

INTERACTION BETWEEN OXYGEN STEELMAKING SLAG AND WATER CONTAMINATED WITH METALLOID IONS

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Introduction

Industrial wastewater is often contaminated with heavy metals as well as metalloids like arsenic. A wide range of materials, including metal powders, zeolites and carbon nanotubes, have been used so far to remove the contaminant(s) from the water stream. However, the financial cost as well as availability of these options often hinder their wide-spread deployment, especially in less-organised sectors and in regions lacking economic development. The communities living in and around these regions, unfortunately, remain exposed to this hazard due to seepage into aquifers and contamination of drinking water.

Slag generated from oxygen steelmaking is typically perceived as a “waste” due to limited value-added use and difficulty in disposal. However, the constituents in the steelmaking slag may be capable of immobilising these contaminants, either by physical adsorption or chemically through precipitation of insoluble product(s). Initial results show that reduction of arsenic concentration in contaminated water is indeed possible by exposure to granulated BOF slag. This material is relatively inexpensive and available in large quantities.

Arsenic is a particularly lethal contaminant due to its long-term impact on health and lack of immediate symptoms in affected individuals. The present investigation is aimed at establishing the mechanism of interaction between the slag constituents and dissolved arsenic species, and to assess the stability and longevity of the slag as a permeable reactive barrier.

Literature Study

A permeable reactive barrier (PRB) is a porous divider placed in the path of contaminated water, either underground or in exposed channels, where the barrier material reacts actively with the contaminant species and thus reduces their concentration in the water passing through. Research has been going on for several years to optimise various contaminant-specific barrier materials. The most commercially successful reactive media used to date for arsenic removal is zero-

valent iron (ZVI), while materials like limestone, activated carbon, hydrated lime, zeolites and polysulphide compounds have achieved different levels of success. ZVI is a mild reductant that can remove hexavalent chromium, arsenic and uranium contaminants from water. Activated carbon and zeolites are also widely utilised for treatment of contaminated groundwater. The incentive to use the BOF slag as a potential PRB material arises from its low cost, easy availability and fairly large scale of generation around the globe (> 100 million tonnes annually).

The electron configuration of elemental arsenic is $[\text{Ar}] 3d^{10}4s^24p^3$. Arsenic exhibits a variety of oxidation states, examples of which are AsH_3 (−3), As (0), HAsO_2 (+3) and H_3AsO_4 (+5).

Experiment Details

BOF slag samples used for the experiments were collected from different BOF shops. Chemical analysis of the as-received material was carried out using ICP-AES technique and the overall composition is reported in Table 1.

Table 1: Chemical composition** (in wt%) of the slag used

CaO	FeO	MgO	SiO ₂	Al ₂ O ₃	MnO	P ₂ O ₅	Cr ₂ O ₃	TiO ₂
47.02	22.88	8.78	15.76	1.34	0.44	2.11	0.12	0.97

** Major constituents included in the analysis; Other ingredients in trace quantities contribute the balance 0.58 wt%

Around 1 kg of the as-received slag sample was taken, and was crushed into smaller size and sieved to segregate it into different categories by particle size, viz. +6 mm, 3.35–6.0 mm, 2.0–3.35 mm, 1–2 mm, 0.5–1 mm and −0.5 mm.

A stock solution of a given arsenic concentration (230 ppm) was prepared by dissolving the requisite quantity of disodium arsenate heptahydrate in distilled water. 10 grams of slag sample of each particle size range was soaked in 200 ml of the solution. The samples were kept for different time intervals in order to study the influence of exposure time on the interaction. After the soaking duration, samples of the solution were collected to estimate the change in arsenic concentration. Part of the soaked slag was also taken out, rinsed with distilled water and then subjected to subsequent testing to check the tendency of arsenic leaching back into fresh water. This stage of the investigation is crucial to decide on a safe disposal route for the used slag. About 5 g of used slag particles was added into approximately 30 ml of distilled water and kept for different time intervals for this purpose.

Results and Future work

ICP-AES analysis conducted on the arsenic solution samples after the stipulated reaction durations shows a drop in As concentration over time (Figure 1) and this confirms that BOF slag particles have definite capability to remove arsenic from contaminated water. However, the effectiveness increased with decreasing particle size, owing to enhanced surface area for adsorption of the arsenic species.

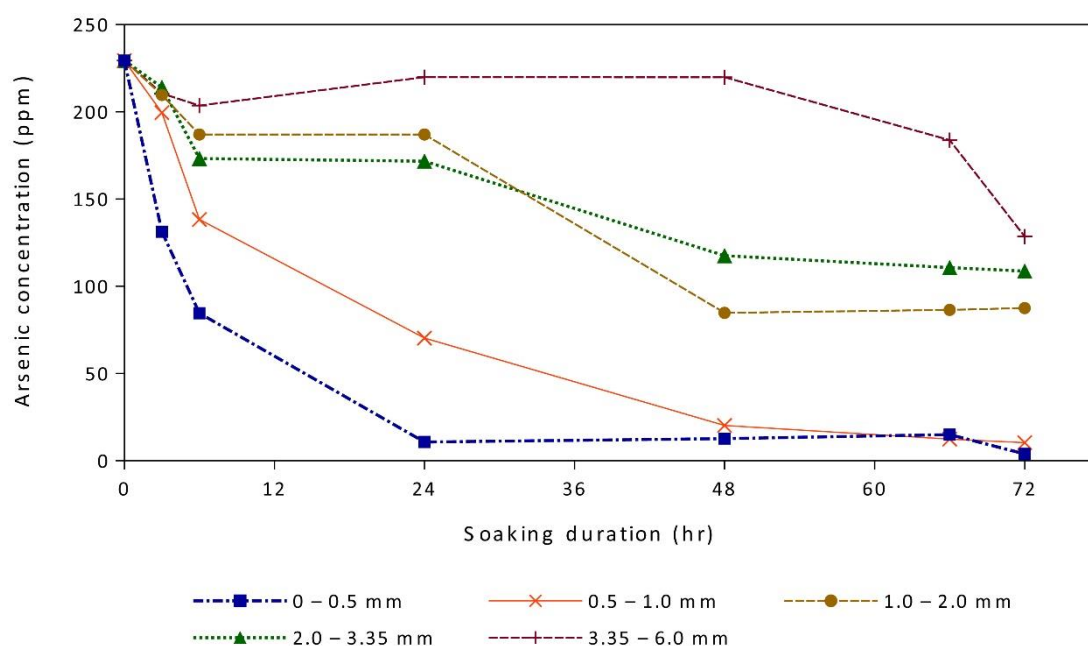


Figure 1: Adsorption patterns for different size ranges of slag particles, as function of soaking duration

The soaking was continued up to 21 days but changes beyond 7 days were insignificant, irrespective of slag particle size. The work on leach-back of arsenic from the soaked slag is in progress and the results are not conclusive yet. More experiments are required to establish the influence of factors like temperature and water pH on the mechanism of adsorption as well as leaching back of the arsenic-containing species.

Acknowledgement

The authors wish to thank Steel Authority of India Ltd. (SAIL), and Rourkela Steel Plant in particular, for providing the BOF slag used in this work. The contribution of IIT Bombay towards facilitating the experimental work is also gratefully acknowledged.

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