Chemical Engineering Doctoral Defense
Separation of Oil and Other Organics from Water Using Inverse Fluidization of Hydrophobic Aerogels

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abstract

Hydrophobic silica aerogel has been used for oil removal and organic separation due to its desirable properties. This dissertation is dedicated to systematically studying the sorption mechanisms of hydrophobic silica aerogel (Cabot Nanogel®) granules for oil and volatile organic compounds (VOCs) in different phases, and investigating the performance of Nanogel for removing oil from laboratory synthetic oil-in-water emulsions and real oily wastewater, and VOCs from their aqueous solution, in both packed bed (PB) and inverse fluidized bed (IFB) modes.

The sorption mechanisms of VOCs in the vapor, pure liquid, and aqueous solution phases, free oil, emulsified oil, and oil from real wastewater on Nanogel were systematically studied via batch kinetics and equilibrium experiments. The VOC results show that the adsorption of vapor is very slow due to the extremely low thermal conductivity of Nanogel. The faster adsorption rates in the liquid and solution phases are controlled by the mass transport, either by capillary flow or by vapor diffusion/adsorption. The oil results show that Nanogel has a very high capacity for adsorption of pure oils. The rate for adsorption of oil from an oil-water emulsion on the Nanogel is 5-10 times slower than that for adsorption of pure oils or organics from aqueous solution. For an oil-water emulsion, the oil adsorption capacity decreases with an increasing proportion of the surfactant, with a much lower sorption capacity and a slower sorption rate for a real oily wastewater sample due to the high stability of the real oily wastewater.

The performance of Nanogel granules for removing emulsified oil, oil from real oily wastewater, and toluene at low concentrations in both PB and IFB modes was systematically investigated. The hydrodynamics characteristics of the Nanogel granules in an IFB were studied by measuring the pressure drop and bed expansion as a function of superficial water velocity. The density of the Nanogel granules was calculated from the plateau pressure drop of the IFB. The oil/toluene removal efficiency and the capacity of the Nanogel granules in the PB or IFB were also studied and predicted by two models based on equilibrium and kinetic batch measurements of the Nanogel granules.

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