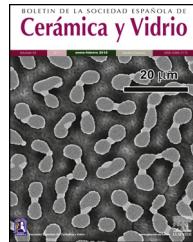




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Production of vitreous materials from mineral coal bottom ash to minimize the pollution resulting from the waste generated by the thermoelectrical industry

Camila da Silva Gonçalves^{a,*}, Adriano Michael Bernardin^b,
Rozineide Aparecida Antunes Boca Santa^a, Cassio Leoni^a,
Geraldo Jorge Mayer Martins^a, Claudia Terezinha Kniess^c, Humberto Gracher Riella^a

^a Chemical Engineering Department, Santa Catarina Federal University, P. O. Box 476, Trindade, 88.040-900 Florianópolis, SC, Brazil

^b Santa Catarina Extreme South University, 88.806-000 Criciúma, SC, Brazil

^c University Nove de Julho, 05001-000 São Paulo, SP, Brazil

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ABSTRACT

Mineral coal bottom ash exerts a great impact on the environment due to the presence of heavy metals in its composition and the lack of an adequate area for disposal. Vitreous materials were synthesized from bottom ash to be employed as a by-product. The bottom ash was subjected to an X-ray fluorescence (XRF) analysis to evaluate the oxide composition present in the material. To study the effect of bottom ash in the attainment of glass, a simplex lattice design for experiments with blends was employed. The elements considered in the design were: bottom ash; sodium carbonate (Na_2CO_3) and calcium oxide (CaO), both used as melting agents; magnesium oxide (MgO), which was used as a stabilizer for the vitreous network. For the characterization of the glasses, X-ray diffraction (XRD), differential scanning calorimetry (DSC) and Fourier transform infrared spectrometry (FTIR) were carried out. Ten different formulations were tested. The results indicated that two out of the ten formulations formed a crystalline phase, which is undesirable for a vitreous material. In the statistical analyses, the Pareto Diagram and the response surface showed that the glass transition and softening temperatures were strongly influenced by the level of calcium oxide and magnesium oxide, as well as that of bottom ash, resulting in an increase in the softening and glass transition temperatures.

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* Corresponding author.

E-mail address: goncalvesscamila@gmail.com (C.d.S. Gonçalves).

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Producción de materiales vítreos a partir de escoria de carbón mineral para reducir la contaminación producida por los residuos generados por la industria termoeléctrica

RESUMEN

Palabras clave:

Carbón mineral
Desechos sólidos
Escoria
Contaminación
Vidrios

La escoria de carbón mineral afecta profundamente al medio ambiente por la existencia de metales pesados en su composición y la falta de un área adecuada para su eliminación. Los materiales vítreos se sintetizaron a partir de escoria para ser empleados como subproducto. La escoria se sometió a un análisis de fluorescencia de rayos X (XRF) para evaluar la composición de óxido presente en el material. Para estudiar el efecto de la escoria en la obtención de vidrio, se empleó un diseño de malla simple para experimentos con mezclas. Los elementos que se valoraron en el diseño fueron: escoria; carbonato de sodio (Na_2CO_3) y óxido de calcio (CaO), ambos utilizados como agentes de fusión; óxido de magnesio (MgO), que se utilizó como estabilizador de la red vítre'a. Para la caracterización de los vidrios se llevaron a cabo difracción de rayos X (XRD), calorimetría de barrido diferencial (DSC) y espectrometría de infrarrojos por transformada de Fourier (FTIR). Se probaron 10 formulaciones diferentes. Los resultados indicaron que 2 de las 10 formulaciones formaron una fase cristalina, que es indeseable para un material vítreo. En los análisis estadísticos, el diagrama de Pareto y la superficie de respuesta mostraron que la transición vítre'a y las temperaturas de reblandecimiento estaban muy influidas por el nivel de óxido de calcio y de óxido de magnesio, así como por el de escoria, lo que aumentaba las temperaturas de reblandecimiento y transición vítre'a.

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Introduction

The coal-based thermoelectrical energy sector is an activity with large impact on the environment [1]. Mineral coal is one of the most employed resources throughout the world for energy production. Despite being a potentially polluting fuel, coal will probably continue leading as a source of energy generation [1]. According to the International Energy Agency and the World Coal Association [2], the combustion of mineral coal currently contributes with about 30% of the global primary energetic needs. The current coal reserves are estimated to be enough to meet the global production for approximately 150 years [2,3].

A crucial problem presented by mineral coal in thermo-electric is the generation of industrial waste, among which are tons of bottom ash and fly ash [4]. Fly ash are particles which move with the combustion gas as it leaves the furnace, while bottom ash are the particles which sediment at the furnace's bottom [5]. Bottom ash is considered one of the main industrial by-products [6]. The growing generation of ashes has long been source of environmental, technological and economic problems around the world [7]. According to data from the American Coal Ash Association (ACAA), in 2014 approximately 12 million tons of bottom ash were produced, and only 12% of those were subsequently used [8]. Given this context, the low frequency of utilization of this residue justifies the scarce existing research on the use of bottom ash [9].

Most technical and environmental problems associated with the use of mineral coal arise due to its inorganic components, especially the non-combustible ones [10]. According to Kim [11], the composition of bottom ash is basically constituted of SiO_2 (53.5%), Al_2O_3 (23.9%) and an acidic/basic oxides ratio of 2:1. The composition of the two ashes is practically

the same, but the bottom ashes have more moisture [8], and larger particle size. According to Ulusoy and Igathinathane [12], particle size distribution is an important measurement of the physical characteristics of ash, exerting influence in various aspects concerning its utilization, such as heat and mass transfer, as well as homogeneity of its mixture with other components.

In this context, this research was elaborated to evaluate the potential of bottom ash obtained in the south region of Santa Catarina, Brazil, to be used as the main raw material in the production of glasses, thus minimizing the environmental impacts and obtaining new materials with added value. An experimental design for mixtures was utilized to constitute 10 glasses using sodium carbonate and a 2:1 mixture of CaO/MgO , respectively, as melting agents. The effects of each component in the thermal properties of the glasses were determined.

The sodium-calcium glasses were prioritized for this study because they comprise 90% of all glass produced on Planet Earth [13], that is, the demand for these materials is extremely high.

The large proportions of SiO_2 found in bottom ash form the glass phase, and the alumina (Al_2O_3) acts as an intermediate cation, making the chemical bond more stable with oxygen, increasing the viscosity of the medium and acting as modifiers when the medium is favorable [14].

Few researches are available on the application of bottom ash in the production of glasses. Choi and Kang [15], for instance, investigated the degree of surface crystallization and the crystallization mechanism for $\text{SiO}_2\text{-Al}_2\text{O}_3\text{-Li}_2\text{O}$ glasses containing coal bottom ash. Kim and Kang [16] studied TiO_2 additions on the crystallization kinetics of a coal bottom ash Li_2O glass system. The main publications found with

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