Chemical Engineering Journal 200–202 (2012) 338–343

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Preparation of sorbents containing ettringite phase from concrete sludge and their performance in removing borate and fluoride ions from waste water

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HIGHLIGHTS

- Sorbents containing ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$ made from concrete sludge.
- Thermal treatment of sorbents enhances boron and fluoride removal performance.
- Enhancement is due to formation of metaettringite phase.
- Boron and fluoride removal performance can meet the effluent standard in Japan.

ARTICLE INFO

Article history:
Received 25 May 2012
Received in revised form 14 June 2012
Accepted 14 June 2012
Available online 23 June 2012

Keywords:
Ettringite
Boron removal
Fluoride removal
Waste water treatment
Concrete sludge

ABSTRACT

Concrete sludge is an industrial waste slurry containing hydrated cement, aggregates and water. Solid sorbents containing ettringite, $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$, were prepared from concrete sludge by adding various amounts of aluminum sulfate to enhance ettringite formation. Anion exchange performance of the sorbents was examined using model waste waters containing boron or fluoride ions. The removal behavior depended on the calcium/aluminum ratio and the heat treatment temperature after drying. For the same Ca/Al ratio, improved removal performance was observed for sorbents treated at higher temperatures. The highest removal capacity was found when the sorbent was prepared with a molar ratio of Ca/Al of 3.2 and heat treatment at 175 °C. The final concentrations of boron and fluoride were 6.3 mg-B/L, and less than 4 mg-F/L for initial concentrations of 100 mg-B/L and 300 mg-F/L. Treatment of the sorbents at higher temperature dehydrated the ettringite phase to form metaettringite phase. The sorbents prepared in the present study can be used in a boron and fluoride removal process that meets the effluent standard in Japan.

1. Introduction

Concrete sludge is an alkaline industrial waste composed of hydrated cement, aggregates and water. About 1–2% of fresh concrete prepared for construction use is discarded as concrete sludge because it is necessary to prepare excess concrete to avoid shortages at construction sites, and also because the quality of the prepared concrete does not always match the required specifications. Concrete sludge has been used as a landfill material after solid/liquid separation followed by neutralization with an acid. This treatment process can be costly, and an effective and economical recycling or reuse process for concrete sludge is required.

So far some recycling methods for concrete sludge have been proposed, including reuse as a raw material in cement production, use as road–bed materials, soil neutralizers, neutralizers for waste incinerator gas, and fine aggregate for concrete production. Use of sludge water for concrete production [1], reuse as soil mixed with construction sludge [2], as water treatment materials [3,4], as a calcium source for a mineral carbonation process to reduce CO_2 emission [5,6], and for desulfurization [7] has also been investigated. These processes are based on the fact that concrete sludge is strongly alkaline and rich in calcium.

Our previous paper [8] reported preparation of a new type of sorbent from concrete sludge for boron removal from waste water. The sorbent showed excellent anion removal performance. The mechanism for anion removal was assumed to be ion exchange by the sulfate ions in the ettringite [$Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$] phase that was formed during the hydration of Portland cement [9–13].

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http://dx.doi.org/10.1016/j.cej.2012.06.064