ABSTRACT

Water pollution caused by synthetic dyes such as methylene blue (MB) is a serious environmental issue due to their toxicity, stability, and resistance to natural degradation. This study aimed to synthesize, characterize, and evaluate the effectiveness of a polyeugenol–Fe,N-TiO_2-based hybrid molecularly imprinted membrane (HMIM) for MB degradation. Polyeugenol, TiO_2, and Fe,N-TiO_2 were synthesized and characterized, while their photocatalytic activities were compared to determine the most effective photocatalyst. Subsequently, polyeugenol–PVA hydrogels with a mass ratio of 1:2 (0.333 g:0.667 g) containing Fe,N-TiO_2 at concentrations of 0.1%, 0.3%, and 0.5% were fabricated into non-imprinted membranes (HNIM) and HMIMs. Characterization was performed using FTIR, XRD, UV–Vis DRS, PSA, and SEM–EDX mapping. The results confirmed the successful synthesis of polyeugenol and Fe,N-TiO_2, indicated by characteristic Fe–O–Ti and N–Ti–O absorptions, a particle size of 805.4 nm, a crystallite size of 6.9 nm, an anatase phase at $2\theta = 25.32°$, and a reduced band gap of 2.85 eV. Membrane characterization revealed the formation of imprinting sites in HMIM, enhancing its interaction with MB. HMIM containing 0.5% Fe,N-TiO_2 achieved the highest degradation efficiency (92.36%), exceeding that of HNIM (66.79%). The degradation process followed pseudo-first-order kinetics, with a higher rate constant for HMIM (0.0154 min^{-1}) than HNIM (0.0056 min^{-1}). HMIM also exhibited good stability over three cycles and achieved 91.58% degradation of MB in fish antimicrobial solution. These findings demonstrate the potential of polyeugenol–Fe,N-TiO_2 HMIM as an effective, selective, and stable material for MB wastewater treatment.

Keywords: Hybrid molecularly imprinted membrane, Polyeugenol, Fe,N-TiO_2, Photocatalysis