An Overview of Bauxite Residue Utilisation

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Abstract

Bauxite residue is a solid waste generated during the production of alumina from bauxite. The disposal of this waste is a global challenge due to its potential environmental impact. If not well managed, its high alkalinity is a potential source of contamination of water, land and air in close proximity of the disposal site. Extensive work is carried out by researchers worldwide on value addition and fruitful utilization of bauxite residue. Some of the opportunities for utilization include adsorbents for the removal of heavy metals, dyes, phosphate, nitrate and fluoride; preparation of catalysts; recovery of iron, titanium and other trace metals; production of radio opaque materials; production of construction bricks; wood substitutes; cement; geo-polymers; development of coatings and pigments. This paper examines the details of bauxite residue utilization with the ultimate aim of solving the challenges of disposal and environmental impact.

Keywords: Bauxite residue utilization; wood substitutes; coatings and pigments; radio opaque material;geo-polymers

1. Introduction

Aluminium is a light weight,high strength structural material. Bauxite is the most economically important aluminium ore due to the presence of its high alumina content. Bauxite is a lateritic rock and contains mainly gibbsite, boehmite and diaspore. Bauxite also includes the iron oxides, goethite, hematite and small amounts of titanium, silica and other minerals and other impurities in minor or trace amounts. Bauxite usually contains the clay mineral kaolinite and has a density ranging from 2 600 to 3 500 kg/m^3. Bauxite colour varies from whitish to pink to reddish brown depending on the iron content in the bauxite[1]. Globally, estimated bauxite resources are 55 to 75 billion tonnes, located in Africa (33 %), Oceania (24 %), South America and Caribbean (22 %), Asia (15 %) and elsewhere (6 %). India is self-sufficient in bauxite and has 3 billion tonnes of bauxite reserves out of global reserve of 65 billion tonnes. This places the country 5th in rank in the world [2].Bauxite is classified based on ore type. These are mineralogically different and their occurrence in different countries is given in Table 1.

Table 1. Bauxite ore type indifferent countries [3].

Gibbsitic	Boehmitic	Diasporic
Australia, Brazil, Guyana, India(Eastern Coast),Indonesia, Jamaica, Malaysia, Sierra Leone, Suriname, Venezuela.	Australia, Guinea, Hungary, USSR, Yogoslavia, India (Central part.)	China, Greece, Guinea, Romania, Turkey

Aluminium production involves three stages: bauxite mining, followed by the refining of bauxite to alumina, usually in the Bayer process and smelting of alumina to aluminium by the Hall-Heroult process. Alumina can also be produced from bauxite under alkaline conditions using the lime sinter process [4], Deville Pechiney process(sodium carbonate) [5] and using the Serpeck process at high temperature in a reducing environment in presence of coke and nitrogen [6].The Bayer process[7] is the most economic and prevalent method employed for extraction of alumina from bauxite, where it contains sufficient Al_2O_3 content. Bauxite of higher silica content is not suitable for the Bayer process and is more economically processed by the sintering process. Waste generated from the sintering process is generally brown in colour, contains higher solid contents and lower quantities of Fe_2O_3 and Na_2O.

2. Bauxite Residue (Redmud)

In the Bayer process, the insoluble residue obtained after digestion of bauxite with sodium hydroxide at elevated temperature and pressure to extract alumina is known as red mud, or bauxite residue. Annual production of smelter and chemical grade alumina in 2015 was about 115 million tonnes produced using the Bayer process. The global average for the production of bauxite residue per tonne of alumina varies from 1 to 1.5 tonnes, so it is estimated that about 150 million tonnes of bauxite residue is produced annually. Bauxite residue has been called by different names by various companies. These are registered trademarks and reported in many publication and reports [8, 9]. Bauxite residue seems a more suitable name as some of the muds are brown rather than red and some diasporic derived residues are blackish. Despite this variation in colour, the name "red mud" remains more commonly used in North America and Europe [8, 9].

From an ecological viewpoint, whether it is red or brown mud is unimportant, both require appropriate waste and environmental management. The key risk with residue is the high alkali content, where pH values in fresh residue usually exceed 13. There is a risk of this alkalinity percolating into groundwater, in case of heavy rain and where appropriate monitoring and control measures are not in place. There is a risk of dam collapses (Hungarian alumina refinery, Ajka in 2010) and during the dry period of the year, dusting of the alkaline material may cause issues for local communities [10].

3. Environmental Consequences and Bauxite Residue Management

Bauxite residue produced from alumina refineries is a significant environmental risk for the surrounding environment including soil, vegetation and aquatic life, if not properly managed. The appropriate environmental management and/or utilization of bauxite waste are a major universal concern and preoccupation. The quantity and characteristics of the residue makes the task of safe disposal and utilisation more complex.

Safe storage of such large quantity of residue leads to the increase in production costs of aluminium by 2-5%. Residue storage also occupies large useful land tracts. The design and construction of such residue disposal facilities has varied considerably over the years with disposal practices generally dependent on nature of the immediate environment [11]. It is reported that conventional disposal methods involve the construction of clay lined dams or dykes, into which residue slurry is pumped and allowed to consolidate and dry naturally [12].

A good quantum of research and development work is being carried out all over the world in evolving a solution for the safe storage and utilization of bauxite residue. The current trend in residue storage is the increasing use of dry stacking as the preferred technology and further development in this area is being done to optimize the technology. Partial neutralisation using sea water is practiced at a number of Australian plants close to the sea; carbonation by using waste carbon dioxide from ammonia production has been adopted in Kwinana (Australia) and accelerated carbonation using intensive farming methods (Aughinish, Ireland), shows considerable benefits. Many of these approaches to disposal and management like alkali neutralisation using acid, CO_2 treatment, seawater neutralisation, bioleaching and sintering processes to fix leachables, stockpiling of bauxite residue alongwith their implications are discussed in detail elsewhere [3, 8].

Filtration using drum filters and plate and frame filter presses to recover caustic soda produce a lower moisture. This trend opens up benefits in terms of reuse with less than 28% moisture

The high pH is an issue from both a health and safety aspect and any adverse effects on a particular application product. The impact ranges from poor weather resistance in construction materials to high sodicity when used in soil amelioration. Both high sodium levels and high pH will be reduced when press filters are used. Carbonation using CO_2, intensive farming or acid neutralisation could also be considered. Based on a number of standard test criteria, material with a pH value above 12.5 is often considered as hazardous. Implementation of improved filtering operation, may reduce the pH to a level that avoids skin and eye irritation.

A high moisture level will increase transport costs, so it is beneficial for the bauxite residue to have as high solid content as possible. Additives such as starch have been used for dewatering, but from 1980, there has been a growing use of synthetic flocculants, although the use of plate and frame press filters (in combination with polymer based flocculation) is now being more widely adopted to reduce residue moisture content.

14. Conclusion

The comprehensive utilisation of bauxite residue generated in the process of industrial production of alumina is still a worldwide challenge. The current technologies and practices, the capacity for consumption and secondary utilisation are grossly insufficient to make an impression in the accumulation of bauxite residue inventories. Despite much work done over the last century, only some 2 - 3% of the bauxite residue produced annually is used in a productive manner. The largest future potential uses are as wood substitutes, geo-polymers, iron recovery, cement production, building materials, soil amelioration, landfill restoration and road construction materials.

It is to be noted that very large tonnages of equally hazardous industrial byproducts such as fly ash are routinely used in value-adding industrial applications. The same outcome should be possible for bauxite residue. The need is for bauxite residue producers, technology developers/providers, promoters, construction agencies, funding agencies, entrepreneurs, and users to work together for effective implementation of existing or new technologies and cater to the need, and fulfill the demand for sustainable development.

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