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Characterization of Kenyan Ceramics for Production of Medium Duty Alumina Firebrick Incinerator Linings

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ABSTRACT: The aim of this study was to evaluate locally available ceramic raw materials for the manufacture of Medium Duty Alumina Refractory Firebrick for incinerator lining. The clays were collected from two sites, Eburru in Nakuru County and Mukuruwe-ini in Nyeri County in Kenya. Atomic Absorption Spectrophotometer and X-Ray Diffraction analytical methods were used to determine the chemical composition of the respective clays before and after firing at 1000°C for two hours. Atomic Absorption Spectrophotometer results revealed that Eburru Kaolin contained the highest amount of silica at 72.64% SiO₂ but had the lowest of all other oxides. All the three raw materials were found to increase their oxide percentages after firing due to the loss in moisture and organic matter and reflected on their alumina-silica ratio. The X-Ray Diffraction results showed that the refractory formulated using the clays at a ratio of 2:2:1 Eburru Kaolin : Eburru Fireclay: Mukuruweini Ballclay attained good structural properties after firing at 1000°C for two hours and was comparable to commercial products in the market in addition to meeting the standards of a Medium Duty Refractory Firebrick. This is suitable for manufacture of incinerator linings.

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Refractory firebricks are ceramic materials that withstand high temperatures while maintaining their structural properties as well as resist destructive influences such as abrasion, rapid changes in temperature and pressure, corrosion by slags and fluxes, erosion by molten slags (Chlup *et al.*, 2006). They are also expected to withstand load at service conditions, resist contamination of the material with which it comes into contact, maintain sufficient dimensional stability at high temperature after or during repeated thermal cycling, and conserve heat (Chukwudu, 2008). Principally, they are composed of aluminium silicate. Refractories are employed in great quantities in the metallurgical, glassmaking, and ceramics industries, where they are molded into a variety of shapes to line the interiors of furnaces, kilns, and other devices that process materials at very high temperatures (Sani *et al.*, 2011). The high strengths exhibited by primary chemical bonds in refractory materials, enable most of them to possess unusually good combinations of high melting point and chemical inertness (Gustave and Christian, 2017). Clay based refractories are the fireclay materials and are made from clays containing the aluminosilicate mineral-kaolinite (Al₂[Si₂O₅][OH]₄) plus impurities such as alkalis and iron oxides. The alumina (Al₂O₃) content

ranges from 25 to 45 percent (Chukwudu, 2008). Refractories are classified based on the impurity content and the alumina-to-silica ratio (Al₂O₃/SiO₂).

Refractory firebricks are crucial and play a vital role in industrial development of any nation. Currently, Kenya spends approximately Kenya Shillings 3 billion annually to import refractories mostly from India and China for its manufacturing sector despite availability of raw materials and technology advancement, to sustain its manufacturing industrial sector (KIPPRA, 2013). According to Central Bureau of Statistics report of 2014, Kenya has a potential of cutting down firebricks imports to 20% and increase exports by 15% in 10 years (Makokha, 2015).

The main consumers of the firebricks are cement and extractive industries which are on the rise. In general the demand of refractory firebricks is bound to increase tremendously owing to the increased growth of Kenya's manufacturing sector (World Bank, 2013). The boom in the building and construction industry in Kenya has led to increased volume of utilization of cement, leading to high number of new cement manufacturing factories and consequently increasing demand on firebricks.

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The principal raw materials used in the production of firebricks are clay rich in $\text{Al}_2\text{O}_3\text{-SiO}_2$ which are naturally available. Practically, a range of raw materials are utilized to achieve desirable chemical composition of the firebricks (Harbison, 2005). These raw materials are locally available. Kaolin and fireclay are found in Nakuru County at Eburru hills, Gilgil Sub-county, while the ball clay is found in Nyeri County, Mukurwe-ini sub-county. There has been limited economical utilization of these raw materials and the clays do not sustain agricultural activities.

MATERIALS AND METHODS

Sampling: Eburru Kaolin and Eburru Fireclay were sampled from Nakuru County, Eburru location while Mukurweini Ball Clay was sampled from Nyeri County, Rutune location. Samples were collected using clean plastic hoes in the quarry at a depth of 5cm to 100cm below surface then labelled EK, EF, MBC and transported to KIRDI laboratory for analysis. In the laboratory the clays were crushed, grounded, sieved, weighed and stored at room temperature in the laboratory.

Atomic Absorption Spectrophotometric Analysis: The chemical composition of the EK, EF and MBC raw clay sample in percentage weight of (SiO_2 , Al_2O_3 , Fe_2O_3 , Na_2O , K_2O) was determined by analysing for various metal elements using Varian Spectra AA-10 Model Five milligrams of sample was weighed and digested using Hydrofluoric acid and standardized using Sodium Borohydrate (Varian, 1979). The analyte was then diluted to 50 cm^3 and set for analysis in the AAS. Another set of samples was first fired in a furnace at 1000°C and analyzed in the AAS to determine the firing effect on alumina and silica compositions.

The metal concentrations were obtained after correction with the blank. The initial concentration of metal in each sample resulted to various dilution factors; the quantities of metals in each sample was expressed as mg/g.

Loss On Ignition: The organic and water content percentage, of the raw materials were determined by measuring the weight loss of a known mass of the sample after firing in a furnace at 1000°C for one hour thirty minutes.

RESULTS AND DISCUSSIONS

AAS analysis results on EK, EF and MBC as described are as shown in Table 1. The Silica content of Eburru Kaolin was found to be the highest at 72.4% SiO_2 , though it recorded the least content of all the other oxides. The percentage elemental oxides of all samples was found to increase upon firing at 1000°C due to loss of organic matter, moisture and water of crystallization across all of the raw materials. This was reflected in a slight increase of the alumina-silica ratio in EK and MBC. The alumina-silica ratio of EF and MBC of 0.40 and 0.68 respectively were within the range 0.37-0.60 while that of EK was below the standard limit for production of a medium duty refractory firebrick. The percentage of Fe_2O_3 content of EF, 3.01 and MBC, 4.03, were above the required maximum of 2.50% while that of EK, 0.99, was within the required limit of 0-2.50 wt % Fe_2O_3 . Eburru Kaolin, Eburru Fireclay and Mukurweini Ball Clay were mixed in the ratio 2:2:1 to obtain a formulation with desirable chemical composition as shown in Table 2. The Medium Duty Refractory Firebrick (MDRF) was found to have a comparative chemical composition as commercial imported refractories and within the prescribed standards of a medium duty firebrick.

Figure 1 shows the MDRF, XRD diffractogram while Figure 2 shows diffractogram of the MDRF after firing at 1000°C . In Figure 1, there is presence of kaolinite and quartz while in Figure 2 there is presence of mullite, quartz, cristobalite and absence of kaolinite. At 1000°C temperatures firing, kaolinite transforms to mullite while part of quartz transforms to cristobalite. The peak intensity of quartz in the fired raw materials was low compared to the peak intensity in the raw material samples.

Table 1: Chemical Analysis of Firebricks Raw materials before and after Firing

Constituent	EK		EF		MBC	
	EK ¹	EK ²	EF ¹	EF ²	MBC ¹	MBC ²
% SiO_2	72.64	73.11	66.64	68.01	55.38	57.01
% Al_2O_3	24.74	26.01	26.63	27.41	36.85	38.99
% Fe_2O_3	0.71	0.99	02.78	3.01	3.86	4.03
% K_2O	0.05	0.08	0.19	0.27	1.14	1.61
% Na_2O	0.13	0.23	0.17	0.22	0.43	0.57
% TiO_2	0.73	0.11	2.25	2.87	2.96	3.10
LOI	7.83	<0.01	9.86	<0.01	14.79	<0.01
$\text{Al}_2\text{O}_3/\text{SiO}_2$ ratio	0.34	0.36	0.40	0.40	0.67	0.68

¹ Chemical composition of raw material ² Chemical composition of after firing at 1000°C

Table 2: Chemical Composition Analysis of Sample Firebrick Formulation

Elemental Oxide	Standard	Imported	Sample Firebricks STO_3
%Al ₂ O ₃	26-36	33.80	27.53
%SiO ₂	60-70	57.69	65.87
%TiO ₂	≤4	2.26	3.43
%Fe ₂ O ₃	≤2.5	1.94	2.08
%CaO	≤1.0	0.55	0.11
%K ₂ O	≤3	1.20	0.12
%Na ₂ O	-	0.23	0.07
%MgO	-	0.31	0.18
%MnO	-	0.02	0.12
Al ₂ O ₃ /SiO ₂ ratio	≤0.60-0.37≥	0.59	0.42

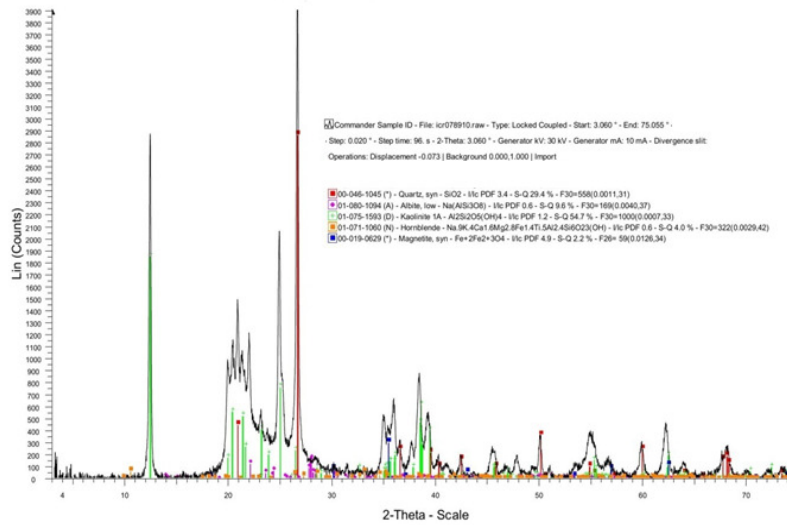


Fig1: Diffractogram of the Sample of the MDRF before firing

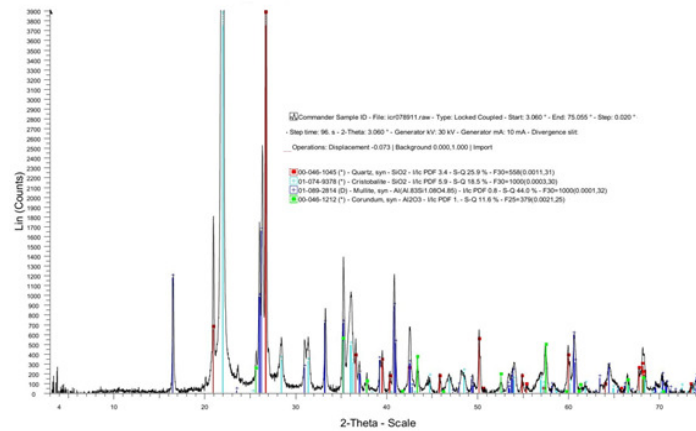


Fig2: Diffractogram of the Sample of MDRF after firing at 1000 °C for two hours

The 2-Theta picks depicting the crystallography of the kaolinite only shifted slightly to the right but generally retaining the structural pattern hence the structural integrity of the constituents of theraw materials.The formulated refractory firebrick samples was found to

retain its structural property after firing it at 1000°C for two hours.

Conclusion:The ceramic raw materials, Eburru Kaolin, Eburru Fireclay and Mukuruweini Ball clays were found to be of suitable quality for the formulation

and manufacture of Medium Duty Refractory Firebricks. The MDRF sample was found to meet the quality standards, and was comparable to the commercial MDRFs in the market. The MDRFs are suitable for the production of incinerator linings in refractories. .

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