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Chapter 1

Documentation, Application and Utilisation of Clay Minerals in Kaduna State (Nigeria)

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Additional information is available at the end of the chapter

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1. Introduction

The significance of solid mineral resources has been of profound value to man since time immemorial. Clay minerals appear not to be the most valuable among the minerals of the earth surface, yet they affect life on earth in far reaching ways. Nigeria in sub-Saharan Africa (surface area: 923,768 km^2) is a country with considerable wealth in natural resources, with a record of over 30 minerals of proven reserves [1]. As far back as 1903 and 1904, geological survey in Nigeria evolved when the Mineral Surveys of the Southern and Northern Protectorates of Nigeria were established under the British colony. The Mineral Surveys carried out broad reconnaissance of mineral resources of the two Protectorates with the prospect of using the raw materials for industries in Britain. In course of these activities, such deposits as Tinstone, Columbite Limestone, Bitumen, Lead-zinc Ores, Coal, Clays, Iron Ore, Gold, and Marble etc were discovered in various parts of the country [2]. After the colonial era, government parastatals have been set up such as the Nigeria's Ministry of Solid Minerals Development, Raw Material Development Research Council (RMDRC) and the Federal Institute of Industrial Research Oshodi (FIIRO) which all tried to establish a comprehensive data list of basic mineral resources as they occur at various geological locations in appreciable millions of tonnage that supports experimental and industrial uses [3, 4]. In recent research purview, various studies on solid mineral resources using geo-scientific surveys and mineralogical charaterisation considered that the understanding of the nation's mineral potentials is critical for efficient exploration and exploitation towards promoting sustainable economic development as shown in [1, 5-8]. Results have shown that Nigeria's geosphere is enriched with a wide range of both metallic and non-metallic minerals deposited across the states of the nation which are and could still be beneficiated to provide the raw materials for industrial manufacturing among other productive purposes. Noteworthy, clay minerals constitute over 50% of the non-metallic, earthy and naturally-occurring resources abounding throughout Nigeria's sedimentary basins and on the

basement [9]. In [5], it was observed that extensive investigation has been carried out on the liquid mineral endowment of the country, while little has been done to solid mineral endowment of which clay is prominent and as a result, adoption of solid mineral on industrial scale is scanty.

Mararaba-Rido and Kachia areas of Kaduna State are among the largest reserves of clay deposits in Nigeria with over 5.3 million tons [9]. Despite the vast potentials, clay minerals are still grossly underutilized and the few pockets of existing clay-based industries have primarily harnessed the raw for the production of ceramic wares and structural products. A growing number of investigations carried on the solid industrial minerals in Nigeria have been broad based and generic with consideration for geological survey and mineral characterization [see 1,4,6,8]. Besides, documented studies on clay minerals in selected areas of Nigeria tend to focus more on the mineral characterisation and with little emphasis on the economic potentials or usage of the minerals as such in [5]. This study had considered the industrial potentialities in addition to the properties study of clay mineral using Kaduna State of Nigeria as a case study. The qualities of clay found determine its application and suitability for ceramic products such as in bricks, ceramic wares, and refractory. The findings of the study were gathered through field surveys with documentation of relevant information on clay reserves, mineral locations, and the economic significance of the minerals. This includes detailed evaluation of report findings from three clay-based industries at Mararaba-Rido, Jacaranda and Maraba areas in Kaduna State, Nigeria. The result shows a significant usage of clay mineral as a principal raw material for ceramic manufacturing such as structural, refractories, and whitewares products. Clay minerals hold high material value to industries in Kaduna utilizing them for ceramic purposes towards socio-economic and industrial development. This supports the main policy thrust of the economic reform program of the Nigerian government which is targeted at mobilizing national capability in converting the country's endowments into utility products and services for the common man [10].

2. Background

2.1. Documentation on clay minerals in Nigeria

The most abundant, ubiquitous, and accessible material on the earth crust is clay [11]. Reference [5] observed that a great emphasis is placed on exploiting the abundant solid minerals endowments in Nigeria with a view to diversifying the economic base of the country, improving Gross Domestic Product (GDP) and industrial activity. One of these endowments with tremendous potential for economic utilization is clay. Clay deposit is spread across the six geo- political zones of the country [12]. Clays have their origin in natural processes, mostly complex weathering, transport, and deposition by sedimentation within geological periods [13].

The abundance of the clay minerals in Nigeria supports its rich and historic traditional pottery industry that dates from the Stone Age. Archeological evidences from the ancient pottery areas of Nigeria such as Iwo-Eleru near Akure in Ondo State, Rop in Plateau state, Kagoro in Kaduna State and Afikpo in Ebonyi state proved that as far back as the late stone

age, the occupants of these areas made productive used of clay for pottery [14]. The composition of clayey and organic materials such as straws made into adobe brick, served as a ubiquitous building material widely used for building weather-friendly houses in the vast rural domains. Modern industrial uses of clay for ceramics and bricks now obtained in notable parts of the country including Kaduna, Northern Nigeria.

Clay is simply defined as earth or soil that is plastic and tenacious when moist and that becomes permanently hard when baked or fired. It consistsof a group of hydrous alumino-silicate minerals formed by the weathering of feldspathic rocks, such as granite. Individual mineral grains are microscopic in size and shaped like flakes. This makes their aggregate surface area much greater than their thickness and allows them to take up large amounts of water by adhesion, giving them plasticity and causing some varieties to swell (expandable clay). Common clay is a mixture of kaolin, or china clay (hydrated clay), and the fine powder of some feldspathic mineral that is anhydrous (without water) and not

No	Mineral	Site Location	State	Estimated Reserve (tonnes)	Remark
1	Kaolin	Kankara	Katsina	20,000,000	Residual
		Major porter, Jos	Plateau	19,000,000	‘’
		Oshide	Ogun	……..	‘’
		Iseyin	Oyo	……..	‘’
		Ifon	Ondo	……..	‘’
		Ozubulu	Anambra	769,000	Sedimentary
		Illo	Sokoto	……..	Residual
		Darazo	Bauchi	10,000,000	……..
		Kpaki; Pategi	Niger	……..	……..
		Igbanke; Ozonnogogo	Edo	……..	Sedimentary
2	Ball clay	Abeokuta	Ogun	…….	Black
		Auchi; Ujogba	Edo	…….	Black; Cream
		Nsu	Imo	…….	Cream
		Giru	Kebbi	…….	…….
3	Common clay	Mararaban-Rido	Kaduna	5,500,000	grey
4	Feldspar	Okuta	Ogun	…….	Potash
		Lanlate	‘’	…….	‘’
		Egbe	Kwara	…….	‘’
		Bari	Niger	…….	‘’
		Okene	Kogi	…….	‘’
		Gwoza	Borno	…….	‘’
		Oshogbo	Osun	…….	‘’
		Ijero	Ekiti	…….	Soda

No	Mineral	Site Location	State	Estimated Reserve (tonnes)	Remark
5	Quartz/ Silica	Pankshin; Shabu	Plateau	27,962;	White; Sand
		Biu	Borno	2,540,000	White
		Ijero	Ekiti	……	Sand
		Lokoja	Kogi	4,000,000	‘’
		Ughelli	Delta	……	‘’
		Badagry	Lagos	……	‘’
		Epe	‘’	……	‘’
		Igbokoda	Ondo	……	‘’
		P/ Harcourt	Rivers	……	‘’
				……	
6	Talc	Shagamu	Ogun	……	……
		Kumunu	Niger	40,000,000	……
		Ilesha	Oyo	……	……
		Okolom	Kogi	……	……
		Zonkwa	Kaduna	……	……
6	Bentonite	Geshua	Yobe	……	……
		M/Belwa	Adamawa	……	……
		Esan/Isan	Edo	……	……
8	Limestone	Okpila	Edo	10,161,000	White
		Jakuru	Kogi	68,000,000	‘’
		Igumala	Benue	30,161,000	……
		Mfamoging	C/river	26,000,000	Grey
		Nkalagu	Enugu	720,000,000	‘’
		Ewekoro	Ogun	7.1 Billion	Clayey
		Arochuku	Imo	101,000,000	……
		Shagamu	Ogun	……	Grey
		Isekulu	Delta	……	……
		Sokoto	Sokoto	……	……
9	Dolomite	Osara	Kogi	2,000,000	White
		Itobe	Benue	1,000,000	‘’
		Igara	Edo	……	“
		Mura	Plateau	……	“
		Elebu	Kogi	……	“
		Igbeti	Oyo	……	“
		Burum	FCT	8,000,000	“
		Kwakuti	Niger	2,540,000	“
		B/Gwari	Kaduna	……	……

Source: (17) 2000

Table 1. A Table Showing Clay related materials and their various locations in Nigeria.

decomposed. Clays vary in plasticity, all being more or less malleable and capable of being molded into any form when moistened with water. The plastic clays are used for making pottery of all kinds, bricks and tiles, tobacco pipes, firebricks, and other products. The commoner varieties of clay and clay rocks are china clay, or kaolin; pipe clay, similar to kaolin, but containing a larger percentage of silica; potter's clay, not as pure as pipe clay; sculptor's clay, or modeling clay, a fine potter's clay, sometimes mixed with fine sand; brick clay, an admixture of clay and sand with some ferruginous (iron-containing) matter; fire clay, containing little or no lime, alkaline earth, or iron (which act as fluxes), and hence infusible or highly refractory; shale; loam; and marl (16). Tables 1-3 below listed industrial clay-based minerals in Nigeria with information about location, reserve, and geology.

States	Location
Cross-River	Appiapumet and Ofumbonghaone, Ogurude, Ovonum
Akwa Ibom	Nkari, Nlung, Ukim, Ikot-Etim, Eket-Uyo, Ekpere-Obom, Ikot-okoro, Ikwa
Benue	Katsina Ala, Otukpo, Buruku, Gwer West,Gwer, Makurdi
Ebonyi	Ohaukwu, Ezza North, Abakaliki, Ezzi, Afikpo South, Ohaozara
Abia	Isikwuato, Ikwuano, Umuahia Bende, Arochukwu
Enugu	Enugu, Isi-Uzo, Uzo-Uwani, Oji River, Udi
Ekiti	Ara-Ijero, Igbara, Ado, Orin
Ondo	Erusu Akoko, Ikale, Ode-Aye, Ute Arimogija, Ifon
Ogun	Bamajo, Onibode
Plateau	Bassa, Barinkin-Ladi, Mangu, Kanam, Langtang north
Niger	Lavun, Gbako Suleja, Minna, Agaie, Paikoro
Kaduna	Kachia, Mararaba-Rido, Farin-Kassa
Kogi	All over the state
Rivers	Etche Ikwere
Kano	All over the state
Delta	Ethiope East, Isoko South, Ndokwa, South/East/West Okpe, Sapele, Ughelli South, Warri North/South.
Niger	Agaie, Bida, Lavun, Mashegu, Murya

Source: Raw Materials Research and Development Council , 2009

Table 2. Locations of Ball Clay in Nigeria [2009 Update]

State	Location
Cross River	Alige, Betukwe, Mba, Behuabon,
Akwa-Ibom	Ibiaku, Ntok Opko, Mbiafum, Ikot Ekwere,
Abia	Umuahia South, Ikwuano, Isiukwato, Nnochi,
Enugu	Uzo Uwani, Nsukka South, Udi, River-Oji, Enugu North,
Imo	Ehime, Mbano, Ahiazu, Mbaise, Orlu, Ngor Okpalla, Okigwe, Oru,
Benue	Apa, Ogbadibo, Okpokwu, Vandikya,
Anambra	Ozubulu, Ukpor, Anyamelum, Ekwusigo, Nnewi South, Ihiala, Njikoka, Aguata,
Ondo	Abusoro, Ewi, Odo-Aye, Omifun,
Ekiti	Isan-Ekiti, Ikere-Ekiti,
Nasarawa	Awe, Keffi,
Ogun	Ibeshe, Onibode,
Kogi	Agbaja,
Niger	Lavum Gbako, Bida, Patigi, Kpaki,
Kaduna	Kachia,
Plateau	Barkin-Ladi, Mangu, Kanam,
Bauchi	Ackaleri, Genjuwa, Darazo, Misau, Kirfi, Dambam,
Yobe	Fika(Turmi),
Borno	Maiduguri, Biu, Dembua,
Edo	All parts of the State,
Delta	Aniochia South, Ndo Kwu East,
Osun	Irewole, Ile-Ife, Ede, Odo-Otin, Ilesha,
Katsina	Kankara, Dutsema, Safana, Batsari, Ingawa, Musawa, Malumfashi,
Kano	Rano, Bichi, Tsanyawa, Dawakin-Tofa, Gwarzo,
Kebbi	Danko, Zuru, Giro, Dakin-Gari,
Oyo	Iwo, Alakia,

Source: Raw Materials Research and Development Council, 2009

Table 3. Sources and Locations of Kaolin in Nigeria [2009 Update]

2.2. Study area and method

Kaduna State is located at the centre of Northern Nigeria (Figure 1). It is situated on the southern end of the High Plains of northern Nigeria, bounded by parallels $9^{0}03'$N and $11^{0}32'$N, and extends from the upper River Mariga on $6^{0}05'$E to $8^{0}48'$E on the foot slopes of the scarp of Jos Plateau [18]. The bedrock geology is predominantly metamorphic rocks of the Nigerian Basement Complex consisting of biotite gneisses and older granites. In the southeastern corner, younger granites and batholiths are evident. Deep chemical weathering and fluvial erosion, influenced by the bioclimatic nature of the environment, have

developed the characteristic high undulating plains with subdued interfluves [18]. In some places, the interfluves are capped by high grade lateritic ironstone especially in the Northwest.However, soils within the "fadama" areas are richer in kaolinitic clay and organic matter, very heavy and poorly drained characteristics of vertisols.

Kaduna State is endowed with minerals which include clay, serpentine, asbestos, amethyst, kyannite, gold, graphite and siltimanite graphite, which is found in Sabon Birnin Gwari, in the Birnin Gwari local government. The soils and vegetation are typical red-brown to red-yellow tropical ferruginous soils and savannah grassland with scattered trees and woody shrubs. The soils in the upland areas are rich in red clay and sand but poor in organic matter. In [15], Kaduna area is noted as a historic home of the Nok culture, the earliest producer of terracotta sculptures in the whole of sub-Sahara African, dating over 2,000 years ago (Figure 2). This reference has provided an index to age-long clay mineral heritage; besides serving as a mirror to civilization with which the modern man has been able to find out more about himself and the environment at such point in recorded history [19]

In recent times, apart from traditional purposes, the vast deposit of clay has basically served as raw material for pottery and red bricks production with a handful industrial presence. The fieldwork survey identified three prominent clay-based industries striving to survive the threats of unfavorable economic factors. The clay industrial sites were examined in relation to productive means of utilising the raw materials. The industries included Kaduna Clay Bricks at Mararaba-Rido and Jacaranda Pottery both located around Kaduna South and Maraba Pottery Center in Maraban Jos, Kaduna, Nigeria. The firsthand knowledge of the various productive uses of Kaduna's rich clay reserves, however, indicated prospects for industrial expansion if the mineral is properly explored and harnessed.

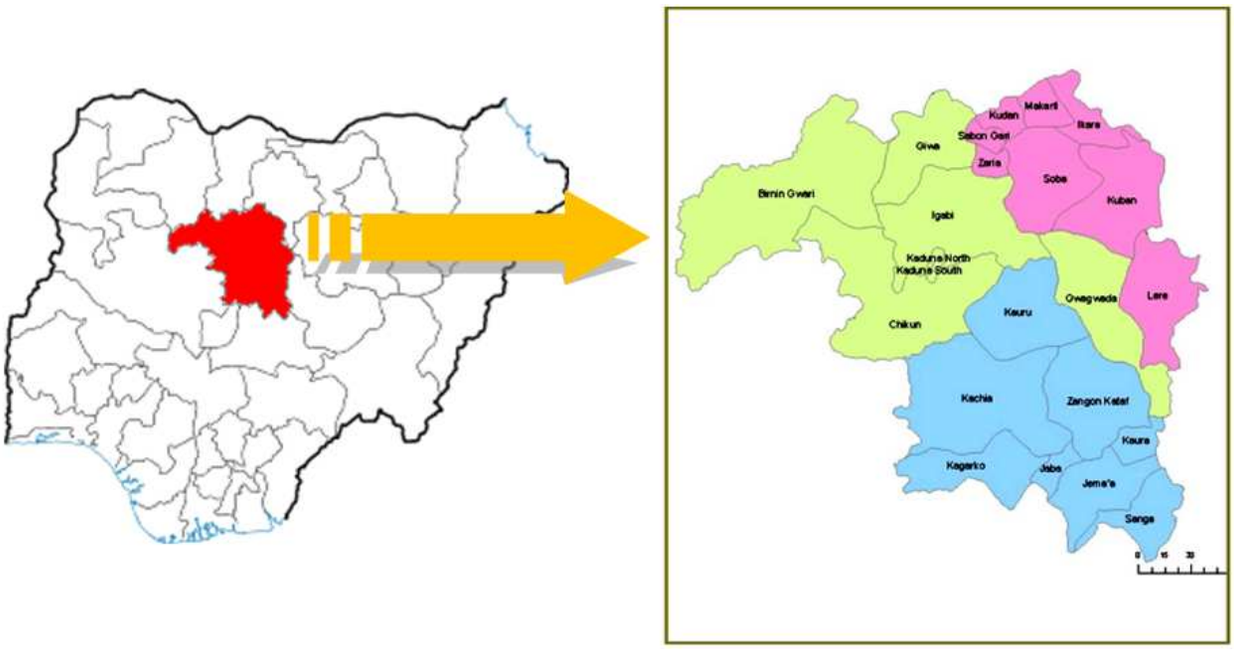

Figure 1. Nigerian map showing location of Kaduna state

Source: Jastrow (2006)

Figure 2. Nok sculpture. Fired clay (Terracotta), 6th century BC–6th century CE, Nigeria. H. 38 cm (14 ¾ in.)

3. Clay minerals and applications in Kaduna State, Nigeria

In most parts of the country, native pottery is a vibrant traditional art practice and an established cottage industry for claywares. Clay has served as an indispensable raw material for the production of products varying from red bricks (for building and decorative purposes) and pottery both at industrial and local levels in Kaduna State. The location of existing brickworks, pottery works and other ceramic production is an evidence of workable deposits within the State.

Specifically, the scope of this study surveyed on the application of the clay deposit as found in Mararaba-Rido, Jacaranda and Maraba outskirt areas of Kaduna State. For these places, the two potential qualities of clay which were of utmost importance to its usage include plasticity and the ability to retain form at the intended firing temperature. The generic property of the clay minerals indicate indicate that of a naturally occurring earthenware/ common clay which is suitable for the production of red bricks and potteries which are refractory enough for stoneware temperature. As observed, majority of the clay fire within the brown-red range of colour commonly referred to as 'terracotta' while grayish/ brownish in its green state.

As noted in [17], earthenware clays are made up of a group of low firing clays that matures at the temperature ranging from cone 08 to cone 02 (940^{o}C- 1060^{o}C). The clays contain relatively high percentage of iron oxide and other mineral impurities, which serve as, flux (a substance that lowers the maturing temperature of the clay). Unlike stoneware clay which is

almost completely vitreous after, earthenware clay is known to be quite porous with porosity between 5 and 15 percent. Usually, when the clay is subjected to temperatures above 1150°C, it deforms, bloats or blisters.

Hence, the clay suitably serves as raw material for commercial bricks making and for fashioning aesthetic and utilitarian vases besides tablewares.

3.1. Commercial bricks making at Mararaba-Rido

The vast clay deposit found at Mararaba-Rido is harnessed for a commercial production of red bricks which are made available for building and decorative purposes. Kaduna Bricks and Clay Products Limited, a factory sited in this area, is highly mechanized, bearing fully automated and capital intensive plants with tunnel kilns built to manufacture clay bricks at large scale. According to the reliable sources interviewed at the site, the factory is said to be capable of producing an average number of 70,000 *medium* sized bricks per day.

The process adopted in the manufacturing of bricks ranging from medium, normal to decorative types involves the following:

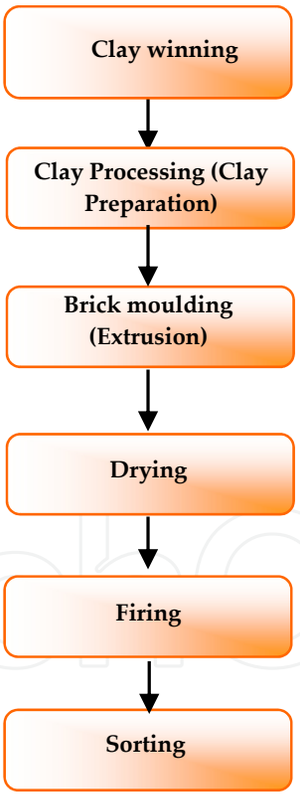

Figure 3. The production process for clay brick industry

- **Clay winning (Quarrying and Transportation)**: This involves the mining of clay from the clay pit or quarry which is situated at about 2km from the main factory. Because the clay material is usually required at bulk quantities, mechanical winning is usually carried out i.e. clay is excavated, transported and dumped at the factory site with the use of drag-line excavator and large dumper truck (Figure 4).

Figure 4. Clay pile at brick factory site for processing

- **Clay Processing (Clay Preparation)**: The processing phases is a stage where heaps of fairly wet clay is being subjected to crushing, grinding and tempering before it can be suitable for shaping/moulding. At the early phase, fairly wet raw clay is dropped inside a box feeder where the clay is being conveyed through a conveyor belt into the wet-pan grinder. With the aid of two high speed rollers inside the wet grinder, the clay is grinded and mixed with water, and then passed through the screen plate into the double shaft mixer for proper mixing (say tempering). Hence, the clay is conveyed into the vacuum double shaft mixer linked to the extruder where the moulding and shaping take place (Figure 5).

Figure 5. Clay processing plants

- **Shaping/ Moulding**: the clay with the aid of an extruder is being shaped into various shapes of bricks and cut into standard sizes with the cutting machine set at a particular cutting length. The shape of extruded bricks is determined by the die mould mounted at the extruder mouth (Figure 6).

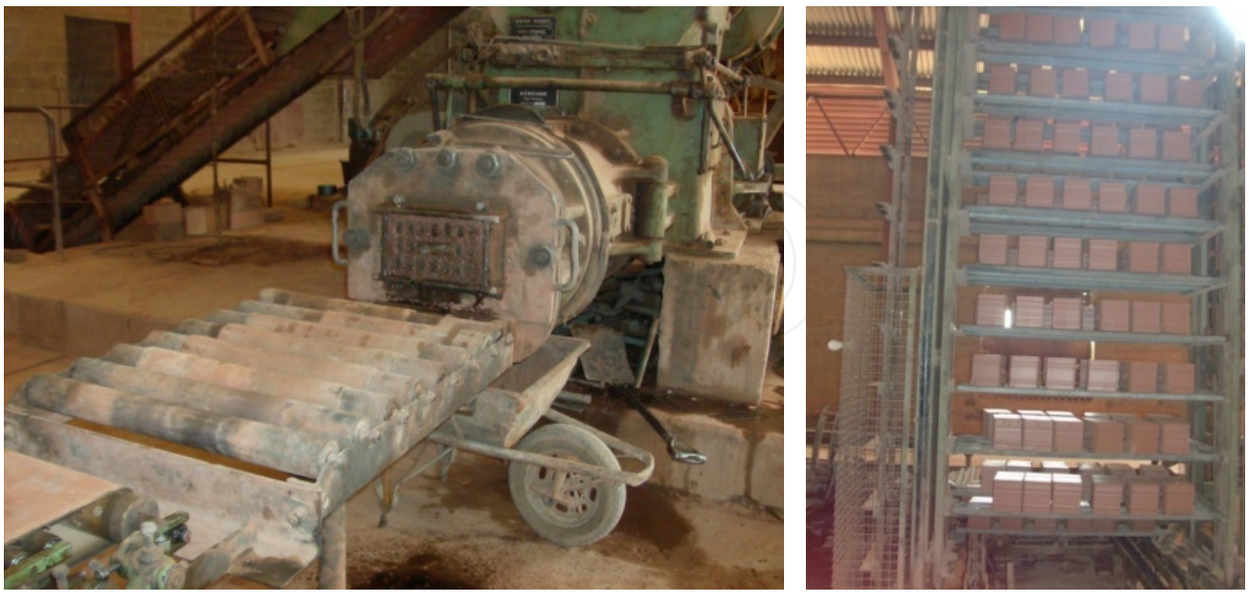

Figure 6. Brick production unit

- **Drying**: Freshly formed green bricks are systematically packed in procession on palettes and loaded through a cross conveyor and the ascending elevator on a finger car truck. With the green bricks arranged on the finger car truck, they are transported to the drier (Figure 7). In the drier, the bricks are being exposed to hot and cold air for an accelerated drying. The hot air is generated from an oven heater (lintel block) besides the heat siphoned from the tunnel kiln.

Figure 7. Brick drying compartment

- **Firing**: Dried bricks are moved from drier with palettes on wheel barrows to the firing chamber after unloading through a downward elevator connected to the cross conveyor at stationed at the dry side. Hence, dried bricks are inter-sparsely stacked in the firing

chamber of the tunnel kiln (Figure 8) and fired to a maturing temperature ranging from 950°C to 1050°C with networks of complex oil burners and fans which help to blow the oil for an accelerated combustion process (air host fixed burner length). Low pour fuel oil (LPFO), also known as black oil mainly serves as the heating fuel.

Figure 8. Tunnel kiln and its inner chamber

- **Dispatching**: Cooled fired bricks are gradually unloaded from the kiln and transported to a designated point around the factory where they are being collected directly by buyers. Prices of bricks products range from N100 (0.63USD) and N38 (0.24USD). Commonly produced brick types include *Medium* size; *Normal* size; decorative types; *Ernest* brick. Refractory bricks (used for the purpose of building furnace, kiln or oven) are also produced but on special demand. In this case, a refractory is composed by blending their clay with other refractory materials like kaolin from Bauchi state, Nigeria.

As noted, Kaduna Bricks and Clay Products Limited is one of the main the main clay-brick producing factories in Nigeria. Most of the brick-making factories that were originally established by the Government are being privatized presently.

3.2. Local pottery production at Jacaranda

The availability of natural earthenware clay at Jacaranda has enabled the production of pottery products varying from decorative and utilitarian vases to tablewares in this area. Situated some few kilometers away from Mararaba-Rido, the clay used in Jacaranda pottery exhibit similar properties in term of plasticity, strength, colour (both at green and fired state). The earthenware clay serves as the basic raw material for the production of pottery articles while some other bodies are derived or composed by blending two or more clay types. For example, a stoneware body will be prepared when tablewares and other articles which require glazing are to be made. Besides, the clay may be enhanced by adding other materials to get a vitrifiable, and more workable clay with less shrinkage.

However, as clearly observed, the pottery center is fully equipped with the basic studio tools and structures required for pottery production. These include kick wheels, throwing

kits, kneading table, studio shelves, dewatering tray, clay pits, fuel kilns and kiln furniture. The production processes used at the center for pottery production is described in the following chart:

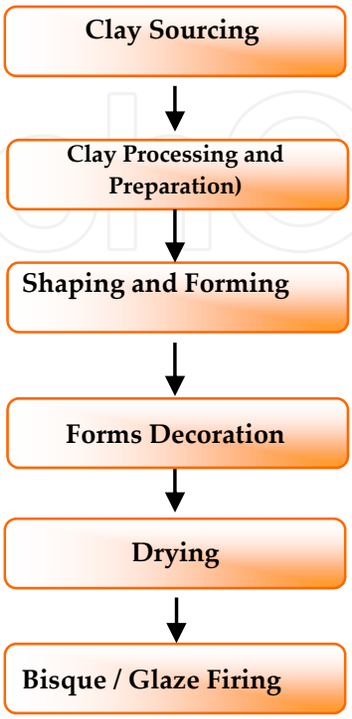

Figure 9. A schematic representation of the pottery production processes and operation

From the information gathered, Jacaranda Pottery is a small-scale ceramic industry which has been in operation since 1982, when it was established by a Briton. Though at present, the ownership of pottery center had been transferred to a Christian organisation with some other assets on the site. This was said to be brought about when the former owner whose residence was in the heart of Kaduna city, got affected by the religious crisis that erupted in the State in 2001 and decided to return to his country. However, the pottery center is still in operation though production activities at the center have not resume to its full capacity as obtained before.

Products include creative ceramic and pottery forms, which serve as ornamental purposes, utilitarian vases and tablewares as shown in Figure 10.

3.3. Maraba pottery, Kaduna

Maraba Pottery is cottage clay industry established in 1985 by set up Danlami Aliyu with the assistance of a British Potter, Michael O'Brien for the purpose of producing local ceramic wares which can meet the needs of local consumers and tourists. The center has also served a skill acquisition center for pottery practice and ceramic studio management. The center was strategically located within the reach of basic raw materials among which are clay minerals carefully collected from nearby sites, blended and manually processed to form stoneware body. The body compositions are basically made from blends of fireclay or ball clay (0-100%) and kaolin (0-70%) Quartz could also be added at 0-30%. Stoneware is generally

Figure 10. Display of unfired and fired pottery wares at Jacaranda Pottery Centre

Figure 11. A cross-section of the clay firing facilities (kilns) at Jacaranda and Maraba Pottery Centres

Figure 12. Clay mineral deposition in an eroded mining site

once-fired with firing temperatures which can vary significantly, from 1100 °C to 1300 °C depending on the flux content. The production process adopts simple machines and improvised tools at various stages such clay processing and preparation, clay forming (Figure 13), decoration and firing. The pottery works from Maraba are culturally inspired with items ranging from tablewares, dinnerwares, decorative wares and souvenirs (Figure 14).

Figure 13. Local clay body preparation and clay throwing process at Maraba Pottery Centre

Figure 14. Unfired pottery and glazed ceramic wares on display at Maraba Pottery Centre

4. Discussions

Reference [20] opined that any ceramic industry, be it big or small, simple or complex, is created to serve some certain immediate and long-term needs within a given societies. Considering the usefulness of various ceramic materials/ products, the ceramics industry especially the local-based ones can play a major role in the socio-economic development of their locality and the country at large.

Housing constitutes one of the most important basic needs of life. A number of building materials exist which have proved themselves to be most suitable material for use in a wide variety of situations, and have a great potential for increased use in the future. Clay bricks

are one of such products, which make use of available indigenous materials which can be manufactured locally.

Considering costs, locally-made clay bricks are among the cheapest of walling material. Besides, it should be borne in mind that if, as stated at a United Nations Conference, a house is to retain its usefulness, it must be maintained, repaired, adapted, and renovated. Thus, choices concerning standards and materials should consider resource requirements over the whole life of the asset and not merely the monetary cost of its initial production. Durable materials such as clay bricks have a cost advantage in this respect [21].

Significantly, the productive applications of clay from the country's vast mineral reserves will foster the conservation of foreign exchange which otherwise cannot be achieved with overdependence on imported materials. It is therefore notable that the efficient utilisation of locally available clay minerals will contributes to the fulfillment of the national socio-economic development through employments generation and industrialization as buttressed in [22]. Nevertheless, environmental issues should not be ignored while benefiting from the wealth of mineral exploitations. Mining operations should be properly coordinated to avoid the adverse effect of environmental depletion (see Figure 12). Reference [22] also noted that the United Nation General Assembly has implied the integration of economic, social and environmental spheres to meet the need of the present without compromising the ability of future generations need.

5. Conclusion

Previous geoscientific mineral studies have revealed that clays of various kinds and grades abound throughout Nigeria's sedimentary basins and on the basement. The mineral hold a significant importance especially to ceramic (pottery) practices in almost all parts of Nigeria from prehistoric period as also noted in [23]. In all parts of the country, native pottery is a vibrant traditional art form and an established cottage industry for earthenwares. There are various applications of clay use among which ceramics and bricks making are prominently featured in this study. Ceramic works at Abeokuta (Ogun State), Ikorodu (Lagos State), Okigwe (Imo State), Umuahia (Abia State) and Suleja in Niger State produce glazed wares from local kaolin. Refractory clays for refractory bricks have been proven at Onibode near Abeokuta where the refractoriness is very high at about 1,750°C.

Having observed the potentialities of clay minerals in the area of ceramic production, more can be achieved if the raw material can be fully exploited and harnessed. When the local raw materials are explored and exploited, it spurs industrial development and self reliance, thus maximizing the use of local raw materials instead of depending on imported ones with its attendant adverse effect on the economy [20]. A good example in this direction has been projected with the case study. Emphasis should be placed more on research through provision of research fund to the higher institutions, investing on the development of local technologies that utilizes local ceramic raw materials. The mining and geological research industries should be revitalized to rise up to the challenges of assisting towards maximum utilization of these raw materials. More research and developmental institutes should be

established and the already existing ones must be properly equipped for effective delivery to researchers.

With the current drive targeted at attaining self-reliance in the local sourcing of industrial raw materials, a new vista can be opened in the previously unexplored areas through mining beneficiation and mineral dressing [24]. This will make it possible to set up profitable ventures for the supply of refined raw materials as feed stock to industries. Furthermore, the empowerment of the small-scale ceramics industry with the ability to compete with foreign products in terms of quality, standard and cost, will better reposition them to contribute immensely to export promotion, employment generation and socio-economic growth of a nation.

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