Marine phages as markers for reactive transport of nanoparticles in subsurface ecosytems

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Manufactured nanoparticles (NP) are considered promising materials for a number of applications and released at relevant amounts into the environment. Soils are an important terminal sink for most NP. Consequently it is essential to investigate the reactive transport of NP in soil. A key problem thereby is the tracing and quantification of NP in complex matrices. In our study we use marine phages as specific markers for reactive transport of NP in soil. Marine phages and their bacterial hosts are naturally absent in soil, harmless to humans and the environment, and will thus be used as specific tracers of the reactive transport of NP. In addition, The possibility to apply as many as 10^{15} phages in tracer experiments and to detect as little as one phage mL^{-1} of recovered water via its specific interaction with the host bacterium provides an enormous sensitivity. Here, we present data evaluating the effects of physico-chemical characteristics of phages and hydraulic water flow regimes on transport of marine phages in laboratory experiments. Phages were characterized by electron microscopy, dynamic light scattering and water contact angle analysis (CA) for their size/morphology, surface charge (ζ) and hydrophobicity. Sand-filled percolation columns and a modified high-throughput plaque assay combined with fluorescence microscopy counting were used to quantify phage deposition during percolation. Our data show that all marine tested phages exhibited relatively low deposition eficiencies and high transport rates in our laboratory setups. Transport rates depended mainly on the size and the hydrophobicity of the phages tested. Despite of similar morphology and surface charge (ζ = -13 mV) of the two phages PSA-HS2 and H40/1, the bigger (60 nm) and less hydrophobic (CA = 40°) PSA-HS2 phage exhibited a lower deposition efficiency than the smaller (39 nm) and more hydrophobic (CA = 52°) H40/1 phage. We conclude that marine phages have a high potential for the use as sensitive tracers of nanoparticle transport in terrestrial systems. The use of phages as markers contributes to a better, mecahnistic understanding of the drivers of nanoparticle transport in subsurface ecosytems.