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Limited effects of different real groundwaters from three coastal cities in China on the transport of low-concentration nanoplastics in quartz sand†

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Nanoplastics (NPs) have been widely detected in soil–groundwater systems. However, to date, the effect of real groundwater on the fate and transport of NPs has been poorly understood. In this study, the transport and retention behaviors of both polystyrene and poly(lactic-*co*-glycolic acid) NPs (PS NPs and PLGA NPs) in different real groundwaters from three coastal cities in China were explored using column experiments. PS (0.51 and 1.1 μm) and PLGA (1 μm) NPs with a low concentration of 2 mg L^{-1} were employed. Close observation showed that the transport of PS NPs was much higher than PLGA NPs in different groundwaters, with an average breakthrough curve plateau (C/C_o) of ~0.81 for PS NPs and ~0.19 for PLGA NPs, respectively. As observed for PLGA, the plastic shape- and size-induced straining may be the reason for the minimal transport. Interestingly, we found that although the physicochemical characteristics of different real groundwaters varied significantly, the transport of certain NPs in real groundwater was similar with negligible differences. Closer inspection indicated that similar pHs of different groundwaters may be the reason contributing to these findings. Further investigation revealed that the transport behaviors of PS and PLGA NPs in real groundwater did not follow the classical DLVO theory. These findings suggest that the fate and transport of NPs in real soil-groundwater systems are much more comprehensive than the prediction based on DLVO theory and need intensive investigation.

Environmental significance

The transport of NPs in real natural groundwater systems remains largely unexplored. In contrast to our hypothesis, although solution chemistry has a strong influence on the transport of NPs, we concluded that different groundwaters did not have significant effects on their transport through the porous media. The similar pH of the different groundwaters may be the reason for these findings. Further investigation revealed that the transport behaviors of the examined NPs in real groundwaters did not follow the classical DLVO theory. Thus, more efforts should be devoted to distinguishing the dominant factors controlling the actual fate and transport of NPs in real terrestrial systems.

1. Introduction

Plastic debris accumulation in the environment, including nanoplastics (NPs), has emerged as an environmental threat globally. The surge in plastic waste production and consumption will lead to an estimated 11 billion tons of plastic waste in the environment by 2025.[1,2] NPs, which are usually defined as plastic particles smaller than 1000 nm, are of particular interest due to their potential to permeate ecosystems and pose risks to both the environment and human health.[3–7] Additionally, NPs can serve as carriers for various pollutants, including heavy metals,[8] organic substances[9] and even antibiotic-resistant genes.[10] NPs can be formed from the breakdown of larger plastic items or be intentionally produced for use in various consumer products.[11–13]

The introduction of NPs in soil–groundwater systems through processes, such as mulching film weathering,[14] irrigation of treated wastewater,[15] urban sewage sludge fertilization[16] and atmospheric deposition,[17] has raised environmental concerns and spurred research on the transport of plastics particles in porous media in recent years.[18–25] Studies have also found that the transport of plastics particles in porous media can be influenced by environmental factors, such as the

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† Electronic supplementary information (ESI) available: Breakthrough mass recovery of column experiments (Table S1); zeta potentials of NPs and quartz sand, and average sizes of NPs with different real groundwaters (Table S2); stability of both PS and PLGA NPs in DI water (Fig. S1); calibration curves of PS and PLGA NPs with fluorescence spectrophotometer (Fig. S2); influence of groundwater on the detection of NPs using fluorescence spectrophotometer (Fig. S3); and additional details on methods are provided. See DOI: https://doi.org/10.1039/d3em00388d

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