Ammonium-functionalized mesoporous silica MCM-41 for phosphate removal from aqueous solutions

Jin-Kyu Kang, Jae-Hyun Kim, Song-Bae Kim, Sang-Hyup Lee, Jae-Woo Choi, Chang-Gu Lee

Environmental Functional Materials & Biocolloids Laboratory, Seoul National University, Seoul 151-921, Republic of Korea, emails: naengie@snu.ac.kr (J.-K. Kang), kjh85@snu.ac.kr (J.-H. Kim), Tel. +82 2 880 4387; Fax: +82 2 873 2087; email: songbkim@snu.ac.kr (S.-B. Kim)
Department of Rural Systems Engineering and Research Institute of Agriculture and Life Sciences, Seoul National University, Seoul 151-921, Republic of Korea
Center for Water Resource Cycle Research, Korea Institute of Science and Technology, Seoul 136-791, Republic of Korea, emails: yisanghyup@kist.re.kr (S.-H. Lee), plead36@kist.re.kr (J.-W. Choi), changgu@kist.re.kr (C.-G. Lee)
Graduate School of Convergence Green Technology & Policy, Korea University, Seoul 136-701, Republic of Korea

Received 10 July 2014; Accepted 27 March 2015

ABSTRACT

The aim of this study was to investigate the removal of phosphate (P) using ammonium-functionalized MCM-41 (A-MCM-41). Batch experiments were performed with A-MCM-41 under various conditions including the adsorbent dose, reaction time, initial P concentration, and solution pH. The results showed that the phosphate removal in the MCM-41 (initial P conc. = 2 mgP L\(^{-1}\)) was negligible with the percent removal of ≤1.0% at the adsorbent dosages between 0.5 and 2.0 g L\(^{-1}\). In the case of A-MCM-41, the percent removal increased from 73.6 to 100% as the adsorbent dose increased from 0.5 to 2.0 g L\(^{-1}\). This indicated an enhancement of the phosphate removal due to the surface modification of the MCM-41 through the functionalization of the ammonium group (NH\(_3\)\(^{+}\)). The results also demonstrated that the phosphate removal by the MCM-41 was minimal throughout the acidic and alkaline pH conditions (3.1% at pH 3.5; ≤1.0% at pH 5.4–10.7), whereas the phosphate removal by the A-MCM-41 was effective throughout the acidic and neutral pH values (94.7–97.6% at pH 3.5–7.4). In highly alkaline conditions, however, the phosphate removal by the A-MCM-41 was greatly reduced (3.4% at pH 10.7) due to the competition of the hydroxyl groups (OH\(^{-}\)) with phosphate ions for sorption sites. The results indicated that the pseudo-second-order model was most suitable for describing the kinetic data with the parameter values of \(q_e = 1.86\) mgP g\(^{-1}\) and \(k_2 = 183.98\) g mgP\(^{-1}\) h\(^{-1}\). The Redlich–Peterson isotherm fits well with the equilibrium data, with the parameter values of \(K_{R/aR} = 7.90\) mgP g\(^{-1}\) and \(g = 0.83\).

Keywords: Mesoporous silica; MCM-41; Phosphate; Sorption; Surface functionalization

*Corresponding author.