Characterization and Comprehensive Utilization of Red mud - An Overview

N. Gangadhara Reddy¹ K. Sarath Chandra²
¹,²M-Tech Scholar
¹,²MANIT, Bhopal, India

Abstract---In the Bayer process of extraction of alumina from bauxite, the insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure is known as “red mud”. With increasing production of red mud, the environmental problems caused by it are increasing seriously, and thus the integrated treatment of red mud is imminent. This article provides an overview of the basic characteristics and comprehensive utilization of red mud is summarized.

I. INTRODUCTION

Industrialization and urbanization are the two world wide phenomena. Though these are the necessity of the society and are mostly inevitable, one has to look into their negative impacts on the global environment and social life. The major ill effect of these global processes is the production of large quantities of industrial wastes and the problems related with their safe management and disposal. Second problem is the scarcity of land, materials and resources for ongoing developmental activities, including infrastructure.

Among such type of hazardous industrial wastes Red Mud is the one. Red Mud is produced during the process for alumina production. Depending on the raw material processed, 1–2.5 tons of red mud is generated per ton of alumina produced [1]. In India, about 4,71million tons/annum of red mud is produced which is 6.25% of world’s total generation [2]. It is the insoluble product after bauxite digestion with sodium hydroxide at elevated temperature and pressure. It is a mixture of compounds originally present in the parent mineral bauxite and of compounds formed or introduced during the Bayer cycle. It is disposed as slurry having a solid concentration in the range of 10-30%, pH in the range of 10-13 and high ionic strength.

Considerable research and development work for the storage, disposal and utilization of red mud is being carried out all over the world [3]. This article provides an overview of the basic characteristics of red mud. The main ways of comprehensive utilization are also summarized. It describes the progress of experimental research and comprehensive utilization. The aim is to provide some valuable information to further address the comprehensive utilization of red mud.

II. PRODUCTION

Aluminum plays a key role in the everyday life of almost every human being on the planet, but behind its multiple uses lies a complex chain of technical processes required to extract the metal from the earth’s crust. While a variety of minerals contain aluminum, only a fraction of them are efficient sources of the alumina used to produce aluminum, and of those bauxite is the most widely used. Bayer’s process is the best process to extract the alumina from bauxite. Our main component which is a major waste material called Red Mud is produced during the Bayer Process. With this process, we can extract the aluminium hydroxides from bauxites and get alumina, which eventually can be smelted and give aluminum.

A. Bayer Process

In 1888, Karl Josef Bayer developed and patented a process, which has become the cornerstone of the aluminium production industry worldwide [4]. The Bayer process, as it has become known, is used for refining bauxite to smelting grade alumina (aluminum oxide), the precursor to aluminium. Typically, depending upon the quality of the ore, between 1.9 and 3.6 tonne’s of bauxite is required to produce 1 tonne of alumina.

The Bayer process is a cyclic one and is often called Bayer cycle. It involves four steps: digestion, clarification, precipitation, and calcination.

Fig. 1: Bayer Process Block Diagram
III. CHARACTERISTICS OF RED MUD

A. Strength and physical parameters of red mud

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Tests</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum dry Density (g/cc)</td>
<td>1.53</td>
</tr>
<tr>
<td>2</td>
<td>Optimum moisture Content (%)</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>Specific Gravity</td>
<td>2.85</td>
</tr>
<tr>
<td>4</td>
<td>Liquid Limit (%)</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>Cohesion (kg/cm²)</td>
<td>0.125</td>
</tr>
<tr>
<td>6</td>
<td>Angle of internal friction(in Degree’s)</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 1: Strength and physical parameters of red mud

Source: Chandra Shekar arya et al., 2013 [5]

B. Chemical and Mineral Compositions of Red Mud

Red mud is mainly composed of fine particles of mud. Its composition, property and phase vary with the origin of the bauxite and the alumina production process, and will change over time when stocked. Chemical analysis shows that red mud contains silicium, aluminium, iron, calcium, titanium, sodium as well as an array of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As, and etc. Tables 2 and 3 list the chemical and mineral compositions of red mud that are produced by the Bayer process.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeO2O3</td>
<td>30-60%</td>
</tr>
<tr>
<td>Al2O3</td>
<td>10-20%</td>
</tr>
<tr>
<td>SiO2</td>
<td>3-50%</td>
</tr>
<tr>
<td>Na2O</td>
<td>2-10%</td>
</tr>
<tr>
<td>CaO</td>
<td>2-8%</td>
</tr>
<tr>
<td>TiO2</td>
<td>Trace-25%</td>
</tr>
</tbody>
</table>

Table 2: Typical composition of red mud

C. Mineralogical Phases

Mineralogical phases of red mud are listed below [7]

Hematite Fe₂O₃
Goethite FeO(OH)
Gibbsite AIOH₃
Diaspore AIOOH
Quartz SiO₂
Cancrinite (NaAlSiO₃)6CaCO₃
Kaolinite Al₂O₃2SiO₂ 2H₂O
CALCILTE [CACO₃]

IV. DISPOSAL

The disposal of RM remains a major problem. Reports on this issue in the open literature seem scarce. Below you can find some general information about the disposal of Red Mud as well as the common practice in India.

V. COMPREHENSIVE UTILIZATION OF RED MUD IN CONSTRUCTION

A. Red mud in cement replacement

Dicalcium silicate in red mud is also one of the main phases in cement clinker, and red mud can play the role of crystallization in the production of cement clinker. Fly ash is mainly composed of SiO₂ and Al₂O₃, thus can be used to absorb the water contained in the red mud and improve the reactive silica content of the cement. Scientists conducted a series of studies into the production of cement using red mud, fly ash, lime and gypsum as raw materials. Use of red mud cement not only reduces the energy consumption of cement production, but also improves the early strength of cement and resistance to sulfate attack [9]

B. Concrete industry

Red mud from Birac Alumina Industry, Serbia was tested as a pigment for use in the building material industry for standard concrete mixtures. Red mud was added as a pigment in various proportions (dried, not ground, ground, calcinated) to concrete mixes of standard test blocks (ground limestone, cement and water) [10]. The idea to use red mud as pigment was based on extremely fine particles of red mud (upon sieving: 0.147 mm up to 4 wt%, 0.058 mm up to 25 wt% and the majority smaller than 10 microns) and a characteristic red colour. Compressive strengths from 14.83 to 27.77 MPa of the blocks that contained red mud between 1 and 32% were considered satisfactory. The reported tests have shown that neutralized, dried, calcined and ground red mud is usable as pigment in the building materials industry. Red oxide pigment containing about 70 % iron oxide was prepared from NALCO red mud by [11] after hot water leaching filtration, drying and sieving.

C. Red mud in the brick industry

D.Dodoo- Arhin, et al [12] have been investigated bauxite residue red mud-Tetegbu clay composites 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) and thermogravimetric (TG) analysis. The red mud-clay composites have been formulated as 80%-20%, 70%-30%, 60%-40%, 50%-50% and fired at sintering temperatures of 800°C, 900°C and 1100°C. 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. Considering the physical and mechanical properties of the fabricated brick samples, the batch formulation which contained 50% each of the red mud and Tetegbu clay is considered the best combination with optimal properties for the construction bricks application and it could be employed in lighter weight structural applications.

Utilization of red mud as filling material

D. Road Base Material

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Industry</th>
<th>Disposal practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NALCO, Damanjodi</td>
<td>Wet Disposal</td>
</tr>
<tr>
<td>2</td>
<td>HINDALCO Industries</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Renukoot</td>
<td>Dry Disposal</td>
</tr>
<tr>
<td></td>
<td>Belgaum</td>
<td>Dry Disposal</td>
</tr>
<tr>
<td></td>
<td>Muri</td>
<td>Wet Disposal</td>
</tr>
<tr>
<td>3</td>
<td>Vedanta</td>
<td>Wet Disposal</td>
</tr>
<tr>
<td></td>
<td>Bhavanipatnam</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sterlite Industries,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Previous BALCO) Korba</td>
<td>Wet Disposal</td>
</tr>
<tr>
<td></td>
<td>MALCO Mettur (Now Closed)</td>
<td>Wet Disposal</td>
</tr>
</tbody>
</table>

High-grade road base material using red mud from the sintering process is promising, that may lead to large-scale consumption of red mud. Qi [13] suggest using red mud as road material. Based on the work of Qi, a 15 m wide and 4
km long highway using red mud as a base material was constructed in Zibo, Shandong Province. A relevant department had tested the sub grade stability and the strength of road and concluded that the red mud base road meets the strength requirements of the highway [14].

E. Mining
Yang et al. [15], from the Institute of Changsha Mining Research, have studied the properties, preparation and pump pressure transmission process of red mud paste binder backfill material. Based on this study, a new technology named “pumped red mud paste cemented filling mining” has been developed by the Institute of Changsha Mining Research, in cooperation with the Shandong Aluminum Company. They mixed red mud, fly ash, lime and water in a ratio of 2:1.05:2.43, and then pumped the mixture into the mine to prevent ground subsidence during bauxite mining. The tested 28-day strength can reach to 3.24 MPa. This technology is a new way not only for the use of red mud, but also for non-cement cemented filling, successfully resolving the problem of mining methods in the Hutian bauxite stop. Underground exploitation practice on the bauxite has proved that cemented filling technology is reliable and can effectively reduce the filling costs, increase the safety factor of the stop and increase the comprehensive benefits of mining [16].

VI. RECOVERY OF COMPONENTS FROM RED MUD
Red mud primarily contains elemental compositions such as Fe₂O₃, Al₂O₃, SiO₂, CaO, Na₂O and K₂O. Besides, it also contains other compositions, such as Li₂O, V₂O₅, TiO₂ and ZrO₂. For instance, the content of TiO₂ in red mud produced in India can be as much as 24%. Because of the huge amount of red mud, value elements like Ga, Sc, Nb, Li, V, Rb, Ti and Zr are valuable and abundant secondary resources. Therefore, it is of great significance to recover metals, especially rare earth elements, from red mud.

Due to the characteristics of a high iron content, extensive research into the recovery of iron from Bayer process red mud have been carried out by scientists all over the world. The recycling process of iron from red mud can be divided into roasting magnetic recovery, the reducing smelting method, the direct magnetic separation method and the leaching extraction method, according to the different ways of iron separation. Researchers in Russia, Hungary, America and Japan have carried out iron production experiments from red mud. Researchers from the University of Central South have made steel directly with iron recovered from red mud [17]. The Chinese Metallurgical Research Institute has enhanced the iron recovery rate to 86% through making a sponge by red mud-magnetic separation technology. Sun et al. [18] researched magnetic separation of iron from Bayer red mud and determined the process parameters of the magnetic roasting-magnetic selecting method to recover concentrated iron ore.

VII. SUMMERY AND CONCLUSION
1) Red mud is a potential source of pollution not only for the atmosphere but also for the other components of the environment. Deposition in storage places can have negative influences on water and soil because of their granulometric and mineral composition as well morphology and filtration properties.
2) Utilization of red mud is established in brick manufacturing, partial cement refilling, in concrete industry and stabilization process.
3) Red mud can also be used to produce other construction materials. A mature, relevant technology would greatly promote the consumption of red mud.
4) A wide variety of potential uses of red mud have been reviewed, yet there is no economically viable and environmentally acceptable solution for the utilization of large volumes of red mud.
5) Recovery of other metals should be made economical by further investigations to reduce high reaction temperatures required

There is urgent need to undertake research and development for studying the metal speciation and the changes associated with red mud reuse in the construction purposes and during the wet storage of red mud in ash ponds.

REFERENCES


[17] Li, WD. New Separation Technology Research of Iron from Bayer Progress Red Mud; Central South University Library: Changsha, China; 2006