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The Interactions and the implications of Nanoparticulate Zero-Valent Iron with Clay Minerals and Natural Organic Matters

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Nanoparticulate zero-valent iron (nZVI), used in a wide variety of applications for the contaminated soil remediation, is increasingly being introduced into the environment; this situation calls for research on the interactions of nZVI with clay mineral particles (CMPs) and natural organic matter (NOM) to regulate the environmental behaviors and risks. Co-settling, kinetic aggregation, calculation of the classical/extended Derjaguin-Landau-Verwey-Overbeek interaction energy, and electron microscopic observation were carried out to investigate the interaction between nZVIs (two naked nZVIs of different sizes and one carboxymethyl cellulose (CMC) coated nZVI) and CMPs (kaolinite and montmorillonite). Based on the analysis of total organic carbon, ultraviolet characterization, high performance size exclusion chromatography, three-dimensional excitation-emission matrices, and Fourier transform infrared spectrum, the preferential sorption of two types NOMs (humic acid and fulvic acid) onto nZVIs surface were illuminated. Lewis acid-base interactions mainly accounted for the attachment between nZVIs and clay mineral particles (CMPs) under alkaline and neutral conditions, while van der Waals, Lewis acid-base, and electrostatic attraction regulated the interfacial interaction under acidic condition. Compared with heteroaggregates formed by nZVIs attaching to CMPs edges and faces under neutral and acidic conditions, the heteroaggregates were smaller with nZVIs mainly connecting to CMPs edges under alkaline condition. Small nZVI homoaggregates were bound to CMP edges at low nZVI concentrations and large nZVIs-CMPs heteroaggregates formed by nZVI bridging with increasing nZVI concentration. The adsorption of NOM on nZVIs improved the stability of nZVIs suspensions. Aliphatic hydrocarbons of high molecular weight were preferentially adsorbed by nZVIs mainly via hydrophobic interaction and ligand-exchange reaction. The NOM solutions after nZVIs adsorption were with low photochemical stability and high reducing capacity due to the unsaturated-hydrocarbon of low molecular weight as residual. These findings are of significance to the environmental remediation application and risk assessment of nZVIs.

Keywords: Interfacial interaction, nano zero-valent iron, clay minerals, natural organic matter