

# Chemical Investigation of Alkalari Kaolin Deposit for Its Potential Industrial Applications

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**Abstract:** The kaolin sample from Alkalari in Bauchi State was analyzed to ascertain its metal and metal oxides content and to investigate their potential use for industrial purposes. Neutron activation analysis technique was used for the metals while the turbimetric and Molybdenum Blue methods were used to determine the sulphates and phosphates respectively. The result showed that the Alkalari kaolin with Fe ( $1.3 \times 10^{-3}\%$ ),  $K_2O$  (0.53%),  $Na_2O$  (0.018%),  $TiO_2$  ( $4.6 \times 10^{-4}\%$ ), meets the specification for paper, ceramics, rubber, porcelain, pharmaceuticals, cosmetics and glaze production but its alumina content is slightly below the minimum requirement for these uses except for rubber for which the content is within the specified value and for tiles for which the value is slightly above the specification. The combination of sulphate and phosphate contents which are 4.71% and 2.18ppm respectively could increase their absorbing property and makes them more useful for medicinal and cosmetic purposes. The pH value of the kaolin was found to be 4.3 which makes it unsuitable for most industrial purposes, e.g. rubber and plastic production, the pH need to be increased to 5-7 range (the preferred value for most industrial uses). The nitrate and chloride contents indicated values of 18ppm and 0.3ppm respectively.

**Keywords:** Alkalari, Kaolin, Neutron Activation, Metals, Metal Oxide

## 1. Introduction

Kaolin, named after Kao-Ling, the location of its first major utilization in China, is a common phyllosilicate mineral of the formula  $Al_2Si_2O_5(OH)_4$  [1]. Kaolin is composed of alternating layers of silicate ( $Si_2O_5$ ) and gibbsite ( $Al_2(OH)_3$ ) [2, 3] and its crystals are usually arranged in pseudohexagonal plates forming flaky aggregates with the same chemistry as its polymorphs halloysite, dickite and nacrite. Kaolin clay is formed as a result of the alteration of aluminosilicates (feldspar, feldspathoid, spodumene, sillimanite) and volcanic glasses, sometimes altered by acidic hydrothermal solutions. Besides kaolinite, kaolin clay usually contains different minerals (such as quartz, feldspar, and calcite). It is mostly white, but it also can be grey, yellow or

red [1].

Kaolin finds wide applications in the production of cement, ceramics, bricks and porcelain [4-8]. The greatest demand for kaolinite is in the paper industry to produce a high quality paper [9-11]. It is also used as filler for paint, rubber and plastics [4, 6, 7]. Kaolin clay found its application in medicine, in toothpaste, in cosmetics and as a food additive. Recently, a specially formulated spray is used in fruit and vegetable production to repel the insects and prevent sun burn [12].

Chemical analysis of Alkalari kaolin has become necessary in order to ascertain its suitability for certain industrial applications.

## 2. Materials and Methodology

### 2.1. Sample Collection and Preparation

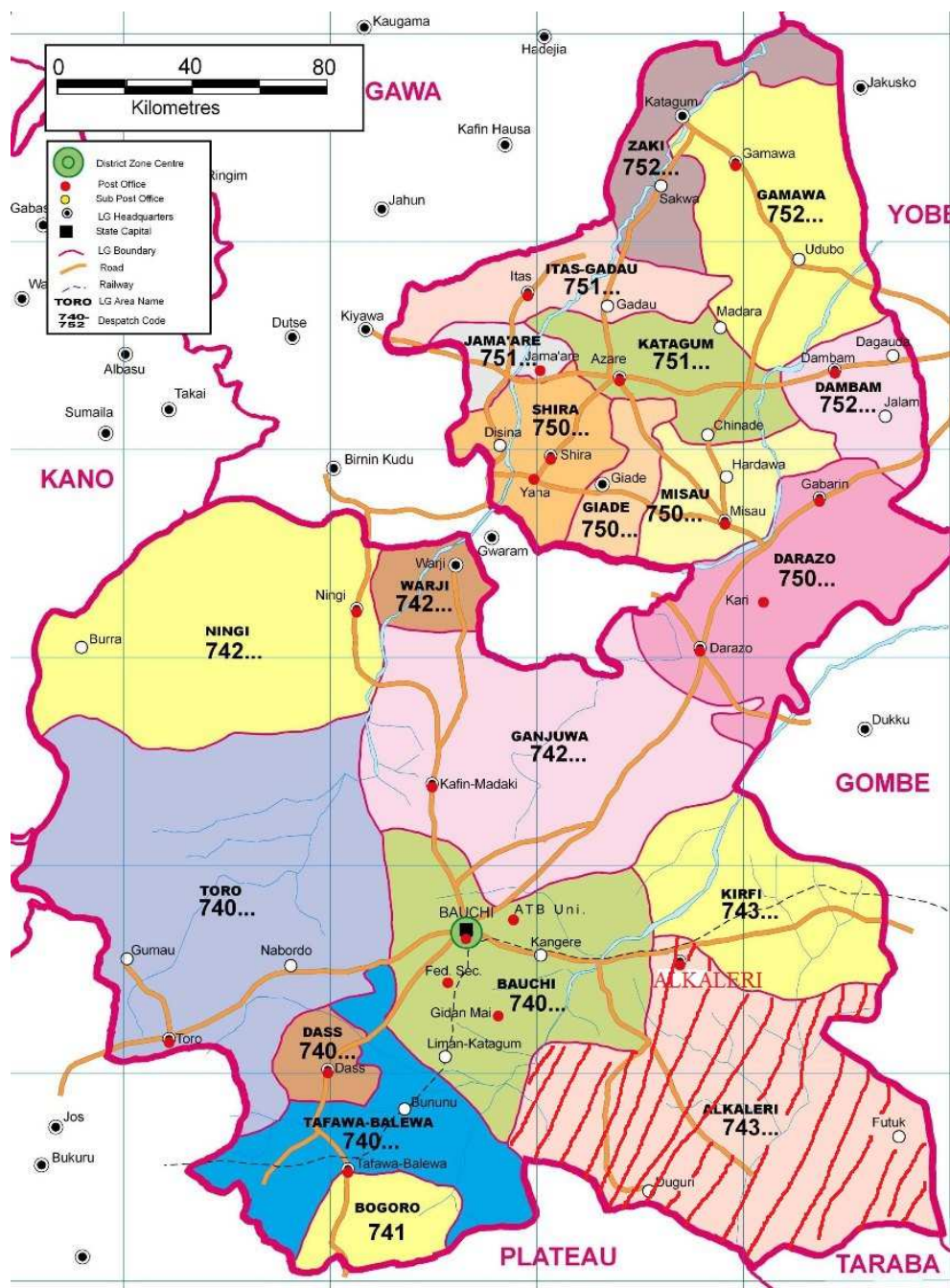


Figure 1. Location map of Alkalari Kaolin Deposit.

Samples were collected from Alkalari in Bauchi state, Nigeria. Alkalari lies between Latitude  $10^{\circ} 16'$  and Longitude  $10^{\circ} 20'$  North Eastern part of Nigeria. The Map of the sample location is shown in Figure 1. The Samples were collected manually into polythene bags at the site at depths of 2m and 4m. They were oven-dried at a temperature of  $100^{\circ}\text{C}$  followed by homogenisation with a pestle and a wooden mortar. This was done through grinding and turning of the mixed samples in the mortar. Thirty-three composite samples

were made from the samples collected at the sites. In order to avoid contamination, samples were kept in a vessel appropriate for the type of irradiation to be performed. Samples requiring short irradiation time ( $< 20$  minutes) and low to moderate flux density were each packed and sealed in  $7\text{ cm}^3$  rabbit capsules. For elements of long activation period, samples were wrapped in polyethylene films and packed in a stack inside the  $7\text{ cm}^3$  rabbit capsule and sealed for irradiation [13].

### 2.1.1. Metal Determination Using Neutron Activation Method

Two analytical procedures of Instrumental Neutron Activation Analysis (INAA) with Near Infra-Red (NIRR-1) carried out at Energy Research Centre of Ahmadu Bello University Zaria were used. The first involved a short irradiation regime of < 20 minutes, followed by gamma ray measurements after appropriate decay period and suitable for identification and quantifying the following elements Al, Dy, Mn, Na, Ti, Zn, Ca. The second procedure involved a long irradiation regime of 6 – 7 hours for identifying and quantifying the following elements; Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Rb, Sm, Ta, Tb, Th, U, Yb.

### 2.1.2. Measurements in Neutron Activation Analysis

The packaged samples were placed near the core of the nuclear research reactor where the neutrons emitted by the reactor interacted with the nuclei of the atoms of the elements causing them to become radioactive. The short regime capsules were sent in for irradiation in turn in an outer irradiation channel B4 where the neutron section or flux is of low to moderate flux densities. The long irradiation regime rabbit capsules were placed in the inner irradiation channels (A1, B1, B2, B3) to take advantage of the maximum value of thermal neutron flux in the inner channels and were irradiated for six (6) hours. The stability of the neutron flux throughout the period was checked by monitoring the neutron flux reading of a fusion chamber connected to a micro-computer control system. Radioactivity measurements of the induced radionuclide was performed by a gamma-ray spectrometry.

### 2.2. Standard for INAA Determination

Varying the accuracy and quantification result of the INAA procedure is as important as with any viable analytical technique, while in theory it is feasible to calculate target atoms mathematically, it is generally not acceptable since there can be significant uncertainties in value available for various nuclear parameters. Equally important is the fact that the neutron energy spectrum and flux densities of the reactor are not always constant and can vary during different irradiation periods. For these reasons, standard certified reference material of the Chinese geo-chemical rock standard GSD -11 and GSR -5 were used as standard for analytical quality control to validate the procedure of elements of interest in the sample [13].

## 3. Results

**Table 1.** Metals and their corresponding oxide composition in Alheri Kaolin.

S/N	METAL	CONTENT	CORRESPONDING OXIDES	CONTENT
1	Al	17.388%	Al <sub>2</sub> O <sub>3</sub>	32.9%
2	Fe	11.07 ppm	Fe <sub>2</sub> O <sub>3</sub>	1.1X 10 <sup>-3</sup> %
3	K	0.44%	K <sub>2</sub> O	0.53%
4	Na	134.7ppm	Na <sub>2</sub> O	0.018%
5	Ti	4.61ppm	TiO <sub>2</sub>	7.9 X 10 <sup>-4</sup> %
6	Ba	42.1ppm	BaO	4.2 X 10 <sup>-3</sup> %

**Table 2.** Metal oxides specifications of kaolin for use in Paper Industries.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	35.0	
2	Fe <sub>2</sub> O <sub>3</sub>	-	4.0

(www.madeinchina.com, 2007)

**Table 3.** Metal oxides specifications of kaolin for use in Ceramics Industries.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	37.47	
2	Fe <sub>2</sub> O <sub>3</sub>	-	0.74
3	K <sub>2</sub> O	-	0.89
4	Na <sub>2</sub> O	-	0.16
5	TiO <sub>2</sub>	-	0.06

(Hansen, 2003)

**Table 4.** Metal oxides specifications of kaolin for use in Rubber and Plastic Industries.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	32.0	45.0
2	Fe <sub>2</sub> O <sub>3</sub>	0.35	0.5
3	K <sub>2</sub> O	0.08	0.1
4	Na <sub>2</sub> O	0.5	1.5
5	TiO <sub>2</sub>	0.05	1.0

(www.tradekey.com/selloffer-view/id/446920.htm)

**Table 5.** Metal oxides specifications of kaolin for use in Pharmaceuticals and Cosmetics.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	38.0	
2	Fe <sub>2</sub> O <sub>3</sub>		0.7
3	TiO <sub>2</sub>		0.05

(www.mp-solutionsinc.com/database, 2007)

**Table 6.** Metal oxides specifications of kaolin for use in Porcelain Products.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	35.0	-
2	Fe <sub>2</sub> O <sub>3</sub>	-	0.8
3	TiO <sub>2</sub>	-	0.2

(www.alibaba.com, 2007)

**Table 7.** Metal oxides specifications of kaolin for use in Glaze production.

S/N	OXIDES	SPECIFICATIONS	
		MIN	MAX
1	Al <sub>2</sub> O <sub>3</sub>	35.0	44.9
2	Fe <sub>2</sub> O <sub>3</sub>	-	0.7
3	K <sub>2</sub> O	-	1.1
4	Na <sub>2</sub> O	-	0.2
5	TiO <sub>2</sub>	-	0.4
6	Ba	-	Insignificant

(www.alibaba.com, 2007)

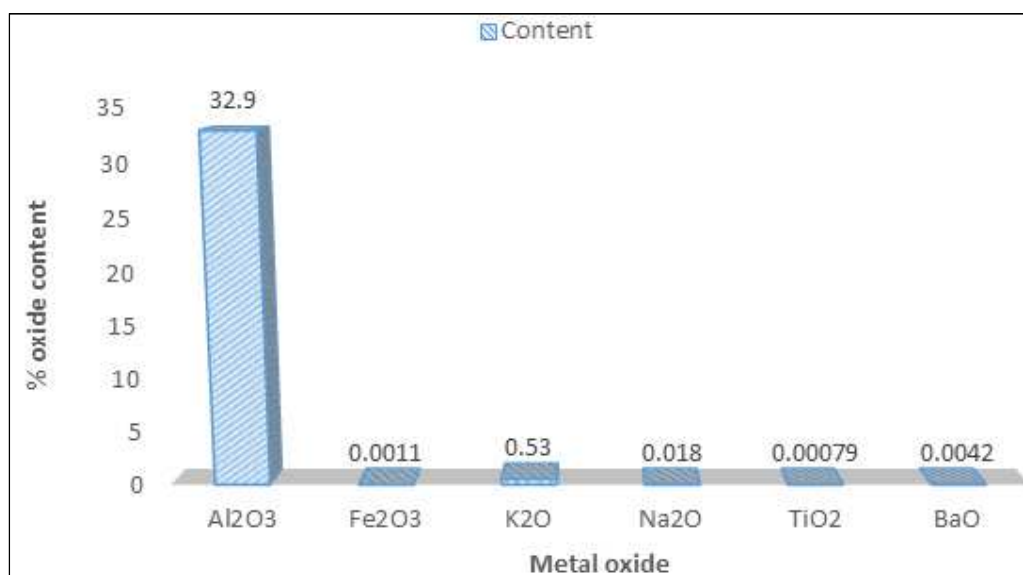
**Table 8.** Metal oxides specifications of kaolin for use in Paints production.

S/N	OXIDES	SPECIFICATIONS
1	Al <sub>2</sub> O <sub>3</sub>	37.0
2	Fe <sub>2</sub> O <sub>3</sub>	0.5*
3	K <sub>2</sub> O	0.04*
5	TiO <sub>2</sub>	0.2*

(www.alibaba.com, 2007), \* = maximum

**Table 9.** Metal oxides specifications of kaolin for use in Tiles.

S/N	OXIDES	SPECIFICATIONS
1	Al <sub>2</sub> O <sub>3</sub>	23.5
2	Fe <sub>2</sub> O <sub>3</sub>	1.1*

**Figure 2.** Percentage oxide content of Alkali Kaolin.

## 4. Discussion

The iron content of ( $1.1 \times 10^{-3}\%$ ) of Alkali kaolin is below the maximum requirement of kaolin for paper production. Thus, it could be used for high quality paper production because the lesser the iron, the better the quality for paper production [14], but the Al<sub>2</sub>O<sub>3</sub> content (32.9%) of the kaolin may reduce its potential use in the paper industry since it is below the minimum specification as shown in Table 2.

According to Hansen (2003), tolerance value for good quality kaolin clay for the ceramic industry is given in Table 3. The Alkali kaolin with the following percentage elemental composition; Fe ( $1.1 \times 10^{-3}\%$ ), K<sub>2</sub>O (0.53%) Na<sub>2</sub>O (0.081%) and Ti ( $4.6 \times 10^{-4}\%$ ) is within the specification for good kaolin clay for ceramic uses, but the Al<sub>2</sub>O<sub>3</sub> content (32.9%) is 2.1% less than the minimum requirement of 35% for ceramic. The Ba content ( $1.2 \times 10^{-3}\%$ ) could pose a health threat in its selective use in the ceramic industry because Ba could be leached from ceramic materials and when ingested is carcinogenic [15] and could cause stomach irritation, high blood pressure, brain, liver and heart damage. This implies that the Al<sub>2</sub>O<sub>3</sub> content which is below the minimum requirement and the Ba content could depreciate the quality

for the ceramic industry.

The industrial chemical specification for kaolin clays used as fillers in rubber and plastic industry given by Ou (2007) is presented in the Table 4. The Al<sub>2</sub>O<sub>3</sub> content (32.9%), Fe ( $1.1 \times 10^{-3}\%$ ), Na<sub>2</sub>O ( $1.81 \times 10^{-4}\%$ ), TiO<sub>2</sub> ( $7.7 \times 10^{-4}\%$ ) are within the specified values for good quality kaolin filler for rubber use. The Mn ( $1.58 \times 10^{-2}\%$ ) though low may affect the vulcanization process, as Mn is expected to be absent in kaolin raw materials for this use. The K<sub>2</sub>O and Mn could reduce the quality but if chemically treated to remove its K<sub>2</sub>O and Mn content, it could be a good quality filler.

The chemical specification in Table 5, implies that the Al<sub>2</sub>O<sub>3</sub> content (32.9%) of Alkali is below the minimum specified range and hence decreased its quality for use in Pharmaceutical and Cosmetic industries but the Fe ( $1.1 \times 10^{-3}\%$ ) and TiO<sub>2</sub> ( $7.7 \times 10^{-4}\%$ ) are within the specified values.

Porcelain material require kaolinite clays with low iron-oxide content to encourage packing and cohesion (binding effect) of the large particle size and minimum titanium content to enhance translucency [15]. This implies that kaolin clay material used for high quality porcelain products should have low iron and titanium-oxide contents. The Fe (0.0011%) and Ti<sub>2</sub>O (0.00046%) values are within the specification

Table 6. However, the  $\text{Al}_2\text{O}_3$  content of 32.9% is below the minimum requirement, hence could reduce the its quality for this use.

Hansen stated that good quality glaze requires kaolin rich in alumina, i.e. the more the alumina the higher their quality and usefulness for glaze manufacture [15]. The general specification for kaolin clay material use for glaze is given in Table 7. The  $\text{Al}_2\text{O}_3$  content of (32.9%) is slightly below the specification but the Fe ( $1.1 \times 10^{-3}\%$ ),  $\text{K}_2\text{O}$  (0.53%),  $\text{Na}_2\text{O}$  (0.081%),  $\text{TiO}_2$  ( $4.7 \times 10^{-4}\%$ ) are all within specification given, and maybe considered good for glaze production.

The specification of kaolin for the paint industry is given in Table 8. The  $\text{Al}_2\text{O}_3$  content of 32.9% is below the specified value but Fe ( $1.1 \times 10^{-3}\%$ ),  $\text{TiO}_2$  ( $4.7 \times 10^{-4}\%$ ) are within specification and could enhanced the quality of Alheri kaolin for this use but the lower  $\text{Al}_2\text{O}_3$  content may slightly depreciates its quality for use in paint industry.

The chemical specification for used for walls and floor is given in Table 9. The Fe ( $1.1 \times 10^{-3}\%$ ) is within the specification but the  $\text{Al}_2\text{O}_3$  (32.9%) is above the specification. Chemical treatment of the Alheri kaolin to reduce it aluminum content could enhance its utility in this regard.

The kaolin indicated a phosphate content of 5.95ppm. The combination of sulphate content of 4.71% enhances it absorbing abilities. Hence, their increased value for cosmetics pharmaceuticals and other scientific use. It also improves the quality for alum production, since sulphate in alum increases its regimentering power. The Nitrate content is found to be 18 ppm. This enhanced the quality of the kaolin for drugs in the treatment of granite poisoning. The chloride content is very low and found to be 0.3ppm. The pH of the kaolin sample is found to be 4.3. This makes it necessary to increase the value to between 5 and 7 so as to make it suitable for most industrial purposes, e.g. rubber production.

## 5. Conclusion

Elemental analysis of the Alheri kaolin has revealed that it has an enormous potential for use as raw material in various industrial applications ranging from pharmaceutical and cosmetic industries, tiles, ceramics, porcelain, paints, rubber and plastics industries as well as paper industries.

The purity and quality of Alkaleri kaolin for any use depends on the alien substances present. While one alien substance can raise the quality of the kaolin for a particular purpose, the same substance could decrease the quality for another purpose. Thus, Chemical treatment of the clay prior to use for specific industrial applications is recommended. It is hoped that the findings of this research would be of immense help to Industrialists and academic researchers globally.

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