MOLECULARLY IMPRINTED CONDUCTING POLYMER HYDROGEL COMPOSITES FOR TETRACYCLINE LOADING AND ELECTRICALLY RESPONSIVE DRUG DELIVERY

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Precise, on-demand drug delivery remains a critical challenge in modern therapeutics, particularly for localized treatments requiring high loading efficiency and spatiotemporal control. Electronic drug delivery systems (EDDS) based on electroactive materials offer programmable release profiles; however, their practical application is often limited by insufficient drug loading capacity and poor mechanical compliance. In this work, we report the development of a molecularly imprinted conducting polymer–hydrogel composite designed to address these limitations and enable electrically tunable drug delivery. The polypyrrole (PPy)–tetracycline complex was synthesized via chemical polymerization of pyrrole initiated by ammonium persulfate (APS). Polymerization was carried out for 24 h in an ice bath at approximately 0 °C. The template was subsequently removed using isopropanol and deionized water to obtain molecularly imprinted polypyrrole (MIP-PPy) powder. MIP-Ppy was incorporated at varying concentrations (0–2%) into a hydrogel matrix to enhance selective tetracycline recognition. Drug loading was quantified using UV–Vis spectroscopy at 360 nm, while swelling behaviour was evaluated to elucidate structure–property relationships. The composites exhibited reproducible tetracycline adsorption, with loading strongly dependent on PPy content. A low PPy concentration (0.2%) produced the highest adsorption capacity (≈381 μg g^{-1}). We attribute this to enhanced π–π and electrostatic interactions between tetracycline and the conducting polymer. In contrast, higher PPy contents (≥0.4%) led to reduced drug loading, which correlated with lower swelling ratios and greater network rigidity. Swelling systematically decreased from 84.1% for the PPy-free hydrogel to 71.3% at 2% PPy, highlighting the trade-off between binding selectivity and hydrogel permeability. These results demonstrate that careful optimization of conducting polymer content is essential to maximize drug loading while maintaining favourable hydrogel swelling properties. The presented molecularly imprinted PPy–hydrogel platform shows strong potential for integration into electroceutical systems, enabling high drug loading combined with electrically controlled, on-demand release.

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