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Scenarios to valorize treated spent pot lining in cement and concrete

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Abstract

Concrete is the most widely used construction material in the world because of its durability and strength. Cement is the most common used binder in the concrete. Their production generates greenhouse gas emissions. However, supplementary cementing materials (SCMs) can sometimes replace cement and other components in the production of certain materials by acting as a binder, but their availability is increasingly limited. Rio Tinto plant is currently producing an inert material called Low-Caustic Leaching and Liming (LCLL) ash, which is obtained from the spent pot lining (SPL) refractory materials. Recent study showed that this by-product can have SCM's properties/characteristic after calcination above 900°C (Brial et al. 2021). LCLL ash can be used as a raw material for clinker in cement and concrete production. The goal of this study is to valorize the SPL by evaluating the valorization across three scenarios, the environmental impacts, the losses, and the gains of CO_2 related to their use as raw material in the cement plant and as supplementary cementing materials in the concrete design. This study will consider the whole life cycle, i.e., the extraction, the production and the emissions associated with the production of the SPL, cement, and concrete. The following scenarios will be evaluated: the first option is to landfill the SPL. The second option is to use the SPL as a raw material to produce clinker. The third scenario is to calcine the SPL at a temperature of 1050°C to use it as supplementary cementitious material in the production of concrete. The assessment of the environmental impact through the life cycle analysis of the studied materials will be carried out from cradle to gate and cradle to grave according to the above-mentioned recovery options.

Keywords: Treated spent pot lining, supplementary cementitious materials, life cycle analysis, environmental impact, cement production, concrete, primary aluminium production, Low-Caustic Leaching and Liming.

1. Introduction

Cement and concrete are the most widely used materials in the construction sector and its production poses environmental and economic problems. Because of their large-scale uses, their production leads to significant emissions of greenhouse gases like CO_2, dust, particles (Penrose 2014) and mercury (Van den Heede and De Belie 2012). In addition global warming, there is also the local shortage of non-renewable resources, energy consumption (Environment et al. 2018) and water use (Miller, Horvath, and Monteiro 2018). To date, the demand for cement and concrete continues to increase so it would be important to implement strategies to limit their impact on the environment in order to reduce greenhouse gas (GHG) emissions (Habert et al. 2020). Thus, to limit these problems, researchers have thought about the use of supplementary cementitious materials (SCMs) which will reduce the emissions of GHG. Among the potential source of supplementary cementitious materials, this paper considers a by-product of spent pot lining (SPL) treatment. SPL is a waste of primary aluminum production. However, Rio Tinto developed an industrial solution to produce industrial and valuable by-products (Birry, Leclerc, and Poirier 2016). Using the process called Low-Caustic Leaching and Liming (LCL&L), Rio Tinto's plant can produce from the refractory portion of the SPL, an inert material referred to internally as LCLL ash. This inert material is composed of 60-70% SiO_2 and Al_2O_3 and can be used as a raw material for clinker in the manufacture of cement when LCLL ash is calcinated at 1450°C Figure 1. Recent R&D projects conducted at ETS have shown that LCLL ash can be considered as a cementitious admixture in concrete production if calcined at a temperature of 1050°C. These calcined LCLL ash showed reaction properties similar to those of a calcined clay but no delay in hydration or expansion (Brial et al. 2021).

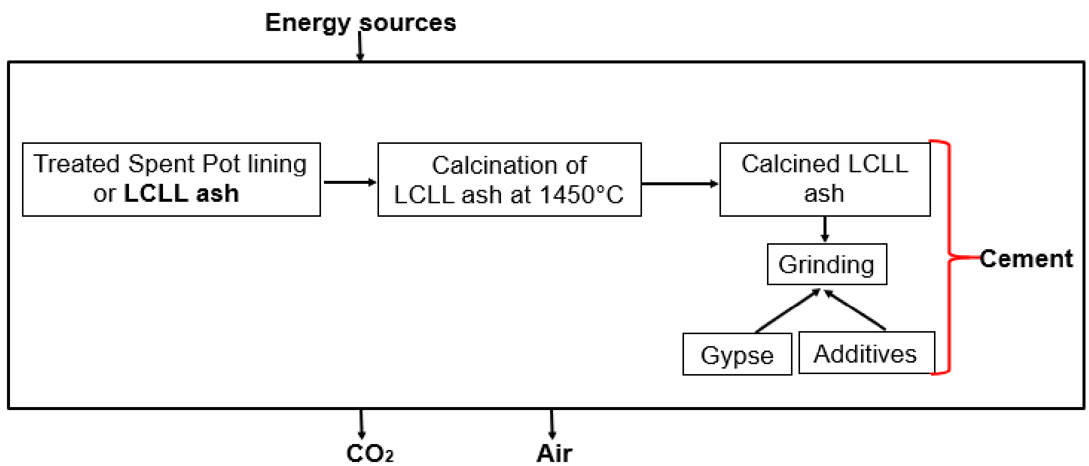

Figure 1: Cement production with as raw material treated spent pot lining calcined at 1450^0 C

The objective of this research is to evaluate the potential to valorize the LCLL ash, by-product of the SPL treatment, in cement and in concrete. In order to evaluate the environmental impact, a life cycle analysis of this material will be conducted from cradle to grave and cradle to gate, depending on the valorization scenarios.

2. Valorization scenario and environmental assessment

The first step is to define the analysis system and its limits. The materials used in this research are treated used tank linings, cement, and concrete. The analysis is carried out from cradle to grave and gate to gate. The cradle to grave in LCA is the whole life of the material, until its end of life (Wu, Xia, and Zhao 2014), so from the extraction of the raw materials to the production of the materials to be used, from the distribution to the landfill or recycling of the materials already used. The cradle-to-gate is an approach that has four-step process : the definition of goal and scope, the inventory analysis, the impact analysis and the interpretation (Wu, Xia, and Zhao 2014). On the other hand, the gate to gate only takes into account a single process in the entire production chain, so it concerns the entire production cycle of the product (Tait and Cheung 2016).

2.1. LCA to assess the environmental impacts

The studies are defined according to the ISO 14040 and 14044 standards by determining the inputs and outputs of the different material flows (Finkbeiner 2014). The raw material for this step comes from Rio Tinto SPL treatment plant, Usine de Traitement de la Brasque (UTB). Figure 2 shows the defined system with three different options. Option 1 concerns "cradle-to-grave" production where the treated SPL is sent to landfill and to know the CO_2's gain. Option 2 describes the second "cradle to grave" scenario where treated SPL is used as a raw material by a cement plant at 1450°C to produce cement. Option 3 focuses on the "cradle to gate" scenario where the treated SPL is pre-calcined at 1050°C to be used as a SCM to produce concrete.

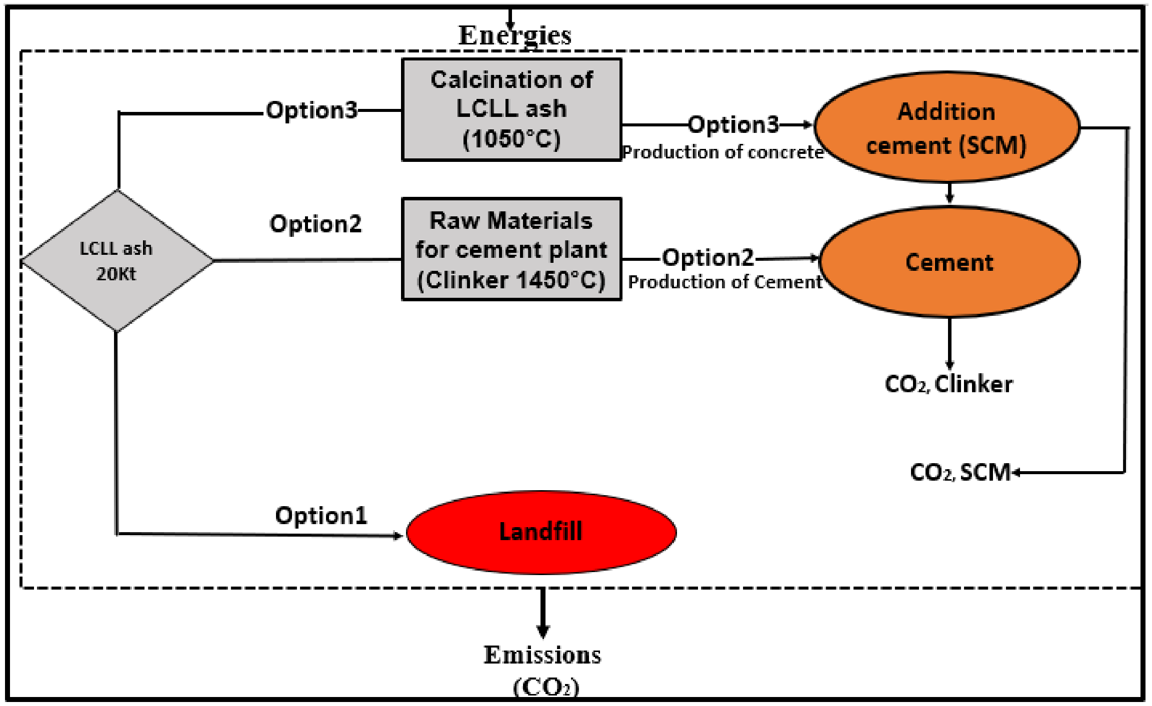

Figure 2: Use of treated spent pot lining in cement and concrete's productions

2.2. Data sources

The majority of the information sources come from the Ecoinvent database 3.10.1, which has made it possible to find disaggregated processes of the reference and elementary flows of each product. This database made it possible to obtain data on cement and concrete components more precisely in Quebec-Canada. The missing data was found on the Internet through articles and sites dedicated to construction materials, for example, electricity consumption for the manufacture of cement and concrete, for their transportation and for their burial. Data on electricity for municipal waste treatment was also found in the literature. The chemical compositions of LCLLash and calcined LCLLash are from the recent R&D projects conducted at ETS obtained by X-ray fluorescence bed fusion (XRF) (Ouellet-Plamondon et al. 2020).

2.3 Expected results

The results will be calculated at the midpoint and damage level using the IMPACT 2002+ method as this model is one of the most widely used models in LCA analysis. Due to the ability to obtain data, midpoint categories including non-carcinogens, respiratory inorganics, respiratory organics, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nitrification, aquatic acidification, aquatic eutrophication, global warming, and non-renewable energy, as well as human health, ecosystem quality, resource depletion, and climate change parameters will be selected in this study. In addition, normalization will be applied in this study to analyze the respective share of each median impact to the total impacts as well as to compare the median impacts with each other. The analysis will allow to know the environmental impacts generated by the treated pot lined products, cement, and concretes, on the one hand, but also the CO_2 gains obtained by using the treated pot lined products as raw material in the manufacturing of construction materials.

3. Expected benefits and industrial impact

From a sustainable development perspective, this project will bring to light on the benefits of using treated spent pot lining in the production of cement and concrete, in a perspective of a circular economy. It will also contribute to the Aluminium stewardship commitment of the industry.

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References

Birry, Laurent, Simon Leclerc, and Stéphane Poirier. 2016. "The LCL&L process: A sustainable solution for the treatment and recycling of spent potlining." In *Light Metals 2016*, 467-471. Springer.

Brial, Victor Jules, Hang Tran, Luca Sorelli, David Conciatori, and Claudiane Ouellet-Plamondon. 2021. "Evaluation of the reactivity of treated spent pot lining from primary aluminum production as cementitious materials." *Resources, Conservation and Recycling* 170:105584.

Environment, UN, Karen L Scrivener, Vanderley M John, and Ellis M Gartner. 2018. "Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry." *Cement and Concrete Research* 114:2-26.

Finkbeiner, Matthias. 2014. "The international standards as the constitution of life cycle assessment: the ISO 14040 series and its offspring." In *Background and Future Prospects in Life Cycle Assessment*, 85-106. Springer.

Habert, Guillaume, SA Miller, VM John, JL Provis, A Favier, A Horvath, and KL Scrivener. 2020. "Environmental impacts and decarbonization strategies in the cement and concrete industries." *Nature Reviews Earth & Environment* 1 (11):559-573.

Miller, Sabbie A, Arpad Horvath, and Paulo JM Monteiro. 2018. "Impacts of booming concrete production on water resources worldwide." *Nature Sustainability* 1 (1):69-76.

Ouellet-Plamondon, Claudiane, Victor Brial, Hang Tran, Luca Sorelli, David Conciatori, Laurent Birry, and Houshang Alamdari. 2020. "AL18-Valorization of Treated Spent Pot Lining By-Product in Concrete." *Conference and Exhibition of the International Committee for Study of Bauxite, Alumina & Aluminium, (9)*.

Penrose, Beris. 2014. "Occupational exposure to cement dust: changing opinions of a respiratory hazard." *Health and history* 16 (1):25-44.

Tait, Michael W, and Wai M Cheung. 2016. "A comparative cradle-to-gate life cycle assessment of three concrete mix designs." *The International Journal of Life Cycle Assessment* 21 (6):847-860.

Van den Heede, Philip, and Nele De Belie. 2012. "Environmental impact and life cycle assessment (LCA) of traditional and 'green'concretes: literature review and theoretical calculations." *Cement and Concrete Composites* 34 (4):431-442.

Wu, Peng, Bo Xia, and Xianbo Zhao. 2014. "The importance of use and end-of-life phases to the life cycle greenhouse gas (GHG) emissions of concrete–a review." *Renewable and Sustainable Energy Reviews* 37:360-369.