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

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Methods:

Goal and Scope:

Objectives of the study are to:

- ❑ evaluate the environmental impacts of magnesia-carbon (MgO-C) bricks to identify ecological hotspots;
- ❑ compare two bricks, one produced in China and another in the Netherlands.

Functional unit: Providing refractoriness to a 1 m^2 area with 178 mm thick lining in the slag line of a steel ladle.

System boundary: A cradle-to-gate LCA is conducted including mining of ore, processing of raw materials, production of bricks, and transport of bricks to the steel plant (Figure 1). Two MgO-C bricks are considered, one produced in China, labeled Brick A, and another manufactured in the Netherlands but the key raw material, fused magnesia, was outsourced from Australia, labeled Brick B. **Reference flow** for Brick A and Brick B are **537,56 and 530,44 kg** respectively. 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 countries while in scenario 2, 100% hydroelectricity was assumed to be used in bricks and fused magnesia production.

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

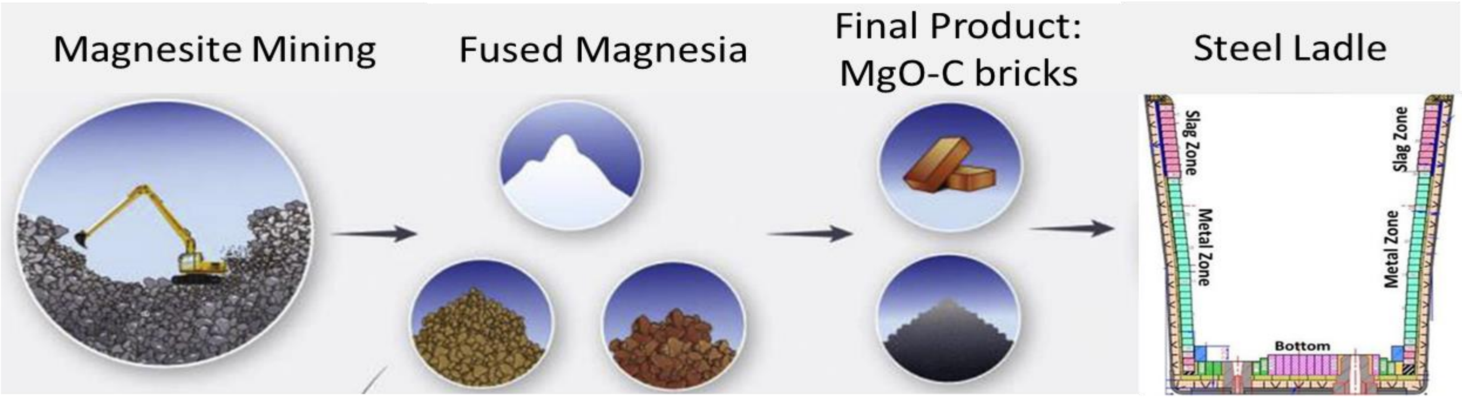

Figure 1. A schematic diagram of MgO-C bricks production for steel ladle (An et al., 2018; Bharati et al., (2014).

Inventory:

Table 1. Life cycle inventory for 1t of fused magnesia (Li et al., 2016)

Item	Unit	Quantity
Magnesite	kg	3000
Electricity	kWh	3000
Graphite electrode	kg	38
Dust emissions	kg	5,5
CO_2 emissions	kg	1565,7

Table 2. Life cycle inventory for 1t of MgO-C bricks production

Item	Unit	Quantity	
		Brick A	Brick B
Fused magnesia	kg	799	821
Graphite	kg	156	93
Phenolic resin	kg	25	46
Aluminium	kg	20	20
Silicon	kg	-	20
Electricity	kWh	90,37	90,37
Natural gas	m3	15	15
Transport, see	tkm	23300	21700
Transport, lorry	tkm	50	42

Results and Discussion:

Fused magnesia has the highest contribution to the overall impacts of the most impact categories ranging from a low of 3,5% for Acidification in scenario 2 for Brick B and a high of 81% for climate change in scenario 1 for Brick B as shown in Figure 2. The large contribution of fused magnesia to various impact categories is associated with the enormous consumption of electricity in its manufacturing processes.

Aluminum has a significant contribution in all impact categories. Transportation has the largest contribution to Acidification in both scenarios. The eutrophication impact for Brick B is much higher than Brick A in scenario 1. This is caused by hard coal and lignite mining for electricity production in Australia where the fused magnesia is produced for Brick B.

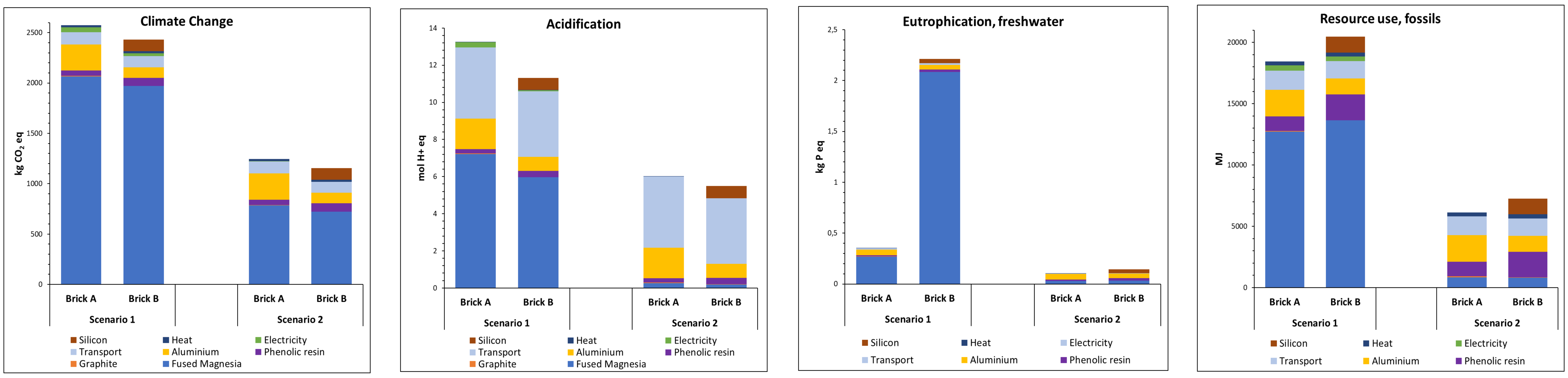

Figure 2. Environmental impacts of Brick A and Brick B in scenario 1 and scenario 2.

Conclusions:

- Environmental hotspots: fused magnesia followed by transport and aluminum.
- Brick B performs better than Brick A in climate change and acidification impact while Brick A performs in eutrophication and resource use.
- Hydroelectricity can reduce overall environmental impacts by at least 50% compared to the national grid electricity mix.
- 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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Beneficiaries