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Empirical Review of Processing Potentials for Investing in Ohiya-Ibere Industrial Clay Reserves

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ABSTRACT

The effects of beneficiation/acid leaching on the compositions and specific applications of industrial clay reserves at Ohiya and Ibere in Abia State of Southeastern Nigeria were experimentally assessed in this study to resolve the conflicting reports on their quality that scare investors. The clay samples were analyzed/characterized with Atomic Absorption Spectrophotometer (AAS), Lweropho reflectometer and X-ray Diffractometer (XRD) and graded using Ideal pure-kaolin, Chester and Grimshaw kaolin compositional and ISO-brightness (R 457) specifications. Results confirmed that both Ohiya and Ibere clays are kaolinitic with total clay minerals content of 89.8% and 81.9% respectively while alumina and silica constitute dominant oxides in both clays. Beneficiation improved alumina and silica contents of both clays within the set limits and deteriorated their iron oxide contents and brightness/whiteness indices but acid-leaching brought these parameters to specifications. Thus, the raw clays can be used as fireclay refractory and ceramics materials only but beneficiation/acid leaching are essential for their effective ceramics, filling, pharmaceutical, coating and allied industrial applications.

1. INTRODUCTION

Clay is a fine-grained natural rock or soil materials with traces of metal oxides and organic matter which is plastic and tenacious when moist but becomes hard when baked or fired (*Adeagbo et al.*, 2016). It is one of the most used materials due to its low cost, easy procurement from its natural deposit and wide-ranging applications (Carter and Norton, 2013). Clay minerals can be used as mined for bricks, potteries and refractories where the raw material's specification is less vital or as beneficiated/blended clay substrate with consistent properties desired for industrial high-quality production. A clay deposit can be dominated with kaolinite (china and ball) or montmorillonite (bentonite) depending on its mineralogical bonding and properties (Harraz, 2016). China clay is kaolinite dominant clay used for ceramic, filling and coating applications where products appearance is very essential (Jepson, 1984). Ball clay is a kaolinite dominant plastic clay with illite as essential components which provide strength and malleability to a ceramic body prior to firing as well as binding of refractory and non-shrinking components during firing (Manning, 1995). It is best for moulding ceramics such as tableware, stoneware, sanitary ware tiles and bricks as well as production of sealing materials for landfill waste disposal. Bentonites are smectite clays with traces of illite which are used where absorbance is important and in suspensions or slurries where its interaction with the liquid gives a fluid with particular mechanical properties such as formulation of oilfield drilling fluids, cat litter and other animal husbandry products and hydraulic barriers as in waste disposal applications (Odom, 1984; Manning, 1995). Hence, precise mineralogical data of clay reserves is paramount for its effective industrial utilization.

Large scale natural clay reserve command investors' interests but the bulk deposits of this mineral at Ohiya and Ibere in Abia state of Nigeria remains abandoned and left for artisan applications due to declining interest of investors (Ikechukwu, 2018; Nwankwojike, *et al.*, 2020). Investors are scared due to conflicting reports on their compositions and possible applications as well as defects which often characterized artisan potteries made from them (Ikechukwu, 2018; Nwankwojike *et al.*, 2020). Mark and Onyemaobi (2009) showed through mineralogical/chemical analyses that the clays were predominantly kaolinite with silica and alumina as the principal oxides which conform to specifications for ceramics and refractory applications. Mark (2010) also corroborated the viability of Ibere and Oboro Ikwuano clays for refractory applications while Mark *et al.* (2011) stressed that Ohiya clay belongs to the fireclay class of alumina-silicate refractories. Azunna *et al.* (2017) also showed a bulk kaolin reserve of about 74.38 million metric tons at Ohiya from self-potential and lithology tests while Onyekuru *et al.* (2018) revealed that its kaolinitic minerals, silicon and aluminum oxides contents meet general specification for industrial applications. The works of Cajetan *et al.* (2015) and Chima *et al.* (2017) also showed the viability of Ohiya clay for electrical porcelain insulators production. However, the review report of Afolabi *et al.* (2017) which portrays Ohiya and Ibere clays as bentonite prompted doubts and instigated fright on potential investors in these abundant clay minerals. Hence, it is of economic sense to reevaluate the raw composition and processing potentials of Ohiya and Ibere clays reserves in order to encourage investors and provide effective utilization guide in this sector; thus, this study.

2. MATERIALS AND METHODS

The raw clay samples used were obtained from their mining sites at Ohiya and Ibere communities in Abia State of Nigeria. Thereafter, 7 kg of each sample was charged into a rotating cylindrical ball mill to obtain a homogeneous fine particle before beneficiation and acid leaching. Each milled clay test specimen was sieved, dispersed in water inside a plastic container pre-treated with deionized water and stirred vigorously to ensure proper dissolution. At this stage, lime was added to stabilize compositional deficiency of each clay sample. The dissolved clay (i.e., the slurry) was pumped into a vibro-screen of 0.425 mm mesh size to get rid of gangue particles and impurities. The filtrate was then pumped into a filter press to dewater it. The resulting filter cake was finally dried, milled and passed through a finer mesh to obtain the concentrates (beneficiated clay samples). The beneficiated samples (100 g of each clay deposit) were leached with oxalic acid of 40 kgm^{-3} concentration. The mixture was maintained at 80 °C for 5 hours while stirring. It was then filtered, dried at 110 °C to obtain the acid leached specimen. Thereafter, the raw clays were analyzed to determine their mineralogical constituents using X-ray Diffractometer while chemical compositions of the raw, beneficiated and acid-leached-beneficiated clay-samples were determined with Atomic Absorption Spectrophotometer at National Root Research Institute Umudike, Nigeria.

The chemically combined or constitutional water content of the samples was determined using loss on ignition (LOI) test. This involved heating 5 g of each test sample (oven dried at 105 °C for 12 hours) placed in a crucible of known weight (W_I). This was fired at 1000 °C for 1 hour. The crucible was removed from the furnace and allowed to cool down to room temperature before it was reweighed (W_F). The loss on ignition of each test sample was determined from this relation:

$$LOI, \% = 100\left\{\frac{W_i - W_f}{W_i}\right\} \quad (1)$$

The brightness or whiteness indices of four pressed tablets of each clay test sample were determined in accordance with ISO-brightness procedure using a Lweropho reflectometer (SO/CD, 2000). Thereafter average value for each sample were computed and recorded

3. RESULTS AND DISCUSSION

The experimental results of X-ray mineralogical phase analyses shown in Table 1 confirmed that Ohiya and Ibere clays are predominantly kaolinite with total clay minerals content of 89.8% and 81.9% respectively while the chemical analyses results presented in Table 2 showed the dominant oxide compositions detected in both clays, which are the components of the kaolinite formula i.e., alumina (Al_2O_3), silica (SiO_2) and H_2O (LoI). Only small amounts of other metal oxides were present. It is very obvious from Table 2 that beneficiation improved the chemical compositions of both Ohiya and Ibere raw clays by increasing the alumina (Al_2O_3) contents from 32.16 to 39.41% and 30.85 to 39.33% and decreasing the silica (SiO_2) contents from 49.02 to 46.20% and 51.89 to 45.97% respectively within the set limits. The beneficiated samples have deficits of only 0.09% Al_2O_3, 0.35% SiO_2, 0.19% H_2O for Ohiya clay and 0.17% Al_2O_3, 0.58% SiO_2, 0.34% H_2O in the case of Ibere clay. The sum of the associated chemical oxide impurities such as K_2O, Fe_2O_3, CaO, MgO and Na_2O was limited to an acceptable level of 3.99% for Ohiya beneficiated clay and 3.34% in the case of Ibere beneficiated sample. It is also clear from the same Table 2 that beneficiation caused undesired increased from 0.97 to 1.08% and 0.78 to 1.01% in iron oxide (Fe_2O_3) content of Ohiya and Ibere clays respectively. The reason for the presence of increased iron oxide in the beneficiated product may be associated to the impurity bearing compounds that are part of the fine fraction of the beneficiated sample and cannot be removed by just only beneficiation. In addition, the brightness indices/whiteness of the clays decreased after beneficiation (Table 3) while acid-leaching brought the iron oxide contents and brightness/whiteness indices of the beneficiated samples to the desired set limits. Therefore, Ohiya and Ibere clays qualify as fireclay refractory and ceramics materials only without beneficiation since the test-result of the raw samples met Chester and Grimshaw's specifications for refractory and ceramics applications (Grimshaw, 1971; Chester, 1973). Beneficiation and acid leaching improved the parameters of the clay samples close to Ideal pure-kaolin grade (Table 2) thereby making them suitable for general industrial applications. Thus, processed Ohiya and Ibere clays is suitable for refractory and ceramics, filling, coating, pharmaceutical and allied industrial applications.

Table 1: X-ray mineralogical phase analyses results of Ohiya and Ibere clays

Constituents (%)	Ohiya clay	Ibere clay
Kaolinite	77	68
Free Quartz	3.6	4.5
Illite	7	14
Chlorite	2.3	5.9
Montmorillonite	6.9	3.5
Feldspar	2	2
Clay Content = S/N[1+3+4+5]	89.8	81.9

Table 2: Chemical analyses of raw/processed Ohiya and Ibere clays

		Composition (%)							
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	LOI
Specifications	Ceramics applications (Grimshaw, 1971)	40–60	25 – 45	1 – 5	< 2.0	2 – 5	< 2.0	< 2.0	5–14
	Refractory applications (Chester, 1973)	46 – 62	25 – 39	0.4–2.7	0.2- 1.0	0.2- 1.0	0.3 – 3.0	0.3 – 3.0	8 – 18
	General industrial applications (Ideal pure kaolin value)	46.55	39.50	–	–	–	–	–	13.95
Ohiya raw clay	Raw	49.02	32.16	0.97	0.22	1.34	0.28	1.97	12.55
	Beneficiated	46.20	39.41	1.08	0.36	1.55	0.25	0.75	13.76
	Beneficiated/ acid leached	47.34	39.32	0.68	0.25	1.50	0.38	0.83	13.58
Ibere raw clay	Raw	51.89	30.85	0.78	0.29	1.20	0.37	1.23	10.96
	Beneficiated	45.97	39.33	1.01	0.46	1.40	0.22	0.25	13.61
	Beneficiated/ acid leached	46.88	39.24	0.42	0.35	1.03	0.31	0.33	13.50

Table 3: Whiteness analysis of raw/processed Ohiya and Ibere clays

Sample	Y-Values		
	ISO brightness (R 457)	Ohiya clay	Ibere clay
Raw	84.53	85.66	87.25
Beneficiated	69.95	73.46	75.46
Beneficiated/acid	81.37	82.29	83.08

4. CONCLUSION

This study confirmed that Ohiya and Ibere clay reserves are kaolinitic with alumina and silica as the dominant oxides. Beneficiation improved alumina and silica contents of both clays and deteriorated their iron oxide contents and brightness/whiteness indices but acid-leaching brought these parameters to desired set limits. Thus, the raw clays can be used as fireclay refractory and ceramics materials only but beneficiation and acid-leading are essential for their effective ceramics, filling, coating, pharmaceutical and allied industrial applications.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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