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Application of 2D electrical resistivity imaging for monitoring subsurface contaminant plumes at Challawa Industrial Estate

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Abstract:
Geoelectrical methods provide valuable tools for detecting and monitoring subsurface contamination. This study applied two-dimensional (2D) electrical resistivity imaging (ERI) using Wenner array configurations across four profiles in the vicinity of the Challawa Industrial Estate, Kano State, Nigeria. Field data were acquired at electrode spacing of 5 to 25 m, and inverted using RES2DINV and ZONDRES2D software packages. The resistivity models delineated five main subsurface layers: topsoil, laterite, weathered basement, fractured basement, and fresh basement. Zones of anomalously low resistivity (< 350 Ωm) corresponded to contaminant plumes derived from tannery and textile effluents. Results correlated strongly with borehole lithological logs and physico-chemical water analysis, confirming the reliability of ERI for monitoring contamination. The study demonstrates that electrical resistivity imaging provides an efficient, cost-effective method for delineating subsurface pollution and informing groundwater management strategies in industrial environments.

Keywords: *Contaminant plumes, Electrical resistivity, Imaging, Pollution, Wenner array*

1. Introduction

Groundwater contamination has become a critical environmental issue in urban and industrial areas, particularly in developing countries where industrial effluent management is often inadequate. Traditional hydrochemical analysis provides detailed information on water quality but offers limited insight into the subsurface pathways of contaminants. Geophysical methods, especially 2D electrical resistivity imaging (ERI), have gained increasing attention for mapping contaminant plumes and characterizing subsurface structures. Studies such as Dahlin (2001) and Loke (2004) have demonstrated the potential of ERI for environmental monitoring. However, few studies have integrated ERI with hydrochemical analysis in the context of Nigeria's industrial zones. This research applies 2D ERI to delineate subsurface contaminant plumes from the Challawa Industrial Estate, Kano State, Nigeria, and evaluates its effectiveness by correlating geophysical data with borehole logs and water quality results.

2. Methodology

2.1 Study area

The study was conducted at the confluence of the Challawa River and industrial effluent channels draining from the tannery and textile factories. The region is underlain by Basement Complex rocks, comprising laterite, weathered basement, and fractured basement aquifers.

2.2 Data acquisition

Four survey profiles were established perpendicular to the effluent flow path. A Wenner array configuration was adopted due to its high sensitivity to vertical resistivity variations. Electrode spacing ranged from 5 to 25 m, yielding adequate depth penetration for detecting shallow to intermediate contamination zones.

Table 2.1: Survey profile specifications for profile 1

S/N	I(A)	V(V)	R (Ω)	ρ(Ωm)
1	7.90	99.40	12.58	395.08
2	6.40	172.70	26.98	847.31
3	6.00	85.10	14.18	445.36
4	0.10	4.20	42.00	1318.80
5	8.70	64.90	7.46	234.24
6	0.10	141.70	1417.00	44493.80
7	1.00	246.00	246.00	7724.40
8	1.00	97.50	97.50	3061.50
9	1.00	0.30	0.30	9.42
10	1.00	1.50	1.50	47.10
11	0.19	0.10	0.53	16.53
12	0.01	0.10	10.00	314.00
13	0.10	0.10	1.00	31.40
14	0.02	1.60	80.00	2512.00
15	0.10	0.30	3.00	94.20
16	0.10	2.70	27.00	847.80
17	0.10	0.20	2.00	62.80
18	0.10	1.40	14.00	439.60
19	0.10	0.40	4.00	125.60
20	0.60	1.20	2.00	62.80
21	0.40	2.00	5.00	157.00
22	0.10	0.20	2.00	62.80

S/N	I(A)	V(V)	R (Ω)	ρ(Ωm)
23	0.10	0.10	1.00	31.40
24	0.30	0.10	0.33	10.47
25	0.10	0.10	1.00	31.40
26	0.20	0.20	1.00	31.40
27	0.10	0.20	2.00	62.80
28	0.10	0.20	2.00	62.80
29	0.20	0.10	0.50	15.70
30	0.30	0.30	1.00	31.40
31	0.10	0.60	6.00	188.40
32	0.10	0.20	2.00	62.80
33	0.10	0.10	1.00	31.40
34	0.30	0.20	0.67	20.93
35	0.10	0.20	2.00	62.80
36	0.10	0.10	1.00	31.40
37	0.10	0.10	1.00	31.40

Spacing, a = 5m; Width of the river = 57m

2.3 Data processing

Field data were processed and inverted using RES2DINV (Geotomo Software) and ZONDRES2D software. Both software packages employed smoothness-constrained least-squares inversion to generate 2D resistivity models.

3. Results and discussion

3.1 Subsurface resistivity structure

The resistivity models revealed five major subsurface layers: Topsoil (100–250 Ωm), Laterite (250–800 Ωm), Weathered basement (150–400 Ωm), Fractured basement (400–800 Ωm), and Fresh basement (>1000 Ωm). Zones of anomalously low resistivity (< 350 Ωm) were interpreted as contaminant plumes infiltrating the shallow aquifers.

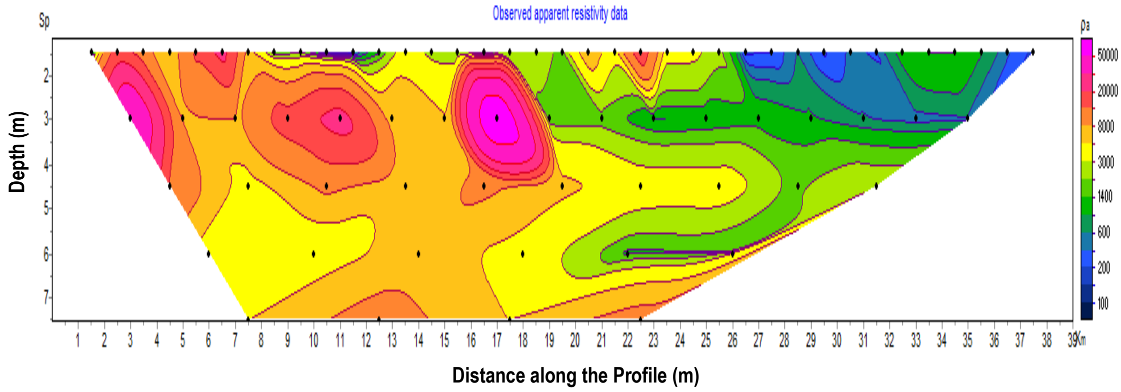

Figure 1: Calculated apparent resistivity data of profile 1

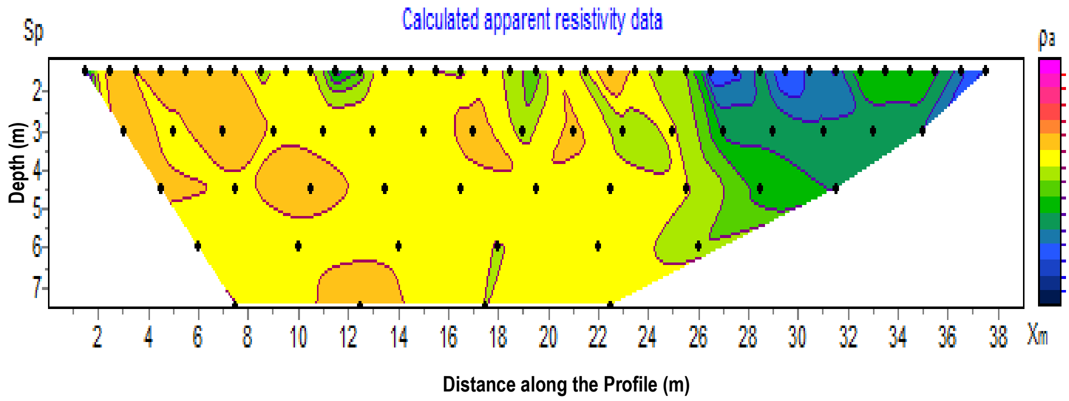

Figure 3: Calculated Apparent Resistivity Data of Profile 1

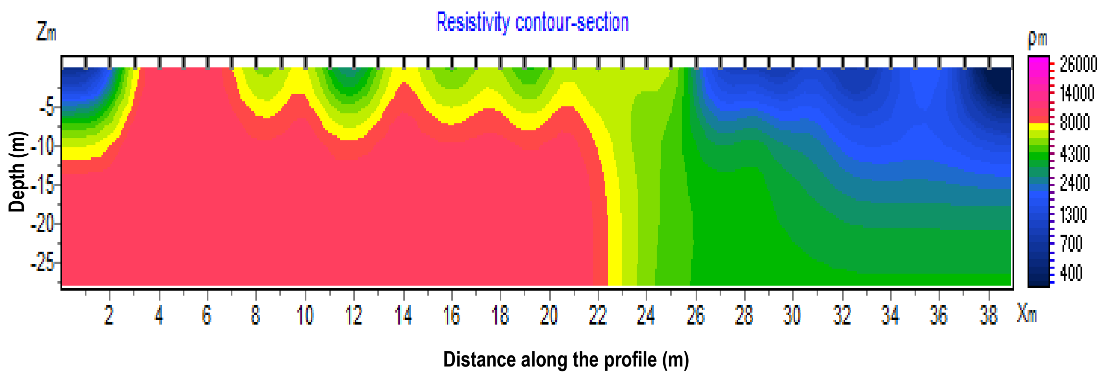

Figure 4: Resistivity contour-section of Profile 1

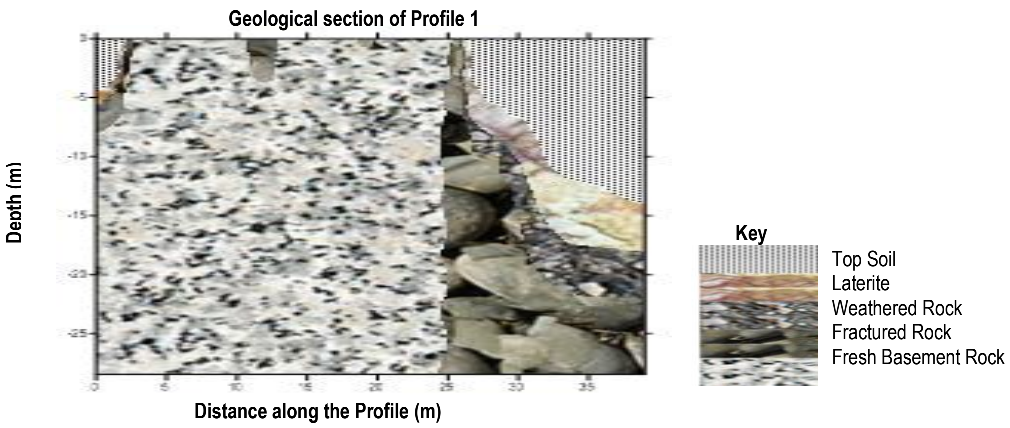

Figure 5: Geologic Section of Profile 1

3.2 Correlation with borehole logs

Borehole lithological data confirmed the presence of porous lateritic and weathered zones that act as pathways for contaminant migration. The overlap of geophysical anomalies with hydrochemical evidence (elevated chromium, sulphur, and iron concentrations) validates the geophysical interpretation.

3.3 Implications for environmental monitoring

The ability of ERI to delineate contaminant plumes provides valuable insight into the spatial distribution of pollution. Compared with traditional hydrochemical methods, ERI offers rapid, non-destructive, and cost-effective subsurface imaging, making it highly suitable for groundwater monitoring in industrial environments.

4. Conclusion

This study successfully applied 2D electrical resistivity imaging to detect and monitor subsurface contaminant plumes in the Challawa Industrial Estate, Kano State. The resistivity models delineated multiple subsurface layers and identified low-resistivity anomalies consistent with effluent infiltration. Strong correlations with borehole logs and hydrochemical data confirm the reliability of ERI in environmental monitoring. The findings highlight the method's potential as a cost-effective tool for early detection of groundwater contamination and for informing remediation strategies.

Acknowledgment

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