

ABSTRACT

The pharmaceutical industry generates wastewater containing complex micropollutants that are difficult to degrade biologically, posing a potential risk of environmental contamination. Conventional treatment plants have proven ineffective, particularly against resistant compounds characterized by low BOD/COD ratios. This study aimed to optimize H₂O₂ dosage, FeSO₄ dosage, and reaction time within the Fenton oxidation process to enhance pharmaceutical wastewater treatment efficiency. Optimization was conducted using Response Surface Methodology (RSM) with a Central Composite Design (CCD), alongside statistical and environmental analyses to evaluate factor effects and variable interactions. Tested parameters included BOD, COD, TSS, total-N, phenol, and pH, benchmarked against national regulatory standards. Results indicated optimal conditions of 303.231 mmol/L for H₂O₂ dosage, a 3:1 H₂O₂/FeSO₄ ratio, and a reaction time of 40.123 minutes. Fenton oxidation optimization was shown to improve biodegradability and reduce other pollutant parameters. Furthermore, the iron sludge (Fe(OH)₃) byproduct could be activated and utilized as a substitute for FeSO₄ reagent, supporting concepts of circular use and the circular economy. Analyses of hydrodynamics, reaction kinetics, and chemical mechanisms deepened the understanding of the process. From an environmental-economic perspective, OPEX and BCR values demonstrated the feasibility of implementing the Fenton oxidation scheme. Overall, the findings confirm that statistically optimized Fenton oxidation, combined with an environmental analysis approach, offers an effective and efficient solution for pharmaceutical wastewater treatment while contributing to the development of eco-friendly technologies in the industrial sector.

Keywords: *Advanced Oxidation Process (AOP), Fenton Oxidation, Response Surface Methodology (RSM), Environmental Analysis Optimization, Circular Economy*