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Synthesis of amino functionalized hollow core-mesoporous shell silica spheres for heavy metals adsorption and recovery

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The contamination of water with heavy metal ions is a worldwide environmental problem. Many techniques have been used to remove heavy metals including chemical precipitation, electro-flotation, ion exchange, reverse osmosis, and adsorption. Mesoporous silica nanoparticles are considered as versatile unique materials due their chemical and thermal stabilities, low toxicity, tunable porosity and compatibilities with other nanoparticles. Outstanding textural properties of mesoporous silica make it a powerful platform for many applications. Functionalized mesoporous silica nanoparticles with organic functional groups were considered as proper adsorbents for environmental pollutants removal because they possess high surface area and large adsorption capacity. Herein, we report a simple synthesis for hollow core-mesoporous shell silica spheres (HCMSSs) by ultrasonic assisted soft-templating method. Synthesis parameters such as effect of solvent type and acid concentration have been investigated to accomplish hollow core-mesoporous shell silica spheres with superior textural. In addition, optimizing adsorption parameters of Pb, Cd, and Zn on HCMSSs as well as conducting kinetic and thermodynamic studies have been also addressed in this work. It was found that ethanol was appropriate solvent to construct hollow core structure. At 0.09 g/ mL ethanol, spherical hollow silica can be obtained with clear porous structure and thick shell. The concentration of acid affected the degree of neutralization of surfactant that, in turn, affects the formation of hollow core structure. The amino functionalized HCMSSs showed high efficiency in adsorption of Pb(II), Cd(II) and Zn(II) metal cations as compared to non-functionlized HCMSSs. The maximum adsorption capacity was obtained at pH 6 and contact time 150 min. Adsorption kinetics was analyzed by pseudo first and second order equations and results showed that Pb, Cd and Zn adsorption onto HCMSSs followed second order kinetics model. Thermodynamic parameters; ΔGo, ΔHo and ΔSo indicated that the sorption process was spontaneous and endothermic in nature. Effective recovery of Pb, Cd and Zn was obtained with 3 M nitric acid and the prepared HCMSSs showed reasonable reusability.