

## EVALUATION OF BAUXITE OF KHUSHAB (PAKISTAN) AS A RAW MATERIAL FOR EXTRACTION OF ALUMINUM

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**ABSTRACT:** Bauxite ore found at Punjab Quarry, Khushab (Pakistan) has been analyzed and evaluated to determine its constituents and feasibility of extracting aluminum by Bayer Process. Al, Fe, Ti, Ca, Na, K, Mg, Cl, and Si have been estimated in the samples. The highest alumina ( $\text{Al}_2\text{O}_3$ ) content (60 to 73 %) has been found in the deposits of Punjab Quarry. From the data obtained in this study, it may be safely said that bauxite of this area is suitable for extraction of aluminum by a small size Bayer Process Plant having annual feed of 1.2 million tons.

**Key words:** Aluminum; Bayer process; Bauxite; Minerals; Ores.

### INTRODUCTION

Aluminum is the third most abundant element of the earth crust (7.5%) after oxygen (46.4%) and silicon (28.2 %) (Mistrik and Huttova, 2002). It is an important metal which has immense utility in different fields from kitchen ware to aircraft industry. It is an excellent conductor of electricity and heat as well as a good reflector of light and radiant heat. Characteristics and versatility of aluminum can be improved by alloying it with other metals (copper, magnesium, manganese, silicon and zinc). Aluminum's tensile strength, hardness, corrosion resistance and heat treatment properties make it useful metal to be used in domains of transportation (29%), packaging (23%), building, construction (19%), electrical (8%), machinery, equipment (8%), and consumer goods (6%). Mankind has been using copper, lead and tin for thousands of years and yet today more aluminum is produced than all other non-ferrous metals. Annual primary production in 1999 was about 24 million tons and secondary - recycled - production to some 7 million tons. The total of some 31 million tons compares with 14.1 million tons of copper, 6.0 million tons of lead and 0.2 million tons of tin (Chevalier, 1996).

Aluminum is never found in nature as an element because of its chemical reactivity, but only exists in very stable combinations with other materials (particularly as silicates and oxides) consisting of a mixture of hydrated aluminum oxides and hydroxides, generally contaminated with compounds of iron, which impart red colour. It is formed by the chemical weathering of rocks in tropical and sub-tropical climates. The areas include Africa, the West Indies, South America and Australia. There are also some deposits in Europe. Guinea possesses the largest deposit of bauxite in the world (Glenn and Considine, 2000). Bauxite is an important ore of aluminum, consisting of aluminum oxide of various degrees of hydration (amorphous aluminum

oxide dihydrate is  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ), varying in colour from white to brown, and is dull in appearance. The name bauxite was given in Mesoic era when bauxite was discovered in the village Baux in France (Hurlbut and Sharp, 1995). Bauxite ore is not only used as source of aluminum but red mud also, (recovered as a byproduct after the processing of bauxite by Bayer process) finds several applications such as for water treatment: e.g. removal of phenols (Tor, *et al.*, 2006), heavy metals (Gupta and Sharma, 2002; Genc, *et al.*, 2003; Lo'pez, *et al.*, 2003; Genc-Fuhrmab, *et al.*, 2004, 2005; Santona, *et al.*, 2006; Zhang, *et al.*, 2008), nitrates (Cengeloglu, *et al.*, 2006), phosphates (Li, *et al.*, 2006), dye colours (Wang, *et al.*, 2005), for decontamination of acidic leachates (Komnitsas, *et al.*, 2004), for remediation of soil and mine sites (Gray, *et al.*, 2006; Bertocchi, *et al.*, 2006), for manufacturing of building material like cement (Li, *et al.*, 2003; Tsakiridis, *et al.*, 2004), ceramics (Peng, *et al.*, 2005; Pontikes, *et al.*, 2007), casting components (Smith, *et al.*, 2006), for recovery of metals (Cengeloglu, *et al.*, 2003), for production of pozzolanic pigments (Pera, *et al.*, 1997), for treating gold ores (Browner, 1995), as sorbent of  $\text{SO}_2$  (Dhupe, *et al.*, 1988), and adsorbent for  $\text{H}_2\text{S}$  (Snigdha and Vidia, 2008), for preparing X-ray shielding materials (Hala'sz, *et al.*, 2005) and as corrosion inhibitor for carbon steel (Amritphale, *et al.*, 2007).

In Pakistan bauxite is found in Kotly, Muzaffarabad, Ziarat, Sibbi, Attock, Hazara, Loralai and Khushab districts. Bauxite reserves of Pakistan are estimated about 74 million tons by Geological Survey of Pakistan. Pakistan is developing country and consumption of aluminum is rapidly increasing in industrial and domestic domains which necessitate the exploration of new aluminum resources and evaluation of existing reserves for extraction of aluminum.

Keeping in view the importance of bauxite, this project was designed to evaluate the aluminum reserves

of Khushab District to determine the utility of the ore for extracting aluminum.

## MATERIALS AND METHODS

**Sample collection and general procedure:** The samples of bauxite were collected from Punjab Mineral Development Corporation, Khushab which had been collected from 6-10 feet depth of the surface of deposit by removing 5-6 feet weathered soil surface. Physical appearance of different samples and their sites of collection are given in Table -1. Ten samples from each site (triplicate) were taken and ground, homogenized and passed through 200 mesh sieve.

All chemicals used in the analysis were of A. R grade, manufactured by E. Merck, Germany and were used as such without purification. Sub-boiled deionized water was used for making all solutions. A Hitachi Z6100 Zeeman atomic absorption spectrophotometer was used for the absorbance measurements, and reagents were prepared as reported in literature (Lau, *et al.* 1995).

### CHEMICAL ANALYSIS

**Determination of moisture contents:** Two g powdered sample was taken in the platinum crucible heated in an oven at 110° C for 2 hours. The crucible was cooled and weighed. Percentage moisture content of each sample was calculated.

**Loss of mass on ignition:** Dried samples were heated in the furnace at 400-500°C and temperature was raised to 1000 °C for 1 hour. The samples were cooled and weighed to calculate the weight loss on ignition.

**Estimation of silica:** Silica in the samples was determined by a combined gravimetric and atomic-absorption spectrophotometric procedure (Walsh, 1977).

**Estimation of R<sub>2</sub>O<sub>3</sub> GROUP (R= Al<sup>3+</sup>, Fe<sup>3+</sup> AND Ti<sup>4+</sup>)** Fifty mL stock solution was taken into 250 mL beaker, 2-3 drops of nitric acid were added and solution was heated, boiled and cooled. 5.0 g ammonium chloride was added and mixture was again boiled, cooled and few drops of methyl red and ammonium hydroxide were added. Mixture was again boiled, cooled and filtered. The precipitate was ignited to constant weight and percentage of the R<sub>2</sub>O<sub>3</sub> group was calculated for each sample.

**Estimation of Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, MgO, CaO, Na<sub>2</sub>O and K<sub>2</sub>O:** A portion of sample (0.100 g) was weighed accurately and mixed thoroughly with 0.8 g of the fusing agent, namely, oxalic acid, lithium carbonate, lithium tetraborate (1:1:1), in a platinum crucible, which was then covered and placed in a muffle furnace at 925°C for 10 min. The crucible lid was then transferred to a 400 mL beaker containing 100 mL of boiling distilled water and 10 mL of concentrated hydrochloric acid. The crucible was cooled by washing its exterior walls with a stream of

water. It was then placed in the same beaker and covered with a watch glass. The solution was heated until the fusion cake was dissolved, filtered if necessary and then diluted to 500 mL in a calibrated flask. This sample solution was reserved for SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, Na<sub>2</sub>O, K<sub>2</sub>O and Al<sub>2</sub>O<sub>3</sub> determinations. For CaO and MgO determination, 10 mL of the sample solution was pipetted into a 100 mL calibrated flask followed by the addition of 4 mL of lanthanum nitrate solution and the mixture was diluted to the mark with distilled water. For the preparation of standards, 0.100 g of a fly ash standard (e.g. ASCRM 010) was mixed with 0.8 g of the fusion agent and treated similarly as for the sample, and the solution was diluted to 250 mL in a calibrated flask and labelled as the stock solution. Standard solutions were prepared by pipetting 25, 35, 50, and 75 mL of the stock solution separately into a series of 100 mL calibrated flasks and diluting to the marks with distilled water. These standard solutions were used for the determinations of SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, Na<sub>2</sub>O, K<sub>2</sub>O and Al<sub>2</sub>O<sub>3</sub>. Standards for the determinations of CaO and MgO were prepared by pipetting separately 10 mL of each standard solution prepared as above into a series of 100 mL calibrated flasks, adding four mL of lanthanum nitrate solution to each flask and diluting to the mark with distilled water (Lau, *et al.* 2000).

**Estimation of chloride:** Chloride contents of the samples were determined by the Volhard's titrating method (Swift, *et al.* 1950).

## RESULTS AND DISCUSSION

In Khushab district, bauxite reserves are found in an area of about 50 Km<sup>2</sup>. The study area lies at latitude 32, 30', 66" to 32, 35', 32", longitude 72, 15', and 42" to 72, 30', and 66" and falls in topo sheet No.43D/6 of the Survey of Pakistan, Map Publications, Rawalpindi. Total bauxite deposits in Khushab district are estimated at about 25 million tons.

Analysis of bauxite ores collected from the cited area has been tabulated in table-1. Moisture contents and weight loss of the samples have been found from 0.54 to 4.1% and 8.5-19.4% respectively. In all samples, high level of moisture contents and weight loss indicates the presence of water contents and organic carbon and confirms the presence of shallow depth of ore (Tariq, *et al.* 2004; Collazo, *et al.* 2005). Silica is main impurity in the bauxite of this area and may be removed to improve the mass ratio of Al<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> of diasporic-bauxite for the Bayer process (Tariq, *et al.* 2006). In the study area, silica contents of the soil were estimated between 5.2 to 29.35%. Minimum silica was detected in the samples collected from Punjab quarry and maximum silica was found in the samples of Arara North. The highest percentage of alumina (73.41%) was noted in the samples

of Punjab Quarry whereas the lowest (31.20%) percentage was observed in the samples of Arara North. Alkaline earth metals were evaluated as CaO and MgO and were revealed to be in the range of 1.09% - 4.02% and 1.08%-3.25% respectively. Alkali metals (Na and K) were estimated as Na<sub>2</sub>O and K<sub>2</sub>O and were not found more than 0.2 %. Similarly chloride content was never more than 0.01%. In the presence of low silica contents and high percentage of Al<sub>2</sub>O<sub>3</sub> found in the bauxite ore available on the surface, it is evident that the recovery of aluminum will be the maximum at the lowest cost. This study reveals that two main varieties of bauxite are available in Khushab district. One is whitish, containing high percentage of silica and other is reddish which contains higher amount of Fe and TiO<sub>2</sub> which could be exploited in several ways (Wang, *et al.* 2004).

Iron content of the bauxite ore is an important factor which determines its quality and utility. Iron was determined as Fe<sub>2</sub>O<sub>3</sub> and has been assessed in the range of 1.0 to 17.8 percent. A Maximum percentage of iron oxide was found in the samples of Arara Main (17.88%) and minimum quantity of Fe<sub>2</sub>O<sub>3</sub> was present in the bauxite of Arara North (1.04%). After the extraction of

aluminum, bauxite ore enriched with iron oxide, known as red mud, is left behind. Versatile characteristics of iron present in the red mud as ferric oxide (Fe<sub>2</sub>O<sub>3</sub>) i.e., high surface area, sintering resistance and resistance to poisoning makes it attractive and potential catalyst of low cost for many reactions (Liu, *et al.* 2007). Titanium oxide has been estimated in the range of 0.5%- 4.10%. Maximum concentration of TiO<sub>2</sub> was noted in the area of Arara North (Light pink, 4.1%) whereas minimum concentrations were observed in the areas of Arara North (Dark pink, 0.5%) and Sultan Mehdi Ziarat (Light pink, 0.5%). Thermally activated titanium rich bauxite has been established as the best adsorptive for the removal of excess fluoride from drinking water (Das, *et al.* 2005).

Analytical study of the bauxite ore of Khushab district and topographic data suggests that these deposits are suitable in quality and sufficient for a small size Bayer Process Plant having annual feed of 1.2 million tons. Bauxite required for this purpose should contain 40% alumina and bauxite of this area is suitable for this purpose. Moreover, bauxite can be brought to this area from Attock and Margalla Hills regions where suitable quality bauxite is also available.

**Tale 1: Ore sampling sites, color and different constituents as (w/w) percentage**

Sam ple #	Location	Color	% Wt. loss	Moisture	Silica	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	Chloride	Na <sub>2</sub> O	K <sub>2</sub> O
1	Muhammad-wala Chauhar	White	12.25	1.7	29.1	3.5	1.5	44.32	4.02	3.25	0.078	0.121	0.02
2	Sultan Mehdi Ziarat	grey	13.4	1.12	17.90	5.40	0.50	55.10	5.04	1.44	0.081	0.144	0.032
3	Punjab quarry	Light pink	9.2	0.72	8.13	1.67	3.45	73.41	3.02	1.81	0.074	0.073	0.012
4	Chamil More	Grey like clay	15.6	4.10	18.56	5.28	2.58	51.3	1.05	1.81	0.067	0.031	0.018
5	Punjab quarry	Mustered yellow	12.1	2.50	11.78	5.28	1.00	63.49	3.04	1.44	0.106	0.016	0.050
6	Punjab quarry	Reddish pink	8.5	0.95	5.29	16.08	3.50	62.60	1.50	2.17	0.099	0.049	0.015
7	Arara Main	Pale green	12.3	0.54	27.14	15.48	3.78	37.62	2.06	2.17	0.049	0.060	0.036
8	Arara North	White	18.1	2.66	29.35	1.04	0.50	44.55	2.05	1.81	0.103	0.169	0.048
9	Arara North	Dark pink	10.9	3.93	22.97	8.35	4.10	46.71	1.09	2.53	0.042	0.035	0.115
10	Arara Main	Light pink	19.4	3.20	24.19	17.88	2.21	31.20	2.80	1.08	0.049	0.081	0.024

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