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Next-Gen Advanced Oxidation Processes and their Role for Elimination of Pharmaceutical Emerging Pollutants from Waters

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ABSTRACT

Amidst growing concerns over global water scarcity and pollution, the persistent challenge of pharmaceutical pollutants in water sources highlights the limitations of conventional water treatment methods. Advanced Oxidation Processes (AOPs) offer a promising solution by utilizing highly reactive hydroxyl radicals to degrade these complex molecules. This study explores the efficacy of various AOPs, including UV/03, Electrochemical oxidation, and sonochemistry, in the experimental degradation of such pollutants. By examining recent advancements in AOP technologies like enhanced photolysis and catalysis, this research assesses their potential to not only degrade challenging pollutants but also reduce operational costs and energy consumption, thus paving the way for their application in large-scale wastewater treatment scenarios. The study underscores the urgent need for adopting these innovative technologies to address severe environmental and public health risks, while also supporting sustainable development goals.

Keywords: Advanced Oxidation Processes, pharmaceutical contaminants, water treatment, hydroxyl radicals, reactor design, degradation efficiency, sustainability assessment, techno-economic analysis.

1 Introduction

The global decrease in water levels, exacerbated by population growth and increasing pollution, notably from industrial and pharmaceutical residues, creates an urgent environmental crisis [1]. These pollutants, although present in low concentrations, are resistant to conventional treatments, threatening biodiversity and human health [2]. Advanced Oxidation Processes (AOPs) offer a promising solution by destroying these substances through hydroxyl radicals [3]. Innovation in AOPs, including photolysis, sonochemistry, and the development of new catalysts, aims to improve efficiency while reducing costs and energy consumption, paving the way for sustainable pollutant management [4].

2 Experimental

In an experimental setting, the efficiency of various Advanced Oxidation Processes (AOPs), such as UV/O3, Electrochemical oxidation, sonochemistry, and photocatalysis, was evaluated for treating water contaminated with pharmaceutical pollutants. Using reactors equipped for each method, the experiments varied pollutant concentration, reaction time, and catalyst dosage to optimize degradation.

3 Results and Discussion

The comparative analysis of Advanced Oxidation Processes (AOPs) reveals a wide range of efficiencies in the degradation of pharmaceutical pollutants compared to conventional processes [5]. Recent advances in the optimization of these processes have marked a turning point, significantly improving degradation efficiency at the laboratory scale. The precise adjustment of operational parameters and reaction conditions, combined with innovation in catalyst development and advanced reactor design for AOPs [6], has enabled

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the achievement of unprecedented performance levels as shown in Table I. While encouraging outcomes have been observed at the laboratory scale for emerging AOPs, there have been limited trials focused on scaling up these processes. The primary obstacle hindering the implementation of full-scale AOPs is the high operational expenses [7]. Consequently, it is imperative to conduct technoeconomic assessments to ascertain the most viable AOPs for scaling up and practical operation in treating real wastewater, as illustrated in Figure I.

Figure 1: Scall-up of advanced oxidation process

Table 1: *AOP Efficiency: Key Developments in Reactor Design and Performance*

Process		Polluant	Water matrix	Reactor design	Optimum Conditions	Degradation rate	Ref
Photo based POA	UV/O3	Acetaminophen	Synthetic hospital wastewater	A stainless-steel cylinder reactor (16.4 cm in diameter and 49 cm in height) equipped with complex O3 microbubbles and fitted with a low-pressure 254nm UV lamp.	[ACT]=0.1 mM/L [O3] = 1.5 mg/L pH=8 t < 10 min	100 %	[8]
Photocatalyst	UV/g-C3N4	Tetracycline	Double distilled water	A split-type photocatalytic membrane reactor (PMR), incorporating suspended graphitic carbon nitride (g-C3N4) as photocatalyst	[TC]= 22.16 ppm pH = 9.78 [g-C3N4] = 0.56 g/L t= 113.77 min	94.8 %	[9]
Electrochemical Oxidation	ECO/BDD	Ciprofloxacin	Ultrapure water from Elga Lab Wate	A batch electrolysis pre-pilot reactor with a boron-doped diamond (BDD) anode for the degradation of emerging pollutants by electrochemical oxidation.	[CIP]= 10 mg/L [Na2SO4] = 5 mM. pH= 10 t= 300 min	99.9 %	[10]
Hybrid process	UV/US/FeII-MGP/H2O2	Tetracycline hydrochlo	Deionized water	The reactor used is a Teflon-lined vacuum reactor at 100 °C for 12h for FeII-MGP catalyst synthesis, followed by post-synthesis treatments including centrifugation, washing, and vacuum drying.	[FeII-MGP] =0.3 g/L [H2O2] =20mM pH=7 t= 7 min ultrasonic power of 100 W	83.3 %	[11]

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4 Conclusions

In conclusion, recent advancements in Advanced Oxidation Processes (AOPs) offer promising prospects for the treatment of pharmaceutical pollutants in water. These recent studies highlight their potential in degrading pharmaceutical pollutants in water, although obstacles remain in terms of costs and scaling up to industrial levels.

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