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A Study on the Conductivity and Quality of Household Electrical Wires in Nigeria

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Abstract

Electricity powers essential services like appliances, healthcare, and transportation, but its widespread use also introduces risks, especially with defective wires or improper installations. This study investigates the resistivity of household electrical wires in Nigeria due to increasing fire incidents linked to poor wiring. Ten cable brands were tested for conductor and insulation resistance. Results showed significant variability in quality, with only two brands (20%) meeting acceptable standards for conductor resistance, while the other 80% exceeded safe limits, raising the risk of electrical hazards such as overheating. All brands, however, met the required standards for insulation resistance, indicating adequate outer protection. The findings stress the need for careful assessment of electrical wires, particularly with economic pressures leading to substandard materials in the market. This study aims to raise awareness about electrical safety and guide future regulations and policies to improve household electrical standards in Nigeria.

Keywords:
Electric cable, Resistivity, Standards, Safety, Nigerian Markets

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Background to the Study

In today's world, electricity plays an indispensable role in maintaining essential services, including household appliances, internet services, banking operations, and transportation networks (Neitzel, 2015; Zohuri, 2016). Research in Nigeria has raised concerns about the quality of electrical wires and cables used in residential buildings. Both Odoh (2022) and John (2021) found that many of these materials do not meet national and international standards, with high electrical resistivity creating a potential fire risk. Odoh (2022) particularly highlighted the widespread use of substandard materials. The reliance on electricity, however, introduces significant risks, including electric shocks and fires from faulty systems and unsafe installations, often resulting in severe consequences such as loss of life and property damage (Barrett et al., 2010). Residential properties are especially vulnerable, with a high incidence of electricity-related fatalities reported globally (Barrett et al., 2010). In the Global South, many Nigerian cities frequently experience electrical fires, leading to significant injuries, fatalities, and property losses. Studies in Lagos, Nigeria, have shown a high fatality rate in residential building fires caused by electrical faults (Adekunle et al., 2016).

Economic pressures in developing countries contribute to this problem, as individuals often opt for substandard building materials due to their affordability (Madueme, 1997). The use of substandard electrical materials, including motors, generators, transformers, and cables, increases the likelihood of equipment failure, and poses significant safety risks (Patel, 2023). Recognizing the severe implications of using substandard materials, various countries and regulatory bodies have established standards and regulations to ensure the quality and safety of electrical components and installations. Examples include initiatives by the Standards Organization of Nigeria (SON), the Nigeria Industrial Standard (NIS), Nigeria National Building Code (NNBC) among others (Barrett et al., 2010; Madueme, 1997). According to the Nigeria Industrial Standards (NIS), all electrical wiring and materials, including electric cables, must efficiently deliver the required electrical energy without heating the cables, which can lead to electrical fires (John, 2021). Moreover, these cables must withstand environmental conditions and mechanical forces encountered in the field (Tenega, 2008).

Despite these regulations, economic pressure, inadequate skilled workforce and the infiltration of unqualified individuals into the building industry have resulted in the use of substandard materials and procedures, leading to significant human and material losses (Obukoeroro and Uguru, 2021). The pervasiveness of substandard materials is further highlighted by a recent raid conducted by the Standards Organisation of Nigeria (SON) on June 11th, 2024, which confiscated counterfeit electrical cables and wires valued at N30.5 million (The Daily Punch, 2024). Numerous incidents of building failures and electrical fires in Nigeria are linked to the nonadherence to standard engineering guidelines in materials and procedures used in building construction (Okieke, 2023).

Several factors contribute to the safety and performance of household electrical wires, including the quality of conductor and insulation materials, mechanical strength, thermal properties, voltage rating, compliance with standards, durability, and lifespan (Zweigbergk, 1972; Muhsin, 2021). However, this study opts to focus on investigating resistivity. Resistivity plays a crucial role in determining the efficiency and safety of electrical current conduction. Elevated resistivity in conductors can result in energy losses, excessive heat generation, and an increased likelihood of electrical fires. Conversely, insufficient resistivity in insulators may lead to leakage currents and electrical shocks. Despite its significant importance, resistivity has not received extensive scrutiny, particularly within the Nigerian market context. This research gap implies that the specific challenges and potential risks associated with the resistivity of electrical cables sold in Nigeria remain insufficiently explored by researchers.

Materials and Methods

Ten major electrical cable brands were selected based on their prevalence and popularity to ensure the findings represent commonly used household cables. To ensure countrywide representation, electrical dealers' stores were randomly sampled from the five geopolitical zones of Nigeria. The selected cities, which serve as major commercial hubs within their respective zones include Lagos (South West), Abuja (North Central), Kano (North West), Port Harcourt (South-South), and Onitsha (South East). The 2.5mm² cable size was chosen for this study due to its widespread use in household wiring for general-purpose applications such as lighting circuits and small power appliances. Maintaining low resistivity in these cables is essential for safe and efficient operation. The ten selected brands of 2.5mm² cables were purchased from randomly sampled electrical stores in the five cities. Cables were sourced from different dealers to avoid bias. Each cable sample was labelled and documented, including brand name, purchase location, and date of purchase, ensuring traceability.

The collected cable samples underwent laboratory tests to measure their electrical resistivity. Each sample was cut into standardized lengths of 1 meter, labeled anonymously (Samples A-J), and insulation was stripped at both ends to expose the conductors. A precision ohmmeter measured the electrical resistance of the conductor by passing a known current through it and measuring the voltage drop. The standard electrical Resistance was calculated using the formula:

$R=\rho L/A$

Where:
R = is the resistance of the wire
ρ = (\rho) is the resistivity of conductor the material the wire is made of
A = is the cross -sectional area of the wire
L= is the length of the wire

The standard resistivity of copper conductor is $1.68\times10^{-8}\Omega m$
Given: $A=2.5\ mm^2\ (2.5\times10^{-6}\ m^2)$
$L=1\ m$
$\rho=1.68\times10{-}8\ \Omega\cdot m$

Plugging these values into the formula:

$$R = \frac{1.68\times10^{-8}\Omega m \times 1m}{2.5\times10^{-6} m^2}$$

$$R = \frac{1.68\times10^{-8}}{2.5\times10^{-6}} \Omega$$

$$R = \frac{1.68}{2.5} \times 10^{-2} \Omega$$

$$R = 0.672\times10^{-2} \Omega$$

$$R=0.00672 \Omega$$

Therefore, the standard conductor resistance of 1m length of 2.5mm^2 copper wires is **0.00672 Ω**

Additionally, a megohmmeter applied a high voltage across the insulation and measured the leakage current, determining insulation resistivity based on the leakage current and applied voltage. Resistivity measurements for conductors and insulators were analyzed to identify trends and variations among the sampled brands. To ensure accuracy and reliability, several quality control measures were implemented including the regular calibration of testing instruments, each resistivity measurement was repeated multiple times for consistency, and laboratory personnel were unaware of the brand or origin of the samples to eliminate bias.

Results and Discussions

The electrical resistance of 2.5mm^2 of all the copper cables (Samples) was measured using a standard Digital Ohmmeter and megohmmeter. The following results were obtained as shown in Table 1 below

Table 1: Experimental test Result of the Resistance of the Electric Wires

S/N	Cable Brand	Conductor Resistance (Ω)	Insulation Resistance (GΩ)
1	Sample A	0.0098	284
2	Sample B	0.0099	213
3	Sample C	0.0088	108
4	Sample D	0.0093	91.4
5	Sample E	0.0080	91.1
6	Sample F	0.0099	140.3
7	Sample G	0.0070	148.9
8	Sample H	0.0105	279
9	Sample I	0.0084	146
10	Sample J	0.0071	96

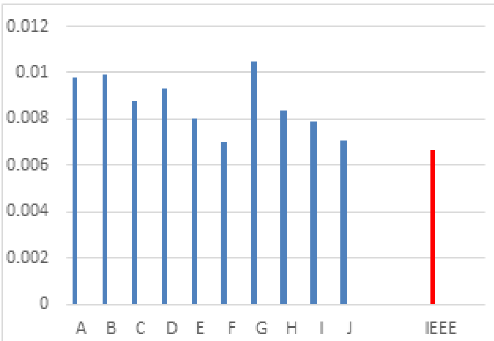

Figure 1: Showing the Conductor Resistance of 2.5mm^2 copper wire

Conductor Resistance Analysis

Conductor resistance, measured in ohms (Ω), indicates how well a cable conducts electrical current without significant energy loss. Lower conductor resistance values imply better conductivity and efficiency in power transmission. From the data:

Range of Conductor Resistance: The values range from 0.0070 Ω (Sample G) to 0.0105 Ω (sample H).

Performance Range: The resistance values recorded in table 1 above revealed that 100% of the samples did not meet up to the standard for conductor resistance. The recommended standard conductor resistance value for 1m of 2.5mm^2 solid core copper wire is 0.0067Ω.

Samples G and J are within the tolerance standard of (±0.001) which represents only 20% of the samples that are good. The remaining 80% of the cables presented resistance values that are higher above the tolerance (±0.001) of the acceptable standard. This revealed that sample A, B, C, D, E, F, H and I constitute the 80% that falls below the tolerance standard. These cable analyses indicated that 80% of the cable tested are substandard and therefore not suitable to carry the rated current under full load conditions for a long period of time.

Sample G exhibits the lowest conductor resistance, indicating superior conductivity among the brands tested. In contrast, sample H demonstrates the highest conductor resistance, suggesting potentially higher energy losses during operation.

Insulation Resistance Analysis

Insulation resistance, measured in megaohms (MΩ), assesses the effectiveness of the insulation material in preventing leakage currents and ensuring electrical safety. Higher insulation resistance values indicate better insulation quality and reduced risk of electrical faults. For typical insulation resistance values, manufacturers often specify much higher resistances, often in the range of tens or hundreds of megaohms (MΩ), or even up to gigaohms (GΩ) for high-quality insulation materials. For circuits with a nominal voltage up to and including 500V, the insulation resistance should be at least 1 MΩ (megohm).
Key observations include:

Range of Insulation Resistance: The values vary from 91.1 GΩ (Sample E) to 284 GΩ (Sample A).

Performance Range: Sample A exhibits the highest insulation resistance, indicating excellent insulation quality. On the other hand, sample E shows the lowest insulation resistance, potentially indicating lower safety margins against leakage currents.

Comparative Analysis and Findings

1. **Best Performers**: Sample A stands out with both the highest insulation resistance (284 GΩ) suggesting superior overall electrical performance and safety. Sample H, despite having the highest conductor resistance (0.0105 Ω), also shows high insulation resistance (279 GΩ), emphasizing its robust insulation capability.
2. **Balance between Conductor and Insulation**: Sample C and Sample I demonstrate a balanced performance with moderate conductor resistance and insulation resistance values. Sample E, for instance, shows a conductor resistance of 0.0080 Ω and an insulation resistance of 91.1 GΩ, indicating a reasonable compromise between conductivity and insulation quality.
3. **Practical Implications**: The findings underscore the importance of balancing conductor and insulation characteristics to ensure both efficient power transmission and electrical safety. Cables with inadequate insulation resistance pose significant risks, potentially leading to electrical faults and safety hazards in residential and commercial settings.

Conclusion

This analysis provides an evaluation of conductor and insulation resistances among selected cable brands in Nigerian markets. These findings highlight the substandard quality of the conductor resistance of the core, which significantly contributes to overheating issues in electrical wires, leading to frequent electrical fires in residential and commercial buildings. Brands like Sample G and Sample J exhibit commendable performance in both parameters, highlighting their suitability for reliable and safe electrical installations. Conversely, brands with compromised conductor resistance may require closer scrutiny and adherence to safety standards to mitigate operational risks effectively. Future research could further explore additional electrical properties and long-term performance characteristics to enhance the understanding and selection of electrical cables for computer and household applications in Nigeria's evolving market landscape.

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