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GEO-ELECTRICAL METHOD OF ASSESSMENT OF COEFFICIENT OF PERMEABILITY AND POROSITY OF SOIL OF A POULTRY FARMLAND

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Article Info	Abstract
Received: 17.06.2021 *Accepted: 22.09.2021* **Keywords:** Porosity, Coefficient of permeability, Profile length, 2D electrical resistivity, leachate migration, highly conductive. .	Leachate collected at the bottom of dead bird's disposal pits may leak and migrate to pollute groundwater when soils and rocks present are porous. This study assessed the coefficient of permeability (K) and porosity (Φ) of soils and rocks in poultry farmland using 2 Dimensional (2D) electrical resistivity method and soil analysis. Geo-electrical data collection was achieved by using the dipole-dipole array. The field resistivity measurement was carried out along three traverse lines (three Profiles) of 100 m long which were oriented along with East-West directions. These measurements were taken in the order of increasing in offset distance interval of 5 m. The acquired apparent resistivity data were inverted using DIPPROWIN modeling software to perform 2D data inversion. Five soil samples from different locations at depths of 0 – 15 cm and 15 – 30 cm, on the poultry farmland, were collected, transported, and tested in the laboratory. K and Φ were determined using falling head and density methods respectively. The results obtained from the processed field resistivity data from the three profiles were presented as field data pseudo-sections, theoretical pseudo-section, and 2D resistivity structures. The 2D resistivity structure revealed three structures viz; highly conductive, slightly conductive, and resistive. The resistivity values of these structures ranged from 14.1-99.0 Ω m, 100-848 Ω m, and 1350-90330 Ω m respectively. The highly conductive structures were found in profiles 1 and 3 due to the downward migration of the contaminants from the dead bird disposal pit 1 and the feces disposal site through clayey sand soil. This occurs at the depth range of few meters from the surface to greater than 20 m. The presence of the slightly conductive structure is a result of filtration of the contaminants by the soil materials which increased the resistivity of the soil. The movement of the contaminant through the soil is an indication of the porous and permeable nature of the farmland. The resistive structure is only noticeable in profiles 1 and 2 but very prominent at the depth range of 5 m to more than 20 m and 5 m to 35 m along the profile length. The results of the analysis of the five soil samples from the poultry farmland showed a high value of 0.552 and $3.554\ x\ 10^{-2}$cm/s of porosity (Φ) and coefficient of permeability (K) respectively. A strong correlation of $R^2 = 0.9878$ existed between Φ and K. With these results geo-electrical method had successfully assessed Φ and K of the soil of the poultry farmland.

1. Introduction

Bird disposal pits are dug mainly to dispose of dead birds to prevent diseases associated with dead animals. The actions of pathogens on these dead birds result in their decomposition. The decomposition of these disposed of dead birds in disposal pits results in the production and release of gases and liquids termed leachate. Among the released gases include ammonia, nitrogen oxide, carbon diode, hydrogen sulfide. Furthermore, the actions of rains and dews on these dead birds in dead bird disposal pits facilitate the decomposition and generation of leachate. This leachate percolates down to the bottom of these pits thereby polluting the soil, groundwater, and the environment of a poultry farm [1, 2, 3]. The environmental risks of pollution arise when these organic and inorganic liquids and gases escape and enter into porous media (soils, rocks). Soils and rocks are termed porous media because of the arrangement of grains that they contain. These grains usually leave space (pores and channels) that are filled with fluids, water, air, gas, oil tar, etc. In addition, rocks when stressed, can become brittle and fractured (joint and faults) and break into blocks of different sizes and shapes. These fractures, particularly joints provide paths along which fluids may move and store through rocks. The fluids in these voids and joints are either stored or transmitted through these openings or interstices of ranging sizes and shapes when connected. The property of the porous media that helps in storing and transmitting these fluids is termed Porosity and Permeability respectively [4].

Porosity is a measure of its ability to hold fluids. It is a property that measures the void spaces in a material. Another property of porous media (soils, rocks) is permeability. Permeability is defined as the property of a porous material that permits the passage or seepage of water (or other fluids) through its interconnecting voids. It is a measure of the ease of flow of fluids through porous solids. According to Darcy law, it is the proportionality constant that relates the volume flow rate for an incompressible fluid to the pressure gradient [5]. The knowledge of these hydraulic parameters (porosity and permeability) will help in the study of water leakages, monitoring contaminant percolation, and oil extraction. So, this study is set to assess the soils and rocks in a poultry farm for their porosity and permeability. These hydraulic parameters serve as an important indicator for various kinds of rocks [6].

Researchers such as Huenges and Zimmermann (1999) [7] and Sudo et al., (2015) [8] have employed numerical and physical methods in solving problems relating to permeability in rocks. Various attempts have been made in assessing, determining, and estimating impurities in groundwater [9, 10, and 11]. The presence of joints, fractures, and voids in soils and rocks favour the leaks of leachate to the surrounding soils and groundwater [12]**.** Porosity and coefficient of permeability of the interconnected soil matrix have a direct impact on the hydraulic gradient of leachates. Moreover, sands/regoliths enable quick exchange between groundwater systems integrated into a Darcy flow [13]**.** The movement of leachate through porous media has been studied by different researchers using geophysical techniques. Among these techniques is the electrical resistivity methods which have proved successful rather than drilling closely spaced boreholes for point sampling, because it is labor-intensive and tedious to carry out [14].

The electrical resistivity method can give the resistivity distribution of the subsurface. Contaminant plumes usually have sufficiently high contrast in physical properties compare with the host media due to an increase in dissolved salts in the groundwater and a resulting decrease in pore water resistivity; therefore geoelectrical resistivity method is suitable for this kind of study [15]. Hydrogeologists such as Zohdy (1965) [16], Page (1969) [17], Meidav (1960) [18], and others have all used electrical resistivity measurements to qualitatively assess permeability and to delineate regions of higher and lower permeability in alluvial and glacial deposits for decades, typically by observing resistivity contrasts between clay-rich low permeability deposits and clay poor high permeability deposits**.** Zohdy (1964) [19] had successfully used electrical sounding in the determination of hydrogeological conditions such as the thickness of soil, depth to the water table, and depth to bedrock while Griffths and Barker (1993) [20] employed electrical imaging to delineate contaminant source. The application of electrical resistivity to waste disposal sites becomes popular because electrical resistivity of the waste in a disposal site varies considerably with time as decomposition happens and in the formation of leachate in this disposal site [21 -25]**.** To adequately quantify the migration of contaminants from a disposal site as well as the chemical and biochemical reactions that take place between components, groundwater and aquifer require the knowledge of the transport model. To be able to do this, the measurement of hydraulic parameters such as porosity and permeability of the principal formations or the features that control groundwater flow is very important. Field information on the geology of the study site is also needed. The information obtained may lead us to the determination of velocity and direction of flow. Researchers such as [26 – 28] have used one dimension (1D) Vertical Electrical Sound (VES) to determine hydraulic parameters from electrical resistivity measurement. Loke et al., (2013) [29], and Samouelian et al., (2005) [30] had demonstrated that 2D and 3D techniques give better and reasonable results since 1D has no regard for horizontal changes in resistivity [29].

Thus, this research aimed at using 2D resistivity in assessing the coefficient of permeability and porosity of the soil in poultry farmland having dead bird's disposal pits. This research includes studies of both containment sites and sites where leachates tend to migrate, to study conditions in the disposal pits, and to use 2D electrical resistivity method to assess coefficients of permeability and porosity of the poultry farm soil in terms of leachate migration originating from dead bird disposal pits and its toxicity on groundwater.

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2. Method and Samples

2.1 Description of the Study Site

The study site, active poultry farmland in which the mortality pits (fig. 1) are located, is in Isundunrin and is just 2 km from the middle of the town (fig. 2). It is easily accessible from Ejigbo by major tarred roads; minor untarred roads and footpaths in Ejigbo Local Government Area of Osun State, southwestern Nigeria. The farm lies within longitude E04^{o}16′34″ – E04^{o} 15′46″ and latitude N07^{o} 51′32″ – N07^{o} 51′52″. The study site lies within the tropical region of Africa and the climate condition is characterized by alternating wet and dry seasons. The wet season is characterized by heavy rainfall which starts in March and ends in October while the dry season is from November to February. The mean annual rainfall, relative humidity, and temperature are 150 cm, 80%, and 28℃ respectively. The vegetation of the study area resembles that of southwestern Nigeria which is evergreen. Around the study site, are residential buildings which make the vegetation sparse while away from it are thicker. The environs of the location site are well-drained with much drainage exhibiting dendrites patterns. Many of the rivers and streams are structurally controlled which favoured the growth of many wetlands around the underlying site.

Figure 1. Dead bird Mortality Pit

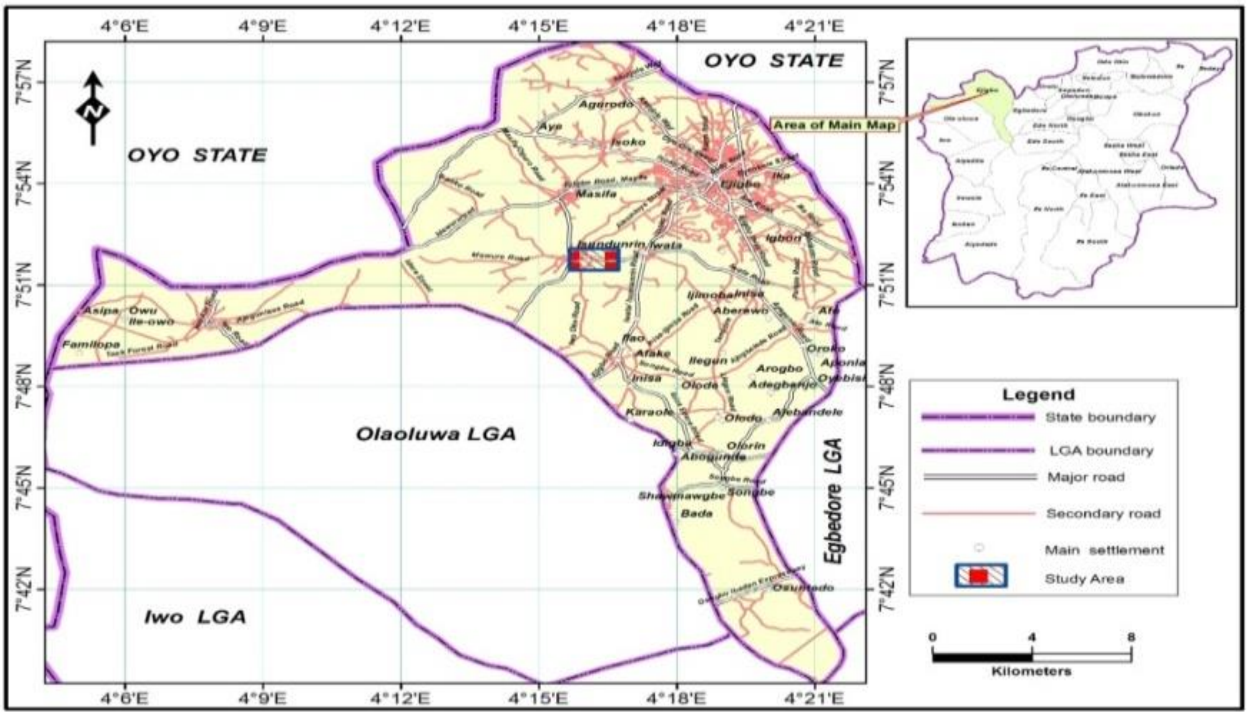

Figure 2. Location Map of the Study Site

2.2 Geology of the Study Site

Geologically, the study site is underlain by the Precambrian basement complex rocks of south-western Nigeria [31] (Rahaman, 1976). The main lithological units identified in this site are migmatite-gneiss and migmatite-gneiss undifferentiated. The geology of the site was classified based on porosity and permeability of various resulting rock debris after weathering. The charnockites weathered into higher permeability sandy clay and sand with higher groundwater discharge capacity while quartzites fractured excellently to increase permeability (see fig.3).

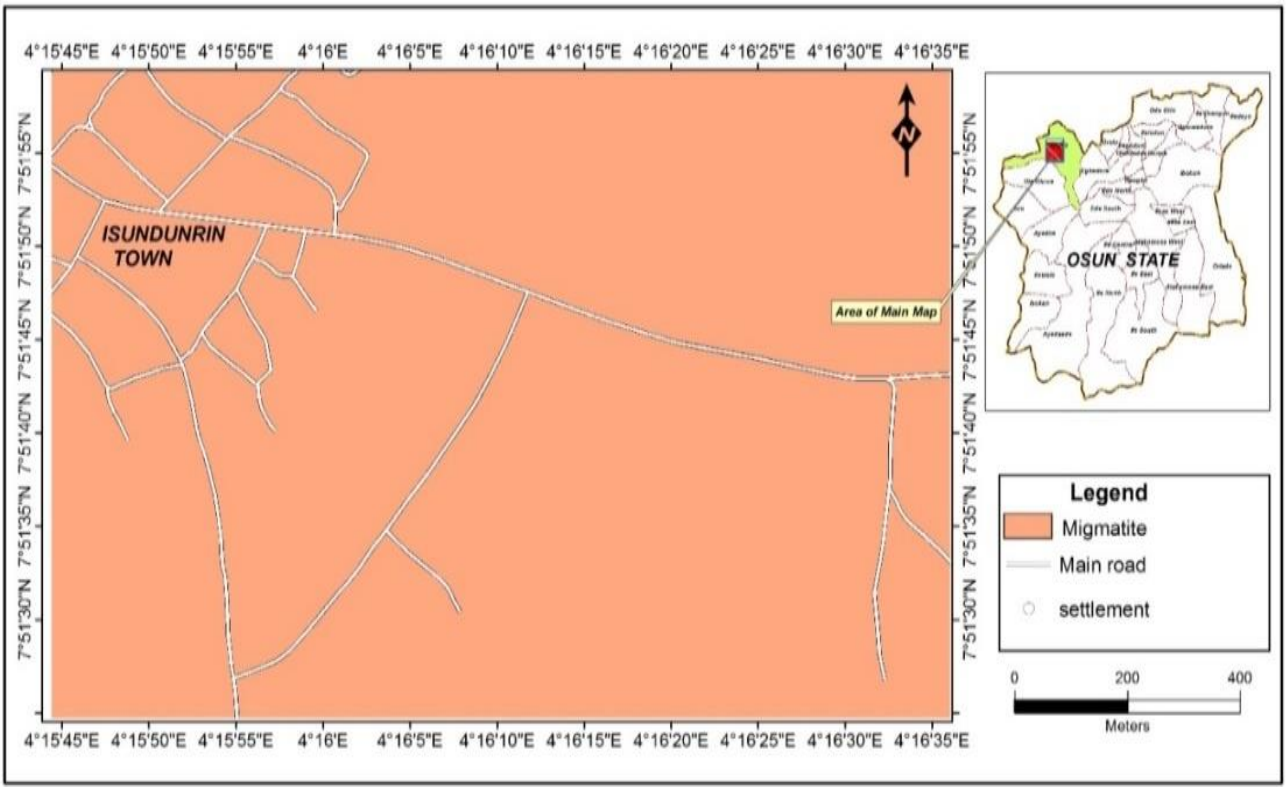

Figure 3. Geology of Isundunrin adapted from [32]

2.3 General Information on Electrical Resistivity Survey

In an electrical resistivity survey, the goal is to determine the resistivity distribution of the subsurface by making measurements on the ground surface. These measurements are possible when an electric current is injected into the ground at electrode C_1 and withdrawn at electrode C_2. The resulting potential difference is measured and recorded by another pair of electrodes P_1 and P_2. The apparent resistivity (ρ_a) for homogenous Earth is calculated using the definition

$$\rho_a = \frac{K\Delta V}{I} \tag{1}$$

Where K is the geometric factor that depends on the spacing between the electrodes

But in practice the instrument used called Resistivity meter (Terrameter) gives a resistance value since $R = \frac{V}{I}$ then the calculated apparent resistivity now is

$$\rho_a = K.R \tag{2}$$

This calculated apparent resistivity value is not the true resistivity of the subsurface. To obtain the true resistivity value, the apparent resistivity value of such a homogeneous ground has to be inverted by using a computer program. In one dimensional (1-D), the interpretation of the measured apparent resistivity values has to be first plotted on a double-log graph paper. The model obtained from this plotting is then fed into computer software for final interpretation. In this interpretation, it is assumed that the subsurface consists of horizontal layers. In this situation, the subsurface resistivity changes with depth but not with the horizontal direction. The limitation of this interpretational method is that it causes changes in the lateral or horizontal subsurface resistivity which affect the subsurface resistivity [29]. The availability of computer interpretation tools and fast inversion software that can handle more data has helped researchers to shift their focus to two-dimensional (2-D) and three-dimensional (3-D) models [33, 34]. In this study, the 2-D electrical resistivity imaging/tomography (ERT) technique is adopted. This technique is based on the traditional way of arranging electrodes. The following are the standard electrode configurations used for 2-D ERT surveys Wenner, Dipole-dipole, Wenner-Schlumberger, pole-pole, and equatorial dipole-dipole [34 – 40]. In this research, dipole-dipole electrodes configuration is used because of its high-density data resolution and multi-channel capability and it also provides highly detailed images.

2.4 2-D Electrical Resistivity Tomography technique Principle

The dipole-dipole array is the most sensitive to resistivity variations below the electrodes in each dipole pair and is very sensitive to horizontal variations but relatively insensitive to vertical variations in the subsurface resistivity. In the dipole-dipole array, the spacing (a) between the two current electrodes C_1 and C_2 is the same as that of the spacing between the two potential electrodes P_1 and P_2. Electric currents are injected via C_1 and C_2 into the ground and the resulting potential difference at the P_1 and P_2 were measured at the subsurface. The data obtained were converted into apparent resistivity (ρ_a). The equation that governs the dipole-dipole array is given by the expression

$$\rho_a = \frac{\Delta V}{I} \pi \text{ a n } (\text{n} + 1)(\text{n} + 2) \tag{3}$$

Where a = current electrode pair separation = potential electrode pair separation, n a = the separation between C_1 and P_1 $K = \pi \text{ a n } (\text{n} + 1)(\text{n}+)$ = the geometric factor, and n = the ratio of the distance between C_1 and P_1 electrodes to the C_1-C_2 (or P_1-P_2) dipole separation (a)

2.5 2-D Electrical Resistivity Tomography Data Collection Procedure

In this research, the apparent resistivity determination was achieved by choosing the electrodes spacing a = 5 m and n = 1, 2, 3, 4, and 5. Three survey profile lines were prepared and laid on the farmland. These profile lines were chosen arbitrarily with profiles 1 and 2 at distances 5.0 m and 61.3 m from the two available dead bird disposals pits 1 and 2 respectively. The third profile was at a distance of 300 m to pit 1 (Fig. 4). During the survey, the first sequence of measurements was achieved by setting a spacing of "1a" between the current electrodes C_1-C_2 and also the P_1-P_2 electrodes. The first sequence of measurements is made with a value of 1 for the "n" factor (which is the ratio of the distance between the C_1-P_1 electrodes to the C_1-C_2 dipole length), followed by "n" equals to 2 while keeping the C_1-C_2 dipole pair spacing fixed at "1a". When "n" equals 2, the distance of the C_1 electrode from the P_1 electrode is twice the C_1-C_2 dipole length. The same process is repeated for measurements with different spacing till “na”. During the survey, the electrodes were expanded and moved in a leapfrog manner until the profile length of 100.0 m was covered. In all the three profiles good resistivity data was obtained using ABEM-SAS (Signal Averaging System) 1000 Terrameter- The calculated apparent resistivity is the weighted average of the values of the resistivity under the four electrodes used to take the reading.

Table 1. Traverse distances and Locations from Dead bird Disposal Pits

Traverse Number	Longitude (°)	Latitude (°)	Distance to Pit 1 (m)	Distance to Pit 2 (m)
1	4° 14′ 16.112″	7° 49′ 15.393″	5.00	61.30
2	4° 14′ 16.080″	7° 49′ 15.454″	15.30	20.30
3	4° 14′ 16.183″	7° 49′ 15.365″	300.00	96.40

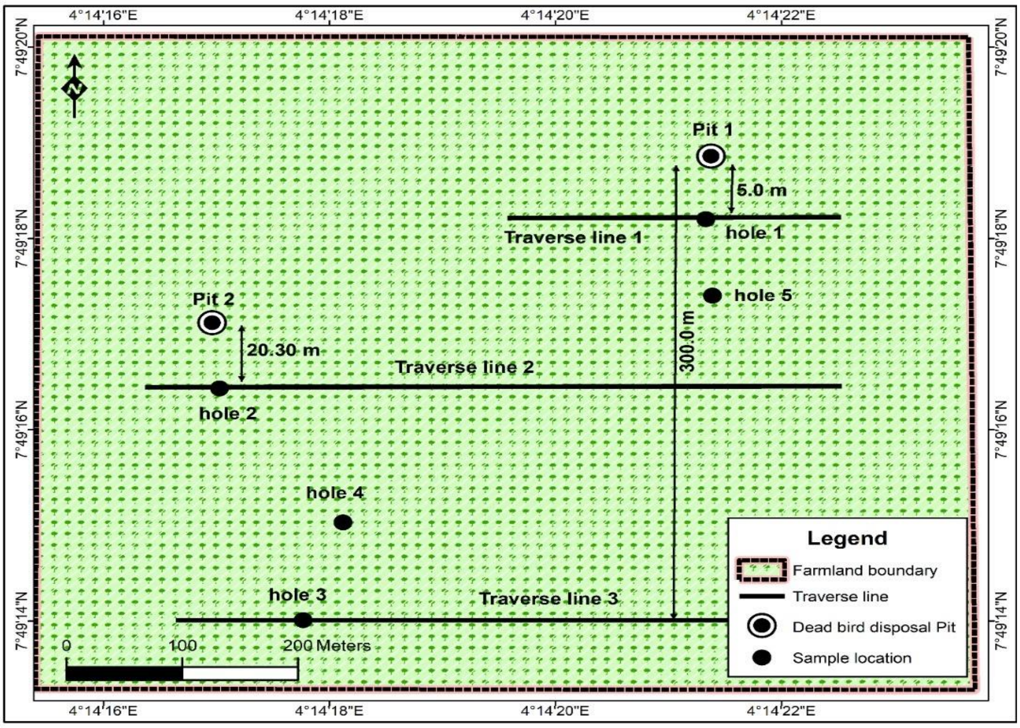

Figure 4**.** Map showing the location of the three profiles and the five soil sample points

2.6 Analysis of 2-D Electrical Resistivity Tomography Data

For smooth apparent resistivity, the data collected was processed using DIPROWIN modelling software to perform 2D geoelectrical data inversion. The inversion procedure uses Gauss-Newton least-squares algorithm (15) [Loke et al; 2003] based on the initiation of a finite element model of the underground surface. The inversion routines are based on the smoothness-constrained least-squares method [42-46], and the forward resistivity calculations were executed by applying an iterative algorithm based on a finite element method. The inversion program divides the subsurface into several small rectangular prisms and attempts to determine the resistivity values of the model prisms directing toward the difference between the calculated and the observed apparent resistivity values. The quality of the fit is expressed in terms of the RMS error. The results obtained from the processing/presentation of field data are presented as 2D resistivity structures, pseudo sections, and theoretical pseudo sections from which the relevance of this result in imaging, the causes of soil and groundwater contamination are discussed in terms of resistivity and conductivity concerning their depth of occurrence.

2.7 Laboratory Determination of Coefficient of Permeability

In this research, the falling head or variable head permeability test method was used to determine the coefficient of permeability. This method is more suitable for small-grained soils which are relatively less pervious because of their poorly connected void structure. In a falling head method, an instrument that consists of a cylindrical mold was used. Fitted to this cylinder are two filter discs that are porous and highly permeable. These discs were provided with inlet and outlet facilities. The inlet is a graduated vertical standpoint. The internal diameter (D) of the cylindrical mold is measured and its area (A) is calculated. The inlet pipe diameter (d) is also measured and its area (a) is also calculated. The soil surface was prepared by removing excess vegetation from the surface. Then the core sampler was driven into the soil by hammering a block of wood placed on the sampler to the ground to reduce pressure on the sampler in five different locations in the poultry farmland. After the core sampler reached the desired depth of 0 – 15 cm and 15 – 30 cm, the soil was excavated and collected. The five soil samples were collected, labelled, and transported to the laboratory for analysis. The soil samples were carefully removed and placed inside the mold between the porous discs. The standpipe is then filled with water; the knob on it is open to allow the water to flow through the soil to saturate it. After this, the water is allowed to flow out for some time until a steady flow is attained. The knob on the outlet was closed to stop the water from flowing. The standpipe was refilled up to a certain height. This height is the head or energy of the water. Let this height be h_1. The knob on the outlet is then opened so that water flows out and overflows the container, a stopwatch is started and a graduated jar was placed to collect the overflowed water. Let the water be collected for a fixed time interval (t) and let the amount of water collected be noted and recorded as Q. The knob on the standpipe was closed and the final head on it is noted and recorded as h_2.

Theory

The hydraulic gradient

$$i = \frac{\mathrm{h}_2 - h_1}{L} \tag{4}$$

L is the length of the soil specimen in which the flow takes place.

For this system, Darcy's law states that the velocity (v) of the flow of liquid between two points in the soil is directly proportional to the hydraulic gradient applied. i.e.

$V \alpha i$

But the discharge rate is

$$q = K\ Ai \tag{5}$$

where K is the constant of the proportionality called the coefficient of permeability.

At every instant the water head in the standpipe is continuously changing, the hydraulic gradient is also changing at that instant. At any instant of time, the water head was between h_1 and h_2. Therefore the difference that is causing the flow through the soil is h. For a very short interval of time dt the head in the standpipe drops by dh height. At the instant when the head is h, the flow rate is

$$q = \frac{\mathrm{KAh}}{\mathrm{L}} \tag{6}$$

The amount of water collected in the jar with this rate in small time interval dt will be q.dt

By equation of continuity, the volume dropped or decrease is negative and is equal to the discharge of water collected or increase in the jar through the outlet i.e. the volume of water dropped in standpipe in time dt = volume of water collected in the jar in time dt

By Darcy's law Discharge rate is

$$a.\,dh = KA\,i\,dt \tag{7}$$

At the instant of time, the hydraulic gradient is $i = \frac{h}{L}$

$$\therefore\ -a\,.\,dh = \frac{KAh}{L}\,dt \tag{8}$$

By rearrangement we have

$$\frac{KA}{a\,L}\,dt = -\frac{dh}{h} \tag{9}$$

But K, A, a, and L are constant, integration of both sides from the head difference at the initial head of h_1 at time t = 0 to the final head difference of h_2 at time t = t we have

$$\frac{KA}{aL}\int_0^t dt = -\int_{h_1}^{h_2} \frac{dh}{h} \tag{10}$$

$$\frac{KA}{aL}\,t = \mathrm{Log}_e\left(\frac{h_1}{h_2}\right) \tag{11}$$

$$\therefore K = \frac{a\,L}{A\,t}\,\mathrm{Log}_e\left(\frac{h_1}{h_2}\right) \tag{12}$$

Therefore [47],

$$K = \frac{2.303a\,L}{A\,t}\,Log_{10}\left(\frac{h_1}{h_2}\right) \tag{13}$$

2.8 Laboratory Determination of Soil Porosity

A hand-operated double cylinder core sampler of diameter (d) of 7.0 cm and height (h) of 15.0 cm was weighed with its lids and recorded as W_1 (g). A smooth undisturbed vertical surface at the depth of 16.0 cm was prepared. The core sampler is then driven into the soil to fill the inner core without inducing compression. The soil core was carefully removed and its ends were trimmed to remove any excess oil. The content of the cylinder was pushed out into a pre-weighed tin which is then weighed as (W_2). The sample was then placed in an oven to dry. After drying and cooling, it was weighed and recorded as (W_3). From the measurement above, the Bulk density (D_b) which is the ratio of the total mass to the total volume is calculated as

Bulk Density

$$D_b = \frac{W_1 - W_2}{V} \tag{14}$$

Where V = volume of the cylinder given by

$$V = \frac{1}{4}\pi\, d^2\, h \tag{15}$$

The specific gravity (G_s) of the soil particles is calculated using

$$G_s = \frac{m_s}{V_s} = \frac{D_p}{D_w} \tag{16}$$

Where D_w = density of water ($1 g/cm^3$) and D_p = Particles density. This is the composite average of the density of all the particles that comprise the soil. In this research, the soil D_p of 2.66 g/cm^3 is assumed which is the value for quartz.

The total porosity (Φ) of the soil is calculated from the particle density and bulk density by using the equation [48]

$$\phi = 1 - \frac{D_b}{D_p} \tag{17}$$

Table2. Soil Samples distance and Location from Dead bird Disposal Pits

Sample No	Longitude E	Latitude N	Distance to Pit 1 (m)	Distance to Pit 2 (m)
1	4° 14′ 16.112″	7° 49′ 15.393″	5.00	61.30
2	4° 14′ 16.080″	7° 49′ 15.454″	15.50	20.30
3	4° 14′ 16.183″	7° 49′ 15.365″	196.40	96.40
4	4° 14′ 25.422″	7° 49′ 15.117″	250.50	165.50
5	4° 14′ 25.490″	7° 49′ 15.286″	300.70	203.60

3. Results and Discussions

3.1. Geo Electrical Results and Discussions

3.1.1. Profile 1

The result of the processed field data of profile 1 is presented in fig. 5 as 2-D resistivity structure, field data pseudo-section, and theoretical pseudo-section. The resistivity values of the 2-D structure ranged from 20.0 Ω m to 90330.0 Ω m. These values of resistivity can be classified into the highly conductive structure, slightly conductive structure, and resistive structure. The resistivity values of the highly conductive structure ranged from 38.5 Ω m to 91.7 Ω m. These structures were located at the depth range of 2.5 m to greater than 20.0 m at the profile points of 7, 8, 9, 10, and 15 to 20 which corresponds to a distance of 35.0 to 50.0 m and 75.0 to 100.0 m respectively. The presence of this structure is an indication that the leachate from the dead bird's disposal Pit 1 has migrated to form a plume. The migration of the leachate plume downward is an indication that it is denser. The fading colour (pale blue) implies that the concentration of the leachate decreases due to the process of filtration as it migrated through the soil. The passage/movement of the leachate downward is a result of the porous and permeable nature of the soil in the poultry farmland. The movement of the contaminant from the point of production (Pit 1) downward is an indication that the permeability of the soil is high which is in perfect agreement with the outcome of the result obtained from the laboratory experiment for the coefficient of permeability. The pocket of a highly conductive structure (deep blue) shows the presence of clay which is porous sediment but is least permeable [49, 50]. The resistivity value of the slightly conductive structure varied from 105.0 Ω m to 848.0 Ω m. This structure covered the entire poultry farmland and could mean that the farmland contains clayey sand soil. The resistive structure is obtainable at below 2.5 m to more than 20.0 m at the profile points 1- 7. The resistivity value of this basement structure ranged from 1350.0 Ω m to 90330.0 Ω m.

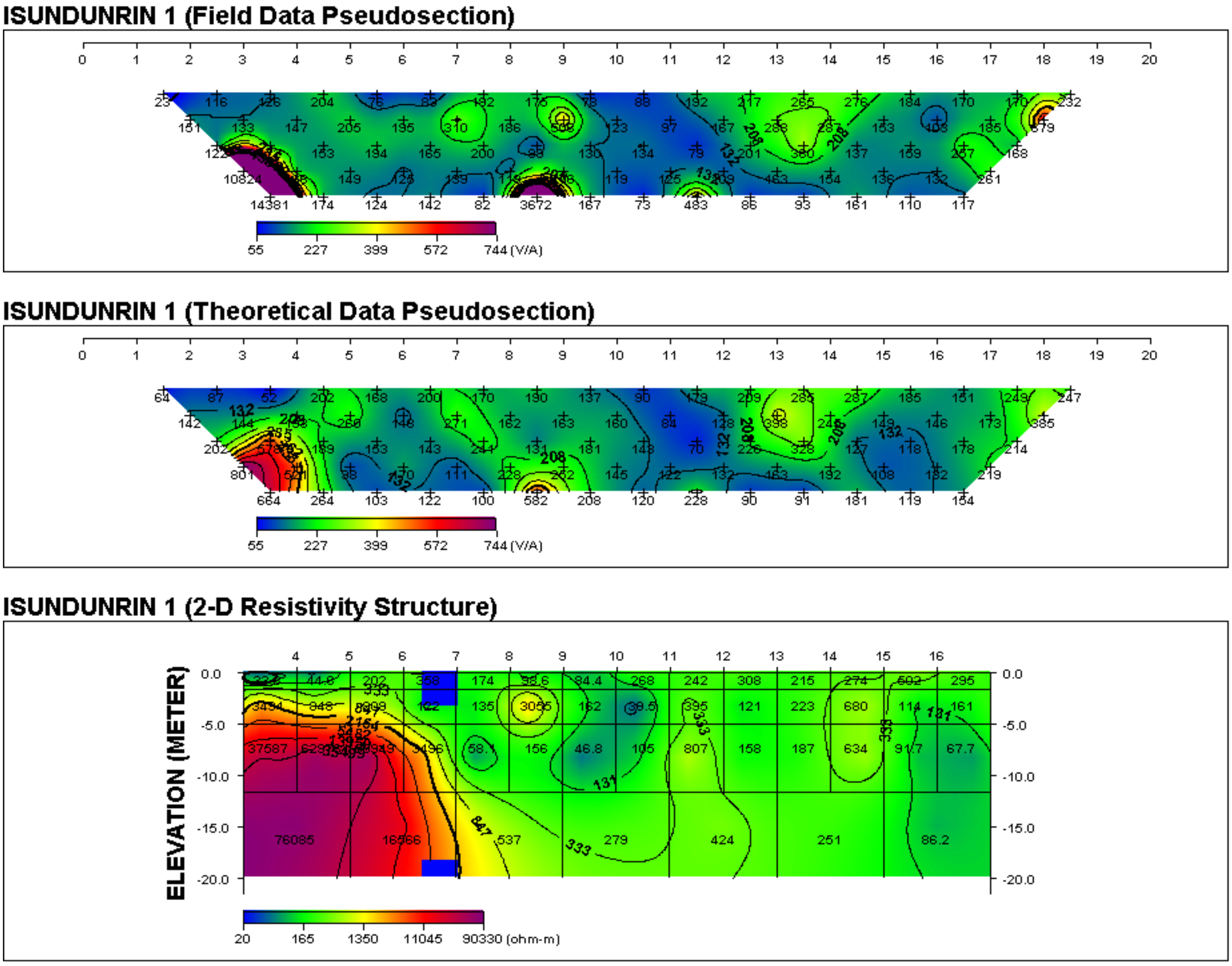

Figure 5. 2-D inversion model for profile 1

3. 1.2. Profile 2

Fig.6 illustrates the result of the processed field resistivity data. The 2-D resistivity structure obtained showed variation in resistivity values from 7.0 Ω m to 2360.0 Ω m. These values can be classified as resistive, slightly conductive, and highly conductive. The resistive structure is the basement which is found below 3.0 m to greater than 20.0 m depth, at the profile points 1 to 6 which correspond to the distance between 5.0 m to 30.0 m along the profile length. The slightly conductive structure has resistivity whose values varied from 126.0 Ω m to 878.0 Ω m across the profile length. This suggests the presence of clayey sand structures in the farmland. There is no record of the migration of leachate plume here because the dead bird disposal Pit 2 has just been resuscitated and only a few dead birds were found in this pit. The farmland could be porous and permeable since it contains clay sand materials.

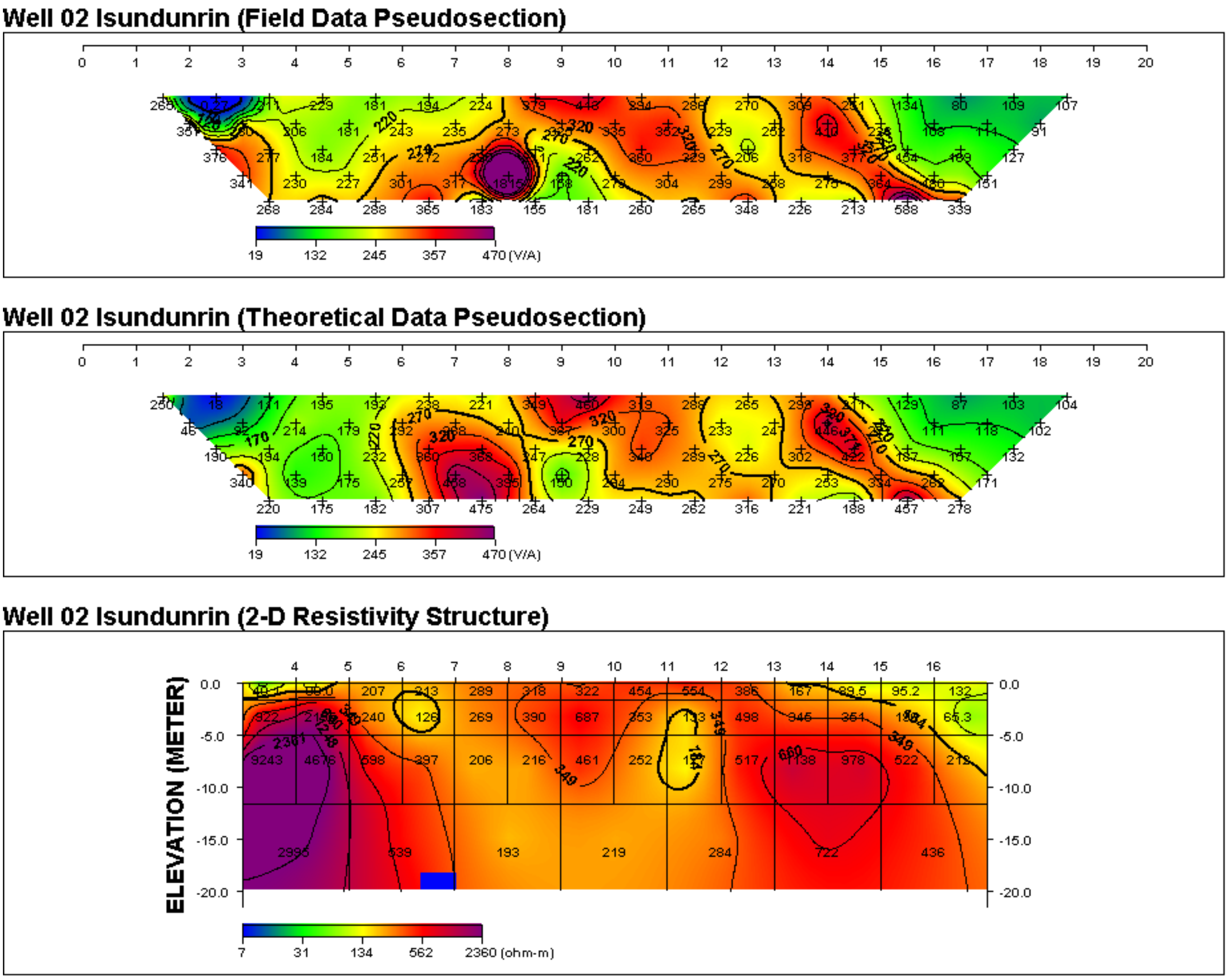

Figure 6. 2-D inversion model of Profile 2

3.1.3 Profile 3

This profile is at a distance of 300.0 m Pit 1 and 203.6 m to Pit 2. Fig. 7 shows the result of the analysis of the field resistivity data. The result is classified into field data pseudo-section, theoretical data pseudo-section, and 2-D resistivity structure. The 2-D resistivity structure resistivity values indicated a highly conductive structure whose resistivity values ranged from 14.0 Ω m to 50.8 Ω m (the green portion of the 2-D resistivity structure). This is an indication of the presence of the conductive contaminant (the decomposed migrated feces present in the farmland) in the clay soil. The occurrence of this structure is found few meters below the surface and extends to 16.0 m depth. This structure is located at every length of the profile but very prominent at the profile length of 47.5 m to more than 90.0 m. The highly conductive material is due to the deposited wastes and feces of these birds found around the survey line which has decomposed and migrated through the clayey sand soil downward. As the contaminants migrated downward, the resistivity values increases (52.7Ω m to 99.0 Ω m). This is attributed to the process of filtration in the soil that decreases the concentration of the contaminant which is noticeable at a depth range of 1.5 m to 20.0 m. The other structure present has 2-D resistivity values ranged from 100.0 Ω m to 172.0 Ω m. This is typical of clayey sand soil. The high resistivity recorded (purple color) at the depth range of 8.0 m to more than 20.0 m at the horizontal distance of 20.0 m to 50.0 m. is an indication of the absence of the contaminant. The presence of the clayey sand material implies that the soil is porous and permeable. As at the time of analysis of the processed field data, there was no indication of the presence of contaminant plume from the two dead bird disposal pits at this distance.

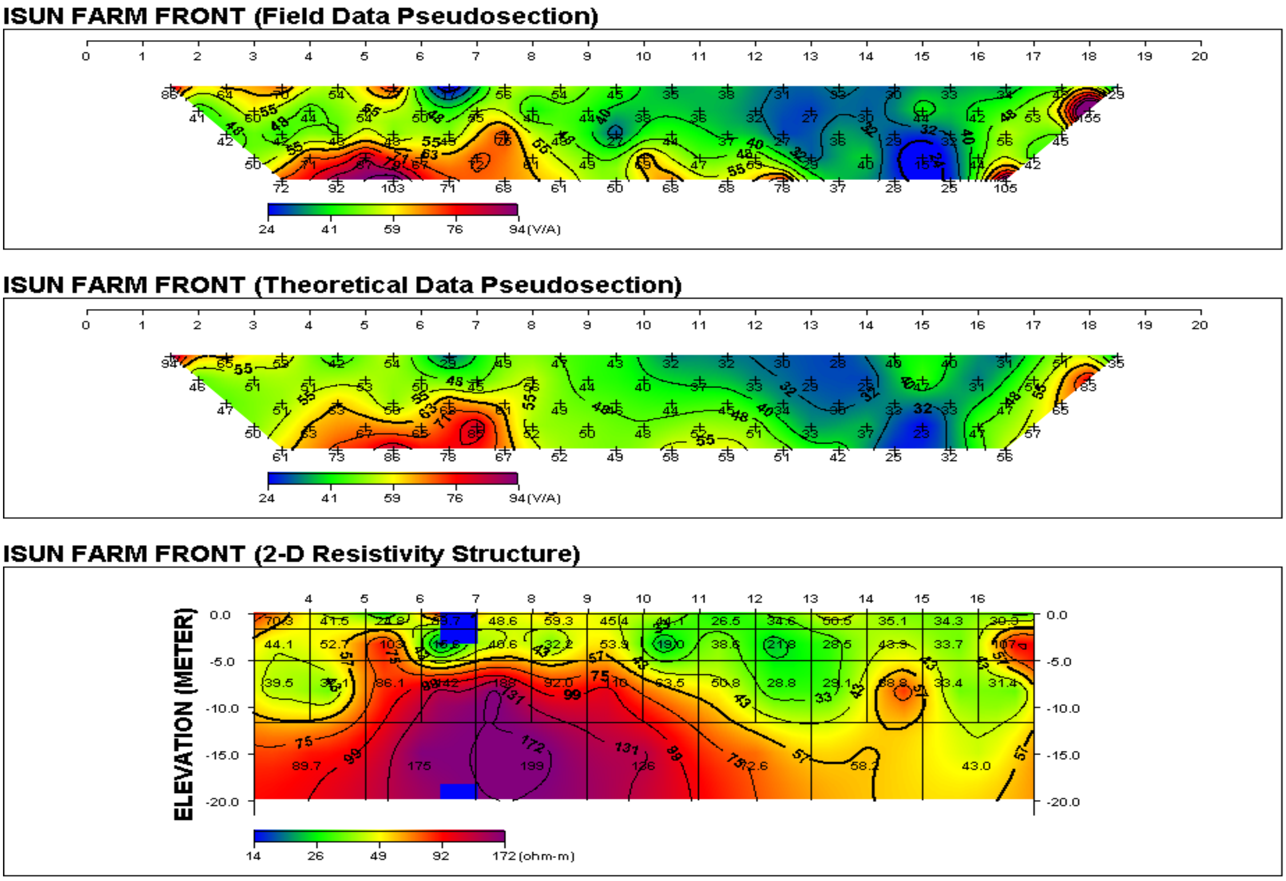

Figure 7. 2-D inversion model of Profile 3 (farmland front)

3.2. Results and Discussions of Porosity and Coefficient of Permeability test

The results of the laboratory test for Porosity (Φ) and Coefficient of Permeability (K) of the soil samples were presented in Table 3 and their relationship is shown in Fig 8. The average value of K is 3.6×10^{-2} cm/s is characteristic of clayey sand thus allow the flow of leachate to the soil and groundwater in the study site. The results of the coefficient of permeability suggested that the poultry farmland under study consists of clayey sand. The values of coefficient of permeability obtained may be influenced by (1) textural properties (i.e. pore size/grain size, grain size distribution, the shape of grains and packing of grains), (2) gas slippage, (3) amount distribution, and type of clays, (4) type and amount of secondary porosity, (5) overburden pressure, (6) reactive fluids and (7) high-velocity flow effects. From the calculated hydraulic conductivity value, it could be deduced that the more the clay content of the soil samples, the lesser is the flow rate and, consequently, the lesser is the value of K; the larger the diameter of the soil sample (the coarser the soil sample), the more is the flow rate, and hence, the higher is the value of K. The value of the porosity is 0.552. The relationship between the porosity and coefficient of Permeability of the soil of the poultry is shown in Fig. 8. There is a perfect correlation between these two quantities ($R^2 = 0.9878$).

Table 3. Laboratory Test result of Coefficient of Permeability and Porosity

Soil sample no	Coefficient of permeability (K) (cm/s	Porosity
1	0.0331	0.52
2	0.0343	0.53
3	0.0352	0.55
4	0.0367	0.57
5	0.0384	0.59
Average	0.03554 or 3.554×10^{-2}	0.552

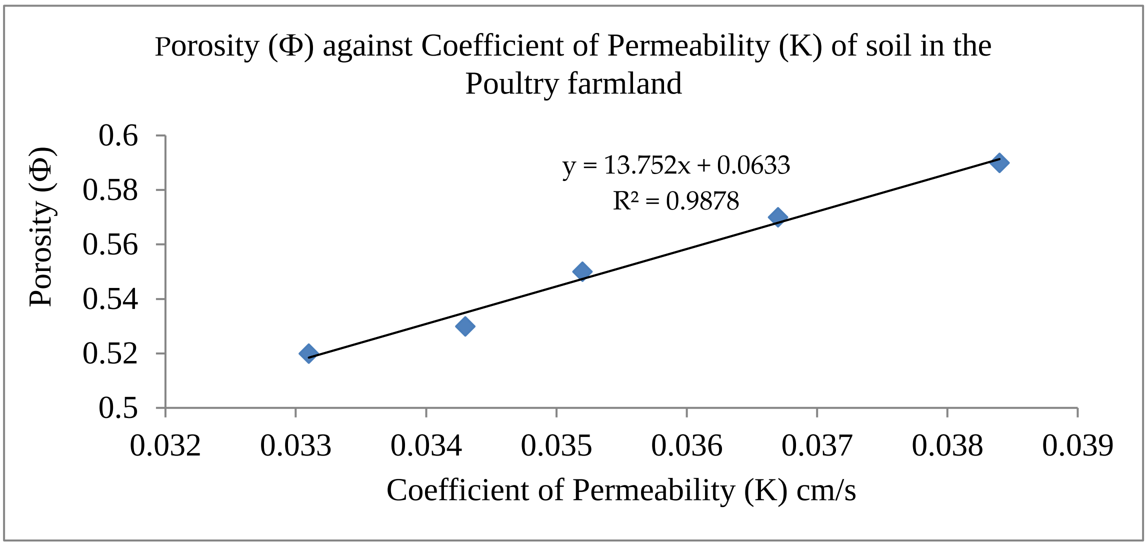

Figure 8. Relationship between Porosity (Φ) and Coefficient of Permeability (K)

4. Conclusions

The result of the 2D electrical resistivity showed that leachate from disposal pit 1 has migrated horizontally and vertically. The horizontal migration occurs at a distance range of 55 to100 m and vertical movement is at the depth of 10.0 m. This is an indication that the soils and rocks are porous and permeable. The results of the laboratory test of coefficient of permeability and porosity also support this outcome with their values being 3.6 x 10^{-2} cm/s and 0.55 respectively. The result of the 2D electrical resistivity of the second pit only indicates the presence of clayey sand in the disposal pit 2, little leachate migration is seen because of the number of dead birds in it. But when the quantity increases with time the migration will be prominent. The 2D electrical resistivity result of the third profile indicated the presence of leachate migration which is attributable to the feces of the poultry been deposited. With this evidences, it can be concluded that the 2D electrical resistivity method can successfully be used to assess the coefficient of permeability and porosity of soils and rocks in poultry farms instead of performing the coefficient of permeability and porosity test.

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