Sustainable Utilization of Spent Pot Lining (SPL) Non-Carbon Portion by Co-Processing in Cement Industries

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Abstract

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Spent Pot Lining (SPL) is hazardous waste generated from the degradation of Hall-Héroult cells in the aluminium smelting process, where aluminium is extracted from alumina using electrolysis. The typical life span of a cell is three to six years. The pot de-lining process produces waste containing carbon and refractory materials. Presence of fluoride and cyanide compounds, high alkalinity and heavy metals handling, transportation, storage and disposal of SPL require special care.

The Central Pollution Control Board (CPCB) has established a Standard Operating Procedure (SOP) for utilizing the carbon portion, which is established with authorized carbon recyclers. The density of SPL refractory portion is typically within a range 1.4–2.2 t/m^3, the pH ranging from 9.5 to 12.5, fluoride concentration is greater than 50 mg/L as per toxicity leaching characteristic procedure (TCLP) and it has compressive strength that averages 20–30 MPa with a typical maximum value of 50 MPa. Cement plants can use SPL from aluminium smelters as an alternative raw material and fuel due to its high carbon content and high calorific value. Co-processing in cement industries is the most efficient approach for eliminating landfilling and ensuring sustainable waste management. This process leaves no residue, as the incombustible inorganic content of waste materials is incorporated into the clinker matrix. The high temperature varies from about 850 °C to 1800 °C and turbulence in cement kilns provide an exceptional destruction removal efficiency (DRE) of over 99 % for all waste types. Refractory part needs to be crushed to below 20 mm size prior to co-processing in cement kilns, hence crusher units, consisting of jaw crusher and vertical shaft impactor (VSI), were installed at Mahan (Singrauli, India), an unit of Hindalco Industries Ltd., along with pollution control devices to bring down the size of the refractory part in the range of < 20 mm and then dispatch it to cement industries.

Similarly, the segregation of the SPL-refractory portion into an acceptable size was a challenge faced by Hindalco's Hirakud unit in clearing an acquired liability of a legacy stockpile of approximately 80–100 kt. Through multiple design iterations, a double-decker vibrating screen with a capacity of 200 t/day was developed, capable of screening material to an -8 mm fraction. This setup enabled the dispatch of 20 kt of screened SPL fines for co-processing in high-temperature cement kilns, ultimately leading to the clearance of the entire legacy stock.

Keywords: Spent pot lining (SPL), Resource recovery and utilization, Sustainability, Zero waste to landfill.

1. Introduction

Mahan Aluminium, a unit of Hindalco Industries Ltd., is situated in Village Orgari, Bargawan, in the Singrauli district of Madhya Pradesh. The plant has the Pechiney AP36 smelter technology supplied by Rio Tinto Aluminium, and its integrated carbon plant is based on Fives Solios technology. The captive power plant consists of six units of 150 MW each, developed using BHEL technology. Commissioned in 2013, the facility currently operates with an aluminium production capacity of 398 kt/y and has 360 pots in one potline.

The Hirakud Smelter was established in 1959 with an initial capacity of 10 kt/y, it was subsequently expanded to 216 kt/y by 2013. The smelter has two distinct types of pots, namely 85 kA and 235 kA. The 235-kA line consists of 80 GAMI pots, while the 85-kA lines have 564 pots. Between 2006 and 2008, the 85-kA potlines were converted to prebake point-break technology from Søderberg technology. These pots, integral to our production processes, rely on a sophisticated array of materials for their lining, including fire bricks, calcium silicate boards, carbon blocks, dry impervious materials, silicon carbide-nitride blocks, all meticulously chosen to withstand the rigors of continuous operation over extended periods.

The aluminium smelting industry, a key segment in global non-ferrous metal production, uses the Hall-Héroult process for extracting aluminium from alumina. This process, though efficient in terms of metal production, generates a substantial quantity of hazardous waste known as Spent Potlining (SPL). SPL is classified as a scheduled hazardous waste under various national and international environmental regulations due to the presence of toxic substances such as fluoride, cyanide, heavy metals, and high alkalinity components [1]. The material arises from the gradual degradation of carbon cathodes and refractory linings in the cells, which typically require re-lining every three to six years [2].

SPL is conventionally divided into two components: the carbonaceous fraction and the refractory fraction. While the utilization of the carbon portion has been increasingly streamlined through authorized carbon recyclers [3], the handling and productive use of the refractory portion remain a logistical and technical challenge [4]. Notably, the refractory fraction, characterized by a high compressive strength (20–50 MPa), a high alkalinity (pH 9.5–12.5), and elevated fluoride levels (> 50 mg/L based on TCLP tests), poses significant issues in terms of transport, processing, and disposal [5].

To address the environmental and economic concerns associated with SPL disposal, cement industries have emerged as a viable co-processing solution. The high-temperature conditions of cement kilns (ranging from 850 °C to 1800 °C) and their superior Destruction and Removal Efficiency (DRE > 99 %) provide a sustainable path for the total thermal destruction of hazardous constituents without residual waste. Furthermore, the inorganic content of SPL becomes part of the clinker matrix, aligning with circular economy principles [6].

Hindalco Industries Ltd. has pioneered practical applications of SPL co-processing in India, particularly at its Mahan and Hirakud units. At Mahan, an integrated crushing unit (Figures 1 and 2) was developed to reduce refractory sizes to < 20 mm, facilitating their use in cement kilns. In Hirakud, a legacy stockpile of 80–100 kt of SPL refractory waste was effectively processed using a customized double-decker vibrating screen system Figure 3 with a throughput of 200 t/day. This setup enabled the dispatch of 20 kt of screened fines to cement plants, contributing significantly to the clearance of the inherited stockpile [7].

residue in cement industries presents an environmentally sound and industrially viable pathway for mitigating SPL-associated risks, provided strict emission and quality monitoring is maintained throughout the process.

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