Relationship between velocities in a single fracture and retardation effects by sorption investigated with laboratory tracer experiments

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[Introduction]
On high-level waste disposal, it is important to evaluate retardation effects of solute transport in groundwater. Matrix diffusion, sorption on the fracture surface and bulk sorption in the matrix retard the transport of solute through fractured rock. In-situ tracer experiment that has been applied in many fractured rocks, is one of the methods for evaluating properties of the solute transport. Multi-rate tracer experiment is proposed to specify several parameters related to solute transport. However, previous study has clarified that sorption distribution coefficients (K_a and K_d) depend on pumping flow rate in the target fracture. Thus, the information about the relationships between a velocity in a fracture and K_a and K_d are important can be a key to improve the accuracy of estimating them. In this study, we conducted the laboratory tracer experiments and discuss relationship between velocities in a single fracture and the retardation effects by sorption. The two-dimensional numerical model composed of a fracture and a rock matrix was applied to simulate breakthrough curve (BTC) that was obtained by lab experiments.

[Methods]
Hirukawa granite rock was cut and shaped to be rectangular prism. Stainless spacers and an acrylic board were put on the granite rock and the 0.5mm of gap between the rock and the acrylic board was used as fracture in lab experiments. Sodium naphthionate (NAP) and Rb^+ were used as nonsorbing and sorbing tracer, respectively. The fracture aperture and the longitudinal dispersivity were calculated from BTCs of NAP and K_a and K_d were estimated from that of Rb^+. The parameters described above were obtained under 2 different flow rates (0.1 and 1.0 mL/min) and they were compared to understand the retardation effect of a velocity in the fracture. In these experiments, the setting fracture aperture is constant. Therefore, different flow-rate conditions are equivalent to different velocity conditions in the fracture.

[Results and discussions]
When the velocity in the fracture is 5.33×10^{-4} m/s, estimated K_a and K_d are 7.81×10^{-5} m and 4.50×10^{-3} m^3/kg, respectively. In the case of 5.95×10^{-5} m/s, the numerical fitting cannot reproduce the experimental BTC indicating that K_d and K_a are strongly dependent on the velocity in the fracture. Thus, revising curve-fitting method and/or construction of new model taking into account the effect of non-equilibrium sorption may be needed to deal with such cases.
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Keywords: Fractured rock, Solute transport, Tracer experiment, Breakthrough curve, Sorption