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Impacts of Fe(0) grain sizes and grain size distributions in permeable reactive barriers

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HIGHLIGHTS

- ▶ Large grain size range of typical granular cast iron for Fe^0 fixed bed filters.
- ▶ Significantly varying porosities of grain size fractions.
- ▶ Visualized pore geometry varies with no significant anisotropy.
- ▶ Highest reactivity for column test with finest grain size fraction.
- ▶ Grain size fractionation for clogging reduction in the influent section.

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ABSTRACT

Permeable reactive barriers consist of heterogeneous Fe(0) shavings that are provided as fixed bed to remove a number of different pollutants from contaminated aquifers. Chemical properties, such as reactivity, and physical parameters, such as porosity or flow velocity, influence the contaminant removal and, in the long term, the susceptibility to clogging and passivation. The grain size and the grain size distribution are important characteristics that can be expected to influence chemical and physical processes. In the present work a typical granular cast iron material has been separated into grain size fractions that have been characterized with regard to physical and, in column experiments, chemical properties. Determined bulk densities and porosities revealed that increased pore volumes and thus increased residence times can be achieved by fractionation. The pore structures of the original grain size composition and of two grain size fractions (0.4–0.5 mm and 0.71–0.8 mm) have been visualized. Column tests with 100 g reactive Fe(0) of different grain size fractions (0–0.4 mm, 0.4–0.71 mm, 0.71–1.0 mm, 1.0–2.0 mm and original grain size distribution) were conducted over a period of 160 d to compare the reactivity with regard to reduction of trichloroethylene, hydrogen gas generation and precipitation of carbonate and calcium. Fractionation of the heterogeneous grain size distribution can be expected to improve the long term efficiency of a permeable reactive barrier. Finally a simple but promising modification of Fe(0) permeable reactive barriers is discussed.

1. Introduction

Permeable reactive barriers consisting of a fixed bed with Fe^0 granules are successfully applied as passive in situ technology to treat plumes of various organic and inorganic pollutants [1–7]. The complete chemical reduction of trichloroethylene (TCE) to ethene, for example, can be described with the following equation:

$$3Fe^0 + 3H_2O + C_2HCl_3 \rightarrow 3Fe^{2+} + C_2H_4 + 3OH^- + 3Cl^- \quad (1)$$

The dissolution of ferrous iron with the concomitant pH increase leads to the precipitation or growth of secondary minerals. The minerals cover and thus passivate the reactive Fe^0 surface and occupy pore space and thus might clog flow paths. The geometry and opening dimension of pores have an influence on the long term permeability.

Fe^0 granules used in permeable reactive barriers, mostly cast iron shavings, include a wide range of grain sizes. Exemplary reported values of frequently used materials are listed in Table 1. Generally heterogeneous grain size distributions achieve lower porosities than more homogenous and narrow grain size fractions.

To date different grain sizes were compared in batch experiments [12,13]. The beneficial effect of large Fe^0 grains was discussed by Li and Benson [14]. Two different grains sizes of

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