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Preliminary Geophysical Assessment of Soil Contaminants around Wacot Rice Factory Argungu, North-Western Nigeria

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Abstract**—**Geophysical investigation was carried out at wacot rice factory Argungu north-western Nigeria, using the 2D electrical resistivity method. The area falls between latitude 12˚44′23″N to 12˚44′50″N and longitude 4032′18″E to 4032′39″E covering a total area of about 1.85 km. Two profiles were carried out with Wenner configuration using resistivity meter (Ohmega). The data obtained from the study area were modeled using RES2DIVN software which gave an automatic interpretation of the apparent resistivity data. The inverse resistivity models of the profiles show the high resistivity values ranging from 208 Ωm to 651 Ωm. These high resistivity values in the overburden were due to dryness and compactness of the strata that lead to consolidation, which is an indication that the area is free from leachate contaminations. However, from the inverse model, there are regions of low resistivity values (1 Ωm to 18 Ωm), these zones were observed and identified as clayey and the most contaminated zones. The regions of low resistivity thereby indicated the leachate plume or the highly leachate concentrated zones due to similar resistivity values in both clayey and leachate. The regions of leachate are mainly from the factory into the surrounding area and its groundwater. The maximum leachate infiltration was found at depths 1 m to 15.9 m (P1) and 6 m to 15.9 m (P2) vertically, as well as distance along the profiles from 67 m to 75 m (P1), 155 m to 180 m (P1), and 115 m to 192 m (P2) laterally.

Keywords**—**Contaminant, leachate, soil, groundwater, 2D, electrical, resistivity, Argungu.

I. Introduction

SOLID or liquid wastes (mostly industrial and garbage wastes) are usually discharged in landfills where it decomposes thereby resulting a leachate that can contaminate underling groundwater [1]. The intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and already have resulted in many incidents of groundwater contamination [2]. Degradation of groundwater quality can take place over large areas from plane or diffuse sources like deep percolation from intensively farmed fields, or it can be caused by point sources such as septic tanks, garbage disposal sites, cemeteries, mine spoils and oil spills or other accidental entry of pollutants into the underground environment [1], [3].

Another possible of contamination is by line sources of poor-quality water, like seepage from polluted streams or intrusion of salt water from ocean [4]. Because groundwater tends to move very slowly, many years may elapse after the start of pollution before affected water slows up in a well. For the same reason, many years may be required to rehabilitate contaminated aquifers after the source of pollution has been eliminated [4], [5].

Leachate from landfills is a wastewater with acute and chronic toxicity. The untreated plume permeates ground water or mixed with surface waters polluting the soil, groundwater, and surface water [6]. Additionally, leachate may cause malodorous and aerosols although these effects are localized and temporary [7]. The composition of the contaminant plume portrays sequential and regional variation, with significant concentrations of contaminants [8]. The organic constituents, ammonia and heavy metals in leachate are the main issues for landfill operators and local authorities. Sanitary landfills are equipped with synthetic or clayey liners to avoid the leakage of the contaminant plume into the groundwater and superficial waters. The control tipping with the aid of liners and pipes channels the leachate to treatment ponds [4].

Usually, wacot rice factory in Argungu discharged materials including liquid waste as well as gases coming out from the company. These rapid increments of contaminants or pollution may likely affect the quality of groundwater within the area. Therefore, it has become imperative and necessary to ascertain the rate of diffusion of these contaminants around the area as well as water quality of wells and boreholes near the company under study and thus, determining the depth of each layer and its importance in assessing the source of contamination about the region has become necessary. This prompted the researcher into this study area. The aim of this study is to establish the environmental impact of industrial waste from rice factory using electrical resistivity method.

The electrical resistivity method measures potential differences at points on the Earth's surface that are produced by directing current flow through the subsurface [9]. The movement of charges through the conducting wire is termed current. Specifically,

$$I = \frac{Q}{t} \tag{1}$$

where I is current in amperes, Q is charge in coulombs, and t is time in seconds. Also, another important concept in electrical resistivity surveying is the current density J, which is defined as the current divided by the cross-sectional area of the material through which it is flowing

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$$J = \frac{I}{A} \qquad (2)$$

From Ohm's law,

$$I = \frac{V}{R} \qquad (3)$$

where V is the voltage and R is the resistance.

One immediate complication is that resistance depends not only on the material but also on its dimensions.

$$R = \rho \frac{l}{A} \qquad (4)$$

In electrical resistivity surveying, our goal is to measure the potential difference between two points just as we often make this measurement in electrical circuits. Fig. 1 illustrates the arrangement of electrodes on the surface of the earth. The inner potential electrodes, P_1 and P_2 measured the potential differences with the aid of two outer current electrodes C1 and C2 [10]. Therefore, the potential difference ΔV equals

$$\Delta V = V_{P1} - V_{P2} \qquad (5)$$

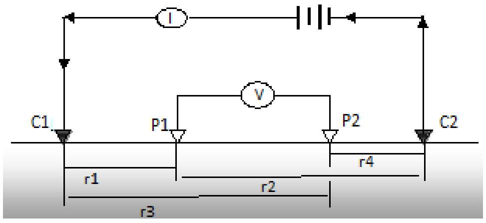

Fig. 1 Diagram used to determine potential difference two points

Inserting (3) and (4) into (5), then

$$\Delta V = \left(\frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2}\right) - \left(\frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4}\right) \qquad (6)$$

$$\Delta V = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \qquad (7)$$

2D electrical resistivity method usually allowed the current to flow into the ground thereby measuring the potential difference that lead to the determination for resistivity of soil/ or common rock. Hence, the resistivity ρ, in (3) becomes.

$$\rho = \frac{2\pi\Delta V}{I}\left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}\right) \qquad (8)$$

Resistivity ρ is thus given as

$$\rho = \frac{2\pi\Delta V}{I} . G = RG \qquad (9)$$

where *G;* Geometric Constant that defines electrode configuration adopted during the survey.

Considering Wenner configuration which have been adopted in this study (Fig. 2), all the four electrodes A, M, N and B are planted along a profile such that

$$AM = MN = BN = \frac{AB}{3} \qquad (10)$$

This distance $\frac{AB}{3}$ is called the electrode spacing *(a)*.

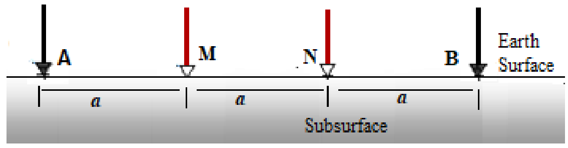

Fig. 2 The Wenner electrode configuration

The outer electrodes, A and B are current electrodes while the inner ones, M and N are potential electrodes. Comparing Figs. 1 and 2,

$$r_1 = a, r_2 = 2a, r_3 = 2a, r_4 = a \qquad (11)$$

Then equation for resistivity (8) becomes:

$$\rho = \frac{2\pi\Delta V}{I\{\left(\frac{1}{a} - \frac{1}{2a}\right) - \left(\frac{1}{2a} - \frac{1}{a}\right)\}} \qquad (12)$$

The apparent resistivity ρ_a measured at a particular value of electrode spacing, (*a*) becomes:

$$\rho_a = \frac{2\pi a\Delta V}{I} \qquad (13)$$

$$\rho_a = G_w . \frac{\Delta V}{I} = G_w . R \qquad (14)$$

where R is the measured resistance in Ohms and $G_w(2\pi a)$ is the geometric factor for Wenner array.

II. General Geology of the Study Area

The study area is located in the northwestern part of Nigeria and lies in the northern part of Kebbi state. The area falls between latitude 12°44′23″N and 12°44′50″N and longitude $4^0$32′18″E to $4^0$32′39″E (Fig. 3) covering a total area of about 1.85 km.

Geologically, study area falls within the sokoto basin that associated with an extensive elongated sedimentary basin underlying in some part of North-western Nigeria and Eastern part of Niger Republic. Sokoto basin was grouped into Sokoto and Rima group [11]. These groups were further classified into Dukamaje Formation, Kalambaina Formation, Taloka Formation, Illo Formation, Gundumi Formation, Gwandu Formation, Dange Formation and Wurno Formation [12]. Specifically, the geology of present Kebbi state, though part of Rima basin, is dominated by Gwandu and Illo formations. However, Illo and Gwandu formations show a lot of features in common as such they are treated together in most literature [13]. Argungu (study area) is part of the Gwandu formation consists of massive of clay interbeded with sandstone as shown in Fig. 4.

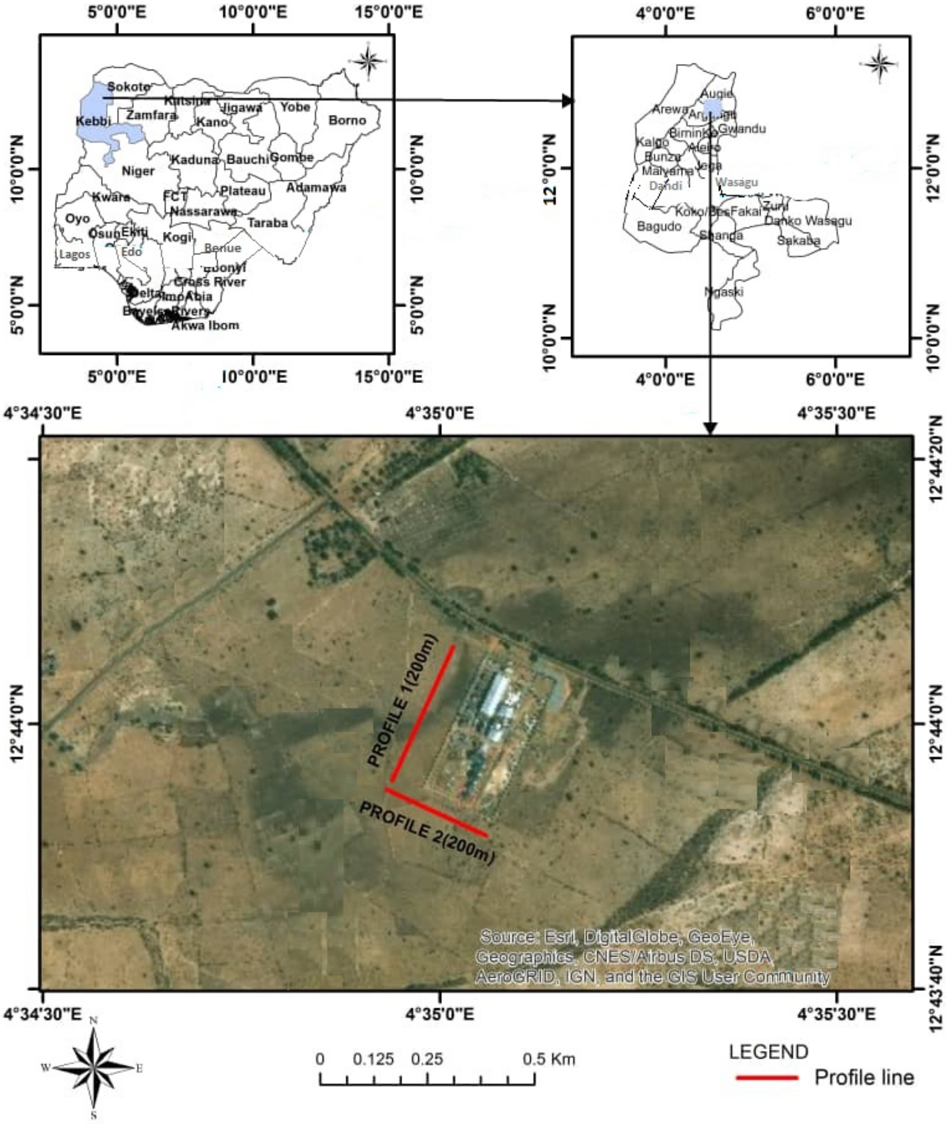

Fig. 3 Location of the Study Area

III. Methodology

The resistivity meter (Ohmega) was set up with all its accessories in place. The electrodes were equally spaced with spacing between the electrodes equals 5 m. The cables which supply current into the ground were connected to C_1 and C_2 ports of the machine.

For the first measurement, electrodes 1, 2, 3 and 4 were used. Electrode 1 was used as the first current electrode C_1at 0 m, electrode 2 as the first potential electrode P_1 at 5 m, electrode 3 as the second potential electrode P_2 at 10 m and electrode 4 as the second current electrode C_2 at 15 m (Fig. 5). For the second measurement, electrodes 2, 3, 4 and 5 were used for C_1at 5 m, P_1at 10 m, P_2 at 15 m and C_2 at 20 m respectively. This was repeated down the profile line of 200 m using 1*a* spacing. This was repeated down the profile line of 200 m using 2*a* spacing and so also for 3*a,* 4*a,* and 5*a,* spacing measurements were obtained. Following the technique as given in (14), product of the resistance measured (R) and the corresponding value of the geometric factor (G_w) is therefore gave the measured apparent resistivity of the study area (see Table I).

IV. Results and Discussion

Geoelectrical Imaging 2-D & 3-D GEOTOMO Software (Version 3.55) was used in processing acquired data from the field which automatically gives the inverse (model) resistivity section. The sections have vertical axis corresponding to depth of investigation and the horizontal distance axis representing along the profile. The inverse resistivity section was generated during modelling to produce the model section. The inverse section of each profile was interpreted in terms of geology (Table II) and related information.

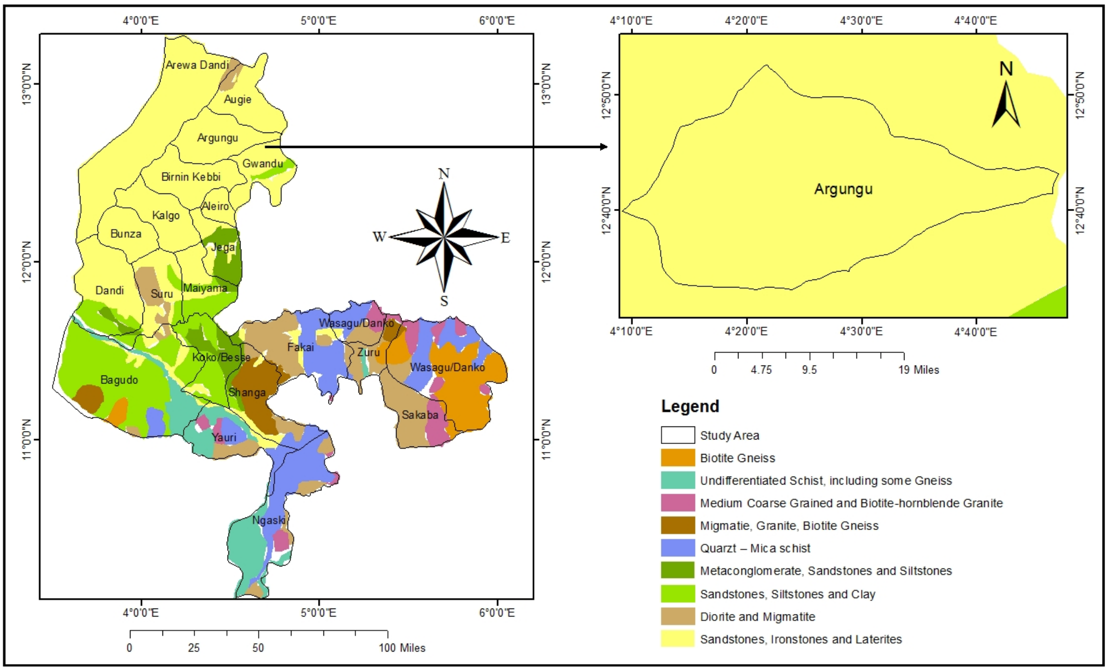

Fig. 4 Geology of the Study Area

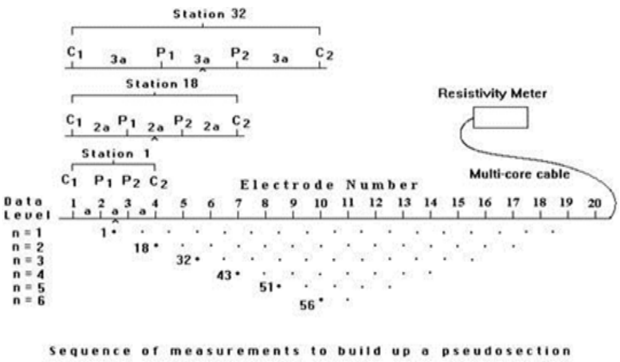

Fig. 5 Demonstration and arrangement of electrodes in datum points

Profile One

The inverse section of the profile one (Fig. 6) showed regions of low and high resistivity values. These values were compared with Table II. The length of the profile is 200 m and measurement commenced from the north side of the profile. Looking at the inverse section under position 67 m to 75 m of the layers having the resistivity value 3 Ω m to 18 Ω m spotted with bottom of the deepest layer appearing at 9 m. When these resistivity values are considered in relation to Table II, the portion of the region was considered to be clayey. Thus it was extended to region ranging 155 m to 180 m along the profile at the depth of 15.9 m. This region is an indication of permeable zones where the infiltration of contaminations occurs which lead to leachate plume. However, there are zones of high resistivity values in the inverse section under positions 35 m to 65 m along the profile. These layers have the resistivity value of 208 Ωm to 472 Ωm which spotted with bottom of the deepest layer appearing at 9.36m. When these resistivity values are considered in relation to Table II, the portion of the regions was considered to be ironstone. These regions also occupied the profile ranging 180 m to 200 m along the profile at the depth of 15.9 m. The high resistivity response of this region shows an indication that the area is free from leachate contaminations and suitable for groundwater development. The result of interpretation of the inverse model section (Fig. 6) was given in geologic section (Fig. 7).

TABLE I
TYPICAL FIELD DATA FOR PROFILE 1

S/No.	*x*-Location (m)	Spacing, *a* (m)	Resistivity, ρ (mΩ)
1	0	5	206.11
2	5	5	130.07
3	10	5	88.29
4	15	5	68.18
5	20	5	72.26
6	25	5	59.38
7	30	5	124.1
8	35	5	87.66
9	40	5	110.28
10	45	5	85.77
11	50	5	90.8
12	55	5	79.49
13	60	5	66.09
14	65	5	4.18
15	70	5	83.26
16	75	5	69.12
17	80	5	59.38
18	85	5	88.29
19	90	5	129.76
20	95	5	81.06
21	100	5	79.49
-	-	-	-
-	-	-	-
-	-	-	-

Profile Two

Fig. 8 gives results of inverse section of the profile two (P2). The length of the profiles is 200 m and measurement commenced from the west side of the profile spotted with bottom of the deepest layer appearing at 15.9 m. Observing this pseudosection very closely under position 115 m to 192 m along the profile of the layer having resistivity values ranging from 1 Ωm to 18 Ωm spotted with bottom of the deepest layer appearing at 15.9 m. These zones with low resistivity values (1 Ωm to 18 Ωm) were compared with Table II and identified to be clayey. This zone is occupied by low resistivity values interpreted as leachate impregnated clay and indicating severe contamination of the aquiferous zone.

The model also reveals homogenous high electrical resistive zone (> 470 Ωm) from 65 m to 105 m along the profile at depth ranging from 6.40-15.9 m across the model. The layer was identified to be sandstone/ironstone when compared in relation to Table II. From the high resistivity response of this zone, it is evident that this area is free from leachate contaminations and suitable for groundwater development. Interpretation of inverse resistivity section (Fig. 8) resulted in production of geologic section shown in Fig. 9 using surfer software.

TABLE II
ELECTRICAL RESISTIVITY VALUES OF THE EARTH MATERIALS [14]

Rock Type	Resistivity Range (Ωm)
Clayey	1-30
Laterite	50-350
Ironstones	9 – 968
Coarse sand	2400 - 10^8
Limestone	50 - 10^7
Dolomites	350 – 5000

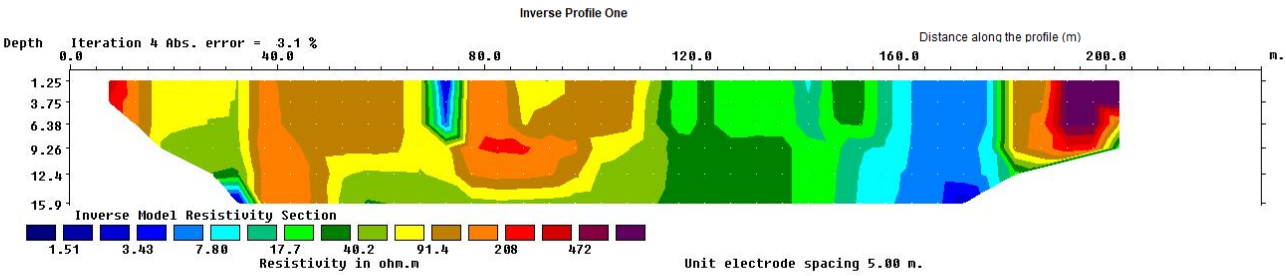

Fig. 6 Inverse Resistivity Section of Profile One

Fig. 7 Geologic Section of Profile One

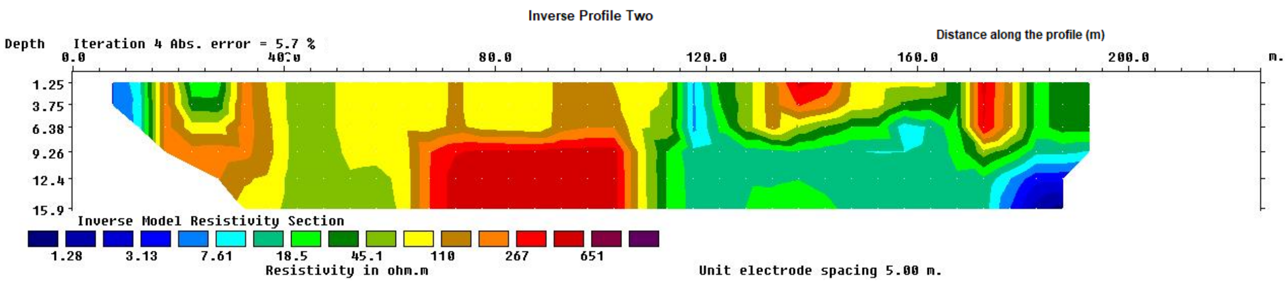

Fig. 8 Inverse Resistivity Section of Profile Two

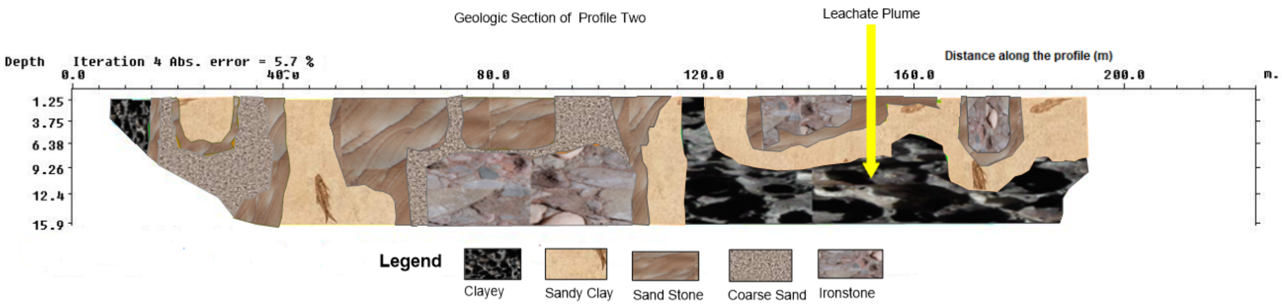

Fig. 9 Geologic Section of Profile Two

V. Conclusion

The 2D electrical resistivity method used in the study area has successfully provided the regions of leachate mainly from WACOT Rice Factory into the surrounding area and groundwater. In general, the maximum leachate infiltration was estimated at depth 1 m to 15.9 m (P1) and 6 m to 15.9 m (P2) vertically. Also, along the profiles from 67 m to 75 m (P1), 155 m to 180 m (P1) and 115 m to 192 m (P2) laterally. Resistivity values ranging from 1 Ωm to 18 Ωm were observed as representing the most contaminated zones in all the geologic sections of inverse models. These zones indicate the leachate plume or the highly leachate concentrated zone due to both clayey and leachate have quite similar resistivity values.

It is recommended to used other geophysical methods like electromagnetic method that could be exploited like transient method which is fast less labour intensive and has high depth of penetration thus it exploring greater depths. It is also recommended in some two to three years another research should be conduct at the same landfill using the same geophysical technique and compare with present work.

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