# Understanding Clay: Its Properties, Characteristics and Uses

**By**

**Charlotte Tam-George, PhD**
**Ignatius Ajuru University of Education**
**Department of Fine and Applied Arts, Ceramics Unit**
**charlottetamgeorge28@gmail.com 08033095728**

**Abstract**

Clay is a naturally occurring material that has played significantly vital role in human existence, from the primitive era through ancient and modern civilizations. Its unique properties such as plasticity, strength, and thermal conductivity, and characteristics such as texture, colour, and workability, make it an essential resource input for various industries, including pottery, construction, electrical/electronics, etc. Understanding the behaviour of clay helps users to apply it properly as raw materials into creating pieces that carry out their purposes as specified. This paper therefore, explores the uses of clay, through a thorough examination of its composition and classifications, its physical and chemical properties, and its diverse applications in different sectors. It also draws insights from both Western and Nigerian scholars, thus, providing a comprehensive understanding of the significance of clay as a genuine raw material in the traditional and modern contexts. Therefore, by understanding the properties, characteristics, and uses of clay, this article aims to provide an intensive guide for artists, craftspeople, engineers, ceramists, and enthusiasts, in working with this remarkable material.

**Keywords**: Clay, clay uses, clay characteristics, clay properties, clay types, ceramics, pottery.

## 1. Introduction

Clay is a type of fine-grained earth material that is plastic when moist, but hardens when heated, consisting of a mixture of minerals, water, and other substances (Velde, 2017). It is a naturally occurring material composed of a variety of minerals, including silicates, oxides, and hydroxides (Murray, 2017). Clay are typically characterized by their small particle sizes, high surface area, and the ability to absorb and retain water (Lopez-Gonzalez, 2018). It is a ubiquitous natural

material utilized by humans for thousands of years, with evidence of its use dating back to ancient civilizations (Rice, 2015). As one of the most fundamental natural materials closest to man, clay has played significant roles in human developments and civilizations, for centuries. Visibly, from ancient pottery and sculpture, to modern industrial applications and construction materials, clay has remained an essential raw material due to its remarkable characteristics and properties. It is a versatile and widely used natural material in many parts of the world.

Norton (2008), highlights the importance of clay in advanced ceramics, construction materials, and technological innovations in many societies in the world. Also, Kingery (2013), equally identified the role of clay as a raw resource for ceramics and modern constructions, and in shaping human culture and technology. Adebayo (2016), claims that Nigerian communities have used clay extensively for pottery, domestic utensils, and architecture for decades. In recent times, clay has become a crucial component in various industries, including ceramics, construction, crafts, and environmental remediation (Murray, 2017).

Despite the widespread use of clay, it is still misunderstood and underappreciated, with many people unaware of its complex properties and characteristics (Velde, 2017). This paper therefore, provides a comprehensive overview of clay, thus, exploring its fundamental properties, characteristics, and diverse uses, in order to promote a deeper understanding and usage of clay materials. By doing this, clay as raw material will be fully appreciated, understood, and explored in diverse forms for creative, functional, aesthetic, developmental and other unimagined activities and end-products.

## 2. Properties of Clay

Clay has several properties that differentiate it from other soil forms, and equally makes it valuable across industries. The properties of clay often determine how it is processed, shaped, and ultimately used by users. Some of these properties have been categorized into two, namely: physical and chemical properties of clay.

**2.1 Physical Properties of Clay:** These are the features of clay that can be observed or measured without changing its chemical identity. Clay exhibits several physical characteristics that define its usability, and makes it a versatile material for various

applications in ceramics, construction, and crafts. Here are some of these physical properties, explained;

- **Plasticity:** Clay is a plastic material that can be moulded and shaped when wet and moist, but becomes hard and brittle when dry. When mixed with water, clay becomes mouldable, thus making it suitable and easier to be formed and shaped into various objects (Ogunyemi, 2015).
- **Shrinkage:** Clay has ability to reduce in size when the amount of water in it reduces, especially when dry. As clay dries, it shrinks, thus requiring careful handling to avoid cracks (Anderson, 2011).
- **Porosity:** Clay is a porous material with tiny pores that allow water and air to pass through. Some types of clay such as earthenware, remain porous even after firing, unless when glazed (Adeoti, 2010).
- **Optical qualities:** This is the ability of clay to showcase colour, transparency, and reflectivity. Clay can have a range of optical properties, including colour, level of transparency, and reflectivity (Kingery, 2013). This property gives it relevance as a good raw material in the optical industry for the production of medicated glasses.
- **Texture:** The fineness of grains in clay, giving it more abilities to be soft, smooth, more plastic and prone to shrinkage.
- **Colour variation:** Clay has the ability to display varied colours. The presence of minerals such as iron oxide affects the colour of clay. According to Peters (2012), depending on the mineral compositions of clay, its colours can range from white to red, brown, and grey.

**2.2 Chemical Properties of Clay:** These are characteristics of clay that describe its ability to undergo chemical changes or reactions under specific conditions. Chemical properties of clay are typically observed when clay interacts with another substance or energy, resulting in a chemical reaction or transformation. Here are some of the chemical properties of clay;

- **Water absorption:** Clay has the ability to hold water, which can be beneficial to plants' growth, but equally lead to poor drainage. Water retention ability helps clay to take diverse forms and shapes, and carved into varied objects. Johnson (2014), opines that the ability of clay particles to attract and retain water, impacts visibly on their workability.

- **Chemical composition:** Clay consist primarily of a variety of minerals, including silicates, oxides, aluminium, and hydroxides. These chemical components give clay edge as a raw material for its applications in various industries, including ceramics where it serves as a primary raw input.
- **Heat resistance:** The ability of clay to help reduce the impact of heat on substances. Certain clay, such as fire clay, has the ability to withstand extreme temperatures, thus making them suitable for industrial use (Okonkwo, 2017).
- **Chemical reactivity:** Clay can react with acids and bases, and can also undergo weathering reactions that alter its composition and structure. Clay can be mixed with other materials to create compounds for industrial and artistic purposes (Norton, 2008).
- **Solubility:** This describes the extent to which clay particles can dissolve or melt in liquids. The solubility of clay can vary depending on its composition and structure, as well as the surrounding conditions of the solution.
- **Chemical stability:** Clay has the ability to exhibit chemical stability, thus resisting changes in its composition and structure over time.

The above physical and chemical properties of clay make it a versatile material for various applications, in craft, ceramics, construction, and environmental remediation, including other industrial purposes. Thus, understanding them and what they are made of, help users to achieve more and better results with little or no difficulties.

## 3. Types of Clay

Clay can be classified based on several factors including composition, plasticity, and firing temperature. It can equally be classified on the basis of its formation and location, as either a primary (residual clay) or secondary (sedimentary clay). Nevertheless these variables, major types of clay are earthenware, stoneware, and porcelain. These clay types have been discussed below as regards there uses.

**3.1 Earthenware:** These are low-fired clay that remain porous unless they become glazed. Earthenware are commonly used in pottery and construction purposes like

in making bricks. The firing range for this type of clay is $1000^0$C-$1150^0$C (Adebayo, 2016).

**3.2 Stoneware:** These clay are more durable and highly strong than earthenware, and are non-porous even without being glazed. Stoneware are best suited for production of tableware, storage jars, and industrial ceramics. This clay requires temperature firing range between $1200^0$C-$1300^0$C (Norton, 2008).

**3.3 Porcelain**: These are highly refined, smooth-textured clay that are highly translucent and strong. They are often used in the production of delicate ceramics and electrical insulators. The porcelain clay requires high-temperature firing between $1300^0$C-$1450^0$C (Johnson, 2014).

**3.4 Ball Clay:** These are highly plastic clay. They are used in clay mixtures to improve flexibility and strength to the piece. Ball clay are very essential for the production of fine ceramics and industrial applications (Ogunyemi, 2015), and also used in pottery, and as a binder in construction materials.

**3.5 Fire Clay:** These are clay that withstand extreme temperatures, and are highly refractory. They are very ideal for making ceramics, furnace linings and refractory bricks. Fire clay are mostly used in high-heat industries, such as metal foundries and kilns (Peters, 2012).

**3.6 Kaolinite Clay:** These clay are soft, white in colour, and have low shrinkage rate. They are often used in ceramics production, paper coating, and as fillers in plastics and rubbers.

**3.7 Montmorillonite-Smectite Clay:** These clay have a high swell potential. It is often used in drilling fluids, as a binder in foundry sands, and in construction materials.

**3.8 Illite Clay:** These are clay minerals that are often used in ceramics, paper coating, and as filler in plastics and materials.

Evaluating and understanding the types of clay gives users informed decision on the best form of clay to use in producing a particular pieces. It equally allows users to apply appropriate caution while using the clay body.

**4. Classes of Clay**

Clay are typically classified into two main categories, namely primary and secondary clay.

- **Primary clay:** This is also known as residual clay. Primary clay is formed in place through the weathering of rocks, typically feldspar-rich rocks, like granite. It's often white or light-coloured, with minimal impurities. A good example of primary clay is kaolin.
- **Secondary clay:** This type of clay is formed when primary clay is transported from its original location through erosion, often by water. As these particles travel, they pick up impurities like iron oxide, which can give a range of colours from tan to brown. Secondary clay are also known as sedimentary clay, and a good example of it is ball clay.

Understanding the classes of clay will help users to know its origin and properties properly, and would be able to make optimum use of the clay body for the production of any clay piece.

**5. Sources of Clay**

Clay have different sources, and the sources they come from affect their properties, characteristics and uses. Some of the sources of clay that impact on their behaviours have explained here;

- **Natural sources:** Clay can be found in natural and undisturbed environments, often in the form of deposits or layers in the earth's crust. Velde (2017), opined that these natural deposits can be formed through the weathering of rocks, erosion, and sedimentation. Thus, these weathered rock particles decay and dissolve over time to become soluble as clay. Clay can equally be formed based on the accumulation of debris in this location, without much human activities. Clay from natural sources are very good for healthcare and pharmaceutical applications, due to their high nutrients in natural deposits.

- **River deposits:** Clay can be sourced in river deposits, such as riverbanks, floodplains, and deltas (Bridge, 2018). These clay are rich in calcium and magnesium, as such are good for treating bones, and skincare applications. They also good for the production of functional wares and other forms of ceramic applications.
- **Sedimentary rocks:** Clay can be gotten from sedimentary rocks, such as shale, mudstone, and claystone (Murray, 2017). Clay from sedimentary rock deposits are very good for industrial applications.
- **Hydrothermal veins:** Clay can be located in hydrothermal veins, formed when hot water rich in minerals flows through rocks (Kerrich, 2018). These type of clay are very rich in minerals, as such would be good for health and pharmaceutical purposes.
- **Weathered rocks:** Clay can be formed through the weathering of rocks, such as granite, basalt, and sandstone (Wilson, 2017). This form of clay is highly rich in chemical content, as such very good for industrial use, especially construction.
- **Marine deposits:** Clay can be found in marine deposits, such as oceanic sediments and marine clays (Weaver, 2018). These clay are very rich in calcium and magnesium, as such good for healthcare, skincare and pharmaceutical applications.
- **Synthetic sources:** Clay can be formed synthetically through processes such as hydrothermal synthesis and sol-gel processing (Santos, 2018).

## 6. Uses of Clay

Clay has a broad range of applications across industries, contributing to art, construction, and technological advancements. Sequel to this, this paper has tried to harmonize some vital roles that clay play across industrial sectors. These areas are in:

**6.1 Traditional and Modern Pottery**: Pottery is one of the oldest applications of clay, with Nigerian artisans continuously using locally sourced clay for domestic and artistic purposes (Adeoti, 2010). In the West, pottery has evolved into both functional and decorative art, with fine ceramics used in modern households (Norton, 2008).

**6.2 Construction and Architecture:** Clay is used for the production of construction materials, such as bricks, blocks, and mortar, due to its strength and ability to bind (Kumar, 2018). Clay products such as bricks and tiles are now essential materials in the construction industry. In Nigeria, adobe houses are built using sun-dried clay bricks, which are cost-effective and environmentally friendly (Okonkwo, 2017). In modern construction, fired clay bricks provide durability and insulation (Peters, 2012). Clay has been found to be a supplementary cementitious material in Portland cerement mortars and concretes, reducing raw materials and CO2 emissions during production.

**6.3 Industrial and Technological Applications:** Refractory materials made from clay are used in kilns, furnaces, and steel production. Also, porcelain clay are critical components in electrical insulators (Johnson, 2014). The production of cement relies on clay as raw material for binding its properties (Norton, 2008).

**6.4 Art and Sculpture:** Clay is a preferred medium for sculptors. Nigerian artists use clay to create culturally significant pieces, while Western sculptors explore its versatility in contemporary art (Adebayo, 2016). It is used as a binding material and filler during the production of art and sculptural pieces.

**6.5 Health and Pharmaceutical Industry:** Clay minerals are used as excipients in pharmaceutical formulations, helping to control the release of active ingredients. Lopez-Gonzalez (2018), disclosed that clay due to the binding and absorption properties of clay, it is used as excipients in pharmaceutical applications such as tablets and capsules production.

**6.6 Cosmetic Application:** Clay is widely used in skincare and medicine production. For instance, bentonite clay is known for its detoxifying properties and as such used in the production of skincare products (Ogunyemi, 2015). Clay is used in cosmetics and personal care products, such as face masks and skincare creams, due to its absorbent and cleansing properties (Liu, 2018). In addition, some clay have medicinal properties, and are used in traditional healing practices (Adeoti, 2010), in parts of the world, including Nigeria.

**6.7 Ceramics and Refractory Industry:** Clay is the primary raw material used in the production of ceramics, coarse ceramics, cements, electro-ceramics, tiles, and refractories. Clay is equally used for the production of sanitary ware, due to its plasticity and thermal resistance (Murray, 2017). Ceramics as one of the products of clay, is a leading construction material in modern day buildings.

**6.8 Environmental Remediation:** Clay minerals can be used in removing pollutants and heavy metals from contaminated soil and water. Clay serves as an agent to remediate soil loss after pollutions.

**6.9 Paper Industry:** Clay minerals are used as fillers and coatings in paper production, improving its printability and durability. Santos (2018), confirms that clay is used as a coating agent in paper production, to improve paper printability and durability.

**6.10 Drilling Industry:** Clay is used in drilling fluids to control fluid loss and maintain wellbore stability (Amanullah, 2018). It is also used for water treatment applications, such as filtration and adsorption, to remove impurities and contaminants from water.

**6.11 Petroleum Industry:** Clay is used as a catalyst support in various industrial processes, such as petroleum refining and chemical synthesis (Zhang, 2018). It can equally act as absorbent in various industrial applications, such as gas separation and purification (Wang, 2018).

**6.12 Geosynthetic Application:** Clay is used in geosynthetic materials, such as geotextiles and geomembrances, due to its strength and durability properties (Koerner, 2018).

Understanding how clay is used in the above domains and more gives users access to the information on the behaviours of clay, and its properties that could be harmful to humans and other habitats. This information on the chemical compositions and applications helps to give informed knowledge on its implications and usage.

**7. Impacts of Clay on the Environment**

Besides every other roles of clay mentioned above, clay also impacts on the environment where it is used. Some of these impacts are in the following areas:

- **Soil contamination:** Clay can be contaminated with heavy metals and other pollutants, which can affect soil quality and plant growth (Kabata-Pendias, 2017).
- **Climate change:** Clay can play a role in carbon sequestration, but its production and use can equally contribute to greenhouse gas emissions (Lal, 2018).
- **Erosion and sedimentation:** Clay can contribute to soil erosion and sedimentation in waterways, thus affecting aquatic habitats and infrastructure (Bridge, 2018).
- **Water pollution:** Clay can contaminate water sources, thus affecting aquatic life and human health (Liu, 2018).

From the above impacts of clay on the environments where it is used, there is need for clay users and industries to find appropriate means of using it, to avoid negative impacts on the environment which could lead to health hazards and environmental pollution and degradation. Waste management patterns of residual clay may help to remediate the pollution impacts on the environment.

**7. Health Implications of Using Clay**

Beside the environmental and other implications of using clay bodies, its health hazards are equally considered in this text. Some of the health implications of clay to be taken seriously are:

- Respiratory problems: Research has found that uncontrolled inhaling of clay dust can cause respiratory problems, such as silicosis and lung cancer (Leung, 2012).
- Skin and eye irritation: Clay can cause skin and eye irritation, particularly if it contains high levels of silica or other abrasive minerals (Lopez-Gonzalez, 2018).
- Gastrointestinal problems: Drinking or tasting clay bodies can cause gastrointestinal problems, such as constipation and intestinal blockages (Kumar, 2018).

- Neurological effects: Being exposed to certain types of clay, such as those containing high level of toxic materials like lead or mercury, can have neurological effects, including cognitive impairment and neurodegenerative diseases (Grandjean, 2018).

**8. Conclusion**

Clay is a form of soil that is plastic when moist, but hardens when heated. It is a fine-grained material that consist of mixtures of minerals, water, and other substances. Clay is a remarkable natural material with its usage and applications spanning from traditional pottery to industrial and technological advancements. Its unique physical and chemical properties make it essential for construction, art and design, medicine, including in other industrial activities where it equally serves as good raw materials. Considerably, both Nigerian and Western scholars recognize the importance of clay in promoting cultural heritage and modern developments. Understanding its properties, characteristics, and uses is crucial for harnessing its full potential.

This paper has provided comprehensive overview of clay by highlighting its unique characteristics, showcasing that the significance of clay lies on the appropriate combination of its properties in creating unprecedented mixtures, forms, and textures.

Obviously, understanding the fundamentals of clay, does not only enhance its uses in creative and industrial contexts, but also promotes sustainable utilization of this invaluable resource input, by impacting positively on its performance and suitability for specific applications. It is expedient to note that this knowledge about clay is essential for researchers, manufacturers, and users of clay-based products, as it will help them optimize their applications, improve product quality, and equally give them edge to explore new uses for this raw material.

**References**

Adeoti, T. (2010). Traditional pottery in Nigeria: A historical perspective. Lagos: University Press.

Adebayo, M. (2016). The role of clay in Nigerian Art and Craft. Ibadan: Heritage Publications.

Afolabi, O. (2018). Nigerian pottery: A review of the literature. Journal of Art and Design Education, 37(2), 147-158.

Amanullah, M. (2018). Drilling fluid optimization using clay-based additives. Journal of Petroleum Science and Engineering, 165, 257-265.

Anderson, J. (2011). Fundamentals of Ceramics. London: Oxford University Press.

Anderson, J. (2011). Fundamentals of ceramics. London: Oxford University Press.

Bridge, J.S. (2018). Rivers and floodplains: Forms, processes, and sedimentary records. Wiley.

Chen, X. (2018). Clay-based water treatment systems for rural communities. Journal of Water, Sanitation and Hygiene for Development, 8(2), 249-258.

Eyo, E. (2017). The Nok culture: Art and archaeology of the Nigerian savanna. Routledge.

Fagg, W. (2015). Nigerian pottery: A study of the traditional pottery of Nigeria. Cambridge University Press.

Grandjean, P. (2018). Environmental and occupational neurology. *Handbook of Clinical Neurology, 157, 111-123.*

Johnson, R. (2014). The science and art of clay. New York: McGraw-Hill.

Kabata-Pendias, A. (2017). Trace elements in soils and plants. CRC Press.

Kerrich, R. (2018). Hydrothermal vein systems. Reviews in Economic Geology, 19, 1-24.

Koerner, R.M. (2018). Geosynthetic materials in civil engineering applications. Journal of Materials in Civil Engineering, 30(10), 04018241.

Kumar, P. (2018). Clay-based construction materials: A review. Journal of Building Engineering, 15, 241-248.

Lar, R. (2018). Soil carbon sequestration and the greenhouse effect. Journal of Soil Science, 168(2), 145-155.

Leung, C.C. (2012). Silicosis. The Lancet, 379(9830), 2008-2018.

Liu, X. (2018). Clay-based water treatment systems for rural communities. Journal of Water, Sanitation and Hygiene for Development, 8(2), 249-258.

Lopez-Gonzalez, D. (2018). Clay-based pharmaceutical applications: A review. Journal of Pharmaceutical Sciences, 107(5), 1231-1238.

Murray, H.H. (2017). Applied clay mineralogy: Occurrences, processes, and application of kaolins, bentonites, palygorskite-sepiolite, and common clays. Elsevier.

Norton, F. (2008). Ceramics: Their properties, manufacture, and applications. Cambridge: Cambridge University Press.

Ogundele, S. (2017). The role of clay in Nigerian pottery. Journal of Ceramics, 2019, 1-9.

Ogunyemi, K. (2015). Industrial applications of clay in Nigeria. Abuja: National Research Institute.

Okonkwo, P. (2017). Building with clay: Traditional and modern approaches. Enugu: Enugu state University Press.

Peters, D. (2012). Refractory clay and its industrial uses. Chicago: Wiley. The role of clay in Ancient and Modern pottery: A case study on Nigeria Pottery.

Santos, P.S. (2018). Clay-based paper coating agents: A review. Journal of Coatings Technology and Research, 15(4), 931-939.

Singh, R. (2018). Clay-based food storage systems for rural communities. Journal of Food Science and Technology, 55(4), 1221-1228.

Velde, B. (2017). Clay minerals: A physico-chemical explanation of their occurrence. Elsevier.

Wang, Y. (2018). Clay-based adsorbents for gas separation and purification: A review. Journal of Materials Chemistry A, 6(35), 16851-16863.

Weaver, C.E. (2018). Clays, muds, and shales. Developments in Sedimentology, 67, 1-24

Wilson, M.J. (2017). Clay mineralogy and geochemistry. Journal of Geochemical Exploration, 175, 1-11.

Zhang, Y. (2018). Clay-based catalysts for petroleum refining and chemical synthesis: A review. Journal of Catalysis, 357, 111-122.