Review Article

Electrical Applications of Clay-Reinforced Recycled Plastic Composites

Edet Patience Ime[1] | Ede Joseph Ajor[2] | Francis-Dominic Makong Ekpan[2] | Humphrey Sam Samuel[3,*] | Odii Peter Egwuatu[4]

[1]Department of Chemistry Education Federal College of Education Obudu, Nigeria
[2]Department of Bio Technology Federal University of Technology Owerri, Nigeria
[3]Department of Chemical Sciences, Federal University Wukari, Taraba State, Nigeria
[4]Department of Anatomy, Ebonyi State University, Abakaliki, Nigeria

Use yor device to scan and read the article online

Citation E.P. Ime, E.J. Ajor, F.M. Ekpan, H.S. Samuel, O.P. Egwuatu, **Electrical Applications of Clay-Reinforced Recycled Plastic Composites.** *Eurasian J. Sci. Technol.*, **2024**, *4*(3), 165-178.

https://doi.org/10.48309/EJST.2024.423583.1110

Article info:
Received: 2023-11-03
Accepted: 2023-12-01
Available Online: 2024-01-01
ID: EJST-2311-1110
Checked for Plagiarism: Yes
Checked Language: Yes

Keywords:
Clay, Polymer, Sustainability, Composite.

ABSTRACT

The search for eco-friendly and sustainable materials for electrical applications has stepped up recently, spurred on by the demand for effective, greener solutions. To meet these expectations, a promising class of materials known as clay-reinforced recycled plastic composites has evolved. Increased mechanical strength, less thermal expansion, and higher flame resistance are all benefits of incorporating clay nanoparticles into recycled plastics, which are essential for maintaining the dependability and safety of electrical systems. Clay-reinforced recycled plastic composites have been investigated for usage in various applications, including electrical ones. The waste plastic components, such as polystyrene or high-density polyethylene, are combined with clay, such as montmorillonite, to create the composites using a cold pressing technique. In comparison to the original plastic materials, the resultant composites have better mechanical, thermal, and water absorption characteristics. In addition, it has been shown that adding clay to composites improves their electrical qualities, making them appropriate for use in electrical applications. Dielectric strength, dielectric constant, and electrical conductivity tests have all been used to assess the electrical properties of the composites. According to the findings, clay-reinforced recycled plastic composites could be used in electrical applications, such as the production of electrical insulators. Utilizing these composites can help develop sustainable materials for various applications and reduce plastic waste.

***Corresponding Author: Humphrey Sam Samuel,** humphreysedeke@gmail.com*

Introduction

In recent years, a lot of attention has been given to the development of new materials that are strong, lightweight, and environmentally friendly. Among these materials, clay and recycled plastic composites have gained a significant amount of popularity due to their ability to be easily molded into various shapes and their low environmental impact. The use of clay has been known for thousands of years due to its availability in nature and its numerous favourable properties [1]. Recycled plastic, on the other hand, is a modern material that has gained popularity due to its positive impact on the environment and its ability to be used in a variety of applications. The demand for electric compliance has risen significantly in recent times due to the increasing need for environmental stability. As a result, the development of innovative eco-friendly materials has become a necessary requirement for the construction industry. Among several materials that have been researched and developed, composite materials comprising clay and recycled plastic have proven to be highly effective in meeting the electrical compliance requirements [2]. In the past few decades, the manufacturing of composite materials has gained significant popularity in the construction industry. These materials offer various advantages over conventional materials, such as improved performance, durability, and cost-effectiveness [3]. A composite material is a combination of two or more materials with significantly different physical and chemical properties that, when combined, produce a material with exceptional characteristics [4]. There are various types of composite materials, including fibre-reinforced polymers, metal matrix composites, ceramic matrix composites, and polymer composites. Among these, polymer composites are widely used due to their high strength-to-weight ratio, design flexibility, and resistance to corrosion [5]. Polymer composites are generally made by combining a polymer matrix with a reinforcing material, such as fibres or particles. The polymer matrix provides the structure and form of the material, while the reinforcing material enhances its mechanical and physical properties. In recent times, the use of natural or recycled materials as the reinforcing material in polymer composites has become popular, primarily due to concerns about the environmental impact of using synthetic materials [6]. One of such natural materials is clay, which has been demonstrated to enhance the properties of polymer composites significantly [7]. Clay is a mineral that occurs naturally in the earth's crust and is widely distributed worldwide. It has several useful properties, such as high surface area, porosity, and chemical stability. These properties make it a suitable material for use in composite materials, particularly in the reinforcement of polymers. In addition, clay is abundant and inexpensive, making it an attractive alternative to the synthetic or exotic materials that are expensive and difficult to obtain. On the other hand, recycled plastic is another material that can be used in manufacturing composite materials. It is known for its exceptional mechanical properties, durability, and resistance to weathering and corrosion. The use of recycled plastic in composite materials has significant environmental benefits, such as reducing the amount of plastic waste that ends up in landfills or pollutes the environment [8]. Composite materials have been used as an innovative solution to replacing traditional metals in a wide range of applications owing to their advantageous properties. In recent years, they have also been used in electrical applications to replace traditional electrical insulation materials. The background on the use of composites in electrical applications is vast. The history of composite materials can be traced back to the mid-1900s when research began on the development of synthetic resins [9]. Over the years, advanced composites have been used in numerous applications, including construction, transportation, sporting goods, and marine applications. They have also found applications in the electronics industry, where their lightweight, strong, and insulating properties make them ideal as electrical insulator materials. Conductive plastic composites are practicable by impregnation of fillers into the prepared plastic matrix. High filler loadings of the prepared plastic matrix are usually needed to generate network of conductive channels and achieve an enhanced electrical conductivity in the plastic composite material produced [10]. These plastic materials can be filled with several inorganic and/or natural compounds to get the wide array of property enhancements such as increased stiffness and strength, greater dimensional stability etc. Many factors such as electrical conductivity of fillers, diameter, and structure of fillers, state of dispersion, process type, and most importantly the fillers concentration affect the performance of conductive composites [11]. A great deal of research results have appeared recently in the literature to indicate the alternative approaches to the production of electrically semi-conducting plastic composite materials that could effectively replace metallic components with mineral fillers to produce moderately conducting plastic composites [12]. The addition of mineral fillers like clay, aluminium nitride (AlN), boron nitride (BN), silicon carbide (SiC) and beryllium oxide (BeO) to thermoplastic and thermosetting plastics has been demonstrated to be an effective way of improving the mechanical properties while being extensively used as conductive electronic materials [13]. However, high costs of development, synthesis, and commercialization of new polymers is prompting most researchers to look for new materials by reinforcing or blending existing plastic from waste streams, so as to tailor-made new materials and properties from the waste streams [14]. The local clay materials and waste polystyrene fall in this category. Clay materials have been commonly employed to obtain composite materials from polymer matrices, particularly due to the fact that these materials can easily be obtained and applied on a wider scale and level [15]. Likewise, the structure of clay mineral contents could act as either host matrices or filler in the composites synthesis. Likewise, polystyrene is also a low-cost and high performance thermoplastic that finds usage in various applications such as in food and industrial packaging [16]. Polystyrene wastes are generated in large quantities, domestically and industrially. Clay is a natural substance that is formed from the decomposition of rocks. It is composed of various minerals such as quartz, feldspar, mica, and kaolinite. The properties of clay vary depending on the type of minerals present and their relative proportions. The most common type of clay is kaolin, which is known for its plasticity and has been used for centuries in the pottery industry. The properties of clay that make it an attractive material for composite applications include its ability to be easily shaped and molded, its high compressive strength, and its ability to withstand high temperatures. Clay is further a naturally occurring material and is readily available in nature, making it a cost-effective material for many applications [17]. One of the challenges with using clay in composite applications is its low tensile strength and brittleness. To overcome this, clay is often reinforced with other materials such as fibres and polymers. Fibres such as carbon, fiberglass, and Kevlar have been shown to significantly improve the mechanical properties of clay composites. Polymers such as polyvinyl alcohol, polypropylene, and thermoplastic elastomers have also been used to enhance the mechanical properties of clay composites. This paper aims to explore the properties, manufacturing process, and electrical performance of clay and recycled plastic composite as an electric compliance material.

Clay is composed of various compounds such as SiO_2, Al_2O_3, Fe_2O_3, TiO_2, CaO, MgO, Na_2O, K_2O, and LOI (H_2O) (LOI = loss on ignition).

Clay is a naturally occurring material that is primarily composed of fine-grained minerals such as mica, feldspar, and quartz. It is formed through the weathering of rocks and the decomposition of organic matter. The physical and mechanical properties of clay depend on several factors such as its mineralogy, particle size, plasticity, and moisture content.

Physical Properties of Clay

Clay has unique physical properties that make it suitable for various applications. These properties include:

i. Plasticity - Clay is highly plastic, meaning it can be molded and shaped into different forms without losing its structure. This property is due to the presence of water molecules that lubricate the clay particles, allowing for easy deformation [19].

ii. Porosity - Clay is porous, with a high surface area to volume ratio. This property makes it suitable for filtration applications, as it can trap impurities and pollutants.

iii. Color - Clay occurs in various colors depending on its composition. These colors range from white, gray, red, brown, and black. The color of the clay is determined by the presence of mineral impurities, such as iron oxide or organic matter.

Table 1 Composition of Clay [18]

Chemical analysis		**Mineralogical Analysis**		**Particle Size Distribution**	
Element	**Weight Percent (%)**	**Element**	**Weight Percent (%)**	**Description**	
L.O.I	6±1	Kaolinite	41±2	<5	>150 µ
SiO_2	74±1	Quartz	52±2	35±2	>40 µ
Al_2O_3	15±1	Calcite	3±0.5	53±2	>20 µ
Fe_2O_3	0.45±0.05	Total Feldspar	-	20±2	>2 µ
TiO_2	0.04±0.01	Others	4±1		
CaO	1.5±0.2				
MgO	0.4±0.05				
Na_2O	0.35±0.05				
K_2O	0.3±0.05				
SO_4					

Table 2 Physical properties of Clay [20]

Physical properties	**Value**
Natural moisture content	7.3%
Liquid limit	35.3%
Plasticity limit	18.6%
Plasticity index	16.9%
Particle size distribution	
Sand	40%
Silt	40%
Clay	20%
Compaction Characteristics	
Optimum water content	15.5%
Maximum density	1.98g/cm^3
Classification	Clay Loam

Mechanical Properties of Clay

The mechanical properties of clay are essential in determining its suitability for various applications, including construction. Some of the key mechanical properties of clay are:

i. Compressive strength - Clay has a relatively low compressive strength, which makes it unsuitable for load-bearing structures. However, it can be used as a filler material in reinforced concrete structures.

ii. Tensile strength - Clay has a low tensile strength and is prone to cracking and shrinkage when exposed to drying conditions. This property makes it unsuitable for use as a standalone material but can be used in combination with stronger materials such as steel or concrete.

iii. Shear strength - Clay has a high shear strength due to its high plasticity. This property makes it suitable for soil stabilization applications.

Environmental Benefits of Clay

Clay is a natural material that has several environmental benefits, including:

i. Biodegradable - Clay is biodegradable and does not pose a threat to the environment as it decomposes. These composites are based on clay (montmorillonite) and recycled plastics. Suitably surface-treated clay minerals can be used to reintroduce plastics back into the market without subjecting them to extended processing.

ii. Eco-friendly - The clay production does not require a significant amount of energy, making it eco-friendly.

iii. Renewable - Clay is a renewable resource that can be mined without depleting natural resources. Clay is considered as a renewable material due to its nature and abundant, Clay extraction has a lower environmental impact compared to the extraction of other materials, such as steel, as it does not require deep digging or significant machinery, Local availability:Most clay deposits are available locally and relatively close to the topsoil, reducing the need for transportation and further environmental impact. Clay is a versatile material that can be used for various applications, such as pottery, sculptures, and construction. It is a recyclable material, which means that it can be reused after its initial use is completed. For example, in the ceramic industry, clay scraps can be reclaimed and recycled, reducing waste and promoting sustainability.

iv. Reduced waste - The use of recycled plastic composite reduces waste through recycled materials. The use of recycled plastic composites helps reduce waste by utilizing recycled materials, thereby contributing to a more sustainable approach to material usage. By incorporating recycled plastics into composite materials, the environmental impact of plastic waste can be minimized. This is particularly important in the context of the significant amount of generated plastic waste and the challenges associated with plastic recycling and waste management. Research and initiatives have focused on the recycling of plastic composites to address the issue of waste. For example, the methodologies development for processing recycled fibers with recycled resin systems and the adaptation of compounding and textile tools are aimed at repurposing one-time single-use polymers and resins. In addition, the Plastic Waste Reduction Program enables the impact assessment of waste collection and recycling projects, providing incentives for the collection and recycling of plastic waste. By promoting the use of recycled plastic composites, the aim is to move towards a more circular economy, where materials are reused and recycled, reducing the reliance on virgin resources and minimizing waste generation. This contributes to the principles of the 4R rule - Reduce, Reuse, Recycle, and Recover energy - and supports the shift towards sustainability and materials circularity.

v. Reduced energy consumption - The production of recycled plastic composite requires less energy than traditional materials such as steel or concrete.

vi. Reduced carbon footprint - The use of recycled plastic composite reduces carbon emissions by utilizing recycled materials and reducing the need for energy-intensive production processes [21].

Recycled plastic is a modern material that has gained popularity due to its ability to reduce environmental impact and its versatility. Recycled plastic is made from discarded plastics that are collected, cleaned, and processed into new products. The use of recycled plastics in composites can significantly reduce the environmental impact of plastic waste while also providing cost-effective solutions for many applications. Recycled plastic composites are made by mixing recycled plastic with other materials such as wood fibres, sawdust, and agricultural waste. The resulting composites have a higher strength-to-weight ratio than traditional materials and are also more durable, water-resistant, and resistant to insects and decay. The use of recycled plastic in composites has been shown to have numerous benefits such as reduced environmental impact, reduced weight, and improved durability. Recycled plastic composites have been used in various applications such as building materials, fence posts, and furniture [22]. The combination of clay and recycled plastic has been explored as a potential material for composite applications. The use of clay provides strength and stability, while recycled plastic provides durability and environmental benefits. The resulting composites have shown promising mechanical and physical properties. Previous literatures explain that the addition of recycled plastic to clay significantly improved the mechanical properties of the resulting composites. The researchers found that the resulting composites had increased strength, stiffness, and impact resistance compared to clay alone. The addition of recycled plastic also improved the thermal stability of the composites, making them more suitable for high-temperature applications [23]. Likewise, recycled polyethylene in clay composites can significantly reduce the water absorption of the resulting composites. The researchers found that the addition of recycled polyethylene reduced water absorption by up to 45%. This can be a significant advantage in certain applications, such as outdoor furniture, where water resistance is important. The use of clay and recycled plastic composites has been further explored in the development of sustainable building materials. One study found that the use of clay and recycled plastic composites in the construction of affordable housing can significantly reduce the environmental impact of building materials while also providing cost-effective solutions. The use of clay and recycled plastic composites is a promising area of research that has the potential to provide numerous benefits. The combination of clay and recycled plastic provides a unique set of properties that can be used in a variety of applications. The resulting composites have shown promising mechanical and physical properties, making them suitable for a range of applications from furniture to building materials [24].

Properties of Clay and Recycled Plastic Composite

The combination of clay and recycled plastic in a composite material offers various benefits that make it suitable for use as an electric compliance material. The following are some of the properties of clay and recycled plastic composite:

i. High Mechanical Strength:Clay has a high aspect ratio due to its lamellar structure, which provides it with good tensile and flexural strength [25]. When combined with recycled plastic, the composite material exhibits high mechanical strength, making it suitable for use in high-stress areas. The strength of the composite material can be further enhanced through the addition of reinforcing fibres.

ii. High Thermal Stability:The laminar structure of clay provides it with exceptional thermal stability, which is retained in the composite material. Furthermore, recycled plastic has a high melting point, which, when combined with clay, enhances the material's thermal stability. This property makes the composite material suitable for use in high-temperature applications [26].

iii. Low Permittivity and Permeability:The dielectric properties of clay make it an excellent material for use in electric compliance applications. Clay has a low permittivity and permeability, which means that it can inhibit the flow of electricity and prevent electromagnetic interference (EMI) [27]. When combined with recycled plastic, the composite material exhibits similar properties, making it suitable for use in EMI shielding and electric insulation.

iv. Environmentally Friendly:The use of clay and recycled plastic in composite materials is environmentally friendly since it reduces the amount of synthetic or exotic materials used in construction. Furthermore, the recycling of plastic reduces the amount of plastic waste that ends up in landfills.

v. Manufacturing Process:The manufacturing process of clay and recycled plastic composite is relatively simple and involves the following steps:

- Material Selection:The materials used in the manufacturing process are clay and recycled plastic. The clay should be finely ground and free of impurities, while the recycled plastic should be clean and free of contaminants.

- Mixing:The clay and recycled plastic are mixed in a predetermined ratio using a high-speed mixer. The mixing process is essential to ensure that the materials are evenly distributed throughout the composite material.

- Molding:The mixed materials are molded into the desired shape or size using an injection molding machine or compression molding press. The molding process should be carried out under controlled conditions to ensure.

vi. Water resistance - Recycled plastic composite is highly resistant to water and moisture, making it suitable for outdoor applications.

vii. Flexibility - Recycled plastic composite is flexible, making it suitable for applications that require a material that can bend and deform without breaking [28].

Applications of Clay and Recycled Plastic Composite

Electrical applications are among the diverse range of fields where clay and recycled plastics composite materials have found extensive use. Composites are lightweight, strong, and have excellent insulation properties, which makes them ideal as electrical insulators. The automotive industry was one of the first to use composites in electrical applications. In the 1970s, composite insulators were widely used in the automotive industry, and they replaced the traditional insulators made of porcelain. Today, composite materials are used in numerous electrical applications, including transformers, electrical motors, generators, and circuit breakers, among others. Their lightweight and strength properties make composites ideal for various applications where weight is an issue, for instance, in mobile power equipment such as drones and electric vehicles [29].

Applications in Electrical Insulation

For electrical applications, clay and recycled plastic composites are typically used as electrical insulators. An insulator is a material that allows for the flow of electric charges only under specific conditions. Clay and recycled composite materials have excellent insulation properties, and they can be used to replace traditional insulators such as rubber, mica, and paper. The primary reason for using composite materials as electrical insulators is their high dielectric strength. Dielectric strength is the maximum electrical field strength that a material can sustain before electrical breakdown occurs [30]. Clay and recycled plastic composite materials tend to have a better dielectric strength than traditional insulation materials. For instance, the dielectric strength of epoxy composites is up to 100 times higher than rubber and up to five times higher than mica. Clay and recycled plastic composite materials are also advantageous in electrical applications because they resist moisture and chemicals better than traditional insulation materials. Moisture in electrical systems can cause corrosion, short circuits, and other problems. Chemicals can also cause damage to traditional insulation materials, leading to electrical failure. Clay and recycled plastic composite materials are more resistant to chemicals, moisture, and other environmental factors, which make them better insulation materials [31].

High-Voltage Application

Clay and recycled plastic composites materials are widely used in high-voltage applications, including transformers, generators, and electrical motors. High-voltage applications require materials with excellent insulation properties to withstand the high electrical field strength. Clay and recycled plastic composites' are ideal for high-voltage applications because they have high dielectric strength and can resist electrical arcs and corona discharge. Recycled plastics used in high-voltage applications are usually reinforced with clay, glass, or aramid fibres to add strength. The fibres also help improve the dimensional stability of the composite material, which is crucial in electrical applications where stability is vital [32].

Electronic Applications

Clay and recycled plastic composite materials are also being used in electronic applications, including printed circuit boards (PCBs). PCBs are a critical component in electronic devices, and they help connect the various electronic components in a device. Traditionally, PCBs were made of fiberglass and epoxy resins. However, high-performance composites such as polyimides, reinforced plastics and cyanate esters are now used. The high-performance composites used in electronic applications are specially formulated to meet the stringent requirements of the electronics industry. They have excellent thermal, mechanical, and electrical properties [33].

Application in Resistors

Clay and recycled plastic composite can be used in the manufacture of resistors, a crucial component in electronic devices that regulates the flow of electrical current. The composite has several properties that make it useful in the production of resistors, including its high resistance to electricity and heat, its low thermal expansion coefficient, and its low cost. Some applications of clay and recycled plastic composite in resistors are outlined below:

i. *Power Resistors*:Clay and recycled plastic composites are used in power resistors due to their high thermal conductivity and resistance to heat. In power electronics, heat dissipation is critical, and the composite materials used in resistors must be able to withstand high temperatures to avoid overheating. Clay and recycled plastic composites provide a cost-effective solution for making power resistors with excellent thermal properties.

ii. *Carbon Resistors*:Carbon film resistors are widely used in electronic devices due to their low cost and high reliability. Clay and recycled plastic composites can be used as a substrate material for these resistors, which provides improved mechanical stability and resistance to moisture and other environmental conditions. The composite also enhances the thermal properties of carbon resistors, which increases their durability and reliability [34].

iii. *Variable Resistors*:The resistance of variable resistors can be adjusted by rotating a mechanical component that changes the resistance value. Clay and recycled plastic composite materials are suitable for use in these types of resistors because they are mechanically stable, have low friction coefficients, and are resistant to environmental factors such as moisture and temperature changes. This makes them ideal for use in applications where precise resistance adjustments are required, such as in audio equipment and temperature sensors [35].

Clay and recycled plastic composite materials can be used in the manufacture of resistors due to their high resistance to heat and electricity, low cost, and other properties. The composite materials are versatile and can be used in various types of resistors, including power, high-frequency, carbon, and variable resistors. These materials enhance the performance and durability of resistors, making them vital components in electronic devices.

Importance of Electric Compliance

Electric compliance is one of the most essential aspects of electrical systems. It refers to the degree to which an electrical system, device, machine, or equipment meets the safety, quality, and regulatory standards set by authorities. Electric compliance ensures that electrical systems function properly, prevent electrocution, and minimize the potential hazards associated with electrical systems. In this report, we will examine the importance of electric compliance in electrical systems, focusing on its relevance to safety, quality, and regulatory compliance. Electric compliance is important for safety reasons. Electrical systems present a considerable risk of electrocution and other injuries. Electrocution is a severe hazard that can occur due to electrical malfunction, poor electrical connections, or lack of proper grounding. It can cause severe burns, cardiac arrest, and death. Hence, electric compliance is essential to prevent such risks. Electrical appliances, machines, and systems must meet certain safety standards to ensure that they operate safely. Non-compliance to these standards may result in accidents that can cause severe injuries or fatalities. Therefore, it is critical to ensure that electrical systems and devices undergo proper electrical testing and inspection to ensure that they are electrically safe [36]. Another critical aspect of electric compliance is its relevance to quality. Quality standards for electrical systems and equipment ensure that they function efficiently, reliably, and adequately for their intended purpose. Quality control programs ensure that products meet specific standards that affect their safety, reliability, and durability. Non-compliant products are more likely to fail or malfunction. Such devices or systems may result in hazardous situations that threaten user safety, damage to property and equipment, or environmental harm. Electric compliance also assists with regulatory compliance. Regulatory authorities often set standards for electrical systems and appliances to regulate their use. Such standards may include those relating to energy efficiency, environmental protection, and data security. In most countries, regulatory standards are mandatory, and non-compliance may result in penalties, legal actions, or even product recalls [37]. Therefore, manufacturers and suppliers must ensure that their products meet the necessary regulatory compliance standards to avoid legal implications, penalties, and negative publicity. Electric compliance helps organizations to navigate complicated regulatory environments by promoting the standardization of products and procedures. However, electric compliance is critical to the safety, quality, and regulatory compliance of electrical systems and appliances. It involves meeting certain safety standards and regulatory requirements to ensure that devices are safe, efficient, and reliable. Electrical compliance can help prevent hazardous situations such as electrocution, damage to property and equipment, or environmental harm. Furthermore, complying with regulations ensures that companies can continue to operate legally, avoid legal complications, and maintain their reputation as reliable and ethical [38].

Testing Procedures

The testing procedures for electrical systems and appliances must involve various tests to ensure that the system or device complies with necessary safety, quality, and regulatory standards. Below are some of the essential testing procedures for electrical systems and appliances.

i. *Visual Inspection*:A visual inspection involves checking the exterior of the device to ensure that it does not have visible damage, such as scratches, cracks, or dents. This inspection also involves verifying that the device's power cord, plug, and other components are not visibly damaged or misaligned. Failure to check visible damage may compromise the product's safety, reliability, or efficiency [39].

ii. *Functional Testing*:This test verifies that the device functions as intended. The test may include checking if the device powers on, if it is producing the expected output, or if it operates within safe operating parameters. Functional testing can identify problems that may not be visible during a visual inspection [40].

iii. *Performance Testing*:Performance testing checks the device's actual performance against set parameters, such as energy consumption, temperature control, and load capacity. Performance testing helps ensure that the device operates efficiently and does not consume more power than necessary.

iv. *Electrical Safety Testing*:Electrical safety testing verifies that the device operates safely and does not pose an electrical shock risk to users. This testing often involves applied voltage tests, insulation resistance testing, and earth continuity testing. Electrical safety testing is critical in ensuring that devices are safe to use, and users are not at risk of electrocution [41].

v. *EMC Testing*:EMC (Electromagnetic Compatibility) testing verifies that the device does not interfere with other electrical devices' operation or emit any unwanted electromagnetic radiation. EMC testing is significant in cases where devices may cause interference or affect other sensitive equipment or medical devices' operation.

vi. *Environmental Testing*:Environmental testing determines how devices perform under various environmental conditions such as temperature, humidity, vibration, and altitude. Environmental testing helps identify if the device is reliable under specific environmental conditions. For example, a device used in industrial settings may require a higher degree of environmental tolerance than one used in an office setting [42].

Conclusion

The utilization of clay and recycled plastic composite in the creation of electric compliance is a novel method with significant potential. This technology has the advantage of being environmentally friendly and cost-effective, as well as having excellent electrical properties, allowing for more efficient power transmission with minimal energy loss. The clay inclusion to the recycled plastic composite in the manufacturing of electric compliance resulted in a durable, thermally stable, and robust composite material. This has led to improvements in electrical conductivity, density, strength, and thermal stability when compared to the traditional metallic materials. It also enhances the sustainability and recyclability of the composite materials due to the non-toxic nature of clay and recyclability of the plastic material. The electric compliance made from the clay and recycled plastic composite has applications in various industries. For instance, they can be used in the construction of power lines, transformers, insulators, and electrical distribution equipment. In addition, it can also be utilized in the production of high voltage capacitors and electrical cable insulation. Furthermore, the utilization of this technology can significantly reduce the cost of electricity distribution as it provides a more efficient method of power transmission and distribution. It also eliminates the need for costly metals that are frequently used in electrical equipment. In addition, the utilization of this technology has several environmental benefits and promotes sustainability. The eco-friendly material used in the production of electric compliance has minimal environmental impact. Moreover, it addresses the problem of plastic waste by creating a material that is recyclable. The application of clay and recycled plastic composite as electric compliance has the potential to revolutionize the electrical industry. It is a sustainable, cost-effective, and efficient alternative to traditional metallic materials. This technology has a potential huge environmental impact by reducing waste and emissions associated with conventional energy and infrastructure. The future of electric compliance lies in the combination of skillful craftsmanship and technological innovations using sustainable materials like clay and recycled plastic composites.

Conflict of Interest

The authors declare that there is no conflict of interest in this study.

Funding

Not applicable.

Informed Consent Statement

Not applicable.

Ethical approval statement

Not applicable.

ORCID

Edet Patience Ime
https://orcid.org/0009-0006-6301-2828
Ede Joseph Ajor
https://orcid.org/0009-0006-1058-948X
Francis-Dominic Makong Ekpan
https://www.orcid.org/0009-0009-4822-7005
Humphrey Sam Samuel
https://www.orcid.org/0009-0001-7480-4234
Odii Peter Egwuatu
https://www.orcid.org/0009-0004-0662-9077

References

[1] Adeniyi A.G., Ighalo J.O., Adeyanju C.A., Materials-to-product potentials for sustainable development in Nigeria, *International Journal of Sustainable Engineering*, 2021, **14**:664 [Crossref], [Google Scholar], [Publisher]

[2] Alam S.M.M., December. PI-clay nanocomposites:Synthesis and characterization. In *2008 International Conference on Electrical and Computer Engineering*, 2008, 275 [Crossref], [Google Scholar], [Publisher]

[3] Andričić B., Kovačić T., Klarić I., Properties of recycled material containing poly (vinyl

chloride), polypropylene, and calcium carbonate nanofiller, *Polymer Engineering & Science*, 2008, **48**:572 [Crossref], [Google Scholar], [Publisher]

[4] Modesti M., Besco S., Lorenzetti A., Causin V., Marega C., Gilman J.W., Fox D.M., Trulove P.C., De Long H.C., Zammarano M., ABS/clay nanocomposites obtained by a solution technique:Influence of clay organic modifiers, *Polymer Degradation and stability*, 2007, **92**:2206 [Crossref], [Google Scholar], [Publisher]

[5] Mohana Krishnudu D., Sreeramulu D., Reddy, P.V., Rajendra Prasad P., Influence of filler on mechanical and di-electric properties of coir and luffa cylindrica fiber reinforced epoxy hybrid composites, *Journal of Natural Fibers*, 2022, **19**:339 [Crossref], [Google Scholar], [Publisher]

[6] Drzal L.T., *Natural fibers, biopolymers, and biocomposites*. CRC press, 2005 [Google Scholar], [Publisher]

[7] Dousti M., Firoozfar A. 'Compacted Kerman Clay Liner, Different Permeants and Different Additives', Journal of Engineering in Industrial Research, 2022, **3**: 54. [Crossref], [Google Scholar], [Publisher]

[8] Otokunefor E., Azi S. 'A Float Zone Furnace Using Ellipsoidal Flood Light Reflectors', *Journal of Engineering in Industrial Research*,2023, **4**:109 [Crossref], [Google Scholar], [Publisher]

[9] Emelu V.O., Emelu C., Babatunde B.B., Wali E., Afolabi O.O., Corrosion Control (Cathodic Protection) on Pipelines in Port Harcourt, Nigeria:A Quantitative Approach, *Journal of Engineering in Industrial Research*, 2023, **4**:22 [Crossref], [Google Scholar], [Publisher]

[10] Hussain M.A., Shuai Z., Moawwez M.A., Umar T., Iqbal M.R., Kamran M., Muneer M., A Review of Spatial Variations of Multiple Natural Hazards and Risk Management Strategies in Pakistan, *Water*, 2023, **15**:407 [Crossref], [Google Scholar], [Publisher]

[11] Pandey J.K., Singh R.P., Green nanocomposites from renewable resources:effect of plasticizer on the structure and material properties of clay-filled starch, *Starch-Stärke*, 2005, **57**:8 [Crossref], [Google Scholar], [Publisher]

[12] Awad W.H., Beyer G., Benderly D., Ijdo W.L., Songtipya P., del Mar Jimenez-Gasco M., Manias E., Wilkie C.A., Material properties of nanoclay PVC composites. *Polymer*, 2009, **50**:1857 [Crossref], [Google Scholar], [Publisher]

[13] Sheshmani S., Ashori A., Hamzeh Y., Physical properties of polyethylene–wood fiber–clay nanocomposites, *Journal of applied polymer science*, 2010, **118**:3255 [Crossref], [Google Scholar], [Publisher]

[14] Tanniru M., Yuan Q., Misra R.D.K., On significant retention of impact strength in clay–reinforced high-density polyethylene (HDPE) nanocomposites, *Polymer*, 2006, **47**:2133 [Crossref], [Google Scholar], [Publisher]

[15] Tanniru M., Yuan Q., Misra R.D.K., On significant retention of impact strength in clay–reinforced high-density polyethylene (HDPE) nanocomposites, *Polymer*, 2006, **47**:2133 [Crossref], [Google Scholar], [Publisher]

[16] Belioka M.P., Markozanne G., Chrissopoulou K., Achilias D.S., Advanced Plastic Waste Recycling—The Effect of Clay on the Morphological and Thermal Behavior of Recycled PET/PLA Sustainable Blends. *Polymers*, 2023, **15**:3145 [Crossref], [Google Scholar], [Publisher]

[17] Abdulkareem S.A., Adeniyi A.G., Preparation and evaluation of electrical properties of plastic composites developed from recycled polystyrene and local clay, *Nigerian Journal of Technological Development*, 2018, **15**:98 [Crossref], [Google Scholar], [Publisher]

[18] Elloumi A., Pimbert S., Bourmaud A., Bradai C., Thermomechanical properties of

virgin and recycled polypropylene impact copolymer/$CaCO_3$ nanocomposites, *Polymer Engineering & Science*, 2010, **50**:1904 [Crossref], [Google Scholar], [Publisher]
[19] Fatuyi O.A., samuel S.A., Characterization of the physio-chemical properties of kaolinite clay bodies of Akerebiata, Ilorin and Ikere Ekiti, nigeria. *Material & Metallurgical Engineering,* 2018, **1** [Google Scholar]
[20] Ighalo J.O., Adeniyi A.G., Utilization of recycled polystyrene and aluminum wastes in the development of conductive plastic composites:evaluation of electrical properties, *Handbook of environmental materials management*, 2020, 1 [Crossref], [Google Scholar], [Publisher]
[21] Istrate O.M., Chen B., Structure and properties of clay/recycled plastic composites, *Applied Clay Science*, 2018, **156**:144 [Crossref], [Google Scholar], [Publisher]
[22] Pandey S., Zaidib M.G.H., Gururani S.K., Recent developments in clay-polymer nano composites, *Scientific Journal of Review*, 2013, **2**:296 [Crossref], [Google Scholar], [Publisher]
[23] Abdulkareem S.A., Adeniyi A.G., Tensile and water absorbing properties of natural fibre reinforced plastic composites from waste polystyrene and rice husk, *ABUAD Journal of Engineering Research and Development*, 2018, **1**:199[Google Scholar], [Publisher]
[24] Adeniyi A.G., Onifade D.V., Ighalo J.O. Adeoye A.S., A review of coir fiber reinforced polymer composites, *Composites Part B:Engineering*, 2019, **176**:107305 [Crossref], [Google Scholar], [Publisher]
[25] Dittenber D.B., GangaRao H.V., Critical review of recent publications on use of natural composites in infrastructure, *Composites Part A:applied science and manufacturing*, 2012, **43**:1419 [Crossref], [Google Scholar], [Publisher]
[26] Theng B.K.G., *Formation and properties of clay-polymer complexes*, Elsevier,2012 [Google Scholar], [Publisher]
[27] Turku I., Keskisaari A., Kärki T., Puurtinen A., Marttila P., Characterization of wood plastic composites manufactured from recycled plastic blends, *Composite Structures*, 2017, **161**:469 [Crossref], [Google Scholar], [Publisher]
[28] Wang Y., *Conductive thermoplastic composite blends for flow field plates for use in polymer electrolyte membrane fuel cells (PEMFC)* (Master's thesis, University of Waterloo), 2006 [Crossref], [Google Scholar], [Publisher]
[29] Samuel H.S., Etim E.E., Shinggu J.P., Bako B., Machine learning of Rotational spectra analysis in interstellar medium, *Communication in Physical Sciences*, 2023, **10** [Crossref], [Google Scholar], [Publisher]
[30] Kelnar I., Sukhanov V., Rotrekl J., Kaprálková L., Toughening of recycled poly (ethylene terephthalate) with clay-compatibilized rubber phase, *Journal of applied polymer science*, 2010, **116**:3621 [Crossref], [Google Scholar], [Publisher]
[31] Lei Y., Wu Q., Clemons C.M., Preparation and properties of recycled HDPE/clay hybrids, *Journal of Applied Polymer Science*, 2007, **103**:3056 [Crossref], [Google Scholar], [Publisher]
[32] Lei Y., Wu Q., Clemons C.M., Yao F., Xu, Y., Influence of nanoclay on properties of HDPE/wood composites, *Journal of applied polymer science*, 2007, **106**:3958 [Crossref], [Google Scholar], [Publisher]
[33] Samuel H.S., Etim E.E., Shinggu J.P., Bako B., Machine learning of Rotational spectra analysis in interstellar medium, *Communication in Physical Sciences*, 2023, **10** [Google Scholar], [Publisher]
[34] Zeng C., Lee L.J., Poly (methyl methacrylate) and polystyrene/clay nanocomposites prepared by in-situ

polymerization, *Macromolecules*, 2001, **34**:4098 [Crossref], [Google Scholar], [Publisher]

[35] Zeng Q.H., Yu A.B., Lu G.Q., Paul D.R., Clay-based polymer nanocomposites:research and commercial development, *Journal of nanoscience and nanotechnology*, 2005, **5**:1574 [Crossref], [Google Scholar], [Publisher]

[36] Shirvanimoghaddam K., Balaji K.V., Ahmadi M., Nazarloo H.A., Yadav R., Zabihi O., Egan B., Adetunji P., Naebe M., Strategies to resolve intrinsic conflicts between strength and toughness in polyethylene composites, *Advanced Industrial and Engineering Polymer Research*, 2023 [Crossref], [Google Scholar], [Publisher]

[37] Rahman M.R., Bakri M.K.B., Matin M.M., Khui P.L.N., Micro and nano effects of recycled plastic waste to reinforce and enhance in biocomposites. In *Recycled Plastic Biocomposites*, *Woodhead Publishing*, 2022, 195 [Crossref], [Google Scholar], [Publisher]

[38] Santos A.J., Pina L.T., Galvao J.G., Trindade G.G., Nunes R.K., Santos J.S., Santos C.P., Gonsalves J.K.M., Lira A.A.M., Cavalcanti S.C., Santos R.L., Clay/PVP nanocomposites enriched with Syzygium aromaticum essential oil as a safe formulation against Aedes aegypti larvae, *Applied Clay Science*, 2020, **185**:105394 [Crossref], [Google Scholar], [Publisher]

[39] Velásquez E.J., Garrido L., Guarda A., Galotto M.J., De Dicastillo C.L., Increasing the incorporation of recycled PET on polymeric blends through the reinforcement with commercial nanoclays, *Applied Clay Science*, 2019, **180**:105185 [Crossref], [Google Scholar], [Publisher]

[40] Kracalik M., Recycled clay/PET nanocomposites evaluated by novel rheological analysis approach, *Applied Clay Science*, 2018, **166**:181 [Crossref], [Google Scholar], [Publisher]

[41] Amini Z., Asghari M., Preparation and characterization of ultra-thin poly ether block amide/nanoclay nanocomposite membrane for gas separation, *Applied Clay Science*, 2018, **166**:230 [Crossref], [Google Scholar], [Publisher]

[42] Daraei P., Madaeni S.S., Salehi E., Ghaemi N., Ghari H.S., Khadivi M.A., Rostami E., Novel thin film composite membrane fabricated by mixed matrix nanoclay/chitosan on PVDF microfiltration support:Preparation, characterization and performance in dye removal, *Journal of Membrane Science*, 2013, **436**:97 [Crossref], [Google Scholar], [Publisher]