한국지하수토양환경학회 춘계학술대회
2002년 4월 12-13일 서울시립대학교

Using Waste Foundry Sands as Reactive Media in Permeable Reactive Barriers

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요 약 문

Permeable reactive barriers (PRBs) are in-situ barriers constructed in a subsurface to treat contaminated groundwater using various reactive media. The common reactive medium used in PRB is zero-valent iron, which has been widely used to treat chlorinated solvents (i.e., PCE, TCE). A disadvantage of iron media is high cost. In this study, waste foundry sands were tested to determine the feasibility of their use as a low cost reactive medium. Batch and column tests were conducted with TCE to determine transport parameters and reactivity of the foundry sands. The reactivities of foundry sands for common groundwater contaminants are comparable to or slightly higher than those for Peerless iron, a common medium used in PRBs. In addition, the TOC and clay in foundry sands can significantly retard the movement of target contaminant, which may result in lower effluent concentration of contaminant due to biodegradation. In general, PRBs 1-m thick can be constructed with many foundry sands to treat TCE provided the zero-valent iron content in the foundry sand is higher than 1%.

key word : Zero-valent iron, TCE, Foundry sands, Permeable reactive barriers, TOC

1. Introduction

Permeable reactive barriers (PRBs) are a relatively new groundwater treatment technology. As a contaminant plume flows through a PRB, contaminants react with the media contained in the PRB, and are converted into less toxic or innocuous by-products. Effluent exiting a PRB is intended to meet goundwater quality requirements.

A drawback of PRBs is their high initial capital cost. The high cost often prevents their use at small-contaminated sites, which are common in the United States. The objectives of this study was to assess the feasibility of using waste foundry sands as a low-cost reactive medium for PRBs. Twelve foundry sands from Wisconsin, Ohio, and Illinois were evaluated as reactive media in this study. Batch tests were conducted with TCE to assess reactivity and sorptive capacity, and column tests were conducted to determine if results of the batch tests were representative of more realistic conditions. Transport parameters were also obtained from the column tests for use in PRB design.

2. Materials and Methods

(1) Materials

Twelve foundry sands were used in this study. The foundry sands were obtained from Wisconsin, Ohio, and Illinois. Each sand is designated by a number (1 through 12). Each of the foundry sands contains a large fraction of fine sand, organic carbon, and zero-valent iron. Zero-valent iron particles were obtained from Peerless Metal Powders and Abrasives Co. of Detroit, MI. The mean particle size was 0.7 mm and the specific surface area was 0.87 m2/g.

(2) Methods

Batch sorption tests were conducted to determine the sorption capacity of foundry sands for TCE. A tumbling time of 24 hr was used for all subsequent tests to ensure equilibrium was attained. For the batch sorption test with TCE, the amount of sorbent was maintained constant (5g) while the initial concentration of TCE was varied between 1 and 30 mg/L

Batch tests were performed to evaluate the rate of degradation of TCE in aqueous solution in the presence of foundry iron and Peerless iron. A first-order decay model with instantaneous sorption from Koppensteiner (1998) was used to find a bulk reaction rate constant and the partition coefficient for TCE.

Column tests were conducted to determine transport parameters (i.e., partition coefficient, rate constant, and dispersion coefficients) under more realistic conditions for foundry sands, iron, and mixture of foundry sand and iron. The column test data were fitted to an analytical solution of the advection-dispersion-reaction equation (ADRE) provided by van Gunuchten (1981).

3. Results and Discussion

Partition coefficients from the column tests are graphed against those from the batch sorption tests in Fig.1. The partition coefficients from both tests are comparable, but in general the partition coefficients obtained from column tests are slightly higher than those from the batch tests. Thus, designs based on results of batch tests should be conservative.

The bulk first-order rate constants (Kobs) obtained from the column tests under equilibrium conditions are shown in Fig. 2 as a function of specific surface area. As was observed for the batch tests, Kobs increases linearly with increasing SSA. In contrast to the batch tests, however, Kobs for the foundry sands is appreciably higher than that for Peerless iron. The slopes of the lines in Fig. 2 represent the normalized rate constant (KSA). The average KSA is 3.5i¿10-4 L/m2-hr for foundry sands and 6.0i¿10-5 L/m2-hr for Peerless iron; that is, KSA for foundry sands is approximately six times higher than that for Peerless iron. The higher KSA for the foundry sands may be due to different characteristics of iron surfaces in the foundry sands compared to those for Peerless iron. The average KSA for the batch tests (1.6i¿10-4 L/m2-hr) falls between that of foundry sands and Peerless iron.

The normalized TCE concentrations are shown in Fig. 3 for various zero-valent iron contents and barrier thicknesses. PRBs less than 1 m wide can be constructed with foundry sands provided the seepage velocity is less than 0.01 m/day, the zero-valent iron content is at least 0.6%, and the source concentration is less than 400 mg/L. For more severe conditions, a thicker barrier may be required or the reactivity of the barriers may need to be enhanced by adding a modest amount of iron particles to the foundry sands.

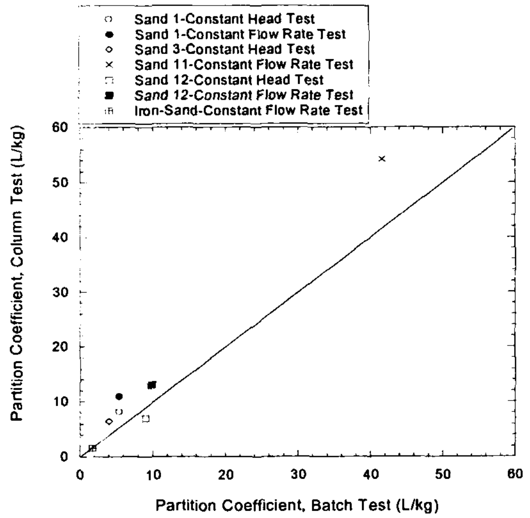

Fig. 1. Partition Coefficients Obtained From Batch Sorption Tests and ColumnTests

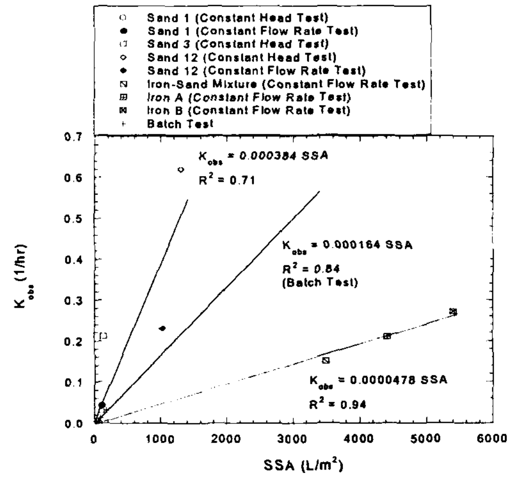

Fig. 2. Kobs for Foundry Sands and Peerless Iron as a Function of SSA. Central Line is for Data from Batch Tests.

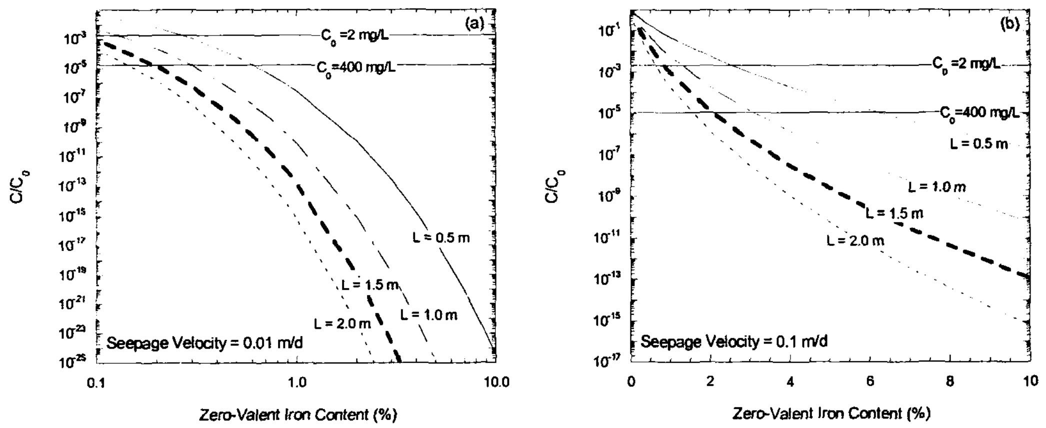

Fig. 3. Required Barrier Thickness as a Function of Zero-Valent Iron Content and Barrier Thickness: (a) VS= 0.01 m/d and (b) Vs = 0.1 m/d.

4. References

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