

ABSTRACT

Pharmaceuticals and personal care products are emerging as significant environmental pollutants, with diclofenac (DCF) drawing particular concern due to its persistent presence in water bodies and harmful effects on wildlife. Among the various treatment techniques available, adsorption has gained prominence as a viable and environmentally friendly method for removing such contaminants. This thesis explores the adsorptive removal of diclofenac, including evaluating and ranking of existing adsorbents and employing pristine and modified sewage sludge biochar in batch and continuous studies. Initially, the study undertakes a comprehensive analysis of existing adsorbents documented in peer-reviewed literature, aiming to establish a theoretical framework. This framework considers key parameters such as adsorption capacity, pH, equilibrium time, material cost, point of zero charge, and surface area. To provide a standardized comparison, these parameters were normalized against those of granular activated carbon, a widely recognized standard adsorbent. Three weighting methods—equal weights (as a control), the analytical hierarchy process (as a subjective approach), and the entropy method (as an objective approach)—were applied to create a ranking system. The adsorbents were then ranked, and the results were compared across the different weighting techniques. Magnetic microporous biocarbon and MgAl layered double hydroxide consistently emerged as top-performing adsorbents. Building on these findings, sewage sludge was selected as a precursor due to its abundance and availability. The sludge was collected and dried from a wastewater treatment plant at IIT Kharagpur and subsequently carbonized at temperatures ranging from 350°C to 950°C, with residence times varying from 30 to 240 minutes. The resulting biochar was extensively characterized to evaluate changes in morphology, surface functional groups, crystallinity, surface area, and elemental composition. Preliminary adsorption tests conducted with an initial DCF concentration of 10 ± 0.103 ppm and a biochar dosage of 10 ± 0.005 g/L identified biochar produced at 950°C with 30-minute residence time as the optimal adsorbent, referred to as PBC. To enhance the adsorption performance of PBC, the precursor was further modified with FeCl₃, a cost-effective and locally sourced material, resulting in iron-modified biochar (Fe-BC). Batch adsorption studies were conducted to investigate the effects of pH, contact time, initial DCF concentration, and temperature. The results indicated that the PBC-DCF system followed pseudo-second order kinetics and conformed to the Langmuir isotherm, achieving an adsorption capacity of 0.814 ± 0.001 mg/g. In contrast, the Fe-BC-DCF system adhered to Elovich kinetics and the Redlich-Peterson isotherm, with a significantly higher adsorption capacity of 18.958 ± 0.417 mg/g. The adsorption process was found to be spontaneous and endothermic in both cases, driven by mechanisms such as hydrophobic interactions, π -electron transfer, and electrostatic attraction. Additionally, continuous flow studies were performed using a fixed-bed setup to optimize operational parameters, including bed height, flow rate, and initial DCF concentration. The optimal conditions determined were a DCF concentration of 1 ppm, a bed height of 3 cm, and a flow rate of 3 mL/min. Under these conditions, the system achieved a moderate adsorption efficiency, with 48.41% of the DCF being removed, corresponding to a total DCF mass adsorbed of 14.6 mg. The study also tested the performance of Fe-BC in real wastewater, demonstrating its moderate effectiveness in reducing DCF concentration alongside other water quality parameters. The findings underscore the potential of Fe-BC as a cost-effective and sustainable adsorbent for practical water treatment applications. In conclusion, this research successfully identifies and ranks effective adsorbents for DCF removal, highlighting the efficacy of sewage sludge-derived biochar,

particularly when modified with iron. The results contribute to the development of sustainable treatment methods, with Fe-BC showing promise for broader environmental applications.

KEYWORDS: Pharmaceuticals, diclofenac, adsorption, sewage sludge, biochar, FeCl₃ impregnation, fixed bed column study