

Factors controlling transport of nanoplastics in saturated iron oxide coated sand columns

Taotao Lu, Stefan Peiffer, Sven Frei, and Benjamin S. Gilfedder

Department of Hydrology, University of Bayreuth, Bayreuth, Germany (cuglutaotao@gmail.com)

Nanoplastic particles are widely applied in industry and agriculture, such as personal care products, pharmaceutical products and application of sewage sludge on farm soils, and thus, may be released into the subsurface environment. Additionally, secondary nanoplastic particles may also form during microplastic and macroplastic degradation.

Charge heterogeneity of porous media is an important characteristic of natural soil with iron oxides being one of the most prominent constituents. Iron oxides are usually positively charged at the pH of groundwater (< 8) and will therefore significantly effect (reduce) the transport and deposition of nanoplastics in the aquifer.

In this research, Polystyrene plastic nanoparticles (Nano-PS) with carboxyl functional groups were employed in column experiments to understand nanoplastic transport processes in the subsurface. Quartz sand coated by iron was used to fill the columns increasing the charge heterogeneity and roughness of the porous media compared to pure quartz sand. Solution chemical factors, such as pH, ionic strength, cation valence and natural organic matter, were taken into consideration. In addition, the properties of the porous media are significant in influencing nanoplastic retention. For example, the content of iron coated sand determines the number of sorption sites that are available for retaining Nano-PS. At the same time, the roughness of porous media is also dependent on coated sand content.

We present column experiments to identify the interactions between the Nano-PS and the porous media. Pure quartz sand and iron oxide coated sand were dry packed into glass columns (7.1 cm length, 1.2 cm inner diameter). The pH of solution was adjusted by addition of 0.1 M HCl or NaOH. Electrolyte solution (0.1 M NaCl, 0.01 M CaCl₂) was added in order to change the ionic strength and cation valence. The experiments were carried out at a constant pump rate of 0.16 mL/min. We performed breakthrough experiments with 0%, 50% and 100% content of iron oxide coated sand at pH 7. At high content (100%) of coated sand, the C/C_0 ratio was ~ 0 within 8 PV (C , C_0 are the concentration of Nano-PS in effluent and influent solution, respectively). However, for pure quartz sand, the C/C_0 ratio increased to 70% after 5 PV. There are two main mechanisms to explain this retention phenomenon. On one hand, under the experimental conditions, the Nano-PS were negatively charged while the iron oxide coating was positively charged despite the quartz substrate being also negatively charged. As a result, the iron oxide coated sand provides more sorption sites for Nano-PS than the pure quartz sand. In addition the roughness of the substrate grains increases with increasing content of iron coated sand. Thus, at high iron content, the permeability of porous media decreases and leads to a higher physical filtering effect for the nanoplastic decreasing the C/C_0 ratio.