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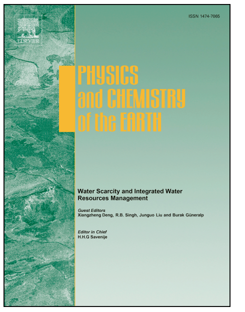

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Reactive Transport Models of a High-pH Infiltration Test in Concrete

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Abstract

A laboratory-scale tracer test was carried out to characterize the transport properties of concrete from the Radioactive Waste Disposal Facility at El Cabril (Spain). A hyperalkaline solution (K-Ca-OH, pH=13.2) was injected into a concrete sample under a high entry pressure in order to perform the experiment within a reasonable time span, obtaining a decrease of permeability by a factor of 1000. The concentrations of the tracers, major elements (Ca^{2+}, SO_4^{2-}, K^+ and Na^+) and pH were measured at the outlet of the concrete sample. A reactive transport model was built based on a double porosity conceptual model, which considers diffusion between a mobile zone, where water can flow, and an immobile zone without any advective transport. The numerical model assumed that all reactions took place in the immobile zone. The cement paste consists of C-S-H gel, portlandite, ettringite, calcite and gypsum, together with residual alite and belite. Two different models were compared, one with portlandite in equilibrium (high initial surface area) and another one with portlandite reaction controlled by kinetics (low initial surface area). Overall the results show dissolution of alite, belite, gypsum and quartz and precipitation of C-S-H gel, portlandite, ettringite and calcite. Permeability could have decreased due to mineral precipitation.

Keywords: reactive transport, double-porosity, concrete, numerical model

1. Introduction

Cementitious materials are used as engineered barriers in order to store radioactive waste. For example, concrete is used to store low- and intermediate-level radioactive waste at El Cabril (Spain), which is the motivation of this work. The problem at El Cabril is that there is flow of water inside the concrete cells used to store the radioactive waste (Chaparro and Saaltink, 2016). It is important to know the transport proprieties of concrete, in order to understand the processes that takes place inside the concrete cells used to store the waste. For this reason, in a previous work, a laboratory-scale tracer test in a concrete sample was performed, and numerical models taking into account the matrix diffusion conceptual model were made (Chaparro et al., 2016). In that experiment, hyperalkaline solution (K-Ca-OH, pH 13.2) was injected into concrete. During the performance of the test the permeability decreased by a factor of 1000 (Figure 1). This could be due to mineral precipitation. Hence, in this work, a reactive transport model has been carried out to study the changes in mineralogy that may have happened during the test.

In the literature, few works have studied infiltration tests in concrete. One of them is the work of Chapwanya et al. (2009), who modelled re-wetting experiments in concrete. They consist of placing dry concrete samples in a liquid bath and observing the progress of the wetting front. Both water and isopropanol were used as infiltration solutions. However, reactions were produced when water was used. Residual alite and belite dissolved, and as a consequence C-S-H gel precipitated reducing the porosity. Works have been published on the geochemical interaction of the cement pore water with granite or clay materials (Pfingsten et al., 2006; De Windt et al., 2008; Kosakowski and Berner, 2013; Soler, 2013, 2016). Reactive transport models in hardened cement were also reported by Soler et al.