FeNi$_3$@SiO$_2$@CuS magnetic nanocomposite: synthesizing, characterization, and application for methylene blue adsorption

Negin Nasseh[a], Tariq J. Al-Musawi[b], Rasoul Khosravi[a], Ayat Hossein Panahi[c], Fatemeh Sadat Arghavan[d], Behnam Barikbin[a,e],*

[a]*Department of Environmental Health Engineering, Faculty of Health, Social Determinants of Health Research Center, Birjand University of Medical Sciences, Birjand, Iran, emails: B_Barikbin@yahoo.com (B. Barikbin), negin_nasseh@yahoo.com (N. Nasseh), khosravi.r89@gmail.com (R. Khosravi)*
[b]*Department of Civil Engineering, Faculty of Engineering, Isra University, Amman, Jordan, email: tariq.almusawi@iu.edu.jo (T.J. Al-Musawi)*
[c]*Social Determinants of Health Research Center, Birjand University of Medical Sciences, Birjand, Iran, email: ayatpanahi@yahoo.com (A. Hossein Panahi)*
[d]*Student Research Committee, Department of Environmental Health Engineering, Faculty of Health, Mashhad University of Medical Sciences, Mashhad, Iran, email: fatemeh.arghavan71@gmail.com (F.S. Arghavan)*
[e]*Social Determinants of Health Research Center, Mashhad University of Medical Sciences, Mashhad, Iran*

ABSTRACT

A novel magnetic nanocomposite adsorbent formed from the coating FeNi$_3$ nanoparticles with SiO$_2$ nanoparticles, and then with CuS nanoparticles (FeNi$_3$@SiO$_2$@CuS) was successfully synthesized and then applied, for the first time, for eradicating methylene blue (MB) dye-laden wastewater. An adsorptive performance test were conducted using a batch system with variations of several water quality parameters, including pH, contact time, MB concentration, FeNi$_3$@SiO$_2$@CuS dose, and competitor NaCl concentration. The characterization study using transmission electron microscopy, field emission scanning electron microscopy, and vibrating sample magnetometer approaches demonstrated that FeNi$_3$@SiO$_2$@CuS has a number of favorable morphological, physiochemical, and adsorptive properties which make it a potential adsorbent toward organic pollutants. The equilibrium analysis of non-linear fit method revealed that the Langmuir equation was the best model for the representation of isothermal data, where the maximum uptake reached 24.457 mg/g. The kinetic adsorption behavior of methylene blue on FeNi$_3$@SiO$_2$@CuS obeyed the pseudo-second-order kinetics. The nature of the adsorption was also endothermic and spontaneous, as the thermodynamic study revealed. During the adsorption experiments, FeNi$_3$@SiO$_2$@CuS magnetic nanocomposite exhibited an excellent adsorption capacity toward MB molecules, where the maximum removal efficiency of 85.21% was recorded at pH = 12, contact time = 180 min, initial MB concentration = 20 mg/L, and FeNi$_3$@SiO$_2$@CuS dose = 2 g/L. It was also found that NaCl presence had a negative impact on that efficiency. The mechanism of MB interaction with FeNi$_3$@SiO$_2$@CuS involved both chemical and physical adsorption processes. Results of this study unraveled that the adsorption process using FeNi$_3$@SiO$_2$@CuS as an adsorptive agent could be a promising treatment technology for the removal of MB dye from high alkaline wastewater.

Keywords: FeNi$_3$@SiO$_2$@CuS; Magnetic nanocomposite; Methylene blue; Adsorption; Characterization

* Corresponding author.