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# Multi-analytical assessment of iron and steel slag characteristics to estimate the removal of metalloids from contaminated water

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A multi-analytical approach was used to develop a mathematical regression model to calculate the residual concentration of borate ions in water present at high initial content, as a function of the main physicochemical, mineralogical and electrokinetic characteristics after adsorption on five different types of iron and steel slag. The analytical techniques applied and slag properties obtained in this work were: X-ray Fluorescence for the identification of the main chemical compounds, X-ray Diffraction to determine crystalline phases, physical adsorption of nitrogen for the quantification of textural properties and zeta-potential for electrokinetic measurements of slag particles. Adsorption tests were carried out using the bottle-point technique and a highly concentrated borate solution (700 mg B/L) at pH 10, with a slag dose of 10 g/L. An excellent correlation between the residual concentration of boron and three independent variables (content of magnesium oxide, zeta potential and specific surface area) was established for the five types of slag tested in this work. This shows that the methodology based on a multi-analytical approach is a very strong and useful tool to estimate the performance of iron and steel slag as adsorbent of metalloids.

**Keywords:** Adsorption, crystal structure, model, morphology, zeta potential.

## Introduction

Iron and steel slags are formed by the reaction of fluxes with the gangue material in the iron ore and the ashes in coke. The primary function of the fluxes is to provide a liquid slag with sufficiently low viscosity and melting point to be easily removed from the liquid bath. They also provide a separation between the reaction zone and liquid metal, protecting the latter. An important secondary function of the slag is the partitioning of metal impurities into the oxide melt. It is the latter aspect which imposes, for a given ore mix, the exact composition of the slag, which consists typically of silica ($SiO_2$), alumina ($Al_2O_3$), calcia (CaO), and magnesia (MgO), which make up 95% of the material.[1]

Minor elements include manganese, iron and sulfur compounds, as well as trace amounts of others. Recently, it has been pointed out that, even when the composition of the slag cannot be altered, its physical and textural characteristics, as well as surface chemistry, can be modified by its cooling and solidification process.[2]

Slag production in iron and steel making depends on the specific process used, but worldwide output was estimated at 400 million tons in 2006.[3] Slag has been considered traditionally as a waste product. Its chemical characteristics are imposed by the specific process and cannot be modified freely. Its usage as asphalt aggregate, railroad ballast or road base material corresponds clearly to applications where disposal, not valorization, is the primary goal. However, the unique chemical properties of many types of slag provide ample options for valorization.

The prime area of research seems to be the concrete industry;[4] substitution of Portland cement by slag or other alternative binders reduces the total $CO_2$ impact in this industry and may also provide superior binder performance. Reported environmental applications of slag include: as an adsorbent for waste water and storm-water treatment, for the remediation of Acid Mine Drainage (AMD), for carbon sequestration and for the sand capping technique used in the marine environment to suppress some nutrients that cause eutrophication of seawater and to eliminate hydrogen sulfide producing blue tides.[5]

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