The Choice of Refractories for Steel Ladle Lining: a Life Cycle Perspective

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European Industrial Doctoral Network CESAREF

Funded by the European Union

Marie Skłodowska-Curie Actions

Context:

The iron and steel industry is the biggest consumer of refractories, with around 70% of the total market share (Muñoz et al., 2020). Magnesia-carbon (MgO-C) bricks are used in the slag line of a steel ladle. It is produced from high-purity fused magnesia and graphite as a source of carbon (Boenzi et al., 2019). In general, refractory production processes (such as sintering, and fusion) are very energy intensive and usually have a high carbon footprint (An et al., 2018). Therefore, it is crucial to assess the life cycle environmental impact of refractories to identify ecological hotspots and to develop strategies to reduce impacts.

Methods:

Goal and Scope

Objectives of the study are to:

- ❑ evaluate the environmental impacts of MgO-C bricks to identify ecological hotspots;
- ❑ compare two bricks, one produced in China and another in Western Europe.

Functional unit: 1t of MgO-C bricks used in the slag line of the steel ladle.

System boundary: A cradle-to-gate LCA is conducted including mining of ore, processing of raw materials, production of bricks, and transportation of bricks to the steel plant (Figure 1). Two MgO-C bricks are considered, one produced in China, labeled Brick A, and another produced in Western Europe, labeled Brick B. Fused magnesia for Brick B was outsourced from Australia while for Brick A, it was locally produced in China. Two scenarios are considered depending on the source of electricity. Scenario 1 is the baseline where electricity was taken from the national grid mix of the respective country. In scenario 2, electricity was considered only from the hydroelectric plant.

Data collection: Life cycle inventory data were collected both from literature and industry.

Method: The EF 3.0 impact assessment method

Impact categories: Climate Change (CO_2 kg eq), Acidification (mole H^+ eq), Eutrophication, freshwater (kg P eq) and Resource use, fossils (MJ)

Database and Software: Ecoinvent 3.8 and SimaPro 9.4

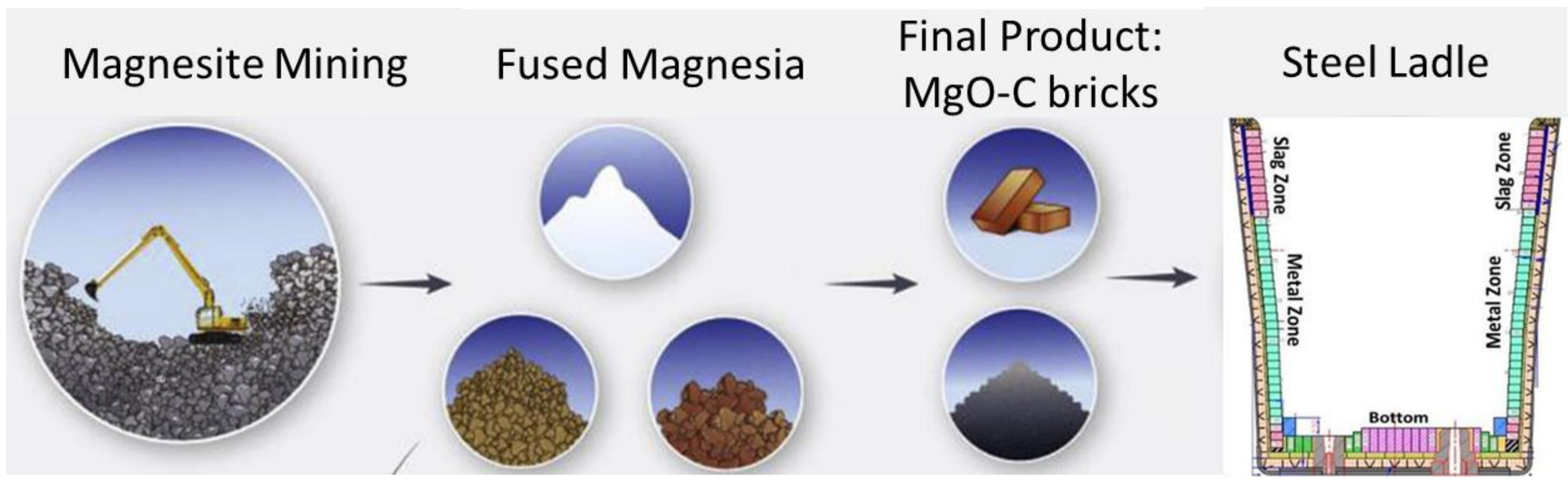

Figure 1. A schematic diagram of MgO-C bricks production for steel ladle (An et al., 2018; Bharati et al., (2014).

Results and Discussion:

Fused magnesia has the highest contribution to the overall impacts of almost all categories ranging from a low of 27% for eutrophication in scenario 2 for Brick B and a high of 82% for climate change in scenario 1 for brick A as shown in Figure 2. Aluminum has a significant contribution in all impact categories. Transportation has the largest contribution to Acidification in scenario 2.

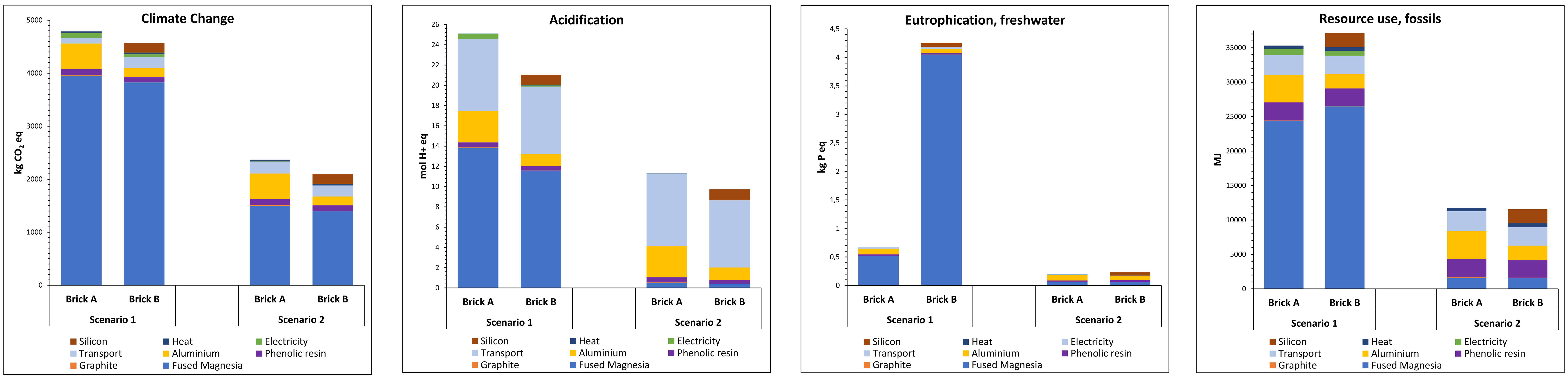

Figure 2. Environmental impacts of Brick A and Brick B in scenario 1 and scenario 2.

Conclusions:

- ❑ Environmental hotspots: fused magnesia followed by transport and aluminum.
- ❑ Brick B performs better than Brick A in all categories except for eutrophication in scenario 1.
- ❑ Hydroelectricity can reduce overall environmental impacts by at least 50% compared to the national grid electricity mix,.
- ❑ In order to reduce the environmental impacts of MgO-C bricks, the focus of the research should be on the optimization of the magnesia fusion process and the use of renewable energy whenever possible.

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Acknowledgements:

This project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement no.101072625

Beneficiaries