Illite spatial distribution regulates Cr(VI) adsorption capacity and kinetics

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This work examined how and to what extent illite spatial distribution regulates adsorption capacity and kinetics of Cr(VI) using column experiment and two-dimensional reactive transport modeling. Two sets of columns were packed with the same total amount of illite and quartz sand however in different spatial patterns. The two differs in the permeability contrast between the quartz and illite zones, with permeability ratios of 1.48 and 32.24 (sand over illite) for C columns (chemically heterogeneous) and PC columns (physically and chemically heterogeneous), respectively. Within each set, columns with different spatial patterns were set up: Mixed column (M), Flow-parallel column (FP), Flow-transverse column (FT1) and Flow-transverse 2 zones column (FT2). Flow-through experiments were carried out with acidic inlet solutions (pH = 4) containing Cr(VI) under the flow velocities of 0.6, 3.0, and 15.0 m/day.

Experimental results showed that illite spatial distribution strongly affects sorption capacity and kinetics, the extent of which depends on permeability contrast and flow conditions. Under the relatively low flow velocity of 0.6 m/day, the Cr(VI) curves of M and FT1 columns overlapped for both C and PC sets while the FP and FT2 columns show much longer tails. The average sorption rate increased with increasing flow velocities while the sorption capacity decreases with the increasing flow velocities. The largest difference were found between M PC and FP PC column at the low flow regime where FP PC column only had 13% of the sorption capacity and 6% of the sorption rates compared to the M PC column.

Reactive transport models that explicitly incorporate the exact mineral distribution were used to reproduce the data and to understand the mechanism. We further explored conditions with a wide range of the permeability-contrast and transverse dispersivity ï¿¡T, the two major variables that control sorption capacity and kinetics. The 2D modeling results showed that the adsorption capacity of FP column increases linearly with ï¿¡T, while the permeability-contrast showed negligible influence. For the FT2 column, however the capacity decreased linearly with permeability ratio. These observations provide valuable insights on key controls of mineral spatial structure controls on Cr(VI) fate and transport in the natural subsurface.