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REVIEW PAPER ON BAUXITE RESIDUE CHARACTERISTICS, DISPOSAL &UTILIZATION

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ABSTRATCT

Worldwide bauxite residue disposal areas contain an estimated 2.7 billion tonnes of residue, increasing by approximately 120 million tonnes per annum. Presently, it is stored on land or in ocean near alumina refineries. However, its high alkalinity is a potential pollution to water; land and air of close proximity .meanwhile high cost are associated with a large area of land needed for storage of residue. In this paper focuses on process of waste generation, its characteristics, conventional disposal method & bauxite residue utilization in building material glass ceramics, concrete, bricks, phosphate removal etc.

KEY WORDS: Bauxite residue, Red mud, Bayer process, Alumina.

INTRODUCTION

Aluminum is a light weight, high strength and recyclable structural metal. It plays an important role in social progress and has a pivotal contribution in transportation, food and beverage packaging, infrastructure, building and construction, electronics and electrification, aerospace and defense. It is the third abundant element in the earth‘s crust and is not found in the free state but in combined form with other compounds.

The commercially mined aluminium ore is bauxite, as it has the highest content of alumina with minerals like silica, iron oxide, and other impurities in minor or trace amount. The primary aluminium production process consists of three stages: Mining of bauxite, followed by refining of bauxite to alumina by the Bayer process (invented by Karl Bayer in 1887) and finally smelting of alumina to aluminium (Hall –Heroult process).

In the Bayer process, the insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure to produce alumina is known as red mud‘ or bauxite residue‘. (1)

Roughly 0.3–1.0 tons of red mud wastes are generated per ton of aluminum produced. The storage of large quantities of alkaline residue (red mud) is expensive(between 1 and 2% of the price of alumina), requiring large disposal areas (about 1 km2 for five years of production for a factory producing 1 million tons of alumina per year) and causing serious environmental problems (2)

Considerable research and development work for the storage, disposal and utilization of red mud is being carried out all over the world. The paper reviews the World and Indian aspects of

production of bauxite and generation of red mud. It describes the characterization, disposal, various neutralization methods and utilization of red mud.

ALUMINA PRODUCTION

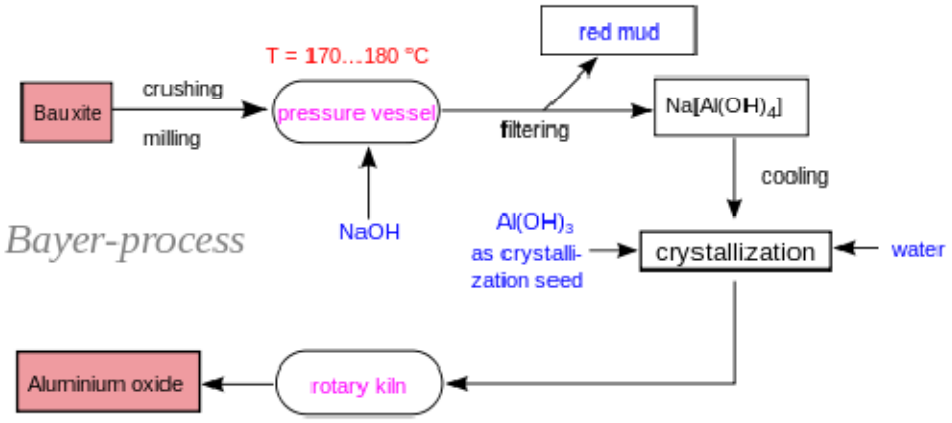
Though alumina can be produced from bauxite under alkaline conditions using lime (Lime Sinter process), sodium carbonate (Deville Pechiney process), at high temperature in reducing environment with presence of coke and nitrogen (Serpeck process) [4], the alkalinisation by the use of sodium hydroxide (Bayer process) [5] which is the most economical process which is employed for purification of bauxite if it contains considerable amount of Fe_2O_3.

Bayers process

During the treatment of the bauxite ore by the Bayer process , it is initially crushed and then mixed with a hot solution of sodium hydroxide, NaOH, at ≈175°C and lime liquor and subjected to attack at high pressure and temperature. This condition makes it possible to convert the hydrated alumina and to obtain sodium aluminate solution, while the impurities remain in a solid state.

$$Al(OH)_3+NaOH \rightarrow AlO_2Na+2H_2O$$

The impurities are separated from the aluminate solution by decantation and filtration, followed by a washing. The solid residues thus obtained are called red mud (7)



CHARACTERISTICS OF BAUXITE RESIDUE

About 1 tonne of alumina is produced from 3 tons of bauxite and about 1 tonne Aluminum is produced from 2 tonne of alumina [9]. Depending on the raw material processed, 1-2.5 tons of red mud is generated per ton of alumina produced.

CHEMICAL CHARACTERISTICS

The amount of alkali in red mud fluid is about 2 to3 g/L (calculated by Na2O), which results in a pH value between 13 and 14. Following table list the chemical compositions of three kinds of red mud that are produced by the Bayer process, sintering and Bayer-sintering process. (a)

Chemical constituents	Fe2O3	Al2O3	SiO2	CaO	Na2O	TiO2	K2O	MgO	Sc2O3	Nb2O5	TREO	Loss
Bayer process	28.3	17.67	8.34	20.88	2.29	7.34	.059	0.65	_	_	_	13.88
Combined process	10.97	7.68	22.67	40.78	2.93	3.26	0.38	1.77	_	_	_	11.77
Sintering process	6.66	9.18	18.1	38.09	4	6.72	6.72	_	.02	0.019	0.25	16.66

PHYSICAL CHARACTERISTICS

In general, red mud is a very fine material in terms of particle size distribution, having an average particle size <10 μm. Typical values would account for 90% of the volume below75 μm. The specific surface area (BET) of red mud is as large as 64–187 m^2g-1, Red mud has a large water content, up to 700to 1000 kg/m3, accounting for 79%–93% of the total weight It has a porous structure with a void ratio of 2.5–3.0, a high compressibility (Eg = 28–40 MPa) and low shear strength (C = 9.6–74.3 kPa; φ = 13.5–21.0°). Despite red mud's properties of high porosityand water content, it will not shrink or expand after drying The sintering process creates relatively coarse particles 0.1–0.02 mm While Bayer process red mud possesses the characteristics of fine particles (0.01–0.005 mm accounting for 65%) (a)

CONVENTIONAL METHODS OF DISPOSAL

Generally there are three ways of deposition of red mud: dumping into the sea, wet and dry disposals. In case of wet disposal the dry matter content is about 30% and remaining 70% is caustic solution with pH 12-13. In contrary to wet disposal the dry technique contains dry material in amount over 65% and caustic solution in amount less than 35% with pH 9-10 and the storage space requirement is less by 50-60% . However, the main problem of the dry disposal is the formation of particulate matter (dust). Alkaline dust causes burning, respiratory tracts injuries and the extensive exposure may lead even to lung diseases (9)

In seawater discharge, after washing and thickening process of red mud, the slurry is disposed directly via a pipeline into the deep sea. (1)

Lagooning is the conventional disposal method in which the residue slurry is directly pumped into land- based ponds. This consists of the construction of clay- lined dams into which bauxite residue slurry is simply pumped and allowed to dry naturally [1].

In dry stacking method, the residue slurry is thickened to 48-55% solids and discharged in thin layers, dewatered and air dried before discharge of next layer on it. After the consolidation of paste to about 65%, it can be safely stacked.

Acid neutralization

Gas phase CO2 or CO2-containing flue gas has been bubbled through aqueous slurries to form carbonic acid in the aqueous phase. Mechanisms of neutralization of red mud by carbon dioxide gas have been studied. The carbonic acid reacts with basic components of the red mud, lowering its pH. (1)

Bioleaching

Bioremediation of bauxite residue in Western Australia by Alcoa of Australia has been carried out by adding some organic substrate to the red mud for growth of microorganisms which generate different organic acids and CO2 (in some cases) which in turn neutralize the red mud. Similar work has also been carried out by using microbes (1)

UTILIZATION

Phosphate removal by using activated red mud

Phosphorus is one of the main elements for living and developing organisms. But this property increases the biological productivity in the water basin and causes eutrophication. Classical wastewater treatment processes arenot effective enough in removal of the phosphate. For this reason, some chemical phosphate removal systems are developed with precipitation. In this study,adsorption method was used to remove the phosphate from the wastewater. Red mud waste of the aluminium factories was used as an adsorbent after activation processes. The substance, produced by activating adsorbent, was used indifferent doses, at the different pH values' It has been found that red mud, wasted from aluminium factory, is, after treatment with concentrated hydrochloric acid, a highly effective reagent for the removal of phosphates from aqueous solutions.

Effect of the addition of red mud on the corrosion parameters of reinforced concrete

Red mud, the main waste generated in aluminum and alumina production by the Bayer process, is considered "hazardous" due to its high pH. The characteristic of high alkalinity associated with the presence of alumin osilicates facilitates the assimilation and formation of compounds by reaction with chloride ions. The high Ph also provides greater protection of rebars, which is reflected in the low corrosion potential and high electrical resistivity (filler effect) of concrete. In this study, the chloride concentration was monitored by measuring the conductivity of the anolyte. Red mud proved to be a promising additive for concrete to inhibit the corrosion process. The corrosion potential was monitored by electrochemical measurements and the electrical resistivity was evaluated using sensors embedded in concrete test specimens. The results showed

that the addition of red mud is beneficial to concrete, reducing its chloride migration rate (diffusion coefficients) and corrosion potential and increasing its electrical resistivity (2)

Fabrication and Characterization of Ghanaian Bauxite Red Mud-Clay Composite Bricks for Construction Applications

The behavior of Ghanaian based bauxite red mud-Tetegbu clay composites have been investigated for their applicability in the ceramic brick construction industry as a means of recycling the bauxite waste. The initial raw samples were characterized by X-ray diffraction (XRD), X-ray Fluorescence spectroscopy (XRF), Fourier transform infrared spectroscopy (FTIR), and thermo gravimetric analysis (Tg-DTA). The red mud-clay composites have been formulated as 80%-20%, 70%-30%, 60%-40%, 50%-50% and fired at sintering temperatures of 800ºC, 900ºC and 1100ºC. Generally, mechanical strengths (modulus of rupture) increased with higher sintering temperature. The results obtained for various characterization analyses such as bulk densities of 1.59 g/cm3 and 1.51 g/cm3 compare very well with literature and hold potential in bauxite residue eco-friendly application for low-cost recyclable constructional materials.(8)

Utilization of Neutralized Red Mud (Industrial Waste) in Concrete

Sustainable industrial development causes accumulation of heaps of waste disturbing the natural mechanism the waste can be sometime best alternative for conventional; material like red mud. Red mud is industrial waste obtained as by product from Bayer method of alluminium extraction in this process, alkaline digestion of 2.5 T of bauxite affords alumina & 105 T of red mud. The average 4 million tones of red mud produces per annum, this amount composed of Fe & Ti oxides behaving as chemically inert material with variable percentage of nominal SiO2, Al2O3 & Na2O3 which are partly present in cement. This paper covers significance of red mud over Portland cement by partial replacement of cement up to certain extent. (5)

Preparation of building materials: Glass ceramics

The glass ceramics have been made from pure raw materials & the products are expensive manufacturing glass ceramics with solid waste could recycle the waste & produce marketable products. Red mud from sintering process contains valuable mineral resources such as CaO, Al2O3, SiO2,fe2O3,TiO2.Chemical composition of red mud is quite suitable for producing glass ceramics. In recent years, significant researches carried out on producing glass &glass ceramics with red mud. The CaO- -SiO_2- Al_2O_3 glass ceramics has been made from red mud & fly ash successfully. The red mud from sintering process is a CaO rich slag. The fly ash is collected from the ESP in the coal combustion power plant as a solid waste a crystalline phase system could be transformed from the parent glass after heat treatment &denser grain structure could be obtain by a suitable two stage nucleation crystallization process. The result show that total amount of these two wastes of red mud & fly ash was up to 85wt. % which means lower raw material cost & greater environmental benefits.

Application in wastewater treatment

Bauxite residue has been studied extensively for potential use as alow cost sorbent for the removal of metal ions. Indeed the adsorbent exhibited high adsorption capacity for cd after specific thermal or chemical treatment. Most researchers have been investigated fine red mud powder as adsorbents for metal ions directly. Powdered red mud adsorbent has specific

adsorption area & other characteristics suitable for adsorption, however the powdered red mud adsorbents are difficult to generated & recycle after application. Prepared granular red mud ceramics & evaluated its potential use to remove cd ions from aqueous solution as a low cost adsorbent. The granular bauxite residue was made with Bayer red mud provides by the Shandong aluminium, co china. They found that adsorption of cd ions on granular bauxite residue spontaneous & feasible & it could be indicated by the endothermic nature for cd adsorption. Modified bauxite residue with $feCl_3$ could be used for removal of arsenate from water. Firstly bauxite residues were sieved & the fine powder was added into water. Then $feCl_3$ solution was added into the mixture drop wise& the resulting solution was aged & washed. Bauxite residue was sieved again& fine powders were used as adsorbent for the experiments. (11)

CONCLUSION

The characteristics of bauxite residues are being made it difficult to be treated & utilize the residue characterized by complex composition, small grain size & large specific area the high water content & high alkalinity create more problems for disposal & reuse of residue.

The problem of large quantity of bauxite residue cannot be solved because of limited consumption & incomplete utilization by existing technologies. Preparation of building material with bauxite residue could consume waste with simple procedures, but use of bauxite residue usually limited by residual sodium & its radioactivity. It would be beneficial to utilize bauxite residue in the preparation of environmental protection material. However market requirements of these productions are very small. A large amount of residue generated after recovery of valuable elements fe, Ti,Sc etc. & the treatment & utilization of this residue faced seriously.

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