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SUSTAINABILITY ASSESSMENT OF BAUXITE RESIDUE REUSE APPLICATIONS: A COMPARISON OF CEMENT AND CLAY BRICK PRODUCTION

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ABSTRACT

Bauxite residue (BR), commonly referred to as red mud is an important by-product from the processing of alumina via the Bayer process which is a critical stage in aluminium production. The hazardous waste constitutes a significant environmental challenge due to the substantial volumes generated, with approximately 1.23 tonnes of BR generated for every tonne of alumina processed on a global scale. The cumulative effect has resulted in an extensive BR stockpile (approximately 4 billion tonnes) which are distributed in various designated storage facilities worldwide. As demand for aluminium grows, storage spaces decrease, and the ever-present environmental risk associated with large scale BR storage remains. There is a need to identify alternative avenues to traditional storage. An appealing avenue is the utilisation of BR into applications such as cement and brick which can consume significant amounts of the material and make use of its properties. To assess the environmental performance of this approach, this study employed life cycle assessment (LCA) to provide environmental insights into two specific BR reuse applications, the manufacture of BR-based cement and brick and compared them with their conventional counterpart processes.

A cradle-to-gate approach was adopted making use of the ecoinvent 3.9.1 database for the background data needed to develop the life cycle inventory, with the open source LCA software Activity Browser 2.8.0 used for modelling. The functional unit chosen for this study was the reuse of 1kg of dry BR for the specified applications. To model cement production it was assumed that calcinated BR replaces 30% of the clinker used in ordinary Portland cement (OPC) while for the manufacture of BR-based brick and in line with literature it was assumed that a combination of BR (20%), coal fly ash (58.80%), $Ca(OH)_2$ (17.20%), Na_2CO_3 (4%) and NaOH (5%) replaces conventional clay-fired bricks. The CML v4.8 2016 characterisation method was selected to perform the LCIA making use of all inherent method impact categories. A sensitivity analysis was conducted exploring the potential effect of varying BR composition on the environmental performance.

The outcome of this study quantitatively demonstrates that the utilisation of BR for cement and brick production has reduced environmental impacts in most of the assessed impact categories than their conventional counterpart technologies (OPC and clay brick). For cement production the BR-based cement has reduced environmental impacts in all categories except marine aquatic ecotoxicity (1.75% higher), energy resource depletion (6.02% higher), and ozone depletion (55.87% higher). The observed disparity in the impact categories can be attributed to the low influence of the clinker, a known significant contributor to the environmental footprint of cement production and higher weighting of kaolin, electricity, and natural gas in the contrasting impact categories. For brick production, negative environmental impacts were calculated in many impact categories, meaning that environmental impacts are reduced using the BR-based technology. For example, BR based brick production has a negative global warming potential value (- 6.25 $kgCO_2$-eq. / kg) indicating a net cooling effect. This reduction in environmental burden is primarily due to the incorporation of coal fly ash, a waste product from coal fired electricity generation with its intrinsic environmental benefit. Comparing the two competing BR reuse applications reveals that only in three (marine aquatic ecotoxicity, abiotic depletion potential and ozone depletion potential) of the eleven selected impact categories did manufacturing BR based brick exhibit a higher environmental burden than BR based cement production per kg of BR treated. This shows the importance of considering BR utilisation strategies other than its use in cement. We expect similar conclusions, that other applications than cement are preferable for reducing environmental impact, may be obtained for utilisation of other industrial by-products. This study represents an initial step towards mapping the environmental impacts of utilising BR in suitable applications contributing to the goal of achieving sustainable alumina generation.

This shows that considering BR utilisation strategies other than its use in cement may be preferable for reducing environmental impact. We expect that similar conclusions may be obtained for utilisation of other industrial by-products.