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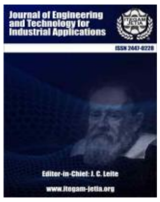

RESEARCH ARTICLE OPEN ACCESS

INVESTIGATION OF LEACHATE MIGRATION USING ELECTRICAL RESISTIVITY IMAGING: A CASE STUDY FROM AN ACTIVE DUMPSITE, ILOKUN, ADO-EKITI, SOUTHWEST NIGERIA

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ABSTRACT

Geophysical study involving electrical resistivity imaging was conducted at Ilokun municipal solid waste disposal site in Ado-Ekiti, Southwest Nigeria. The study was designed to map the leachate accumulation and extent of migration of leachate plumes in the subsurface. Leachate generated from dumpsite has been recognized as a major concern to public health. Three 2D resistivity profiles were established, one within and two outside the dumpsite. A traverse length of 140 m was kept for the survey. The apparent electrical resistivity data were subsequently inverted into the true electrical resistivity distributions using RES2DINV software to obtain the subsurface image. Electrical Resistivity Imaging (ERI) revealed leachate accumulation (low resistivity zones of 4.98 – 13.30 Ωm) within the shallow subsurface of the dumpsite up to a depth of 10 m. A fractured zone was delineated within the subsurface. This zone of enhanced porosity and permeability spanning a distance of about 20 m offers the main conduit / seepage path for the leachate to percolate through the subsurface formation. Landfill leachates are potentially harmful to the environment and to human health. Proper mitigation measures are necessary to protect the shallow groundwater system, soil and the environment.

I. INTRODUCTION

Municipal solid waste (MSW) is continuously produced by human being all over the world. Dumping of solid waste in the non-engineered landfills is very common in the developing countries. Land disposal facilities are increasingly becoming hazardous to human health and the environment [1-3]. Among the disadvantages of open dumping, leachate, the aqueous effluent generated from solid waste owing to physical, chemical, and biological alterations, has been identified as the major concern to public health. Leachate is a wastewater formed due to precipitation, deposited waste moisture, and water formed within the body of the dumpsite. The generation of landfill gasses and secretion of leachate constitute health concerns for the population on-site and vicinity of the dumpsites [1],[4],[5].

Leachate is a toxic by-product generated from the landfills. It remains one of the key anthropogenic heavy metal sources in environment and a major concern to human health [1],[6],[7]. The heavy metals leach out from the soil and enter the underlying aquifer, which affects the livelihood of the surrounding community. It has been a source of groundwater contamination worldwide [6]. Leachate can percolate to the groundwater and consequently migrate in surface water [4],[8],[9].

The leachate composition can vary widely depending on the age of the landfill and the type of waste it contains. It usually contains both dissolved and suspended materials. Precipitation is acknowledged as the principal contributor to generation of leachate [1],[5]. Detailed investigation revealing the leachate curtailment capacity (LCC) of the dumpsite and the adjoining areas is essential [2],[3],[7].

The Ilokun MSW dumpsite, is a piece of land located off Ado - Iworoko Road on the outskirts of Ado Ekiti, Southwest Nigeria (Figure 1). It is an open waste dumpsite designated for disposal of varied categories of waste materials. It accommodates household, industrial and commercial waste. Urban sprawl occasioned in part by the rapid growth in the urban population is fast becoming evident within the axis.

The study area is underlain by the Precambrian Basement Complex, which comprises of the migmatite gneiss quartzite complex; the slightly migmatised to unmigmatised metasedimentary schists and metaigneous rocks; the charnockitic, gabbroic and dioritic rocks; and the members of the older granite suite. Migmatite constitutes the main rock unit at the location. The area is associated with two distinct seasons (wet and dry seasons) typical of the tropical climate with annual rainfall of about 1300 mm and mean annual temperature of 27°C [2],[10].

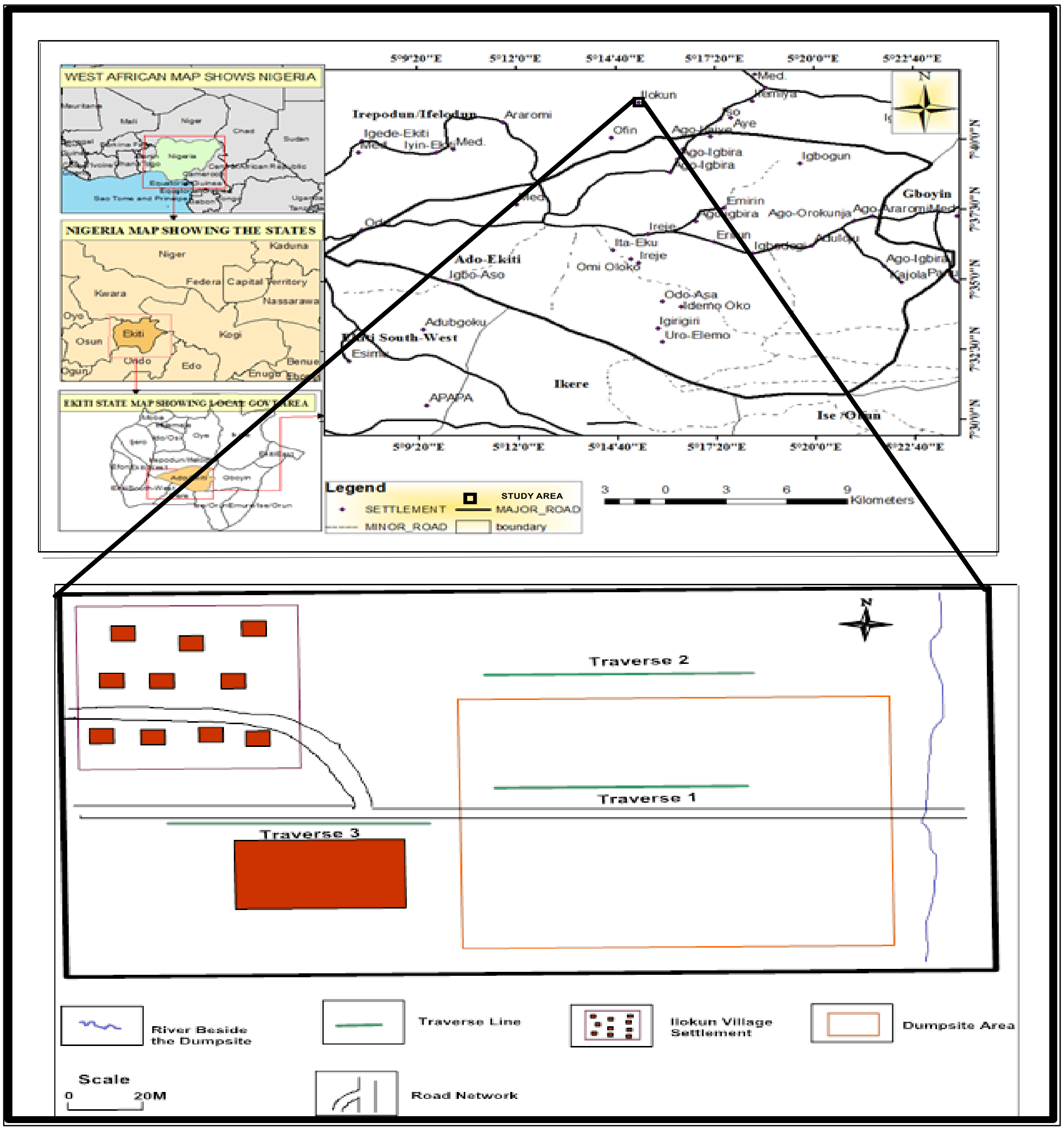

Figure 1: Location map showing the study area.
Source: Authors, (2024).

II. THEORETICAL REFERENCE

Electrical Resistivity Imaging (ERI) is a non-invasive geophysical technique developed to interpret the nature of the subsurface without altering the dynamic status of the soil mass [10-12]. ERI measures the resistivity changes both in the vertical direction, as well as in the horizontal direction along a common survey line simultaneously**.** The technique provides the electrical image of subsurface soil. It is well suited to investigate areas with moderately complex geology such as the crystalline basement complex of southwestern Nigeria [7],[11],[13].

Electrical resistivity tomography is increasingly becoming an essential tool in subsoil characterization including environmental studies as it provides high-resolution electrical images of the subsurface geomaterials and structural disposition. Geophysical methods have been applied to characterize the subsurface with huge success [7],[11],[14],[15]. Leachate accumulation/plume is characterized by typically low resistivity spectrum [13],[16],[15].

This paper examines the phenomenon of leachate migration in the soil at the Ilokun dumpsite, Ado-Ekiti. The use of electrical resistivity imaging, a noninvasive geophysical technique will enable visualization of the leachate migration in the soils and in waste containment application systems in the absence of sanitary landfill liners.

III. MATERIALS AND METHODS

The field investigations utilized Electrical Resistivity Imaging (ERI) technique. It is a geophysical technique for imaging subsurface structures from electrical resistivity measurements made at the surface [11],[14].

Measurements were conducted along three 2-D ERI traverses using dipole-dipole array; a traverse of length 140m located within the dumpsite and two resistivity profiles established outside the dump basically to serve as controls. The field work was run with a unit of OMEGA CAMPUS SAS 1000 RESISTIVITY METER and its accessories. Point coordinates and elevations were recorded using a hand-held Garmin GPS device.

A controlled current (I) was injected into the ground by two steel current electrodes and the potential drop (V) was acquired by two others, the potential electrodes. The terrameter gave the apparent resistivity values digitally as computed from Ohm's law. The apparent electrical resistivity data were subsequently inverted into the true electrical resistivity distributions by the RES2DINV software to obtain the subsurface image. The software employs an optimization algorithm that adjusts the 2-D electrical resistivity model by iteratively reducing the difference between the calculated and measured apparent electrical resistivity values until good fit. Leachate plumes are often more electrically conductive than the host formation. Characteristically low resistivity values are thus diagnostic of the leachate accumulation within the local geological setting [10],[16],[17].

IV. RESULTS AND DISCUSSIONS

The 2-D resistivity image along traverse one located within the dumpsite (Figure 2) delineated leachate accumulation (characterized by typically low resistivity values ranging from 4.98 – 13.3 Ωm) with bluish coloration spanning a distance of about 85 m along the traverse and depth of 10m. [10], reported resistivity value less than 10 Ωm, as an evidence of leachate plume accumulation in the study of Lapite Dumpsite in Ibadan, Southwestern Nigeria. Dumont et al. [16] reported resistivity values of only a few Ωm inside the investigated waste dump. The characteristic value of as low as 5 Ωm was observed within the deposit area while the host formation outside of the landfill was characterized by higher values of resistivity. Similarly, the study of [13] showed the leachate plume as low resistivity zones (4.06 – 48.5 Ωm) in the investigation of leachate migration from Banwuya refuse dumpsite, Bida, Niger State, Nigeria. Higher resistivity values were obtained for areas outside the dump.

Significantly, a structural feature diagnostic of a fracture was observed within distances 90m to 110m along the traverse. Fractures are produced by weathering and tectonic processes. These features are associated with enhanced secondary porosity and permeability [17]. The fractured zone characterized by resistivity values ranging from 13.3 to 22.7 Ωm occurring within the zone suggests a preferred conduit or seepage path for the migration of the leachate into the subsurface formation [15],[18].

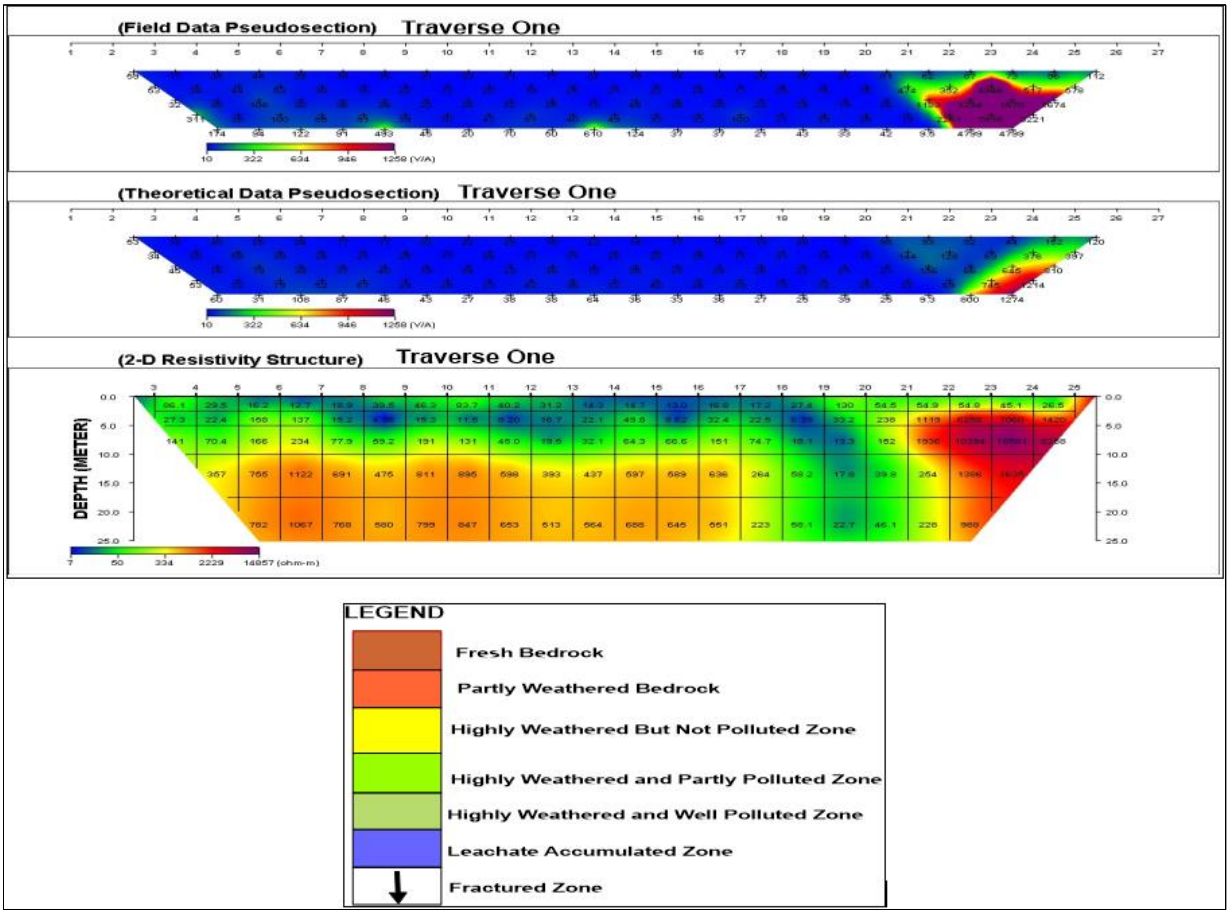

Figure 2: Resistivity 2-D image along traverse one.
Source: Authors, (2024).

The groundwater formations around this area are largely susceptible to the dumpsite leachate pollution as a result of the wide fracture extending to the bedrock. This can pose a great threat to the groundwater quality. [1],[4],[5] and similar works decried the release of pollutants from landfills into the soil, surface water, and groundwater of the surrounding environment as one of the most critical environmental problems of the present age.

Figure 3 shows the 2-D electrical resistivity image of traverse two located beside the dumpsite. This traverse was established to monitor the migration of the leachate into the formations around the dumpsite. The 2-D resistivity image indicated largely weathered and fractured bedrock. The fractures lying along North-south direction of the study area are characterized by resistivity values generally less than 100 Ωm. The graphic depth sections of the thickness and resistivity of the subsurface revealed leachate accumulation within distances 55 to 60m and 75 to 85m at a depth range of 3 to 10m.

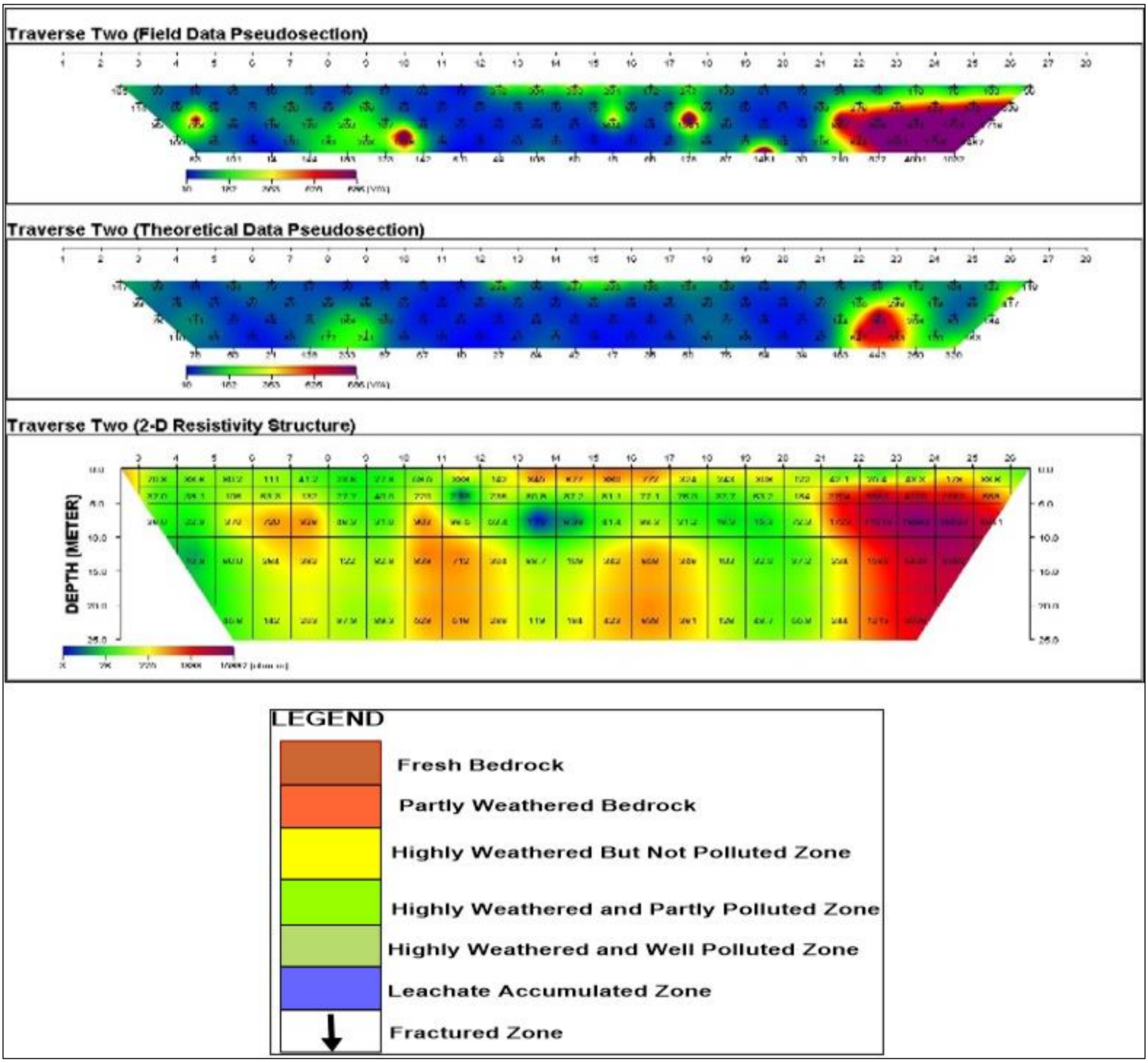

Figure 3: Resistivity 2-D image along traverse two
Source: Authors, (2024).

The 2-D resistivity image along traverse three is presented in Figure 4. The traverse was established outside the dumpsite to observe the migration of the leachate along east-west direction. The section captured the leachate migration along east-west direction as indicated within distances 140/90m in the east-west direction. Relatively very low resistivity values ranging from 2.54 to 4.94 Ωm were observed across the accumulation of the migrated leachate occurring between distances 60 and 85m at depths ranging between 10m and 25 m. The potential of leachate accumulation is relatively higher along the east-western axis.

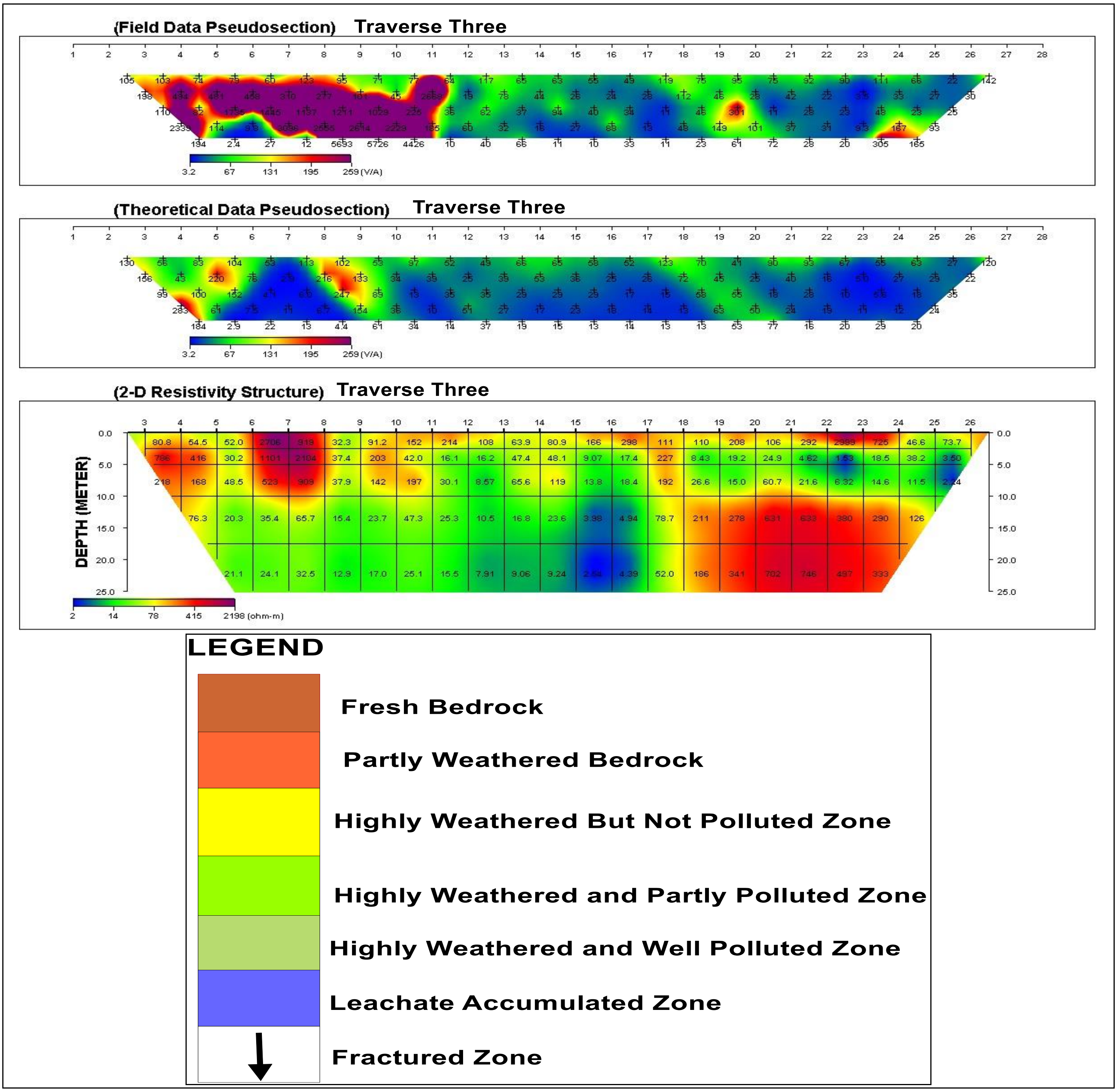

Figure 4: Resistivity 2-D image along traverse three.
Source: Authors, (2024).

The stacked inverse resistivity models of the subsurface, Figures 5 & 6 revealed the fractured zone, leachate accumulation, extent of leachate plumes, bedrock and seepage path from the dumpsite. Remarked that the plume would extend towards the main fracturing direction of the crystalline bedrock [15]. The leachate has virtually permeated the weathered portion of the study area with prevalence along the east-west axis (Figure 6). The horizontal and vertical extent of leachate plumes were delineated by the geo-electrical imaging as a response to the varying electrical resistivity in the contaminated area [10],[17].

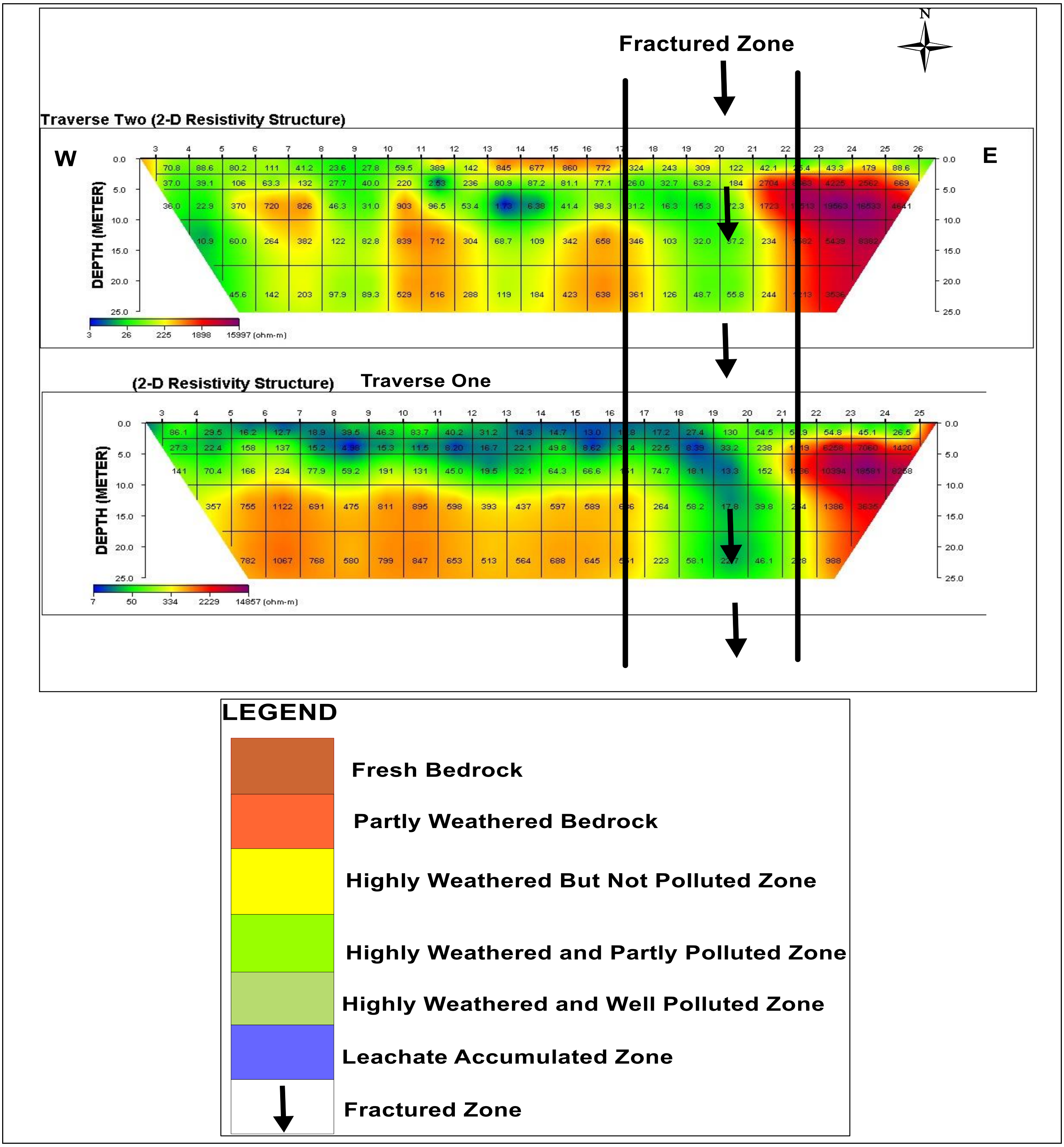

Figure 5: Stacked 2-D Resistivity image along traverse one and traverse two.
Source: Authors, (2024).

Solid waste disposal in a landfill causes leachate production whose discharge to soil layers carries soil and leachate contaminants to the groundwater. Observed that the rate of migration of leachate decreased when the fines content in the subsurface formation increased [6]. With the fines, associated porosity and permeability are reduced in contrast with enhanced porosity and permeability in weathered and fractured formations.

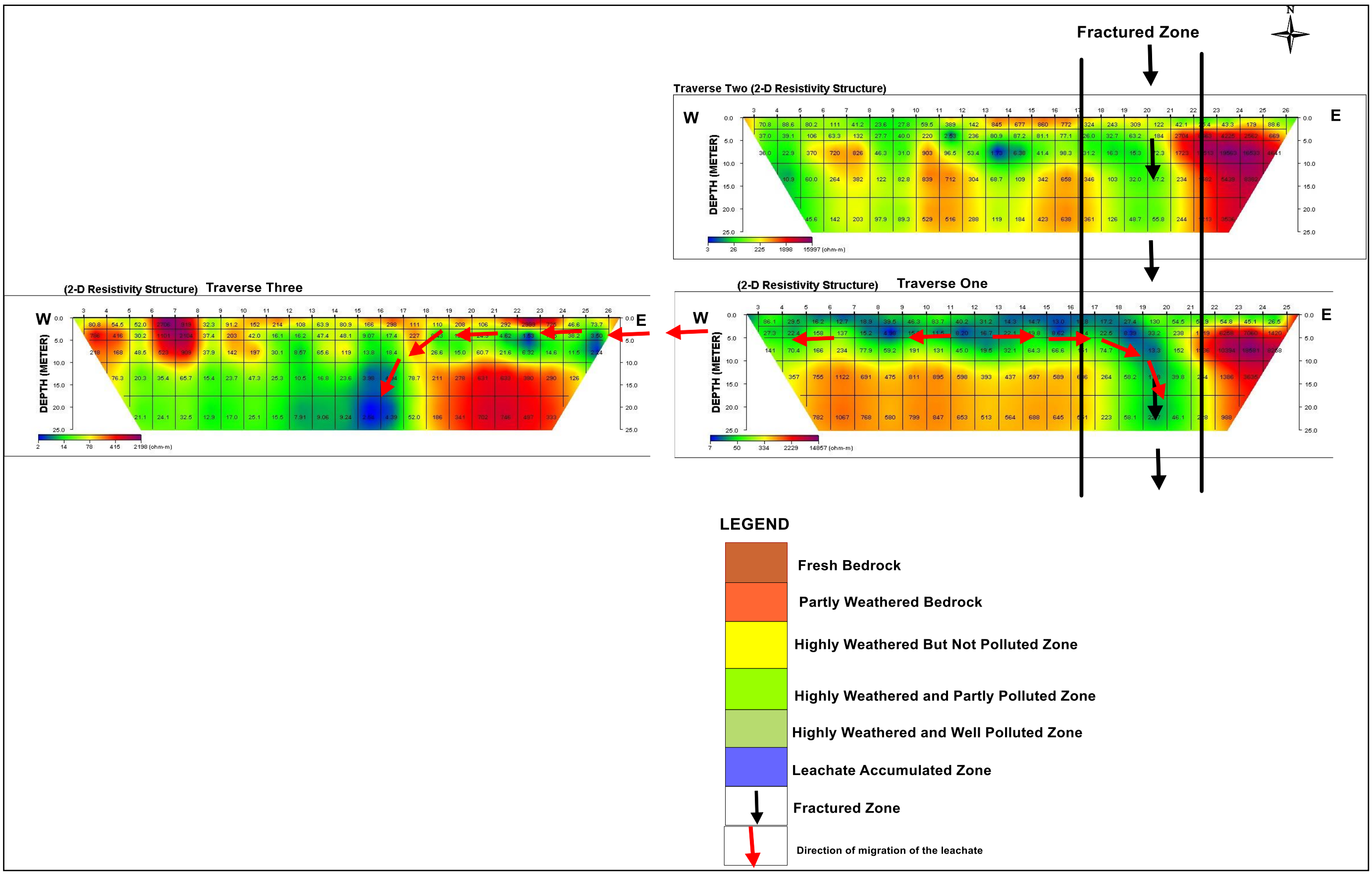

Figure 6: Stacked 2-D Resistivity image along the traverses.
Source: Authors, (2024).

Occurrence of tectonic activities such as fracturing, faulting and intense weathering promotes high porosity and permeability with increase in the rate of migration of leachate. A candidate landfill site should be sufficiently thick and of low permeability (clay material). The geological setting occurring at the Ilokun dumpsite as delineated by the electrical resistivity imaging does not offer requisite minimum leachate curtailment capacity (LCC). A clay overburden thickness of about 15 m which acts as leachate filter is a standard for determining the LCC of a dumpsite. Investigation of the subsurface is thus a compulsion before waste disposal site is developed [2],[7].

Poor management of municipal solid waste leads to potentially devastating environmental and health hazards. The dumpsite leachate inherently results in contamination of the soil, groundwater and surface water in the absence of containment systems with free leachate migration from the dumpsite into surrounding environment [17]. The need to protect groundwater resources cannot be overemphasized in any area where the majority of the population derive potable water from the shallow aquifers. Protection of domestic and public water supplies is sacrosanct basically to avoid unpleasant consequences. In developing countries, it is a general remark that high proportions of diseases are directly related to poor drinking water quality and unhygienic conditions [1],[2],[15]. Proper mitigation measures are necessary to protect the shallow groundwater system.

V. CONCLUSIONS

Leachate generated from dumpsite is a major concern to public health. ERI provides a noninvasive geophysical tool to map the leachate migration. The 2D-ERI method revealed features of the subsurface as topsoil, weathered, fractured and fresh basement. The study delineated the preferential leachate migration pathways within weathered/fractured overburden. This methodology has the added merits of saving cost and time compared to the drilling-sampling-analyses approach. The production of dumpsite leachate and its migration portend huge risk to the environment and public health. The dumpsite of such myriads of solid wastes would contain large numbers of pathogenic and opportunistic bacteria. Waste management should embrace engineered landfill sites in place of unregulated open dumping. Groundwater quality should be monitored with the use of observation wells. Remote sensing, rapid noninvasive field survey and screening should be encouraged for necessary response.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Oyedele
Methodology: Oyedele, Ewumi and Ogunlana
Investigation: Oyedele, Ewumi and Ogunlana
Discussion of results: Oyedele, Ewumi and Ogunlana
Writing – Original Draft: Oyedele
Writing– Review and Editing: Ewumi and Ogunlana
Resources: Oyedele, Ewumi and Ogunlana
Supervision: Ewumi and Ogunlana
Approval of the final text: Oyedele, Ewumi and Ogunlana

VII. ACKNOWLEDGMENTS

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