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Extraction and applications of aluminum hydroxide from bauxite for commercial consumption

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A B S T R A C T

Bauxite ore was collected from Khyber Pakhtun Khawa (KPK), Pakistan for extraction of aluminum in the form of aluminum hydroxide. The ore consists of 31.11% aluminum and other minerals (SiO_2, Fe_2O_3, Na_2O, CaO) was leached with alkaline solution. The aluminum extraction in the form of aluminum hydroxide from the clear solution in filtrate was successfully done by different processes involving autoclave, centrifuge and solvent extraction while the red mud in the form of residue was separated and recycled. The recycling process of iron from red mud was divided into roasting magnetic recovery, the reducing smelting method for iron separation. After extraction the composition of Al, Fe, Si, and Ca were determined from aluminum hydroxide and red mud both by chemical and spectrophotometric analysis. The compound was further characterized by FT-IR and results showed that a considerable amount of aluminum in the form of aluminum hydroxide was extracted along with other minerals.

Capsule Summary: Bauxite ore was leached with alkaline solution, recovered and found that this method possibly be used for the extraction of aluminum in the form of aluminum hydroxide along with other minerals such as Al, Fe, Si, and Ca.

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INTRODUCTION

Bauxite ore is a good source of aluminum, has hard off-white to reddish brown rock color. It is the 3rd most abundant element of earth crust and due to its corrosion resistance, good electrical conductivity and light weightlessness is becoming popular in modern world. It is the 3rd hardest element in nature after diamond and silicon carbide (carborundum) and does not exist in nature in metallic form rather occurs in the form of silicate (clays), oxides and hydroxides due to its high reactivity (Fahad and Iqbal, 2009; Klauber, 2009; Plunkert, 2000; Robert and Charles, 1970; Rai et al., 2012; Shaheen et al., 2010; Shwartz and Lalik, 2012; Sutar and Mishra, 2014; Virotec, 2003; William, 2007). It has a very low solubility at intermediate pH, so biologists consider it non-essential in life processes, although it is wide spread in nature. Bauxite was first found in Les Bauxite (France) in 1821 (Shwartz and Lalik, 2012) and is mainly consists of mixture of hydrous aluminum oxides and

hydroxide, iron hydroxides, free silica and clay as a major constituent (Bush, 2007). With increasing demand of aluminum in modern world, it is being mined in every continent of world except Antarctica, but tropical and subtropical zone are major sources because they provide optimum conditions for production (Sutar and Mishra, 2014). The largest reserves of Bauxite in world are present in Australia (54%), Jamaica, Brazil and Guinea. These reserves are found to be formed by residual concentration of aluminum oxide (hydrous form) during weathering of minerals of aluminosilicates (Lillian and Becker, 2013; Virotec, 2003). Red colored bauxite shows high contents of iron. In Pakistan, Bauxite has been found in Kotly, Muzafarabad, Khoshab, Loralai and in many other cities. Kala Chitta range of Attock contains 30-60% alumina that equals 96 million tons. Aluminum hydroxide also known as hydrated alumina is found in nature as polymorph. It mainly occurs as a mineral Gibbsite and other three polymorphs have also been found. All these form have aluminum hydroxide in $Al(OH)_3$ form, but all these differ in the internal structure, inter-layer spacing and rate of acidic and basic reactions. Four known forms of aluminum hydroxide are Gibbsite, bayerite, ordstrandite and doyleite based different physical and chemical properties. Due to amphoteric nature of $Al(OH)_3$, it is also used as buffering agent (Fahad and Iqbal, 2009; Plunkert, 2000; Robert S., Charles, 1970; Shaheen et al., 2010; Shwartz and Lalik, 2012; Sutar H., Mishra, 2014; William, 2007). It is used in the refining of sewage water, improve the developing quality of photographs, as coating on clothe to make it waterproof, as good fire retardant and as mordant to allow the dyes to go through the fabric. Due to its non-toxic effect on human, it is also used as additive in skin cleansers, moisturizers and body lotions, for manufacturing of heat resistant glass, as an ink preservative and used as an anti-acid to lower the acidity of stomach. The high phosphate in the blood of kidney patients is controlled by $Al(OH)_3$ aluminum hydroxide has pathological persistence and therefore used in formation of vaccines (Fahad and Iqbal, 2009). In Present study, Al(OH)3 was extracted, separated and characterized.

MATERIALS AND METHODS

Analytical grade chemicals and reagent including sodium hydroxide, sodium carbonate and solvents were purchased from Acros Organics, Sigma- Aldrich and Lab Scan, and were used without any further purification. Melting points were determined by electro thermal open capillary method.

In present work, the amount of aluminum hydroxide in bauxite was estimated, collected from KPK, Pakistan by alkali treatment. The method used is known as Bayer's method and involves following steps and scheme is shown in Fig. 1.

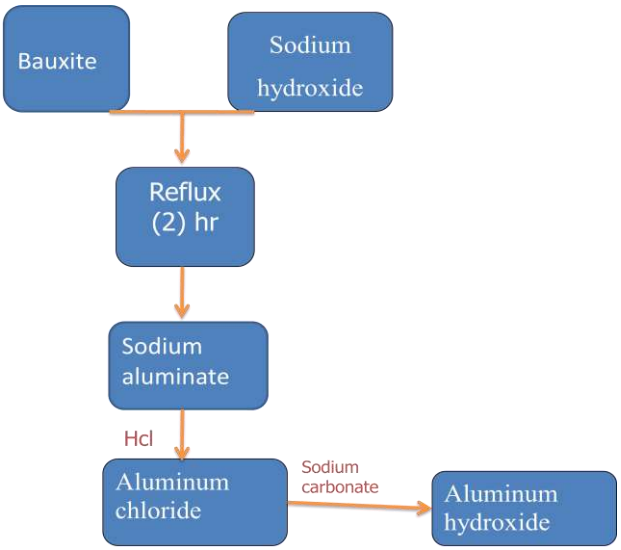

Fig. 1: Schematic diagram for extraction of aluminum hydroxide from bauxite

$$Bauxite + NaOH\ (aq) \rightarrow NaAlO_2 + Red\ Mud + aq. \quad (Basic\ pH)$$

$$NaAlO_2 + HCl\ (excess) \rightarrow AlCl3 + aq. \quad (Acidic\ pH)$$

$$AlCl_3 + Na_2CO_3\ (aq) \rightarrow \downarrow Al(OH)_3 + CO_2\uparrow + aq. \quad (Neutral\ pH)$$

The extracted aluminum hydroxide was characterized by using different spectroscopic techniques. Fourier transform infrared (FTIR) spectra were recorded on a Perkin Elmer FTIR Spectrum B (England). The composition of Al, Fe, Si, and Ca were determined from aluminum hydroxide and red mud by spectrophotometric analysis using double beam

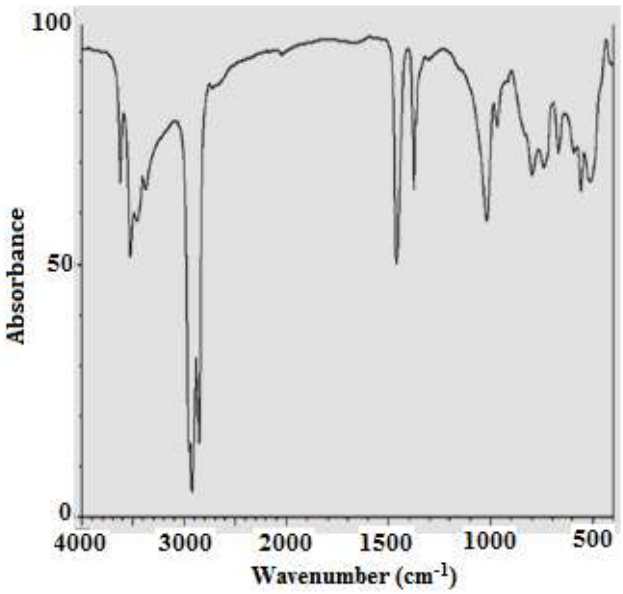

Fig. 2: FT-IR spectrum of aluminum hydroxide

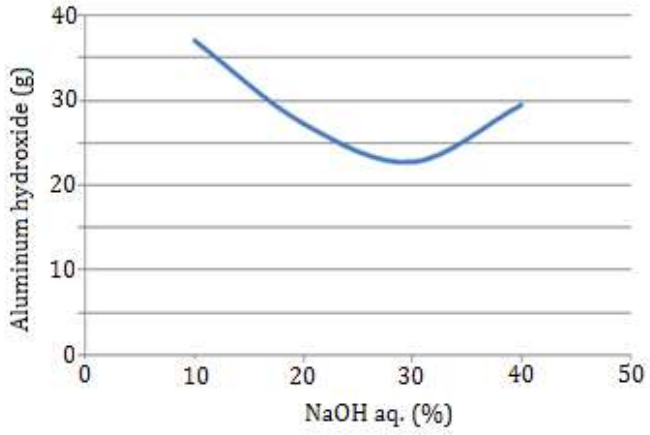

Fig. 3: Different compositions comparison

Spectrophotometer (UV-1700, Shimadzu).

Sample collection and material used

Before extraction, bauxite sample were ground into fine powder and passed through 30 mesh- sieve to obtain a homogeneous sample. All chemical reagents used were of analytical grade and utilized without purification. Distilled water was used for preparation of all solutions. Absorbance measurement was done using A A 700F Shimadzu atomic absorption spectrophotometer (UV-1700, Shimadzu).

Extraction Procedure

NaOH 130 mL (10%) was prepared, powdered bauxite was mixed in it till slurry obtained (~119 g) and solution was heated at 120 atm for 40 min. After cooling clear solution was separated (~75 mL) and slurry was centrifuged at 8500 rpm to extract maximum clear solution and 2*M* solution of HCl was added in clear solution till all the precipitates get dissolved again (~137.5 mL was used) and 75 mL distilled water was also mixed. A 10% aq. solution of Na_2CO_3 was mixed in solution till neutral pH (~85 mL was used), these precipitates were filtered and air-dried and 5% NaOH was added into the solid residue obtained during earlier step (~75 mL) and autoclaved for 10 min. Clear solution was separated and similar process was repeated for this clear solution. Precipitates obtained were air-dried and weighed. This whole process was repeated for bauxite powder with 20%, 30% and 40% aqueous solution of NaOH and data, thus obtained was plotted.

RESULTS AND DISCUSSION

The physical properties of the product were noted and shown in Table 2. FT-IR was used to confirm the functional group of the compound. The range used for the FT-IR spectra was 4000-400 cm^{-1} as KBr pallets. This assignment was made on the basis of previously work (Yousaf et al., 2013). The bending and stretching frequencies for hydroxyl group were

Table 1: Physical properties of bauxite

Location	KPK Pakistan
Color	Light yellow
Bauxite used(g)	119
$Al(OH)_3$ (%)	31.11
Red mud wt (gm)	72.23
Weight loss (gm)	15.7

Table 2: Physical properties of aluminum hydroxide

Parameter	Properties
Molecular formula	$Al(OH)_3$
Molecular mass	78.00 g/mol
Appearance	White amorphous powder
Density	2.42 g/cm^3, solid
Melting point	300 °C (572 °F; 573 K)
Solubility in water	0.0001 g/100 ml (20 °C)
Solubility	Soluble in acids, alkali, HCl,H_2SO_4
Acidity (pKa)	> 7

Table 3: Characteristic IR absorption frequencies of compound in cm^{-1} due to bending and stretching vibrations for hydroxyl group

Frequency type	Observed value	Standard Value
	cm^{-1}	cm^{-1}
Bending Vibrations	3632	3640–3610
Stretching Vibrations	940	950–910

Table 4: Production of aluminum hydroxide at different compositions

NaOH	PPT of $Al(OH)_3$	$Al(OH)_3$
%	g	%
10	37.02	31.01
20	27.21	22.86
30	22.69	19.06
40	29.44	24.73

observed at 3632 cm^{-1} and 942 cm^{-1}, respectively. The results can be visualized from the FT-IR spectrum attached in Fig 2. A 37.02 g of dried precipitates were obtained (comprising 31.11% total bauxite) using 10% NaOH solution and presence of aluminum hydroxide was confirmed using atomic absorption spectrophotometer. Maximum amount of precipitates were obtained using 10% solution while other solutions did not produce cost-effective amount. These precipitates were in the form of beads and they were dissolved in different solvents like water, methanol. Its insolubility in water also added confirmation to presence of aluminum hydroxide. So, demand of aluminum in Pakistan can be fulfilled by using this process. Red mud separated initially is also of great importance because it can be used in many fields like water purification, production of construction material, as a catalyst in many reaction and recovery of other metals in oxide form like Fe_2O_3, TiO_2, ZrO etc.

CONCLUSIONS

It is concluded from the results that 37 g $Al(OH)_3$ obtained from Bauxite collected from KPK, Pakistan contained high amount of Al and this method can be used on industrial scale due to its easiness and low-cost. Moreover, only 10% solution is cost-effective and useful on industrial scale. The alkaline bauxite residue can be used to decrease the acidity of soil which needs investigation for conditions optimization.

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