



Mechanism of solidification of simulated borate liquid wastes with sodium silicate activated slag cements



Nailia R. Rakhimova ^{a,*}, Ravil Z. Rakhimov ^a, Vladimir P. Morozov ^b, Ludmila I. Potapova ^a, Yury N. Osin ^c

^a Kazan State University of Architecture and Engineering, Kazan, Russian Federation

^b Kazan Federal University, Kazan, Russian Federation

^c Interdisciplinary Center for Analytical Microscopy Kazan Federal University, Kazan, Russian Federation

ARTICLE INFO

Article history:

Received 8 November 2016

Received in revised form

18 January 2017

Accepted 8 February 2017

Available online 14 February 2017

Keywords:

Hydration products

Granulated blast furnace slag

Alkali-activated cement

Radioactive waste

Waste management

ABSTRACT

In this study the mineral matrix based on hydrous sodium metasilicate (NSH₅) activated slag cement (AASC) was found to be suitable for solidification of borate solutions with pH 8.5–10.5 and concentration up to 200 g/L. Parameters such as setting times and compressive strength of the waste forms based on AASC and borate wastes can be influenced by the ratio of NSH₅ and H₃BO₃ content. The dosage of 7% Na₂O in the alkali activator per slag provides acceptable setting times and 28-day compressive strength of the waste forms in the range 49.7–56.1 MPa depending on pH of the borate solutions. Lowering the pH of borate solutions results in a reduced rate of setting of the fresh AASC paste, retardation in the structural formation of the hardened AASC paste, a reduced degree of hydration, and a reduction in the amount of calcium silicate hydrates and hydrotalcite. The product of AASC-based mineral matrix and simulated borate wastes interaction is ulexite (NaCaB₅O₆(OH)₆(H₂O)₅).

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1. Introduction

Progress in nuclear power engineering, with its associated formation and accumulation of nuclear wastes and in conditions of rising requirements for environmental safety, has created an urgent need for the improvement of materials and approaches for reliable immobilization of the wastes (Ojovan, 2011; Shaw and Blundell, 2014). Presently, Portland cement (PC), the most widely used material for solidification of low and intermediate level radioactive wastes (RW), does not always ensure the efficiency of immobilization and accommodation of high load with wastes of diverse composition.

A particular “problematic” waste that results when PC is used as mineral matrix for immobilization is boric acid (H₃BO₃), which is one of the most common types of liquid waste concentrate generated by pressurized water reactors. The main problem in the solidification of boric acid and borate using PC is their strong retarding effect on setting times of the wastefoms (Atabek et al., 1992; Demirbas and Karslioglu, 1995; Le Bescop et al., 1990;

Ramachandran and Lowery, 1992). The inhibition effect from the borates often lowers the waste loading needed to obtain qualified solidified waste.

One way to improve the performance of the final wastefoms using cementation technology for “problematic” wastes is to use alternative cements as binders. Alternative cements produce a diverse range of reaction products that, when compared to PC, are characterized by lower solubility and higher ion exchange properties, different pH, faster hardening, and lower permeability of hardened pastes, etc. (Abdel Rahman et al., 2015; Rakhimova et al., 2015; Zhuang et al., 2016; Perna and Hanzlicek, 2014). The differences in composition and structure formation between alternative binders and PC predetermine the differences in the immobilization mechanism. For borate RW, alternative binders such as calcium aluminate, sulphoaluminate, magnesium phosphate, and alkali-activated cements can have higher efficiencies than PC (Champenois et al., 2013, 2015; Qina and Jianlong, 2010; Hall, 2001; Hugo et al., 2015; Yang, 2010; Goni and Guerrero, 2001; Palomo and De la Fuente, 2003; Rakhimova and Rakhimov, 2016).

Previous studies (Palomo and De la Fuente, 2003; Rakhimova and Rakhimov, 2016) have found alkali-activated fly ash and slag cements to be effective in solidifying boron-containing solutions. Experimental results indicated that the leaching indices and

* Corresponding author.

E-mail address: rahimova.07@list.ru (N.R. Rakhimova).