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Enhanced Crystallinity of MIL-53 (Fe) and Improved Pb^{2+} Ion Removal by MIL-53(Fe) in the Presence of TiO_2

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Abstract

Water pollution due to improper disposal of various contaminants is one of the most serious threats faced by living beings all around the world. Lead (Pb) is a heavy metal which is commonly added to the environment by the industries such as battery manufacturing, paints etc. According to the world health organization, the maximum bearable Pb concentration of the human body is 70 µg dL^{-1}. However, in a contaminated water sample, this value could range from 200 to 500 mg L^{-1}. Thus, the efficient removal of heavy metals from contaminated water is vital. Among various removal techniques available, adsorption plays a major role due to its high efficiency, low cost and ease of designing. MOFs are a class of crystalline porous adsorbent material that consists of a metal ion/cluster and an organic linker. Owing to their tailoring ability, high porosity, and high surface area they have been widely used in the removal of contaminants from wastewater. The main objectives of this study are to synthesize MIL-53 (Fe) MOF and MIL-53/TiO_2 composite and determine the Pb (II) removal efficiency under light and dark conditions. MIL-53 (Fe) MOF was synthesized using iron (III) and 1, 4-dicarboxylic acid under solvothermal conditions. The composite was synthesized similarly in the presence of TiO_2 nanoparticles. The successful synthesis of MIL-53 (Fe) MOF and MOF/TiO composite was confirmed by powder X-ray diffraction and Fourier-transform infrared spectroscopy. By the Debye−Scherrer equation, 79.06 nm and 65.46 nm of crystallite size were obtained by the MOF and the MOF/TiO_{22} composite. Atomic absorption spectroscopy was used to determine the metal ion concentration before and after adsorption. The optimum conditions for the Pb(II) removal are as; 50 mg L^{-1}, 25 mg L^{-1} initial Pb ion concentration, 10 mg, 12.5 mg of adsorbent dose (for 25 ml of 50 mg L^{-1} Pb (II)) and 90 min, 90 min contact time for both adsorbents at light and dark conditions respectively. The pH of the solution was kept at a neutral level to ensure the reusability of wastewater after the removal of pollutants. The adsorption isotherms of both adsorbents were well fitted with the Langmuir model indicating the monolayer adsorption. Thus, at pH 7, 396.35 mg g^{-1} and 786.16 mg g^{-1} of maximum Pb (II) adsorption capacity were obtained by the MOF and the MOF/TiO_2 composite respectively. Thus, a significant improvement in the Pb (II) ion removal was observed with the composite compared to the MOF.

Keywords: Adsorption, Heavy metal, Isotherm, MIL-53 (Fe)