Potentials of Alkaleri and KankaraKaoliniteclay for The Production of Aluminum Sulphate

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ABSTRACT

An investigation was carried out on the potentials of Alkaleri and Kankara kaolin for the production of aluminum sulphate using sulphuric acid (H_2SO_4) solutions. The kaolin samples were beneficiated and calcined at 700^{o}C for 7 h to obtain meta-kaolin. The aluminum contents in meta-kaolin were extracted using varied concentration of H_2SO_4 ranging from 30-50% in the increment of 5%. Results obtained revealed that the produced aluminum sulphate were effective in treating Gubi-Dam raw water. Performance evaluations of various parameter tests indicate the superiority of the produced products over the commercial aluminum sulphate and these parameters fell below the World Health Organization Standard. Aluminum sulphate samples produced using 40% and 35% H_2SO_4 gave the best performances for Alkaleri and Kankara clays respectively. Therefore, Alkaleri and Kankara clays can be used to produce aluminum sulphate within the experimental limits used in this study.

Keywords:Beneficiated;Calcined;Kaolin;Sulphuric acid; Coagulant aid.

1. Introduction

The growing need and importance for portable water for domestic and industrial uses cannot be over emphasized. Treatment of raw water to remove unwanted materials is long in practice and the chemical commonly used to achieve this purpose is the aluminum sulphate or otherwise called alum.Alum, $Al_2(SO_4)_3.14\text{-}27H_2O$ or its equivalent double salts of either sodium or potassium is known to be the most common coagulant used in water treatment due to its effectiveness in treating a wide range of water types [1]. Its relatively low cost is the principal factor for its choice as a coagulant despite its shortcomings compared with the more recent coagulants such as polyaluminum chloride (PACl) and polyaluminumsulphate (PAS) [1, 2].

In addition, aluminiumsulphate is a widely used and versatile industrial chemical, playing an important role in the production of many essentials seen and used every day in the home and industry. Most of the alum produced today is used in the pulp and paper industry as well as water and waste water treatment. In Nigeria, it is mainly use as a flocculating agent in purification of drinking water and waste water treatment.In water purification, it causes impurities to coagulate which are removed as the particulates settles to the bottom of the container or more easily filtered. This process is called coagulation or flocculation[3].

There has been steady and growing demand for Aluminiumsulphate (alum) for various technological development and water treatment processes due to increase in portable water demand for domestic and industrial purposes as a result of the increasing global population. Unfortunately, this important chemical is always imported into the country with hard earned foreign exchange. This undoubtedly contributes heavy drain on the national wealth and overdependence on foreign materials. With the growing need for sustainable society and self-sufficiency, it is important to exploit the use of our naturally endowed resources for the betterment of our society.

From time immemorial, aluminum sulphate is produced form raw material called bauxite [4, 5]. Unfortunately, bauxite is often completely absent in known commercial quantity in most developing countries such as Nigeria [6]. Apart from bauxite, the use of kaolin for the production of aluminum sulphate has received great attention in resent time [6, 7, 8]. It has been reported that Nigeria has an estimated reserve of about two (2) billion metric tons of kaolin deposit scattered in different parts of the country [9]. This reserve needs to be properly harness for economic and technological development of the country.

From the aforementioned, an investigation was carried out on the production of aluminum sulphatefrom kaolin locally sourced for Alkaleri Local Government Area in Bauchi State and Kankara clay obtained from Kaduna State.The objectives of this study were; (i) to determine the chemical composition of Alkaleri and Kankara clays, (ii) to determine the chemical composition of meta-kaolin produced from Alkaleri and Kankara clays, (iii) to produce aluminum sulphate from both types of clay using sulphuric acid, (vi) to determine the optimum percentage composition of each type of claywith sulphuric acid and (v) to compare the performance of aluminum sulphate produced to that of commercial one.

If the desired result is achieved, the following benefits would be derived; (i) use of the untapped available raw materials (Kaolin) for creation of wealth, (ii) serves as an import substituting industry, (iii) create job for the teeming unemployed youth, (iv) leads to development of industry and (v) save foreign exchange through self-sustainability.

2. Experimental procedure

2.1. Materials

Alkaleri and Kankara kaolin samples were obtained from Alkaleri Local Government Area of Bauchi State (Nigeria) and Kankara Local Government Area of Katsina State(Nigeria) respectively.The commercial aluminum sulphate used as control and the sulphuric acid used in this study are of analytical grades and were bought from a Chemical Supplier in Bauchi State (Nigeria). Previous investigation carried out on the mineralogical characteristics of both Alkaleri and Kankara kaolin revealed that both clay types are of kaolinite family[10, 11].

2.2. Experimental design

The experimental design used in this study is presented in Table 1:

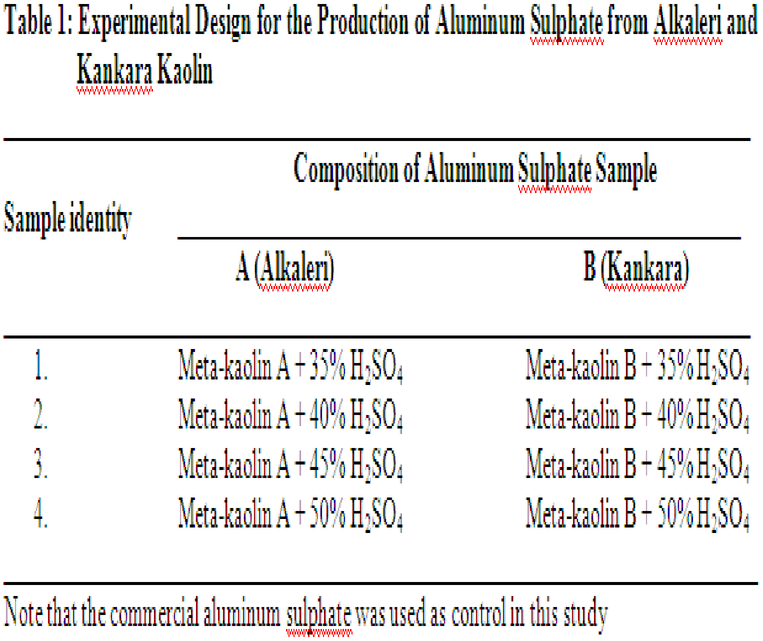

Table 1: Experimental Design for the Production of Aluminum Sulphate from Alkaleri and Kankara Kaolin

Sample identity	Composition of Aluminum Sulphate Sample	
	A (Alkaleri)	B (Kankara)
1.	Meta-kaolin A + 35% H_2SO_4	Meta-kaolin B + 35% H_2SO_4
2.	Meta-kaolin A + 40% H_2SO_4	Meta-kaolin B + 40% H_2SO_4
3.	Meta-kaolin A + 45% H_2SO_4	Meta-kaolin B + 45% H_2SO_4
4.	Meta-kaolin A + 50% H_2SO_4	Meta-kaolin B + 50% H_2SO_4

Note that the commercial aluminum sulphate was used as control in this study

2.3. Methods

2.3.1. Production of aluminum sulphate

Raw kaolin sample obtainedfrom Alkaleri(Sample A) was crushed, groundand washed with distilled water to remove soluble impurities. The washed clay sample was subsequently suspended in water to get rid of intermediate to coarse associated mineral particles. The fine kaolin suspension was allowed to stand for three days to allow proper separation of the solid and liquid into two layers under the action of gravity. The upper layer (i.e. the suspended water) was decanted and the solid layer was further dewatered to a thick mass in a clay bed under the action of pressure. The thick mass of clay resulted was dried for 3 days and then crushed and ball milled into fine powder after which it was classified using 600μm sieves. The sieved particles were calcined to meta-kaolin at a temperature of 700°C for 7hours to activate the kaolin. The activated kaolin known as meta-kaolin was then cooled and the chemical compositionsfor both the raw and meta-kaolin were obtained using the x-ray fluorescence (XRF).

Solutions of 30, 35, 40, 45 and 50% concentrations of sulphuric acid were preparedand used to extract aluminum from the prepared meta-kaolin. Fifty gramseach of meta-kaolin wasmixed with $50cm^3$each of the various concentration of sulphuric acid solution prepared.Each sample was stirred, allowed to settle and decanted; the product obtained after decanting was then washed with distilled water to wash off excess acid and the final product was dried. The samples obtained were used for coagulation experiment on Gubi Dam raw water. The above procedure was repeated for sample B.

2.3.2. Testing of the produced aluminum sulphate samples

Jar tests were carried out to test the coagulation tendencies of the produced aluminum sulphate samples. Details of analyses of the produced samples were presented as follow;

Jar test

An amount of 1g of commercial alum was dissolved in 100ml of distilled water,and then 400ml of 1% solution prepared was poured into a beaker containing 500ml of Gubi dam raw water.This beaker was placed under the jar test flocculator and then the flocculator lowered into the beaker. The jar test flocculator was then switched on and allowed for 3 min.The solution was allowed to settle and the settling time recorded.The solution was then filtered, and the weights of the flocculants recorded. The above procedure was repeated for all the aluminum samples produced and results obtained were presented in Tables 3 and 4.

2.3.3. Quality parameter tests on coagulated water

The following parameters were tested; turbidity, hardness, pH, conductivity, color, conductivity, total dissolved solids, total suspended solids, settling time and floc weight. All the tests were carried out using standard methods well detailed in Abdulsalam*et al*. [12].

3. Results and Discussion

3.1. Analysis of raw and meta-kaolin

The XRF analysis for both raw and meta-kaolin for the Alkaleri and Kankạra clays werepresented in Table2.

Table 2: Elemental Analyses for Raw and Meta-Kaolin for Alkaleri and Kankara Kaolin

Element	**Composition of Samples**			
	A	**A1**	**B**	**B1**
Al	0.1857	0.1910	0.1720	0.1677
Si	0.2340	0.2186	0.1971	0.1910
P	0.0016	0.0000	0.0126	0.0013
Ca	0.0017	0.0019	0.0021	0.0011
Sc	0.0002	0.0000	0.0001	0.0004
Ti	0.0203	0.0370	0.0034	0.0385
V	0.0008	0.0016	0.0014	0.0017
Cr	0.0005	0.0010	0.0006	0.0008
Mn	0.0007	0.0009	0.0001	0.0002
Fe	0.0118	0.0242	0.0175	0.0206
Ni	0.0002	0.0007	0.0004	0.0007
Cu	0.0002	0.0005	0.0004	0.0006
Zn	0.0000	0.0002	0.0004	0.0001
Ga	0.0003	0.0001	0.0002	0.0003
Rb	0.0740	0.0000	0.0896	0.1097
Mo	0.0000	0.0000	0.0025	0.0000
Rh	0.0042	0.0003	0.0138	0.0178
Re	0.0010	0.0021	0.0007	0.0177
Cd	0.0000	0.0175	0.0087	0.0149
Te	0.0000	0.0008	0.0000	0.0000
Ta	0.0000	0.0009	0.0000	0.0000
Ir	0.0000	0.0035	0.0020	0.0038
Os	0.0000	0.0000	0.0011	0.0000
Total	**0.5373**	**0.5029**	**0.5268**	**0.5888**

From Table2, it can be seen that there were changes in the composition of the major elements (i.e. Al and Si) after beneficiation and calcinations stages; these can be attributed to removal of impurities contained within the matrix of kaolin samples. In sample A, the composition of Si decreased from 0.234 to 0.2186 while that of sample B decreased from 0.1971 to 0.1910. These decreased in elemental compositions can be attributed to the removal of sandy and quartz particles during the beneficiation process. Conversely, the alumina composition in sample Aafter beneficiation and calcinations increased from 0.1857 to 0.191. On the hand, the alumina content in sample B decreased from 0.1720 to 0.1677.This can be attributed to contamination of the beneficiated kaolin with impurities during the drying process.

3.2. Quality parameter tests on coagulated water

The results obtained for the quality parameter tests were presented in Tables 3 and 4. From these tables, it can be seen that the parameter values obtained for raw water indicates that it was not portable for drinking and hence treatment wasrequired. Investigationrevealed that parameter values for all the treated samples were below those of commercial aluminum sulphate except flocculant weightsand settling times for both clay samples. From the aforementioned, the flocculants sizes produced from the commercial alum were longer and heavier than those produced using the two kaolin types. The flocculantsizesfor the two kaolin types can be increased by using a coagulation aid such as the polyelectrolyte. Once flocculant sizes are enhanced, it will automatically bring down settling times for these samples.

In addition, the results obtained for all the samples investigated fell below or within the limits specified by the world health organization (WHO) as presented in Table 5. For Alkaleri clay, the sample produced using 40% H_2SO_4 gave the best result while the sample produced using 35% H_2SO_4 gave the best result for Kankara clay. Therefore, these two optimum compositions i.e. 40% and 35% sulphuric acids can be used for commercial production of aluminum sulphate from Alkaleri and Kankara clays respectively within the limit of experimental procedure used in this study.

Table3: Jar Test Analysis for Raw Water and Alum Produced from Alkaleri Kaolin (Sample A)

Parameter	R.W	C. A	Alum produced using various concentration of H_2SO_4				
			50%	45%	40%	35%	30%
Turbidity (NTU)	6.000	1.0000	0.0000	0.0000	1.0000	0.0000	0.0000
Hardness (mg/L)	60.00	60.000	60.000	60.000	60.000	60.000	60.000
TDS (mg/L)	73.40	130.00	150.00	130.00	140.00	140.00	130.00
pH	5.000	7.2000	6.7000	6.9000	7.1000	6.5000	6.9000
Color (ptCo)	29.00	9.0000	2.0000	3.0000	3.0000	0.0000	0.0000
Conductivity (µs/cm)	146.9	260.00	280.00	260.00	260.00	280.00	280.00
Weight of Flocculants (g)	N/A	0.0227	0.0166	0.0131	0.0203	0.0102	0.0183
Settling Time (min)	N/A	42.000	55.000	55.000	45.000	50.000	50.000

C.A: commercial alum; flocs: flocculants; N/A: not applicable; R.W: raw water

Table4: Jar Test Analysis for Raw Water and Alum Produced from Kankara Kaolin (Sample B)

Parameter	R.W	C.A	Alum produced using various concentration of H_2SO_4				
			50%	45%	40%	35%	30%
Turbidity (NTU)	6.000	1.0000	2.0000	0.0000	0.0000	2.0000	0.0000
Hardness (mg/L)	60.00	60.000	60.000	60.000	60.000	60.000	60.000
TDS (mg/L)	70.00	130.00	140.00	140.00	150.00	130.00	140.00
pH	5.000	7.2000	7.5000	7.0000	6.8000	7.2000	7.0000
Color (ptCo)	29.00	9.0000	3.0000	2.0000	3.0000	7.0000	0.0000
Conductivity (µs/cm)	150.0	260.00	280.00	280.00	260.00	280.00	270.00
Weight of Flocculants (g)	N/A	0.0227	0.0156	0.0102	0.0131	0.0211	0.0166
Settling Time (min)	N/A	42.000	50.000	55.000	45.000	40.000	50.000

C.A: commercial alum; flocs: flocculants; N/A: not applicable; R.W: raw water

Table 5: Maximum Allowable Limits by World Health Organization for Portable Water

Parameter	Value/Limit
Turbidity (NTU)	0-5
Colour (PtCo)	15 maximum
Conductivity(µs/cm)	1000 maximum
Hardness (mg/L)	150 maximum
pH	6.5-8.5
Total Dissolved Solid TDS(mg/L)	500 maximum

4. Conclusion

From the results obtained in the study, the following conclusions can be drawn;

1. Alkaleri and Kankara clays were very effective for the production of Aluminum Sulphatewithin the limit of experimental procedure used in this study.
2. The optimum H_2SO_4 concentration for the production of AluminiumSulphate from Alkalericlay was 40% and that of Kankara clay was 35%.
3. The Aluminum Sulphate produced from Alkaleri and Kankara clays were very effective in treating Gubi Dam raw water as the quality parameter values for the coagulated water fell below the world health organization standards.

Based on the results obtained in this study, We wish to recommend that the outcomes of this study should be scaled-up for the development of a pilot plant for the production of aluminiumsulphate from the two tested clay types. In addition, further investigations should be carried out on the use of other untapped kaolin deposits in Nigeria for the production of aluminum sulphate and associated products.

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