THESIS TITLE

Development of a Hybrid Technology for Removal of Pharmaceutical Contaminants from Municipal and Hospital Wastewater

ABSTRACT

Rapid urbanization and advancement in healthcare facilities have often resulted in enormous discharges of municipal wastewater (MWW) and hospital wastewater (HWW) into various water matrices. Several harmful and recalcitrant contaminants and their metabolites, particularly pharmaceutically active compounds (PhACs), often enter the water bodies without adequate treatment due to their resistance to conventional treatment processes. The majority of these compounds are persistent and carcinogenic, which can pose a grave threat to the aquatic environment, and prolonged exposure to them may cause adverse health effects in humans and animals. Among the various PhACs, analgesics, antibiotics, and X-ray contrast media are often detected in MWW and HWW. In this instance, a heterojunction composite of 2D bismuth trioxide (Bi_2O_3)/0D manganese dioxide (MnO_2) was synthesized to degrade acetaminophen (ACT), a model analgesic. Multivariate studies were performed to optimize the synthesis parameters of the photocatalysts. The optimized photocatalyst (1-Bi_2O_3/3-MnO_2) (BMO-3) demonstrated excellent performance in degrading up to 94% of ACT within 120 min of light irradiation. Moreover, to improve charge transfer dynamics, enhance visible light absorption, and narrow the overall band gap of the photocatalyst, the already prepared Bi_2O_3 was first doped with sulfur (S) and subsequently a heterojunction composite (S doped 1-Bi_2O_3/1-MnO_2) (S-BOMO) was prepared. However, due to the difficulty in separating the spent photocatalyst from the reaction mixture, the optimized photocatalyst (2wt.%S-BOMO) was immobilized over different substrate materials. The most effective immobilized photocatalyst, i.e., 2S-BOMO coated clay beads (2S-BOMO CCB), was able to successfully degrade around 86% sulfamethoxazole (SMX), a model antibiotic within 240 min of light irradiation and could be easily separated from the reaction medium. Both the nanocomposite and immobilized photocatalysts were thoroughly characterized using various characterization techniques. Further, from the practical point of application, the performance of the immobilized photocatalyst under a continuous flow photocatalytic reactor was evaluated, which has relevance for potential real-world wastewater treatment scenarios. The 2S-BOMO CCB was able to degrade 84.5% of iohexol (IOX), a model X-ray contrast media, in continuous flow conditions within a retention time (RT)of 300 min. The effect of various operating conditions, interfering agents, and scavengers on the photocatalytic degradation of target PhACs was also investigated. Furthermore, intermediate degradation by-products were evaluated, and degradation pathways were proposed. Eventually, 2S-BOMO immobilized photocatalyst could synchronously degrade around 87%, 82%, and 77% of ACT, SMX, and IOX, respectively, in continuous mode from DI water within RT of 300 min. However, the photocatalytic degradation of ACT, SMX, and IOX was significantly lower in real MWW and HWW samples. Therefore, the MWW and HWW were pretreated with a moving bed biofilm reactor followed by a filtration unit (MBBR-FU). The system significantly removed the dissolved organics, turbidity, anions, and solids from the wastewater. The MBBR-FU effluent was photocatalytically treated in continuous mode. ACT, SMX, and IOX removal efficiency of around 94%, 89%, and 85%, and 90%, 84%, and 81% were achieved in MWW and HWW, respectively. Therefore, a combination of biological or physical pretreatment systems, followed by photocatalysis using immobilized photocatalysts, could prove to be an efficient approach for treating wastewater containing PhACs.

KEYWORDS: Pharmaceuticals active compounds, Photocatalysis, Heterojunction nanocomposite, Immobilized photocatalysts, Multivariate experiments, Kinetic modeling, Computational Modeling, Toxicity assessment, Reusability, Intermediate by-products, Degradation pathways, Moving bed biofilm reactor, Filtration unit, Municipal wastewater, Hospital wastewater