Sustainable Management of Red Mud: Lifecycle Assessment and Treatment Techniques

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ABSTRACT

Red mud is a strongly alkaline leaching solid hazardous waste material generated in the Bayer process of alumina production. India ranks 4th place in alumina production. According to the Ministry of Mines (Oct 2022), India produces 9 million tonnes of red mud annually. In nature, red mud is highly alkaline. The high alkalinity and caustic content of red mud will contaminate the groundwater and fertile soil, and also there is a limitation on the utilization of red mud. Due to its low utilization ratio, large amounts of red mud are stacked in disposal areas, which may cause water pollution, soil salinization and heavy metal pollution. Red mud contains toxic metals such as arsenic, chromium, lead, nickel, zinc and radioactive elements such as thorium, potassium, and uranium, which cause severe effects on the environment and also on our health. The objective is to examine the environmental impact, utilization methods and treatment process of the red mud (bauxite residue). Also, scrutinize the biodegradation of heavy metals in red mud.

Keywords: Red mud, Bayer process, toxic metals, radioactive materials.

I INDRODUCTION

Aluminum plays a vital role in day-to-day life. Aluminium is widely used in cans, foils, kitchen utensils, aeroplane parts. After oxygen, silica aluminium is third most abundant material in lithosphere. In 1854, the first production of aluminium is started. There are two steps in the alumina production one is Bayer process and other is hall-Heroult process. In the Bayer process, filtration after the addition of sodium hydroxide produces red mud. 1 ton of alumina production gives 1.5 tons of red mud. Currently about 4.6 billion tons of red mud is stored with an increase of 200mt per annum. Due to its high alkalinity, it causes serious effects to the environment such as human health effects due to the presence of heavy metals, soil pollution, leachate will also affect the ground water.

There is no proper utilization or treatment technique in India. The red mud is disposed as slurry form in sea or lake or it is disposed in dry form in land. In this paper the properties, environmental effects and its disposal and treatment techniques is highlighted.

II BAUXITE:

Bauxite is a rock formed in the laterite soil. The French geologist Pierre Berthier named bauxite in 1821.bauxite contains clay minerals, aluminium hydroxide, hydrous aluminium oxides. The insoluble minerals present in bauxite is hematite, quartz, magnetite, siderite, goethite. The specific gravity of bauxite is 2.6 to 3.5.

Fig 1 Bauxite

Bauxite ore differ three types according to its crystallography. They are Gibbsitic (γ-Al (OH)3), Boehmitic (γAlO (OH)), Diasporic (α-AlO (OH)).

BAXUITE ORE TYPE	COUNTRY
Gibbsitic	Australia, Brazil, Ghana, Guyana, India (eastern coast), Indonesia, Jamaica, Malaysia, Sierra leone, Suriname, Venezuela
Boehmitic	Australia, Guinea, Hungary, USSR, Yogoslavia, India (Central part)
Diasporic	China, Greece, Guinea, Romania,Turkey

Table 1 Bauxite ore of different country

III BAUXITE DEPOSITS OF INDIA

Odisha produces country's 52% of bauxite resource, Andhra Pradesh produces 18%,Gujarat 7%, Chhattisgarh and Maharashtra 5%, Madhya Pradesh and Jharkhand 4%.

Fig 2 Aluminium plants in India

IV **RED MUD:**

A. *Production process:*

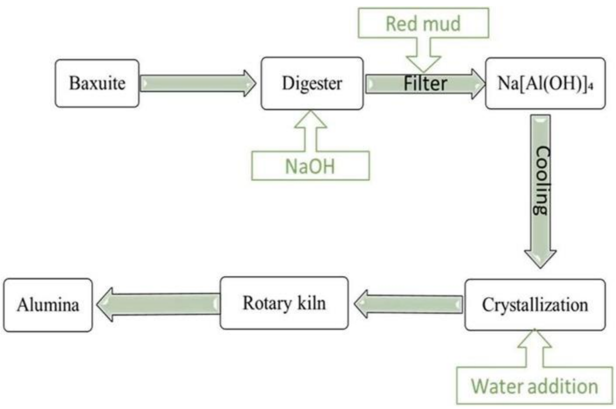

Fig 3 Bayer process

V CHARACTERISTICS OF RED MUD:

A. *Chemical characteristics:*

COMPANY	Al_2O_3	Fe_2O_3	TiO_2	SiO_2	CaO	Na_2O	P_2O_5	V_2O_3	LOI
BALCO	21.9	28.1	15.6	7.5	10.2	4.5	-	-	12.2
HINDALCO	24.3	24.5	18	6.2	-	5.3	-	-	-
NALCO	14.8	54.8	3.7	6.4	2.5	4.8	0.67	0.38	9.5
INDAL	19.4	27.9	16.4	7.3	16.4	11.8	3.3	-	12.6
MALCO	14	18	50	56	2-4	6-9	1-2	-	12.6

Table 2 Chemical concentrations from different companies in India

B. *Physical and geo technical properties:*

pH	10-13.5
Density	2187 kg/m^3
Particle size	2-100µm
Specific gravity	3.15
Moisture content	25.6%
Dry density	1.619 gm/cm^3
Liquid limit	24.75%
Plastic limit	17.5%
Plasticity index	7.25%
IS classification	ML (silt of low plasticity)
Volumetric shrinkage	1.6%
Linear shrinkage	5.26%
Permeability	1-5 x 10^{-4} m/day

Table 3 Properties of red mud

VI HEALTH IMPACTS ON HUMAN

Red mud contains toxic metals like arsenic, chromium, cadmium and nickel. The mud also contains radioactive elements and is highly alkaline, caustic enough to burn skin and eyes. Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. It has also been associated with cardiovascular disease and diabetes. In utero and early childhood exposure has been linked to negative impacts on cognitive development and increased deaths in young adults.

Adverse health effects associated with Cr(VI) exposure include occupational asthma, eye irritation and damage, perforated eardrums, respiratory irritation, kidney damage, liver damage, pulmonary congestion, upper abdominal pain, nose irritation and damage, respiratory cancer and skin irritation.

Breathing high levels of cadmium damages people's lungs and can cause death. Exposure to low levels of cadmium in air, food, water, and particularly in tobacco smoke over time may build up cadmium in the kidneys and cause kidney disease and fragile bones. Cadmium is considered a cancer-causing agent.

Nickel (Ni) is a hard, silvery-white metal that may cause irritation to the skin. Exposure can harm the lungs, stomach, and kidneys. Exposure to nickel may lead to cancer.

VIIDISPOSAL TECHNIQUES

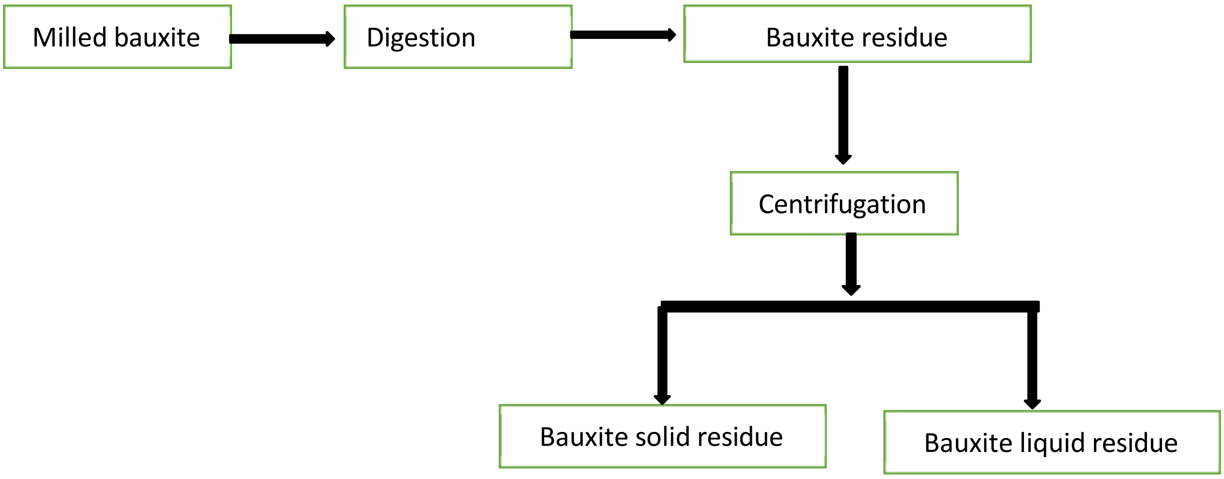

Fig 4 Separation of liquid from bauxite

The environmental risk associated with the disposal of red mud is due to high alkalinity, presence of radionuclides and toxic elements. The traditional disposal technique includes slurry disposal, dry mud disposal, sea or lake disposal, closed cycledisposal, modified closed cycle disposal methods.

Sea disposal: the slurry from the Bayer process is directly disposed to the sea through the pipeline. This may reduce the land pollution, but it increases the turbidity level in sea due to the formation of colloidal aluminium and magnesium compounds.

Conventional wet disposal: by dewatering process the sodium hydroxide is separated from the redmud slurry. Due to the seepage

VIII UTILIZATION OF RED MUD

Now a days red mud is effectively used in engineering field. The red mud contains sufficient amount of silica, alumina, iron oxides so it can be used in the cement of alkaline content the groundwater got contaminated.

Dry disposal: The slurry is dewatered and dried up to 48-58% of solids. This reduces the area of disposal. In India mostly dry disposal is used.

manufacturing. And in concrete red mud can be partially replaced in place of cement. In the wastewater treatment the red mud act as a adsorbent for the removal of heavy metals. It can be also used in brick manufacturing.

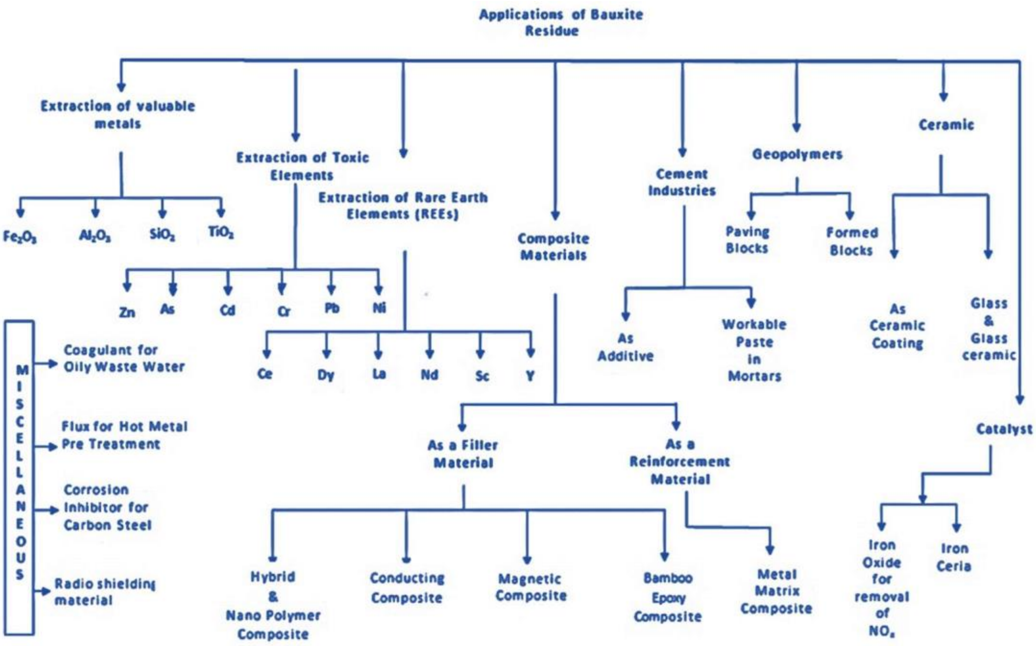

Fig 5 Utilization methods

IX CONCLUSION

In this review article the production process and characteristics of red mud is discussed. As the production of alumina continues, the red mud accumulation will also increase.1 ton of alumina produces 1.5 tons of red mud. In India, it is mostly disposed in dry form in open spaces, allotted for the disposal. It possesses severe negative impacts on environment and on human health. To minimize the impact, we could consider the conversion of this element into another form rather than disposing it to open spaces or oceans. It is best to utilize this waste as a raw material for another process. By using it in cement and brick manufacturing as a resource, the waste exchange process can be effectively done. Due to its absorptive property, it can be even used to absorb heavy metals in wastewater treatment process. Still, a deep and continuous research work should be carried out for the termination of the problem caused by red mud.

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