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Investigation of Electrical Resistivity and Conductivity of a Geological Material (Clay) in Some Parts of Ilorin West Local Government, Kwara State

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ABSTRACT

The cost and availability of electrical components have been a major challenge to Nigerian scientists and engineers. Thus, this study aimed at investigating geological material (clay) to alleviate the challenge facing the field of science and engineering. The study determined the electrical resistivity and conductivity of a geological material from three different locations in Ilorin West Local Government Area, Kwara State: Egbejila, Oko-Erin and Baboko. The samples were sieved, molded into cylindrical form and dried. Thereafter, their electrical properties were determined using electrical method. The resistance of the samples was determined from the voltage-current (V-I) graph. Consequently, the resistivity was determined by using sample's resistance, area and length. The conductivity was calculated from the reciprocal of resistivity. The electrical resistivity and conductivity of the samples from Egbejila, Oko-Erin and Baboko were 0.0850 Ωm and 11.7647 $(\Omega m)^{-1}$, 0.0924 Ωm and 10.822 $(\Omega m)^{-1}$, and 0.0251Ωm and 39.841 $(\Omega m)^{-1}$ respectively. The result obtained from the study showed that the geological material (clay) can be used as alternative material for industrial (based) resistor, the study further reduced the stress, cost, and non-availability of resistors' importation and thereby our locally made geological material can be used as a substitute.

Keywords:
Conductivity,
Electrical-component,
Egbejila,
Geologic-material,
Resistivity.

INTRODUCTION

Kwara State, situated in the North-Central region of Nigeria, exhibits a diverse geological landscape characterized by various rock formations and soil types. Within the state, Ilorin West Local Government Area is of peculiar interest due to its strategic location and geological composition, which includes significant clay deposits. Clay, a naturally occurring sedimentary material composed of fine-grained minerals, holds considerable importance in both local construction practices and broader industrial applications (Johnston 2002; Adegoke et al., 2016; Egbeyale, 2022;).

The electrical properties of clay, namely resistivity and conductivity, are essential parameters that influence its behavior in different environmental and engineering contexts but not fully exploit in these mentioned areas. By definition, electrical resistivity refers to as a material's ability to impede the flow of electrical current, while conductivity is the inverse of resistivity, indicating a material's capacity to conduct electricity. These properties are influenced by various factors, including clay mineralogy, moisture content, compaction, and temperature (Adeoti et al., 2018).

In engineering and construction, understanding the electrical characteristics of clay is critical for assessing its suitability as a building material and determining its load-bearing capacity. Clay's electrical resistivity can provide insights into its moisture content, compaction, and structural integrity, which are essential considerations in foundation design and stability analysis (McCurry, 1976). Moreover, the conductivity of clay influences its response to electrical grounding systems, affecting the safety and performance of electrical infrastructure.

Beyond engineering applications, the electrical properties of clay also play a significant role in environmental studies, particularly in groundwater exploration and contamination remediation (Olorunfemi, 2017; Manoj et al., 2014; Rahmatun et al. 2019). Clay layers act as natural barriers to fluid flow, influencing the movement and distribution of groundwater in subsurface environments. Electrical resistivity surveys can help delineate aquifer zones, assess groundwater quality, and identify potential sources of contamination, thereby guiding effective

management and remediation strategies (Olorunfemi, 2017; Ariyo et al., 2013**)**.
Previous research conducted in similar geological settings has demonstrated the utility of geophysical methods, such as electrical resistivity tomography (ERT) and vertical electrical sounding (VES), in characterizing clay deposits and subsurface structures (Ariyo et al., 2013; Omowumi, 2001). By integrating geophysical data with geological observations and laboratory analyses, researchers can obtain a comprehensive understanding of clay properties and their spatial distribution within the study area.
In the context of Ilorin West Local Government, Kwara State, investigating the electrical resistivity and conductivity of clay holds significant relevance for sustainable development, infrastructure planning, and environmental management. By elucidating the subsurface characteristics of clay deposits, this study aims to provide insights into the electrical properties of clay in selected areas of Ilorin West Local Government, Kwara State. By employing Physics principle methods such as Ohm's law to determine the electrical conductivity and electrical resistivity of a molded clay material and to contribute valuable insights that can inform decision-making processes in various sectors, including construction, industry and environmental resource management.
Several studies have demonstrated the importance of electrical resistivity and conductivity measurements in characterizing clay materials. For instance, research by Adeoti et al. (2018) highlighted the use of ERT in mapping clay deposits and delineating subsurface structures in similar geological settings; Adegoke et al., (2016) worked on the effect of cation exchange capacity of clay pn thermal conductivity and, Egbeyale and Adegoke (2018) on characterization of thermal properties behaviour of clay in Ekiti state, south western Nigeria. Furthermore, the work of Olorunfemi (2017) emphasized the significance of electrical resistivity surveys in groundwater exploration and quality assessment, particularly in regions with clay-rich formations (Lanson and Bouchet, 1995; Shaikh and Wik,1986; Obaje 2009).
In light of these considerations, this investigation seeks to contribute to the body of knowledge regarding the electrical properties of clay in Ilorin West Local Government, Kwara State. By providing a comprehensive analysis of the electrical property, we aim to offer valuable insights for both academic research and practical applications in engineering and environmental management.

Location and geology of the Study area

Oko Erin, Egbejila and Baboko lies between the latitude $08^0 43^0 53''$N - $08^0 42' 47''$N and longitude $00408^0 28'55'$E-$004^0 30'00''$E and are clay rich settlement in Ilorin West local government. (Figure 1). The study areas fall within the Precambrian basement complex of Nigeria covering a surface area of approximately 4.03 sq km. The geological information of the ares has been described to consist older and younger metasediments, older and younger granite and volcanic intrusive (Badraoui 1987; McCurry and Wright (1971) Cooray, 1972; Oyawoye, 1972 and Rahaman,1976).

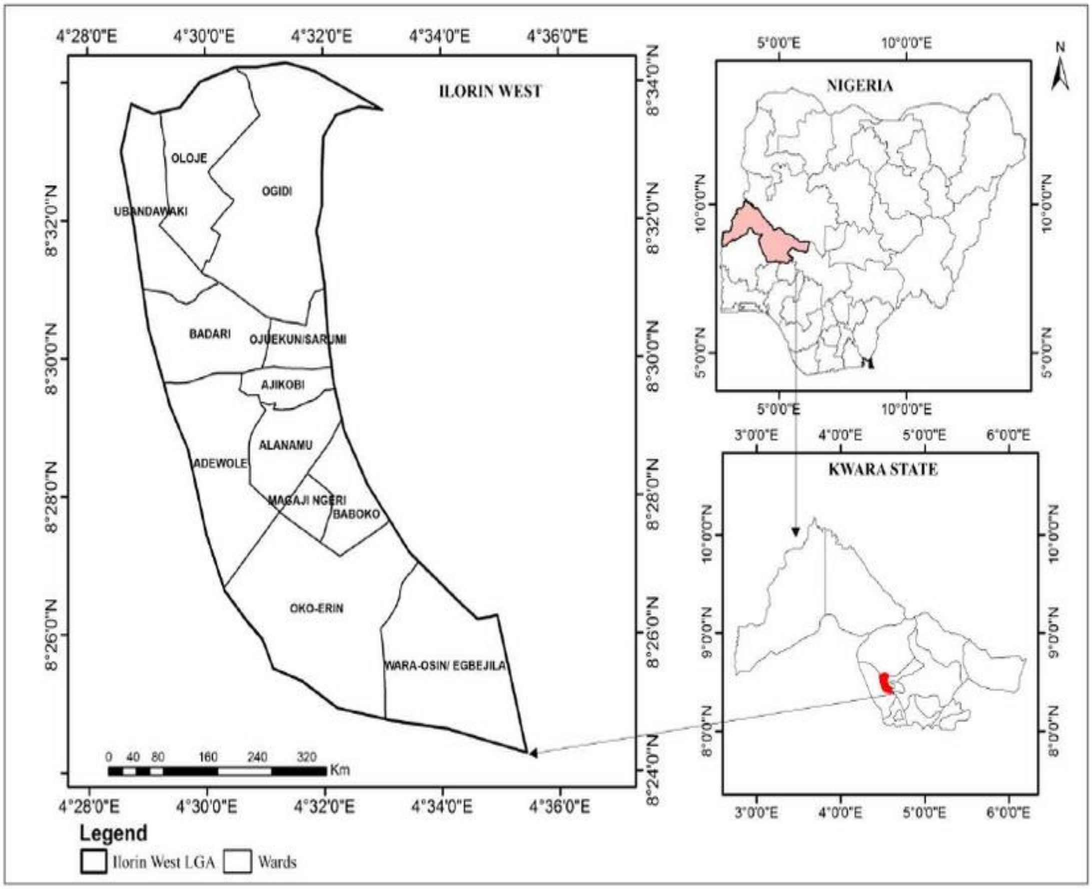

Figure 1: Map of Ilorin west showing the locations the samples were taken (Mustapha et al., 2016)

MATERIALS AND METHODS

Clay samples were collected from the mentioned locations (Oko Erin, Egbejila and Baboko) and processed in the laboratory. Sets of molded cylindrical clay of thickness 1 cm were made from each location. Then Ohm's law principle was adopted to measure and determine the resistance offered by the clay samples. After which, Physics formulas were introduced to find the electrical resistivity and conductivity. The data obtained were presented on the Table 1

The method used in this research work is referred to as Ohm's law method.

$$V = IR \quad (1)$$

where Volts (Volts), 1= Current (amps) and R=resistivity (π) of the geological sample.

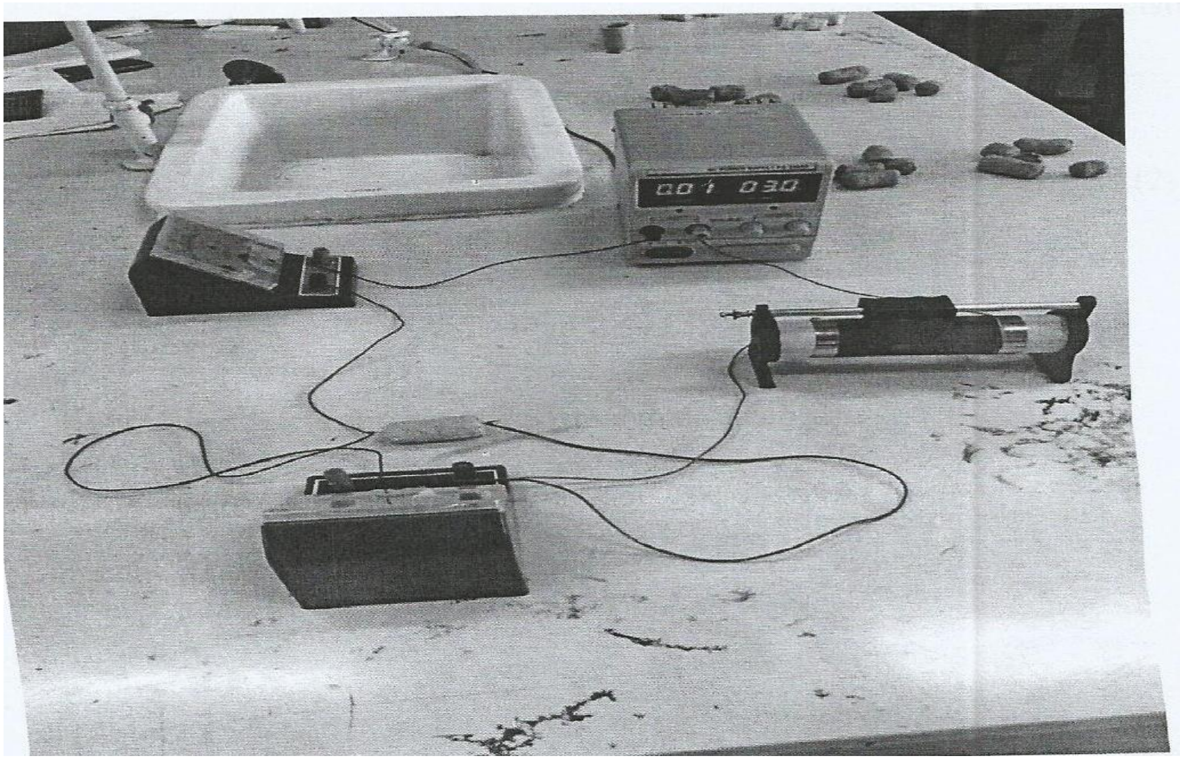

Figure 2: Experimental set up

$$R = \rho\frac{L}{A} \quad (2)$$

where R = Resistance, ρ = Resistivity (Ohm m), L = Length (m), A= Cross sectional area (cm^2)

Re-arranging the above equation we have

$$\rho = \frac{RA}{L} = \frac{V}{I}\left(\frac{A}{L}\right) \quad (3)$$

which presents electrical resistivity as the resistance between opposite faces of a cylindrica1 geological sample. And the V/ I represent the slope of the graph obtained.

Determination of electrical resistivity and conductivity of the geological material.

$$\rho = \frac{RA}{L} \quad (4)$$

$$\frac{\text{Slope x } \pi\frac{d^2}{4}(m)}{L(m)} \quad (5)$$

and

$$\sigma = \frac{1}{\rho} \quad (6)$$

RESULTS AND DISCUSSION

Table 1: Resistance, electrical resistivity and conductivity of clay samples collected from different locations

Location	Resistance (Ω)	Electrical Resistivity (ρ)	Electrical conductivity (σ)
Egbejila	0.0514	0.0850	11.7647
Oko-Erin	0.4706	0.0924	10.8225
Baboko	0.1280	0.0251	39.8406

The graphs of the relationship between potential differences across the sample and current were presented (Figure 3, 4 and 5). The results showed linear correlations, meaning that the material (sample) obeys Ohm law and can act as a resistor.

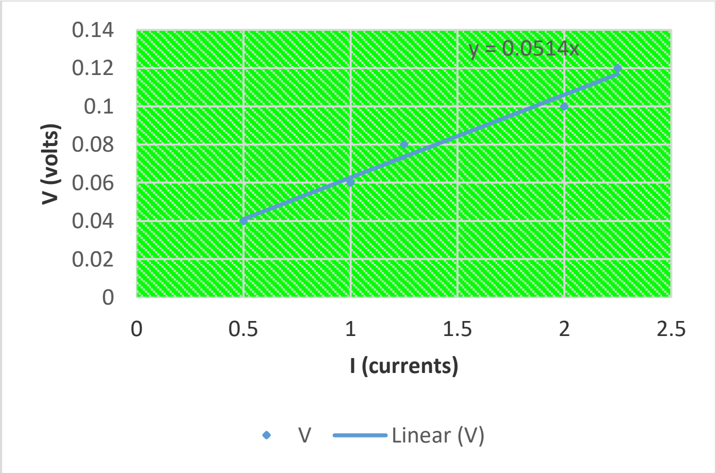

Figure 3: Graph of V against I (Egbejila)

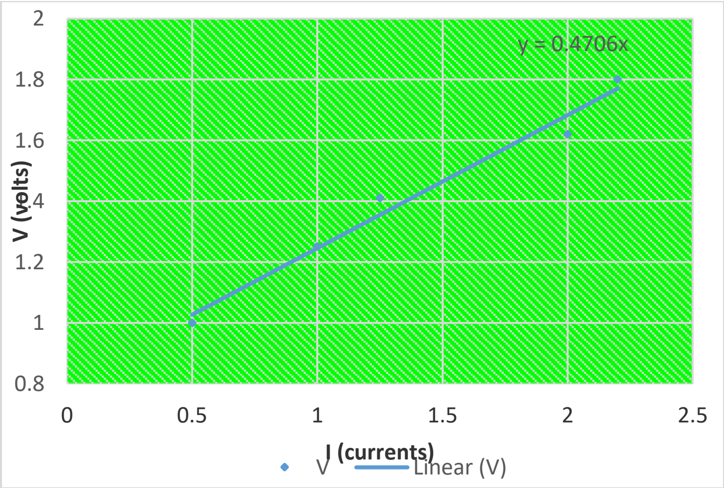

Figure 4: Graph of V against I (Oko-Erin)

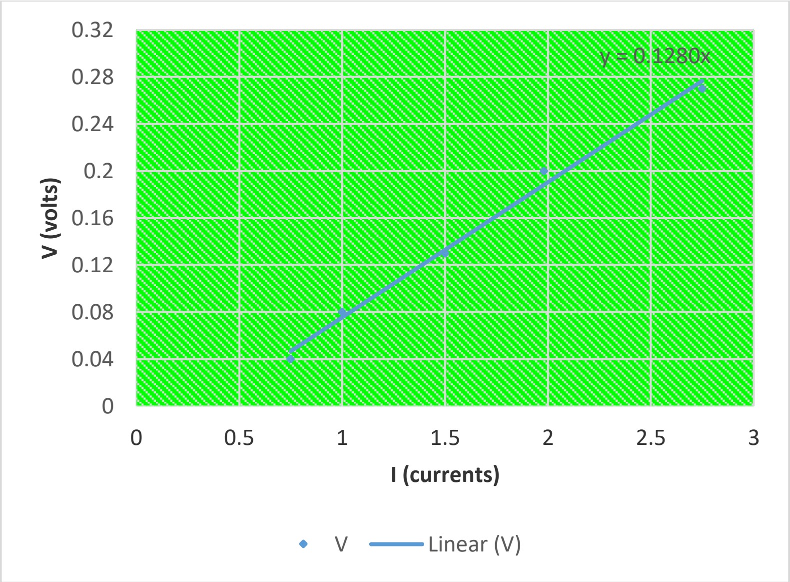

Figure 5: Graph of V against I (Babako)

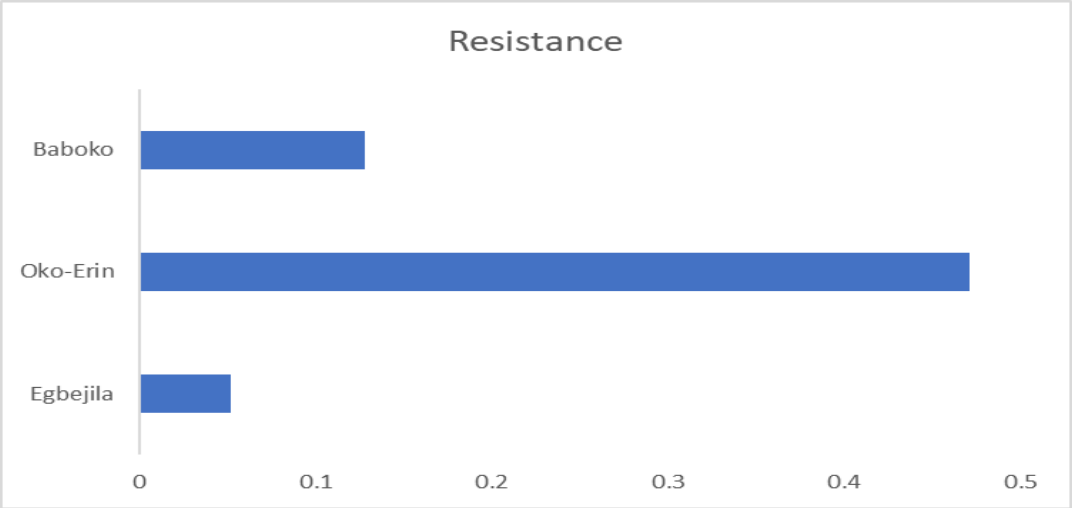

Figure 6: Sample resistance to the current flow

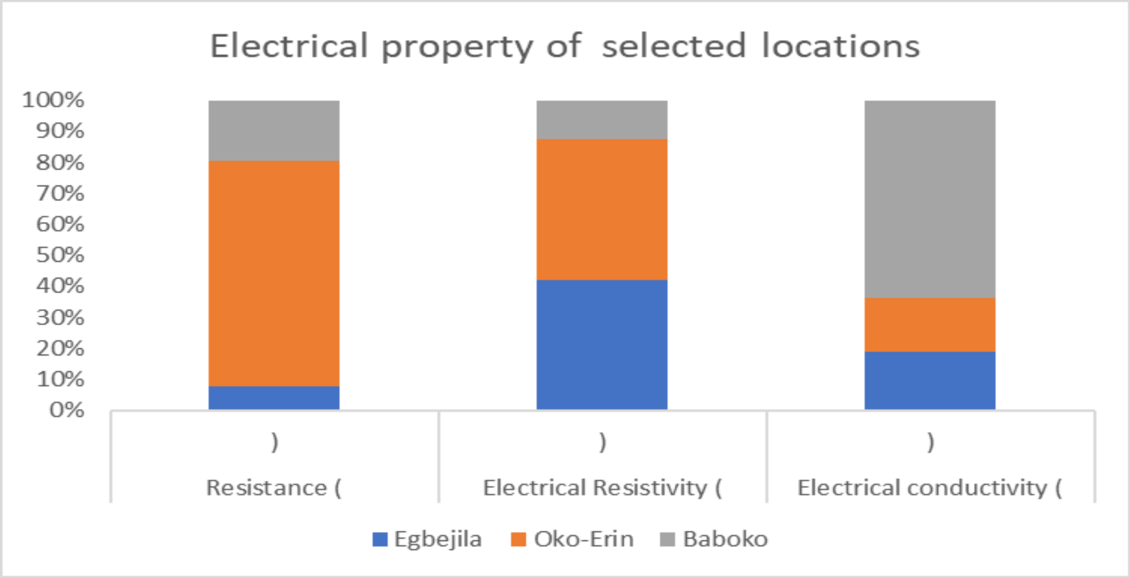

Figure 7: Bar Chart showing the electrical resistivity conductivity of the sample at different locations

The graphs showed that current flowing through the sample (clay) increases as the voltage increases. The current increase as the potential difference across the sample increases (Table.1) and this is an evidence that the clay sample materials can be used as resistor in the Laboratory (small value) The slope of the graphs (Figure 3, 4 and 5) represents the resistance offered by the each sample, respectively. This value of the resistance was then used to calculate the electrical resistivity. The electrical conductivity was found by taking the reciprocal of the electrical resistivity. These parameters indicate the electrical property of the considered material clay sample)

Equation (5) and equation (7) were used to calculate the electrical resistivity and conductivity respectively of each sample at different locations. The electrical resistivity of the samples from Egbejila, Oko Erin, and Baboko are 0.0850, 0.0924, and 0.0251 respectively. Oko Erin has the highest electrical resistivity (Figure 7) because of the elemental composition of the clay.

CONCLUSION

This study has focused on the investigation of the electrical properties of the geologic sample (clay) from different locations in Ilorin West, Kwara state, Nigeria. The results obtained from the study showed that the geological material (clay) can be used as an alternative material for industrial resistors, the study further reduced the stress, cost, and non-availability of resistors importation from abroad and thereby locally made geological material (clay) can replace imported resistor.

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