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Removal of Pb^{2+}, Cr^{3+} and Hg^{2+} ions from aqueous solutions using SiO_2 and amino-functionalized SiO_2 particles

ALEKSANDRA LOBNIK[1], NENA DIMITRUÅ¡EV[1] AND A. F. P. ALLWIN MABES RAJ[2]

[1]University of Maribor

[2]Institute of Environmental Protection and Sensors

Presenting Author: aleksandra.lobnik@um.si

Herein we present silica (SiO_2) and amino-functionalized SiO_2 particles ($NH_2@SiO_2$) based on the Stöber method involving the reaction of hydrolysis and condensation of alkoxide precursors tetraethoxysilane (TEOS), 3-(trimethoxysilylpropyl) diethylenetriamine (DETA) and (3-aminopropyl) trimethoxysilane (APTMS) for specific and selective removal of heavy metal ions such as Pb^{2+}, Cr^{3+} and Hg^{2+}. The prepared silica and amino-functionalized silica particles were characterized by FT-IR spectroscopy, thermogravimetric analysis (TGA), specific surface area (BET), transmission electron microscopy (TEM), zeta potential measurements and potential titration measurements. We studied the adsorption efficiency of the prepared adsorbent materials toward heavy metals ions (Pb^{2+}, Cr^{3+} and Hg^{2+}) in model salt solutions. The adsorption process was evaluated in terms of adsorption efficiency, adsorption capacity, adsorption isotherms, kinetics and thermodynamic based on the result of the atomic absorption spectroscopy (AAS) measurements for Pb^{2+} and Cr^{3+} ions and inductively coupled plasma optical emission spectrometer (ICP-OES) measurements for Hg^{2+}. Particles with the adsorbed ions were treated with hydrochloric acid or citric acid in order to evaluate the desorption efficiency. The results showed the highest adsorption efficiency and adsorption capacity for heavy metal ions (Pb^{2+}, Cr^{3+} and Hg^{2+}) adsorption using APTMS precursor to functionalize SiO_2 particles. Furthermore, the adsorption capacity was 54.13 mg/g in the case of Pb^{2+}, 29.16 mg/g in the case of Cr^{3+} ions and 14.4 mg/g for Hg^{2+} with more than 96 % of heavy metal ions (Pb^{2+} and Cr^{3+}) and 88% for Hg^{2+} removed from aqueous solution. The adsorption process for Pb^{2+}, Cr^{3+} and Hg^{2+} ions using non-functionalized SiO_2 and functionalized ($NH_2@SiO_2$) particles follow the kinetics of pseudo-second-order and is best described by the Langmuir adsorption model. The desorption results showed potential for reuse of functionalized ($NH_2@SiO_2$) particles with more than 91% of Pb^{2+} ions desorbed using 0.1 M hydrochloric acid and 100% of Hg^{2+} desorbed using 1.5 M citric acid.