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Deposition and Release Behaviour of ZnO Nanoparticles in Saturated Quartz Sand: Role of Biofilm, Ionic Strength, and pH

Gukhwa Hwang (1), Yosep Han (1), Donghyun Kim (1), Scott A. Bradford (2), Byoungcheun Lee (3), Igchun Eom (3), Pil Je Kim (3), Siyoung Q. Choi (4), Youngsoo Lee (1), and Hyunjung Kim (1)

(1) Department of Mineral Resources and Energy Engineering, Chonbuk National University, Jeonju, Jeonbuk 561-756, Republic of Korea (Tel: +82632702370; Fax: +82632702366 kshjkim@jbnu.ac.kr), (2) USDA, ARS, US Salinity Laboratory, Riverside, CA 92507, United States, (3) Risk Assessment Division, National Institute of Environmental Research, Hwangyeong-ro 42, Seo-gu, Incheon 404-708, Republic of Korea, (4) Information Electrical Research Institute, KAIST, Daejeon, 305-701, Republic of Korea

The influence of biofilm, ionic strength, and pH on the deposition and release behavior of zinc oxide nanoparticles (ZnO-NPs) was systematically investigated in well-controlled saturated sand column. The results for the initial transport of the ZnO-NPs at pH 9 showed significant retention at the inlet of the column with hyper-exponential retention profiles regardless of solution ionic strength investigated (0.1 and 10 mM) and Pseudomonas putida biofilm coating; however, the increase in solution ionic strength and the presence of biofilm onto quartz sand tended to increase the retention of ZnO-NPs. The trend was likely attributed to more favorable NPs-NPs interaction and greater surface roughness, respectively. The results were well supported by the DLVO interaction energy profiles and Electron Microscopic observations. For the release tests, particle free solution at pH 6 was continuously injected into the column with the ZnO-NPs retained during the initial transport tests. The results for breakthrough curves and time-lapsed retention profiles showed that reducing solution pH led to the release of large amount of the initially retained ZnO-NPs, and the release rate was observed to be greater for bare silica than biofilm-coated sand. The release of ZnO-NPs was likely attributed to the dissolution of Zn2+ due to the change of pH. The proposed mechanism was further verified by conducting additional column tests at higher pHs (pH 9 and 10), which showed significantly reduced release of ZnO-NPs, and even nearly no release at pH 10. The findings from this study suggests that there exists high potential of complete transport of ZnO-NPs into groundwater in that the pH of various soil environments typically ranges from 5 to 9.
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