Evaluation of the Earth's Electrical Properties of the Undeveloped Area at the Delta State University of Science and Technology, Ozoro, Nigeria

ABSTRACT

The application of good electrical earthing system is inevitable in every electrical installation. This study was carried out to evaluate the earth's electrical properties of an undeveloped area of Delta State University of Science and Technology, Ozoro, Nigeria. The soil resistance of the study area was determined according to Wenner Four Point method, while the soil resistivity was calculated from the soil resistance obtained. Six locations (A, B, C, D, E and F) were tested across the area; while five probe distances (3 m, 6 m, 9 m, 12 m and 15 m) were adopted at each testing location. Results obtained from the soil test revealed that, the soil resistance and resistivity varied widely across the study area. It was observed that the northern part of the area generally had lower soil resistance and resistivity than the southern part of the study area. The soil resistance ranged between 3.2 Ω and 4.8 Ω at the northern part of the study area; while the soil resistance ranged between 5.1 Ω and 17.2 Ω at the southern part of the study area. In term of the soil resistivity, the results revealed that the northern part of the area had the lowest soil resistivity, compared to the southern part of the area. The soil resistivity ranged from 96.15 Ωm to 324.25 Ωm at the southern region of the area, while at the northern region of the area, the soil resistivity ranged from 60.33 Ωm to 90.49 Ωm. Furthermore, the result established that the northern region of the study area will be suitable for electrical earthing without any soil treatment.

Keywords: Earthing system, electrical installation, soil – treatment, soil - resistance, soil – resistivity, Wenner-Method.

INTRODUCTION

Electrical earthing is an essential component of any electrical wiring/installation system. According to Akpoyibo [1], an electrical earthing of an electrical wiring system implies an electrical connection to general mass of the earth. The earth crust acts as a reservoir for excessive electrical charges, due to its poor electrical conductivity nature; but its resistivity is influenced by the materials that makeup each earth's stratum. Earth resistivity is dependent on the soil geochemical and geotechnical properties of the location. Therefore under certain conditions (soil compaction, high moisture content, high electrical conductivity, etc.) the soil can conduct significant amount of electrical charges [2]. Perfect electrical earthing system must be built on area (soils) with low resistance, substandard materials, among others. Substandard materials and soil with high resistance tend to hinder the discharge of the excessive current within the structure to the sink (earth); hence exposing the occupants to the high electrocution hazard, damage to electrical appliances and materials, instrumentation/electrical failures, electrical fire outbreak, etc. [3, 4, 28]. To optimize the performance of the electrical system, the specifications of earthing materials used for any earthing (grounding) operation, must be chosen in accordance with the electrical load the building was designed to carry. Soil resistivity is the resistance between two opposing surfaces of a $1m^3$ cube of the soil; which is an essential factor to be considered during the design of earthing systems [5,6].

Several studies have been conducted on the state of soil resistivity at various locations, using different testing and computing methods. According to Unde and Kushare [7] weather conditions, earth rod length and depth of placement affected the soil resistivity. It was observed that the soil resistance decreased from 1.937 Ω to 1.853 Ω, as the earth rod length increased from 3 m to 9 m. Additionally, He [8] reported that raining season (soil moisture content) affected the soil resistance capacity; hence, the resistivity developed by the various soil strata affects the safety of grounding system. In freezing climatic condition, the safety of the earthing system is only guarantee when special system designed specifications (e.g. long vertical earthing rods) are adopted. In the work of Ronda [9] on soil resistance and resistivity, they reported that soils with high resistance levels are not appropriate for an effective earthing system, without appropriate soil treatment or addition of external plates. This is because these soils can compromised the optimization of the earthing system; hence endangering the electrical installation inside the structure. Citing El-Sayed [10], the ultilization of additional plates in electrical earthing earthing system, optimize the resistance of the earthing system. This it does by allowing the current to diverge to each conductor; thus offering lower impedance within the system.

Within the past decade some researches had been carried out to determine the electrical properties of Nigeria soils. The resistance of the soils within the engineering complex, Delta State University, Oleh campus was determined [11], and the results revealed a declined in the soil resistances from 20.80 Ω to 0.64 Ω, as the probes spacing increased from 5 m to 30. Additionally, [11] reported that soil pH had significant effect on the durability of the earthing materials. Likewise, the soil resistance of the proposed school of environmental technology, the federal university of technology, Akure, Nigeria area decreased from 54Ω to 13.9 Ω, as the probes spacing increased from 1 m to 17 m; relatively the soil resistivity declined from 1018 Ωm to 262 Ωm, as the probes spacing increased from 1 m to 17 m [12]. Furthermore, Obukoeroro [2] studied the geotechnical properties of soils samples around the school of engineering complex, Delta State Polytechnic, Ozoro, Nigeria. The authors reported that the soil resistance was greatly influenced by the soil geotechnical properties, as the soil resistance decreased from 17.2 Ω to 4.8 Ω, as the soil electrical conductivity increased from 3.09 dS/m from to 5.41 dS/m. Although some literature had been recorded on the electrical properties of some soils samples within Delta state; literature search provides no recorded information on the status of the soil electrical properties, of the undeveloped area of Delta State University of Science and technology, Ozoro Nigeria. Therefore this objective of this study is to determine the resistive and resistivity of soils within the undeveloped area of Delta State University of Science and technology, Ozoro Nigeria, using the Wenner Four Point method. Results obtained from this study will be helpful in designing appropriate earthing system, for the structures that will be later sited in this area

MATERIALS AND METHODS

Study area description

The study was carried out within the premises of the Delta State University of Science and Technology, Ozoro, Nigeria. Ozoro community, were the university is sited, has two major climatic conditions, which are: the dry and rainy seasons. During the rainy season, the area witness bimodal rainfall distribution pattern, with mean annual rainfall of about 2500 mm [13].

The geographical locations of the location from where the earth's resistivity was tested are presented in Table 1. The locations were taken a distance of 200 m from each other; hence the total area cover in this study was 80,000 m^2 (8 hectares). Schematic view of the study area, and the position from the earth resistance was taken is presented in Figure 1. The soil type within the study region is mainly alluvial, and had dense vegetation cover, apart from its southern macro-region that was cleared for road construction [25].

Table 1: GPS co-ordinate of the test locations

Test location	GPS co-ordinate	Remark
A	5.562 N, 6.246 E	Little vegetation cover and close to the main road
B	5.562 N, 6.248 E	Little vegetation cover and close to the main road
C	5.563 N, 6.249 E	Thick vegetation cover
D	5.564 N, 6.246 E	Thick vegetation cover
E	5.563 N, 6.248 E	Thick vegetation cover
F	5.564 N, 6.249 E	Thick vegetation cover

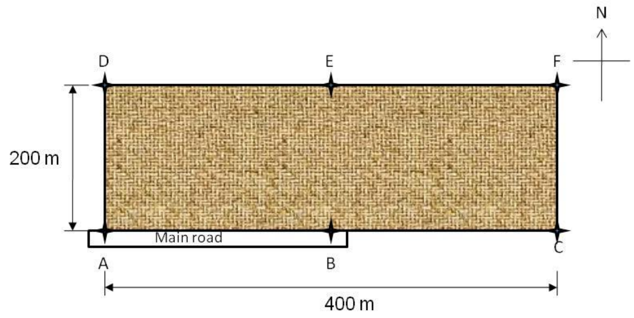

Figure 1: Schematic diagram of the testing locations

Particle size grading

From each test location 1 kg of the soil was uniformly collected across the depth of 1 m. This soil was air-dried in the laboratory under ambient temperature. The sieve analysis of the dried soil was carried on in accordance with NIS-87 standard recommendation, as described by [14]. Then the textural nature of the soil sample was read from the textural triangle.

Earth's resistance testing method

The Wenner Four Point method was adopted for this research work. Four probes are driven at an equal distance apart into the soil, at each testing spot in a straight line. The distance between two probes was taken as "a", while the depth at which each probe was driven into the soil was taken as "b". During the earth's resistance determination, the voltmeter is used to measure the voltage between the two potential probes (electrodes); while the current between the two outer probes was measured with the aid of the ammeter. The schematic view of the experimental setup is presented in Figure 2. This research was carried during the beginning of rainy season (April, 2020), when the soil was not fully saturated with water.

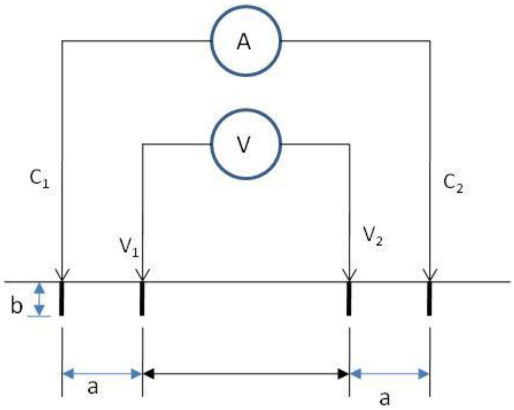

Figure 2: A schematic view of the experimental setup

At each testing location, the GPS co-ordinates of the place were taken and the values recorded accordingly. Then the probes were driven into the soil at a depth "b" of 0.5m, according to a predefined spacing order. Five distances (3 m, 6 m, 9 m, 12 m and 15 m) between the probes were adopted for this study. The connections were secured before the earth's resistivity meter was turn on. As the meter was powered on, current passes between the C_1 and C_2 terminals; while the resulting voltage in the experimental setup was measured between the V_1 and V_2 terminals, with the aid of the voltmeter [2,15].

From the current "I" and voltage "V" values obtained from the experimental setup, the earth's resistance can be calculated using equation 1 [15].

$$R = \frac{V}{I} \quad (1)$$

Where:
R = resistance (Ω),
V = potential difference across the conductor (V),
I = current flowing through the conductor (A).

Then the earth resistivity (ρ) was calculated from the calculated resistance and the distance of the probe spacing, as given in Equations 2 and 3 [24].

$$\rho = 2\pi a \frac{V}{I} \quad (2)$$

Then substituting $\frac{V}{I}$ for "R" in Equation 2, the resistivity becomes:

$$\rho = 2\pi aR \quad (3)$$

Where:
ρ = Resistivity (Ωm)
a= Probe spacing (m)
V= Voltage measured (V)
I = applied current (A)
R = Measured resistance (Ω)

Data analysis

The obtained data were statistically analyzed using the MS Excel 2015 (Microsoft Corporation Redmond, WA 98052). The mean results were plotted by using Microsoft Excel.

RESULTS AND DISCUSSION

Particle size distribution

The results of the particle sieve analysis which were read from the textural triangle are presented in Table 2. As shown in Table 2, area is dominated with clay (fine particles) soil. At Location A, the soil texture was sandy clay; then at Location B, the soil texture was sandy clay loam nature; while at Location C, the soil texture was also sandy clay loam nature. Similarly, Locations D, E and F soil textures were clay, clay and sandy clay, respectively. The relative fine soil particles found in this area, will have significant effect on the soil resistance and resistivity. Previous researchers [16, 17] reported that as fine grain soils (clay) tread to have lower soil resistance and resistivity, compared to their coarse grain counterpart soils.

Table 2: Particle size distribution of the soil particles

Spatial Location	Soil texture
Location A	Sandy Clay
Location B	Sandy Clay Loam
Location C	Sandy Clay Loam
Location D	Clay
Location E	Clay
Location F	Sandy Clay

Earth's resistance

Results obtained from the earth's resistance test are presented in Figures 3 to 8. As presented in the results, the earth's resistance varied across the study area. Regardless of the testing location, the earth's resistances decreases at the probes distance increased from 3 m to 15 m. The results revealed Location B had the highest soil resistance, irrespective of the probe distance; while Location E had the lowest soil resistance, irrespective of the probe distance. As seen in the results the southern part (Locations A, B and C) of the area generally had higher soil resistance, compared to the northern part (Locations D, E and F) of the study area. The high soil resistance recorded at location A and B, could be attributed the road compaction, little vegetation cover and probably the soil texture and moisture. According to According to Agbi et al [26] human induced activities (e.g. humus) can influenced the soil's ability to resist the transmission of charges; hence, affecting the soil resistance. Additionally, it had been reported that soils with high compaction and coarse texture trend to have higher soil resistance, compared to their counterparts with poor compaction and fine texture [18].

The soil's resistance decreases from 18.4 Ω to 8.5 Ω as the probe distance increased from 3 m to 12 m; but then increased from 8.5 Ω 10.2 Ω, as the probe distance increased from 12 m to 15 m (Figure 4). This irregularity could be attributed to the variation in the soil geotechnical and physiochemical properties, along the testing area [2]. Previous research [25, 27] depicted that metals ions varied widely across the study region (university premises). Similar results were obtained by [12], where the soil resistance at some locations at the Federal University of Technology, Akure, Nigeria fluctuated with increased in the probe distance.

This study outcomes revealed that, apart from Locations A and B, the other Locations are ideal for electrical earthing, without special soil conditioning, due to their poor (low) soil resistance. Idoniboyeobu [19] reported that soils with low soil resistance (about 5 Ω) are good for earthing system; since soils with low resistance are good conductor, which facilitate easy discharge of the excessive charges into the earth reservoir. The Nigerian Electricity Management Services Agency (NEMSA) prescribes the maximum earth resistance of 2.0 Ω as recommended value for earthing of structures within the country. While the Institute of Electrical and Electronics Engineers (IEEE) and National Electric Code (NEC), prescribe the maximum earth resistance of 5.0 Ω [20].

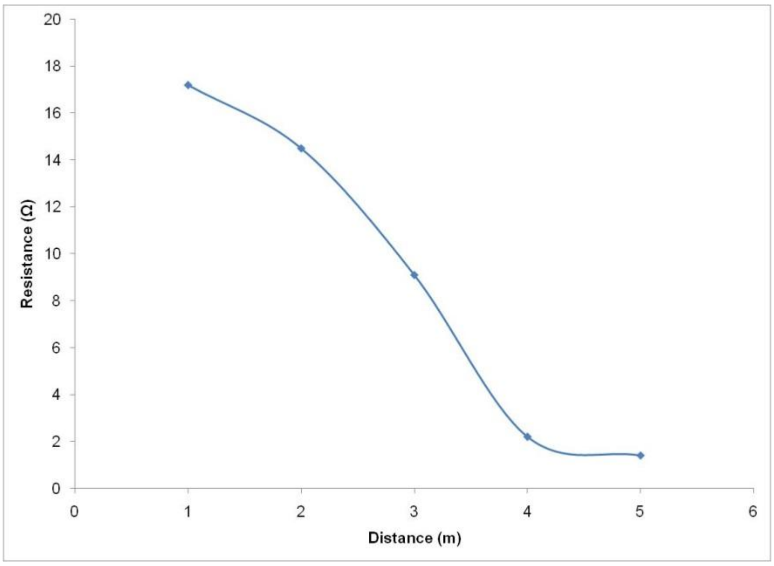

Figure 3: Soil resistance at Location A

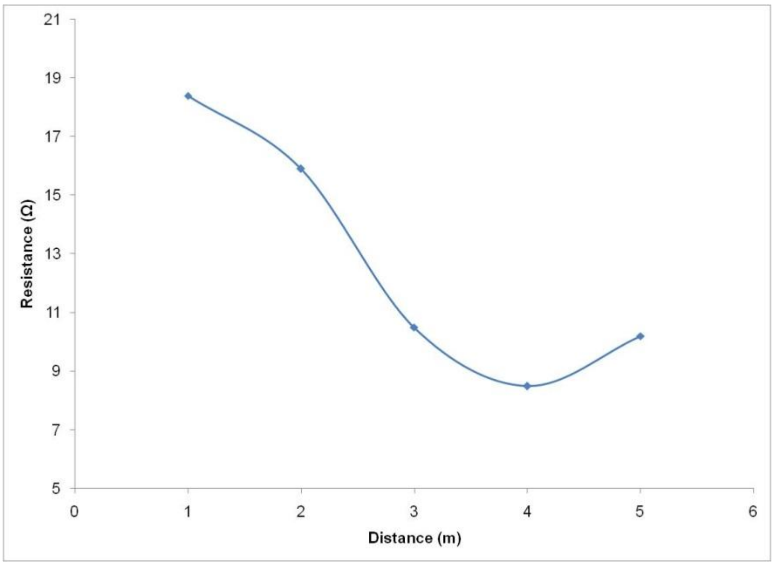

Figure 4: Soil resistance at Location B

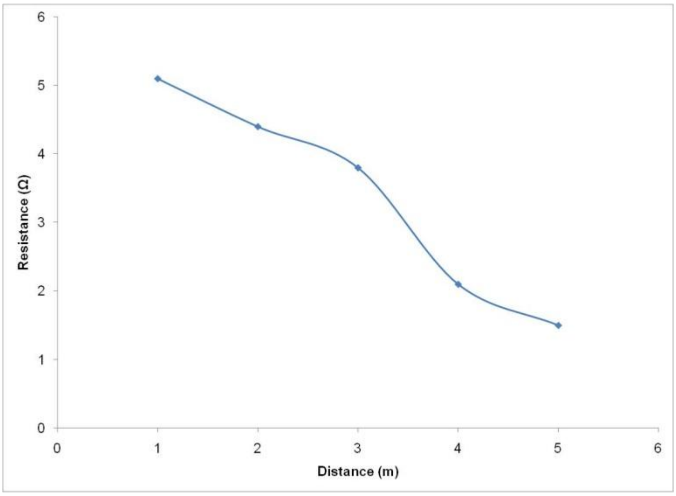

Figure 5: Soil resistance at Location C

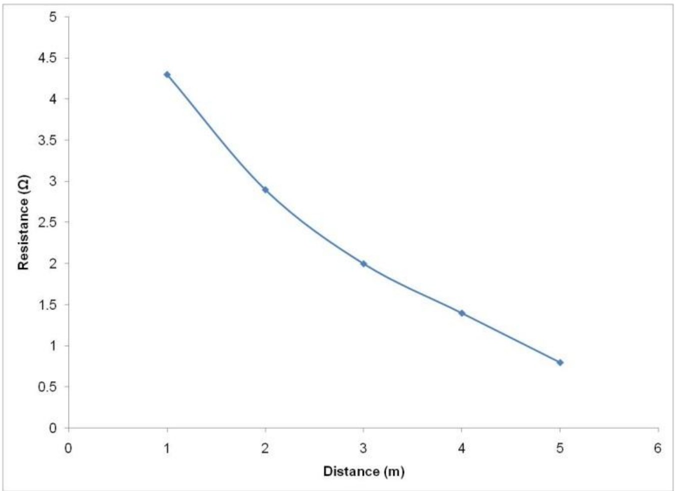

Figure 6: Soil resistance at Location D

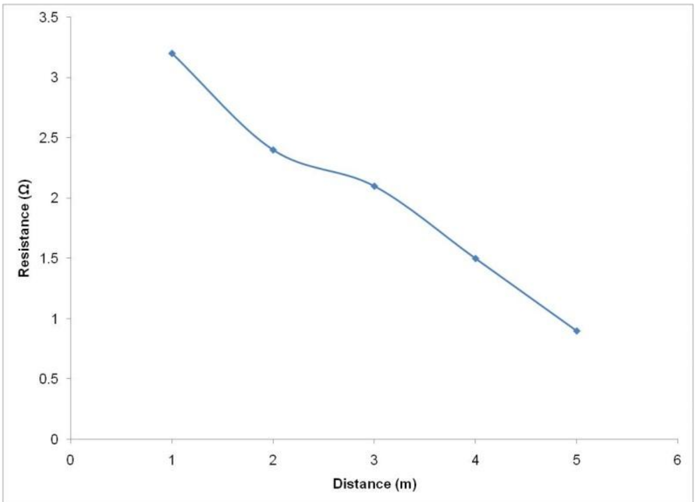

Figure 7: Soil resistance at Location E

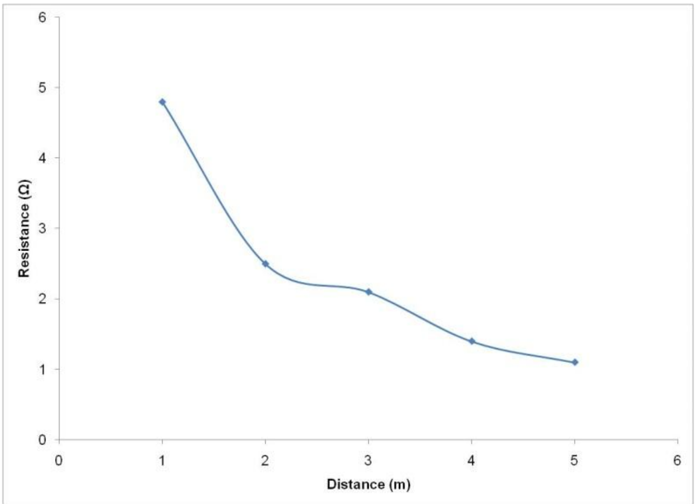

Figure 8: Soil resistance at Location F

Soil resistivity

The results of the soil resistivity are presented in Table 3. From the analysis of the results shown in Table 3, it can be seen that Locations A and B had the highest soil resistivity, while Locations D and E had the lowest soil resistivity, irrespective of the testing location. The lower soil resistively recorded at Locations A and B, could be attributed to the fine nature of the soil grains (Table 2). Fine grain soils trends to have lower resistance and resistivity than large grain soils. Hence, sandy clay soil will trend to have lower soil resistance and resistivity, when compared to stoney soil [12, 21].

It was also observed from the results (Table 3) that the soil resistivity generally increased as the probe spacing increase between 3 m and 9 m; whereas, as the probe spacing increased from 9 m and 15 m, the soil resistivity declined respectively at Location A, B, D, E and F. These variations could be attributed to the geotechnical and geochemical properties of the soils. Siow [22] states that fine soil texture, high moisture content and high soil electrical conductivity can lower the soil resistivity, at a particular location. Similar results were obtained by [11, 12], when the values of the soil resistivity fluctuated with increased in the probe distance, at some testing locations at Ondo and Delta States of Nigeria, respectively.

From the results, it can be seen that apart from Locations A and C, the other locations are ideal for electrical earthing, without special soil treatment, due to their superiors electrical properties. According to Gabriel [23], soil resistivity is a key component, which is used to evaluate the resistance of the charging electrode will be, and the depth the earth rod must be buried into the ground in order to achieve an ideal low earth resistance. Hence, soils with low resistivity are chosen over soil with high resistivity.

Table 3: Soil resistivity at different location and spacing

Spatial point	Soil resistance (Ωm)				
	3 m apart	**6 m apart**	**9 m apart**	**12 m apart**	**15 m apart**
Location A	324.25	546.71	514.66	165.90	131.96
Location B	346.88	599.49	593.84	640.97	961.45
Location C	96.15	165.90	214.91	158.36	141.39
Location D	81.06	109.34	113.11	105.57	75.41
Location E	60.33	90.49	118.77	113.11	84.83
Location F	90.49	94.26	118.77	105.57	103.69

CONCLUSION

The study was done to evaluate the electrical properties (soil resistance and soil resistivity) of an undeveloped area of Delta State University of Science and Technology. The soil resistance was tested by using the Wenner Four Point procedure, at six different spatial locations. Additionally, soil resistivity of the region was calculated from the values of the soil resistance obtained. Results obtained from the research revealed that the soils' resistance and resistivity varied greatly across the study area. Soils located at the northern region of the study area had the lowest resistance and resistivity, when compared the soils situated at the southern region of the study area. This portrayed that the soils located at the northern region of the study area are ideal for electrical earthing, without prior special soil treatment; because the soils' resistances were fairly within the range approved Institute of Electrical and Electronics Engineers and National Electric Code.

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