Aggregation, sedimentation, transport, and retention of nanohybrids of reduced graphene oxide/carbon nanotubes and metal/metal oxides in aqueous solutions and saturated porous media

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Abstract

Nanohybrids (NHs) of carbonaceous nanomaterials and metal/metal oxides have wide applications, yet their fate and transport including aggregation and sedimentation in the environment are poorly understood. We first investigated aggregation and long-term (25 d) sedimentation of reduced graphene oxide (RGO) and its three successively self-assembled NHs with magnetite (Fe_3O_4) and zerovalent silver (Ag^0) nanoparticles. The aggregation of the NHs in NaCl and $CaCl_2$ solutions was found to be in good agreement with classical Derjaguin–Landau–Verwey–Overbeek (DLVO) theory and the Schulze-Hardy rule. The stability decreased with increasing the ratios of the edge-based surface functional groups (C(O)O and C=O) of RGO quantified by X-ray photoelectron spectroscopy. Natural organic matter inhibited aggregation of RGO and its NHs due to enhanced electrosteric repulsions. RGO NHs were less stable in synthetic groundwater during the 25-d sedimentation test likely due to greater charge screening or neutralization effects imparted by higher monovalent and divalent electrolyte concentrations. Separately, we evaluated transport and retention of the multifunctional carbon nanotube-magnetite (CNT-Fe_3O_4) NHs in water-saturated sand under environmentally relevant conditions. Carboxymethylcellulose was employed to stabilize the NHs. The transport of the magnetic CNT-Fe_3O_4 NHs was lower than that of the parent nonmagnetic CNT due to greater aggregation (induced by magnetic attraction). The DLVO theory well-interpreted the NHs' transport; and secondary energy minimum played dominant roles in NHs' retention. A novel transport feature, an initial low and following sharp peaks occurred frequently in the NHs' breakthrough curves; and the magnitude and location of both transport peaks varied with different experimental conditions due to the interplay between variability of the fluid viscosity and aggregation-dispersion nature of the NHs.

Biography

Dr. Chunming Su is a Soil Scientist in the Groundwater, Watershed, and Ecosystem Restoration Division, National Risk Management Research Laboratory, Office of Research and Development (ORD), United States Environmental Protection Agency (USEPA). Dr. Su's research area includes applications and implications of environmental nanotechnology with respect to the fate and transport of nanomaterials in the subsurface and use of nanomaterials for soil and groundwater remediation; in situ treatment of organic (chlorinated solvents) and inorganic (chromate, arsenic, nitrate, etc.) contaminants in groundwater and soil using permeable reactive barrier technologies and monitored natural attenuation approaches; and green infrastructure for storm water management. He has published over 100 peer-reviewed journal articles, book chapters, and technical reports. He has served as a reviewer for 90 scientific journals. He is a winner of USEPA Bronze Medal, ORD Honor Awards, and USEPA Scientific and Technological Achievement Awards.

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