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Efficiency and mechanism of ciprofloxacin hydrochloride degradation in wastewater by $\text{Fe}_3\text{O}_4/\text{Na}_2\text{S}_2\text{O}_8$

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ABSTRACT

The nanosized Fe_3O_4 catalyst was synthesized via a modified reverse coprecipitation method and characterized by means of a scanning electron microscope (SEM) and an X-ray diffraction (XRD) analysis instrument. The degradation efficiency and reaction rate of Fe_3O_4 in activating sodium persulfate used to degrade ciprofloxacin were determined from the catalyst dosage, oxidant concentration, and initial pH. The results showed that under the optimum conditions of a catalyst dosage of $2.0 \text{ g}\cdot\text{L}^{-1}$, a sodium persulfate concentration of $20 \text{ mg}\cdot\text{L}^{-1}$, and an initial pH of 3.0, the degradation efficiency of ciprofloxacin hydrochloride reached 100% within 120 min.

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Results and Discussion

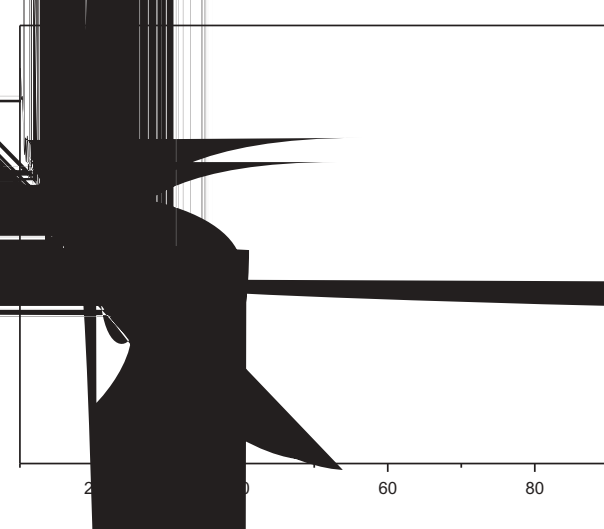
Analysis and Characterization of the physicochemical properties of catalyst Fe_3O_4

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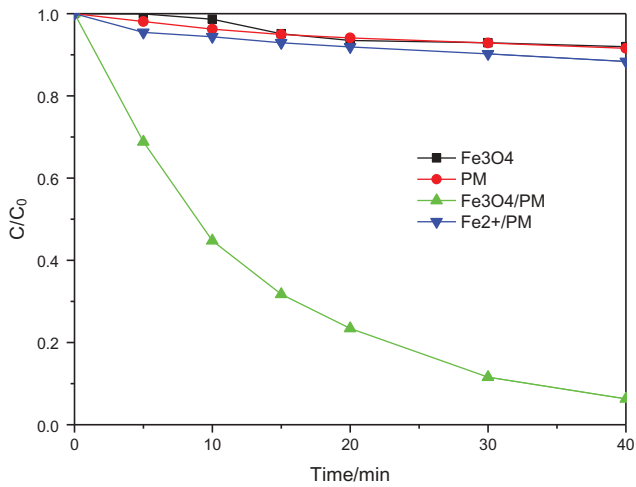


Figure 4. Effect of Fe₃O₄, PM, Fe₃O₄/PM, and Fe²⁺/PM technol-

Impact of the initial pH value on the degradation of ciprofloxacin hydrochloride wastewater

The study investigated the effect of initial pH on the degradation of ciprofloxacin hydrochloride wastewater. The results showed that the degradation rate was significantly higher at pH 7.0 compared to pH 5.0 and 9.0. This is because at pH 7.0, the concentration of Fe²⁺ is highest, which promotes the formation of Fe³⁺ and Fe(OH)₃ precipitates. These precipitates adsorb ciprofloxacin hydrochloride, leading to its removal from the solution. At pH 5.0, the concentration of Fe²⁺ is lower, and at pH 9.0, the concentration of Fe²⁺ is very low, resulting in less precipitation and lower degradation rates.

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Impact of sodium persulfate concentration on the degradation of ciprofloxacin hydrochloride wastewater

The study investigated the effect of sodium persulfate concentration on the degradation of ciprofloxacin hydrochloride wastewater. The results showed that the degradation rate increased with increasing sodium persulfate concentration. This is because sodium persulfate acts as a strong oxidizing agent, which oxidizes ciprofloxacin hydrochloride. The rate of degradation was highest at a concentration of 0.1 g/L and decreased as the concentration increased to 0.2 g/L. This is because at higher concentrations, the reaction becomes more complex and the rate of degradation decreases.

Table 1. Kinetic parameters of CIP by Fe₃O₄ at different pH.

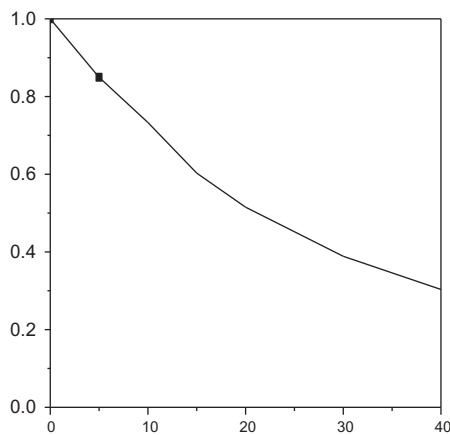
Initial pH	Pseudo-first-order reaction kinetic mode	Correlation R ²
2	$\ln(C_t/C_0) = -(0.00396 + 0.00778t)$	0.996
3	$\ln(C_t/C_0) = -(-0.00155 + 0.01508t)$	0.999
4	$\ln(C_t/C_0) = -(0.00396 + 0.00778t)$	0.996
5	$\ln(C_t/C_0) = -(0.05016 + 0.02925t)$	0.994
7	$\ln(C_t/C_0) = -(0.05871 + 0.06907t)$	0.997
9	$\ln(C_t/C_0) = -(0.01337 + 0.02618t)$	0.999
11	$\ln(C_t/C_0) = -(-0.00113 + 0.01128t)$	0.998

Initial pH 2, 3, 4, 5, 7, 9, 11. Pseudo-first-order reaction kinetic mode. Correlation R² values are 0.996, 0.999, 0.996, 0.994, 0.997, 0.999, and 0.998 respectively.

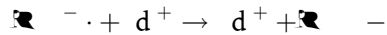


Impact of Fe₃O₄ dosage on the degradation of ciprofloxacin hydrochloride wastewater

Impact of Fe₃O₄ dosage on the degradation of ciprofloxacin hydrochloride wastewater. The graph shows the concentration of CIP (C_t/C₀) versus time (t) for different dosages of Fe₃O₄. The concentration decreases over time, and the rate of degradation increases with higher dosages of Fe₃O₄.



Impact of Fe₃O₄ dosage on the degradation of ciprofloxacin hydrochloride wastewater. The graph shows the concentration of CIP (C_t/C₀) versus time (t) for different dosages of Fe₃O₄. The concentration decreases over time, and the rate of degradation increases with higher dosages of Fe₃O₄.



Impact of Fe₃O₄ dosage on the degradation of ciprofloxacin hydrochloride wastewater. The graph shows the concentration of CIP (C_t/C₀) versus time (t) for different dosages of Fe₃O₄. The concentration decreases over time, and the rate of degradation increases with higher dosages of Fe₃O₄.

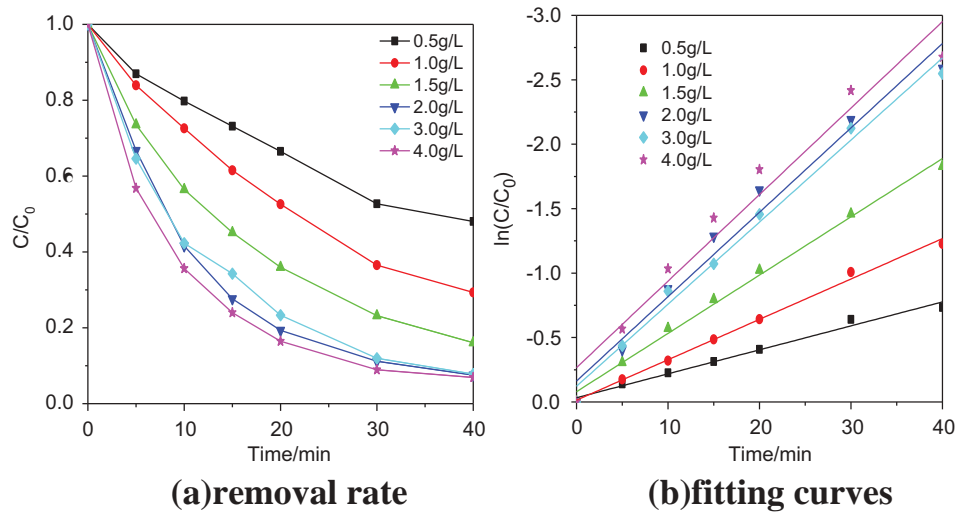


Figure 7. Effect of catalyst dosage on the degradation efficiency of CIP (a_2S_2 : 1 g/L; CIP: 50 mg/L; Fe_3 : 2 g/L; pH: 7.0; 25°C).

Table 3. Kinetic parameters of CIP by Fe_3 at different catalyst dosages.

Catalyst dosage (g/L)	Pseudo-first-order reaction kinetic mode	Correlation R^2
0.5	$\ln(C_t/C_0) = -(0.03271 + 0.01859t)$	0.984
1	$\ln(C_t/C_0) = -(0.01412 + 0.03134t)$	0.995
1.5	$\ln(C_t/C_0) = -(0.07971 + 0.04524t)$	0.993
2	$\ln(C_t/C_0) = -(0.05871 + 0.06907t)$	0.997
3	$\ln(C_t/C_0) = -(0.177899 + 0.06369t)$	/ /

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