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Adsorption of nonsteroidal anti-inflammatory drugs onto composite beads of a 1D flexible framework MIL-53(Al): Adsorption mechanisms and fixed-bed study

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ABSTRACT

The adsorption mechanisms of three nonsteroidal anti-inflammatory drugs (NSAIDs), ibuprofen (IBP), ketoprofen (KET), and naproxen (NPX), applied onto a pristine 1D flexible framework MIL-53(Al) were compared with those adsorbed on MIL-53(Al)/alginate (AM) and polyvinylidene fluoride/MIL-53(Al) (PM) composite beads through investigation of single-solute batch and fixed-bed systems. The 1D flexible framework of pristine MIL-53(Al) exhibited outstanding adsorption capacities for the three NSAIDs (IBP > NPX > KET) in comparison to powdered activated carbon via an increase in pore diffusion through the 1D framework supported by the breathing effect phenomena. The MIL-53(Al)/alginate at 3:25 w/w (AM25) exhibited better adsorption capacities for the three NSAIDs than the composite beads with higher MIL-53(Al) ratios (3:50 and 3:75 w/w). However, the adsorption of the three NSAIDs on AM25 was 2.2–5.5-times lower than that of the pristine MIL-53(Al). The dominant interactions of IBP between MIL-53(Al) were hydrogen bonding between the Al–OH(OH_2) node of MIL-53(Al), the carboxylic groups of IBP, and the carboxylic group of terephthalic acid of MIL-53(Al). AM25 exhibited high selectivity for IBP against the background matrix of wastewater obtained from a hospital, and it could be applied at a low concentration range (μg/L). An increase in the empty bed contact time (38.7 min to 96.9 min) of fixed-bed systems for the adsorption of IBP on AM25 could improve the usage rate and fractional bed utilization; moreover, the breakthrough removal percentage was increased up to 98.1%. The multi-layer log-Thomas model can be fitted well for all breakthrough curves.

1. Introduction

Nonsteroidal anti-inflammatory drugs (NSAIDs) are globally used in approximately 5–10% of all medications prescribed each year as antipyretic, anti-inflammatory, and analgesic agents. A large volume of expired and/or excreted NSAIDs are disposed of via waste pipelines, causing their accumulation in the environment and leading these NSAIDs, which are toxic to living organisms, to cause environmental harm [1–4]. Among nonsteroidal anti-inflammatory drugs (NSAIDs), ibuprofen (IBP), ketoprofen (KET), and naproxen (NPX) have been frequently detected in surface water environments within various concentration ranges; contamination range has been reported to be 5–4900 ng/L for NPX, 381–34,000 ng/L for IBP, and 108–369 ng/L for KET [1–3]. The potential high risks of these NSAIDs in surface waters and sewage effluents, as assessed based on hazard quotient levels, have been emphasized in many regions worldwide [5,6]. Hence, a highly-selective NSAID elimination process that creates lower toxic intermediates should be developed and integrated with conventional wastewater treatment processes.

Recently, the application of metal-organic frameworks (MOFs) for

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