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Effect of the background solution and material composition on the transport of silver nanoparticles in saturated aquifer materials

Yorck Adrian, Uwe Schneidewind, Tomas Fernandez-Steeger, and Rafig Azzam
Department of Engineering Geology and Hydrogeology, RWTH Aachen University, Aachen, Germany (adrian@lih.rwth-aachen.de)

Engineered silver nanoparticles (AgNP) are used in various consumer products such as cloth or personal care products due to their antimicrobial properties (Benn et al., 2010). Their transport behavior in the environment is still under investigation. Previous studies have been focusing on the transport of AgNP in simple test systems with glass beads or soil materials (Braun et al., 2015), but studies investigating aquifer material are rare. However, the protection of fresh water resources in the subsurface is an important part in the protection of human health and the assurance of future economic activities. Therefore, expert knowledge regarding the transport and fate of engineered nanoparticles as potential contaminants in aquifers is essential.
Within the scope of the research project NanoMobil funded by German Federal Ministry of Education and Research, the transport and retention behavior of AgNP in aquifer material was investigated under saturated conditions in laboratory columns for different flow velocities, ionic strengths (IS) and background solutions. The used aquifer material consisted mainly of quartz and albite. The quartz grains were partially coated with iron hydroxides and oxides. Furthermore, 1% hematite was present in the silicate dominated aquifer material. The experiments were conducted using $NaNO_3$ and $Ca(NO_3)^2$ background solutions to examine the effects of monovalent and divalent cations on the transport of AgNP. Flow velocities in the columns were chosen to represent typical flow velocities of groundwater in the subsurface. For the experiments two mean grain sizes of 0.3 and 0.7 mm were used to investigate the effect of the grain size on the transport behavior. Particle concentration was measured using ICP-MS and particle size was determined using flow field-flow fractionation (FlFFF). HYDRUS-1D (Šimůnek et al., 2013) was used to elucidate the transport and retention processes of the AgNP in the aquifer material.
The obtained results show that grain size and background solution as well as mineral composition have an effect on the retention of AgNP. A higher breakthrough of about 75% was observed in the more coarse material compared to 60% in the fine material. Especially, iron oxides and hydroxides provided favorable attachment points for AgNP. Complete retention of AgNP in the aquifer material occurred at 1.5 and 1 mM IS when $Ca(NO_3)^2$ was used as background solution and little breakthrough was observed at 0.5 mM IS. In contrast, when using $NaNO_3$ (1 and 10 mM) a breakthrough of about 50% of the AgNP was observed for 1 mM IS whereas no breakthrough occurred for 10 mM IS. The results show that the divalent background ions and a high ionic strength tend to reduce the transport of silver nanoparticles in aquifer material with this composition.

References

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