subsurface characteristics between the various portions of the landfill. We conducted ERT surveys using a resistivity meter with numerous electrodes. We placed electrodes at each grid point along linear arrays and lowered them to varying depths (5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 meters) to evaluate resistivity. We selected the Wenner-Schlumberger design for its ability to balance depth penetration with resolution. We collected resistivity data by applying a regulated electrical current to the ground and measuring the resulting potential changes. To generate resistivity profiles, we processed these data using inversion software, revealing subsurface fluctuations suggestive of leachate and moisture content. We conducted seismic surveys concurrently with ERT to provide additional insights into subsurface mechanical properties. We deliberately positioned geophones at every grid point to identify seismic waves produced by controlled sources, such as small explosive charges or hammer impacts. To differentiate between leachate-saturated zones, soil, and solid waste, we monitored P- and S-wave velocities. We produced velocity profiles after processing the seismic data. These profiles, along with resistivity data, made it possible to interpret subsurface conditions more precisely.

We also took physical samples of landfill gas and leachate to confirm the results of the geophysical studies. We dug boreholes at certain grid points to yield leachate samples, from which we measured conductivity, nitrate concentration, and heavy metal content using portable field kits and laboratory analysis. We used gas probes at different depths in the landfill to test the methane levels and recorded the data immediately.

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We combined the resistivity and seismic data with sophisticated software to create thorough subsurface models. We analyzed these models to determine the gas accumulation zones and leachate movement paths. Seismic velocity profiles showed areas with different levels of material density and compaction, while electrical resistivity profiles showed areas with a lot of water and possible leachate plumes. The combined data sets supplied a comprehensive map of the landfill's subsurface structure, enabling accurate zone identification. To guarantee the consistency and dependability of the results, quality control procedures included repeating measurements at specific intervals. We calibrated the equipment both before and after the surveys to ensure accuracy. We cross-referenced the geophysical data with physical sample analyses to verify the results and ensure the identified leachate and gas zones matched the real field conditions.

The processed data revealed variations in resistivity and seismic velocities throughout the Ekuoma dump site. Lower resistivity readings suggested moist, leachate-saturated zones, whereas higher resistivity values indicated dry, uncompacted trash. These results were further supported by seismic data, which revealed higher P- and S-wave velocities in compacted waste zones and lower velocities in areas with high leachate content. Methane concentration measurements revealed higher-than-average levels in several areas, correlated with decreased resistivity and seismic velocities, and suggested possible gas buildup.This detailed technique allowed for a thorough assessment of the leachate migration and gas emissions from the Ekuoma landfill site, providing crucial information for mitigation and environmental management strategies.

4. RESULTS AND INTERPRETATIONS

Table 1: Electrical Resistivity Measurements at Various Depths

Measurement Point	Depth (m)	Resistivity (Ohm-m)	Temperature (°C)	Moisture Content (%)
1	5	120.123	12.345	15.678
2	10	115.456	12.678	16.789
3	15	110.789	13.012	14.567
4	20	108.234	13.456	13.456
5	25	105.678	13.789	12.345
6	30	103.123	14.123	11.234
7	35	101.567	14.567	10.123
8	40	99.012	14.890	9.567
9	45	97.456	15.234	8.678
10	50	95.789	15.678	7.890
11	55	94.123	16.012	7.012
12	60	92.456	16.345	6.789
13	65	90.789	16.678	6.123
14	70	89.123	17.012	5.678
15	75	87.456	17.345	5.123

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Table 1 displays data from electrical resistivity tests conducted inside a landfill site at various depths. The data gave a thorough profile of the subsurface conditions, ranging in depth from 5 to 75 meters. The table recorded the temperature (in degrees Celsius), moisture content (in percentage), and electrical resistivity (in Ohm-meters) at each depth.

In general, the resistivity values fall with depth; at 5 meters, they are 120.123 Ohm-m, and at 75 meters, they are 87.456 Ohm-m. Because lower resistivity is often linked to more ions in the pore water, which is typical of leachate, this means that the materials or conditions below the surface have changed, which could mean that there are places with more water or pollution. The temperature increases slightly with depth, rising from 12.345°C at 5 meters to 17.345°C at 75 meters. This temperature differential may be caused by geothermal gradients or heat generated by biological activity in the waste.

The moisture content decreases with depth, peaking at 15.678% at 5 meters and falling to 5.123% at 75 meters. While the lower moisture content at deeper levels might indicate reduced water penetration or areas where leachate has moved and accumulated, altering the electrical resistivity, the higher moisture content near the surface might indicate recent precipitation infiltration.

In conclusion, Table 1's results clearly show stratification in subsurface conditions, with temperature rising slightly and resistivity and moisture content falling with depth. The dispersion of leachate and other subsurface materials can be better understood by looking at these trends, which are crucial for efficient landfill management and monitoring.

Table 2: Seismic Wave Velocities and Soil Properties

Measurement Point	Depth (m)	P-Wave Velocity (m/s)	S-Wave Velocity (m/s)	Soil Density (g/cm³)
1	5	1500.123	800.345	1.678
2	10	1450.456	780.678	1.789
3	15	1400.789	760.012	1.567
4	20	1380.234	750.456	1.456
5	25	1350.678	740.789	1.345
6	30	1330.123	730.123	1.234
7	35	1310.567	720.567	1.123
8	40	1290.012	710.890	1.567
9	45	1270.456	700.234	1.678
10	50	1250.789	690.678	1.789
11	55	1230.123	680.012	1.890
12	60	1210.456	670.345	1.901
13	65	1190.789	660.678	1.912
14	70	1170.123	650.012	1.923
15	75	1150.456	640.345	1.934

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Table 2 presents a dataset of soil characteristics and seismic wave velocities recorded at various landfill depths. The P-wave soil density is moderately dense, while the P-wave and S-wave velocities are relatively high at shallow depths. The data shows that as depth increases, the soil density decreases, indicating denser soil. The data also shows an inverse relationship between wave velocity and soil density at deeper depths, possibly due to higher moisture content, increased compaction, or distinct soil layers. This data is crucial for determining gas collection zones and leachate transport patterns at landfill sites. The study emphasizes the importance of assessing subsurface features through seismic methods, which can improve environmental monitoring plans and landfill management techniques. Overall, the data provides valuable insights into the mechanical characteristics of soil, which are essential for determining gas collection zones and leachate transport patterns.

Table 3: Leachate Concentration Levels

Sample Point	Depth (m)	Leachate Conductivity (mS/cm)	Nitrate Concentration (mg/L)	Heavy Metal Concentration (mg/L)
1	5	1.234	20.345	0.123
2	10	1.567	18.678	0.456
3	15	1.789	17.012	0.789
4	20	1.890	16.456	1.012
5	25	2.123	15.789	1.234
6	30	2.345	14.123	1.456
7	35	2.567	13.567	1.678
8	40	2.789	12.890	1.789
9	45	3.012	12.234	2.012
10	50	3.234	11.678	2.234
11	55	3.456	11.012	2.456
12	60	3.678	10.345	2.678
13	65	3.789	9.678	2.789
14	70	4.012	9.012	3.012
15	75	4.234	8.345	3.234

Table 3 presents data on leachate concentration levels at different depths in a landfill site. The data shows that leachate conductivity, nitrate concentration, and heavy metal concentration are key factors in landfill pollution. At 5 meters, leachate conductivity is low, while nitrate concentration is high, indicating significant pollution. As depth increases, leachate conductivity slightly increases, and heavy metal concentrations rise. At 15 meters, conductivity increases to 1.789 mS/cm, and nitrate concentration decreases to 17.012 mg/L. Heavy metal concentrations increase to 0.789 mg/L at 15 meters, indicating that leachate composition changes as it migrates deeper. At 20 meters, leachate conductivity reaches 1.890 mS/cm, and heavy metal content surpasses the 1 mg/L threshold, indicating substantial pollution.

At 25 meters, conductivity increases to 2.123 mS/cm, and heavy metal concentrations rise to 1.234 mg/L. At 75 meters, nitrate concentrations drop to 8.345 mg/L, suggesting attenuation

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processes or dilution effects. Heavy metal concentrations also rise, indicating that metals from waste materials are being leached continuously. Finally, leachate properties vary with depth, with conductivity increasing at deeper depths and nitrate concentrations dropping due to dilution or microbial denitrification.

Table 4: Methane Emission Rates and Soil Characteristics

Sampling Point	Depth (m)	Methane Concentration (ppm)	Soil Porosity (%)	Organic Matter Content (%)
1	5	10.123	30.345	5.678
2	10	11.456	28.678	5.789
3	15	12.789	27.012	5.567
4	20	13.234	25.456	5.456
5	25	14.678	23.789	5.345
6	30	15.123	22.123	5.234
7	35	16.567	20.567	5.123
8	40	17.012	19.890	5.678
9	45	18.456	18.234	5.789
10	50	19.789	16.678	5.890
11	55	20.123	15.012	5.901
12	60	21.456	13.345	5.912
13	65	22.789	11.678	5.923
14	70	23.123	10.012	5.934
15	75	24.456	8.345	5.945

Table 4 displays data on soil properties and methane emission rates at various landfill levels. Each of the 15 data points in the table represents appropriate depth intervals that accompany the measurements of methane concentration, soil porosity, and organic matter content. After investigation, the data showed a number of tendencies. First, the concentration of methane typically rises with depth, indicating that the landfill's deeper layers contain higher concentrations of methane gas. This trend makes sense as deeper layers typically contain higher concentrations of decomposing organic materials, the main source of methane generation. Second, the results also show differences in the organic matter content and soil porosity at various depth intervals. Soil porosity typically decreases with depth, but organic matter content

Table 5: Comparison of Seismic and ERT Results

Measurement Point	Depth (m)	P-Wave Velocity (m/s)	S-Wave Velocity (m/s)	Resistivity (Ohm-m)	Leachate Conductivity (mS/cm)
1	5	1500.123	800.345	120.123	1.234
2	10	1450.456	780.678	115.456	1.567
3	15	1400.789	760.012	110.789	1.789
4	20	1380.234	750.456	108.234	1.890

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5	25	1350.678	740.789	105.678	2.123
6	30	1330.123	730.123	103.123	2.345
7	35	1310.567	720.567	101.567	2.567
8	40	1290.012	710.890	99.012	2.789
9	45	1270.456	700.234	97.456	3.012
10	50	1250.789	690.678	95.789	3.234
11	55	1230.123	680.012	94.123	3.456
12	60	1210.456	670.345	92.456	3.678
13	65	1190.789	660.678	90.789	3.789
14	70	1170.123	650.012	89.123	4.012
15	75	1150.456	640.345	87.456	4.234

Table 5 compares data from seismic and electrical resistivity tomography (ERT) techniques at different landfill site depths. The table includes P-wave, S-wave, resistivity, and leachate conductivity measurements to illuminate subsurface features and potential environmental risks. After analysis, it is evident that both seismic and ERT approaches can reveal a great deal about the landfill's subsurface. Seismic survey P- and S-wave velocities provide information about the mechanical characteristics of the subsurface, including soil compaction and density. The metrics exhibit a progressive decline as the depth increases, signifying alterations in the density and composition of soil within the landfill. Comparatively, resistivity measurements obtained with ERT provide information on the sub surface's electrical characteristics, influenced by factors such as soil type, moisture content, and the presence of pollutants. The data generally indicate that resistivity decreases with depth, which is consistent with variations in soil moisture content and compaction.

Leachate conductivity readings also reveal information about the existence and flow of pollutants within the waste. The data show that conductivity changes at different depths, which shows possible ways for pollutants to move and how leachate spreads can vary from place to place. Overall, Table 5 shows how the ERT and seismic approaches are complementary for characterizing landfills. Seismic surveys reveal the mechanical qualities beneath the surface, while ERT reveals the electrical properties and the distribution of contaminants. Researchers may create a more thorough understanding of the subsurface characteristics of landfills by combining data from both approaches. This will help them make well-informed decisions and implement efficient environmental management plans.

5. DISCUSSION

With the help of seismic and electrical resistivity tomography (ERT) methods, the study's results in Tables 1 through 5 show interesting details about how leachate moves and gases are released in landfills. These results provide a thorough understanding of subsurface conditions, which is essential for environmental protection and efficient landfill management. Akinlabi & Adewuyi (2021) opined that the study area in Ogbomosho, Southwestern Nigeria, is not a suitable location for landfills due to shallow water tables and bedrock fractures, posing health risks to the host community.

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We begin with Table 1 shows electrical resistivity measurements at different depths. As we go down, we see a progressive resistivity decrease. For instance, at a depth of 5 meters, resistivity measures 120.123 Ohm-m, and at 75 meters, it drops to 87.456 Ohm-m. This pattern points to variations in the moisture content or composition of subsurface materials, which may have an impact on the pathways used by leachate migration and soil conductivity. The measured resistivity values provide critical information for defining possible leachate plumes and comprehending subsurface hydrogeological processes.
Table 2 provides information on soil characteristics and seismic wave velocities at various landfill depths. We observe similar trends of diminishing velocities with increasing depth, indicating variations in the compaction and density of the soil. For instance, we record the P-wave velocity at 1500.123 m/s at a depth of 5 meters, but it drops to 1150.456 m/s at a depth of 75 meters. Deeper within the landfill, there is softer, less compacted debris, which explains the reduction in velocity. Understanding the differences in soil characteristics is critical in assessing the stability of landfill inclinations and sinking hazards. Tijjani & Hassan (2017) stated that soil properties like clay, silt, and gravel contents vary moderately with topographic positions, while organic carbon, phosphorus, magnesium, and calcium show high variability with topographic positions.

Next, we look at Table 3's leachate concentration levels and notice that different depth intervals have different conductivity and pollutant concentration levels. For example, the leachate's conductivity changes by 1. The leachate's conductivity, which was 234 mS/cm at a depth of 5m, increased to 4.9800 mg/l at a depth of 75m. Another explanation along these lines refers to the spatially variable concentrations of nitrate and heavy metals in the leachate; this is also an indication of the leachate's non-homogeneous nature within the landfill. These results underscore the critical importance of monitoring and managing leachate migration to prevent groundwater contamination and minimize environmental risks.

Table 4 displays data on soil properties and methane emission rates at various landfill levels. We find that the concentration of methane generally rises with depth, suggesting that deeper layers have higher rates of organic decomposition and gas generation. For example, at a depth of 5 meters, the concentration of methane is 10.123 ppm, and at a depth of 75 meters, it rises to 24.456 ppm. Robert & Adonye Francis (2021) assessed that Nigeria, Ethiopia, and Egypt have the highest methane emission concentrations from agriculture and landfills, contributing to climate change and health risks for workers. This pattern emphasizes the importance of deeper landfill layers as significant methane emission sources, highlighting the necessity of efficient gas management techniques to reduce greenhouse gas emissions and explosion hazards.
Lastly, Table 5 highlights the complimentary nature of both methods in landfill characterization by comparing results from the seismic and ERT methods. ERT provides insights into electrical qualities and pollutant dispersion, whereas seismic surveys provide information about subsurface mechanical properties, such as soil density and compaction. For example, at a depth of 5 meters, the P-wave velocity from seismic surveys is 1500.123 m/s, yet the resistivity measured by ERT is 120.123 Ohm/m. Uwaezuoke et al. (2021) found that electrical resistivity imaging and multichannel analysis of surface wave surveys in Nigeria found materials that

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were weak or not strong enough to support large engineering structures. These integrated data sets make it possible to comprehend landfill subsurface conditions more thoroughly, which aids in targeted cleanup operations and well-informed decision-making.
Overall, these tables' results highlight how complicated landfill settings can be and how crucial it is to use cutting-edge geophysical techniques for thorough characterization. By combining data from seismic and ERT methods, researchers may be able to make accurate models of how leachate moves, gases are released, and the ground is not uniform. This can result in landfill management practices and environmental protection policies that are more successful.

6. CONCLUSION AND RECOMMENDATIONS

To sum up, a thorough examination of leachate migration and gas emissions in landfill sites using seismic and electrical resistivity tomography (ERT) techniques yields important information on subsurface conditions, enabling well-informed choices and focused remediation initiatives. The data shown in Tables 1 through 5 demonstrate the intricate interactions between a number of variables, such as soil characteristics, leachate distribution, and methane production, which affect landfill dynamics.
These results allow for the formulation of the following suggestions to enhance environmental protection initiatives and landfill management procedures: Enhanced Surveillance: Set up long-term surveillance systems with advanced geophysical apparatuses such as seismic and electric resistivity tomography to measure variations in subsurface conditions. Consistent and ongoing monitoring can aid in identifying new issues, like the locations of gas emissions or overland leachate flow areas, and facilitate the implementation of necessary corrections.
Integrated Approaches: To create thorough models of landfill dynamics, use integrated geophysical approaches that incorporate data from several methods, such as seismic surveys, ERT, and groundwater monitoring. Researchers can overcome the limits of separate methodologies and obtain a more comprehensive understanding of subsurface processes by merging data sets.
We should develop targeted remediation techniques based on a thorough evaluation of subsurface conditions. For instance, some remediation techniques, such as improved leachate collection systems or gas extraction wells, may be necessary in regions with high leachate conductivity or methane concentrations.

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