Value-added upgrading of blast furnace slag into varied mineral products

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The aim of this work is to develop a zero-waste process for storing CO_2 in a stable and benign mineral form, while producing zeolitic materials with sufficient heavy metal adsorption capacity, for wastewater treatment application, and pozzolans that can develop cementitious character, for use in cement blends or inorganic polymers. To this end, blast furnace slag, from ironmaking, was utilized as the starting material. This work follows on the works of Chiang et al. (2014) and De Crom et al. (2015), who showed that high quality PCC and unique zeolitic materials can be synthesized from this type of industrial residue.

Selective cooling of ironmaking molten slag can lead to the production of four distinct types of blast furnace slag, each produced at different ironmaking facilities: (i) air-cooled (i.e. crystalline), (ii) granulated (i.e. vitrified), (iii) expanded (otherwise known as foamed), and (iv) pelletized. The three first slags, respectively, find application in a variety of ways: as aggregate, in slag cement manufacture, as lightweight aggregate in structural and masonry concrete (Emery, 1980). Pelletized slag, initially developed by National Slag Limited (Hamilton, Ontario) is commercialized for either of the latter applications, and moreover is an improvement over the conventional expansion process as it reduces associated hydrogen sulfide gaseous emissions (Emery, 1980). In this work, granulated and pelletized slags will be tested. One aim is to find if the added porosity of pelletized slag accelerates calcium extraction by leaching and/or improves the pozzolanic activity of the resulting leaching residue.

The conceived multi-step multi-product process (illustrated in Figure 1) begins with an extraction step. Calcium is selectively withdrawn from the slag by leaching using acetic acid (CH_3COOH) as the extraction agent. At this stage, a high degree of extraction is achieved (≥90 %, measured by ICP-MS/ICP-OES) to ensure suitability of the solid residue for further valorization. The filtered leachate is then carbonated to form precipitated calcium carbonate (PCC) of high purity (<2 wt% non-calcium impurities) (according to ICP-MS/ICP-OES analyses); sodium hydroxide is added to neutralize the regenerated acetate. PCC, a carbon sink, finds applications as filler or pigment in paper, polymers, paints, among other uses.

The solid residues of the extraction stage can be utilized in two ways. Their high amorphous silica content of this material enables it to be used as a pozzolan in cement blend applications (e.g. mortar or concrete). The pozzolanic activity of the residues was measured using the Chapelle methodology and by conductivity measurement. In parallel, the residual solids from the extraction stage are subjected to hydrothermal conversion in alkali solutions (made up with NaOH) of different compositions (sodium metasilicate was used as an additive) that leads to the formation of several types of zeolitic as well as alkali activated materials (e.g. tobermorite ($Ca_5(OH)_2Si_6O_{16}\cdot 4H_2O$), sodalite ($Na_8Al_6Si_6O_{24}Cl_2$), lazurite ($Na_6Ca_2(Al_6Si_6O_{24})(SO_4,S_3,S_2,Cl,OH)_2$), and analcime ($NaAlSi_2O_6\cdot H_2O$)). Based on their ability to adsorb heavy metals (e.g. Cu and Zn), the final products can be used in industrial wastewater treatment applications. Pozzolanic activity also renders some of these materials as suitable reactive aggregates for building materials.

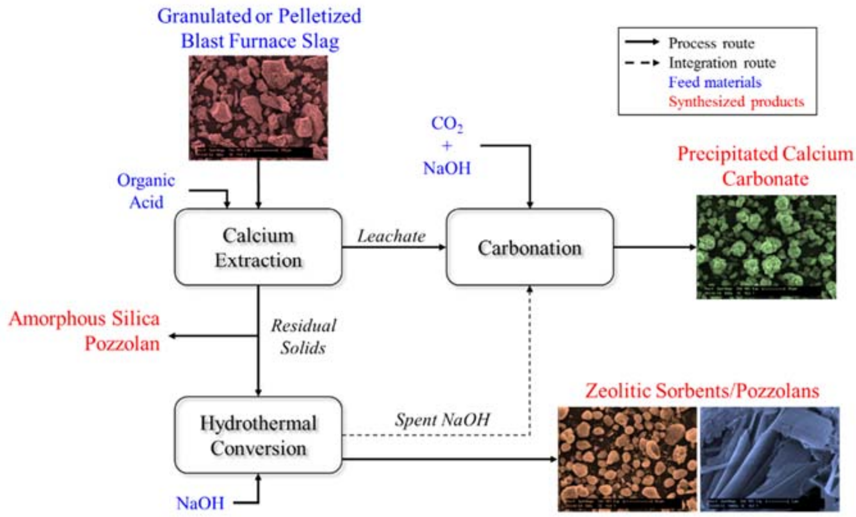

Figure 1. Conceptualized flowsheet of multi-way, zero-waste, blast furnace slag valorization.

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