

Removal of Phosphate from Wastewater by Adsorption on Marble Waste: Effect of Process Parameters and Kinetic Modeling

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Abstract

Batch adsorption experiments were carried out, aiming to remove phosphates ions from water samples using powdered marble (PWM) as an effective inorganic sorbent, which is cheap, widespread. Operating parameters such as pH, sorbent, and phosphates concentration, shaking time, and temperature influencing the sorption process, were investigated. The results obtained showed that the sorption of phosphates ions onto PWM was fitted well with the linear Langmuir model over the concentration range studied. Phosphate removal by PWM was a pH-dependent process. Mechanisms for phosphate removal mainly involved adsorption and precipitation, varied with equilibrium pH of the solution. The sorption on PWM increased with increasing temperature. The pseudo-second-order model characterized the kinetics of the removal process by PWM adsorbent. The synthesized adsorbents before and after phosphate adsorption were characterized by powder X-ray diffraction and Fourier-transform infrared spectroscopy. The calculated thermodynamic parameters ($ΔG^{\circ}$, $ΔH^{\circ}$, and $ΔS^{\circ}$) showed that the adsorption of phosphate onto powdered marble was feasible, spontaneous and endothermic at 15–40 °C.

Keywords Powdered marble · Adsorbent · Phosphate removal · Adsorption kinetics · Modeling · Thermodynamic parameters

Introduction

Phosphate in wastewater sources is an essential nutrient for the growth of photosynthetic algae and other biological organisms in wastewaters. However, excess phosphate concentration in the effluent discharge can lead to eutrophication of the receiving confined wastewaters. Consequently, the amount of phosphate in domestic and industrial discharges must be controlled using wastewater treatment technology (Nguyen et al. 2014; Zhao et al. 2009). The phosphorus content of effluents or streams that discharge directly into lakes and dams is regulated by national and international water standard authorities with

maximum limits ranging from 0.1 to 2.0 mg L⁻¹ as P, and many established at 1.0 mg L⁻¹ (Hammer and Hammer 2011). In wastewater treatment technology, many methods have been developed for phosphate removal, which includes physical, chemical, and biological processes. Physical processes have proved to be either too expensive, as in the case of electrodialysis and reverse osmosis (Kartashevsky et al. 2015) or inefficient, removing only 10% of the total phosphorus (Mulkerrins et al. 2004). Enhanced biological treatment can remove up to 97% of the total phosphorus, and it is low cost. However, the variability in chemical composition and temperature of wastewater would make the implementation of this process not feasible for wastewater treatment (Li et al. 2006). The most effective and well-established method is chemical removal techniques; chemical treatment is applied for the removal of phosphorus, generally aluminum sulfate, followed by iron III, iron II, and finally calcium (Yeoman et al. 1988). The removal of phosphate from aqueous consists of the conversion of soluble phosphate into an insoluble solid phase. This solid phase can be separated from water using sedimentation or filtration. In wastewater

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