The Enhanced Adsorption Capacity of Ziziphus jujuba Stones Modified with Ortho-Phosphoric Acid for Organic Dye Removal: A Gaussian Process Regression Approach	
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Publication Year	2024
Grant Number	IMSIU-RP23013
DOI link	10.3390/w16091208

Abstract: Here, the chemical modification of Ziziphus jujuba stones (ZJS) treated with ortho-phosphoric acid (ZJS-H3PO4) is investigated to enhance its adsorption properties for organic dyes. The physicochemical properties of ZJS-H3PO4 reveal increased porosity (87.29%), slightly higher bulk density (0.034 g mL−1), and enhanced acidity (31.42 m eq g g−1) compared to untreated ZJS. XRF analysis confirms the successful incorporation of orthophosphoric acid during treatment due to a significant increase in phosphorus content. The maximum adsorption capacity of methylene blue on ZJS-H3PO4 is found to be 179.83 mg g−1, demonstrating its efficacy as a potential adsorbent for organic dyes. These findings suggest that modifying ZJS with orthophosphoric acid could be a promising strategy to enhance its adsorption performance in various environmental applications. Furthermore, Gaussian process regression (GPR) is employed to model MB adsorption by ZJS-H3PO4. Optimization of the GPR model involves evaluating different kernel functions and meticulously adjusting parameters to maximize its ability to capture complex relationships in the data. The obtained GPR model demonstrates remarkable performance with high correlation coefficients (R) and low root mean square errors (RMSEs) across all study phases. Model validation is performed through residual analysis, confirming its effectiveness and accuracy in predicting MB adsorption. Finally, a user-friendly interface is developed to facilitate the usage of the GPR model in future applications, representing a significant advancement in environmental process modeling and ecosystem management.