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Ultrasound-Assisted Persulfate as a Promising Technology for the Removal of Emerging Contaminants

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ABSTRACT

Emerging contaminants pose a significant and urgent environmental challenge, as their presence can have detrimental effects on ecosystems and human health. In response to this challenge, Advanced Oxidation Processes (AOPs) have emerged as a promising solution. Recently, there has been a notable surge in interest in sulfate-based AOPs, driven by the distinct advantages offered by sulfate radicals ($SO4^{-\cdot}$) over hydroxyl radicals $^{\cdot}OH$. Notably, research into the performance of the ultrasound-enhanced persulfate (US/PS) system for removing various emerging contaminants from water has demonstrated high efficiency, ranging from 51% to 100%. However, this efficiency is subject to significant variability depending on factors such as the nature of the pollutants, initial concentrations of both oxidants and pollutants, and reaction time. Understanding these factors, among others, is crucial for optimizing treatment processes, reducing costs, and facilitating broader adoption of AOPs on a large scale.

Keywords: Water pollution, emerging contaminants, POA,ultrasound, persulfate.

1 Introduction

Water pollution threatens ecosystems and human health globally. Diverse treatment techniques are being studied and developed to face this challenge. Notably, research on AOPs has demonstrated significant growth, as evidenced by an analysis of publications retrieved from Google Scholar and Scopus databases. Over the span of 19 years, from 2000 to 2018, the volume of publications in this field increased by more than fourfold [1]. Seven main areas of research were predominantly investigated during this period (Figure 1). According to these statistics, there's a growing interest in sulfate-based AOPs, particularly due to the persulfate oxidation method. This method offers diverse activation modes and induces acidic conditions post-dosing. Activating $S_2O_8^{2-}$ yields a potent sulfate radical ($SO_4^{-\cdot}$) with advantages over $^{\cdot}OH$, including a longer half-life, stronger oxidizing ability, and broader pH range (pH = 3–11). These attributes enhance its effectiveness in degrading organic molecules, making it appealing for industrial applications [2]. However, the direct reaction between persulfate and many pollutants is slow and requires an activation through alternative means to generate $^{\cdot}OH$ and $SO_4^{-\cdot}$. This work investigates the ultrasound-activated persulfate for the degradation of emerging pollutants in water.

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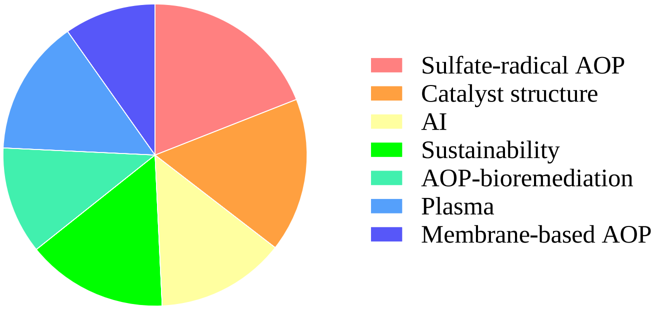

Figure1: Trends of contributions on research areas from 2000 to 2021 (data from [1])

2 Methodology

A systematic analysis of research published during the past two decadeswas conducted on the degradation of emerging contaminants using ultrasound-activated persulfate. This involved an exhaustive review of relevant literature, aiming to compare the performance of different treatment systems and elucidate the underlying mechanisms governing the process.

3 Results and Discussion

Several studies have highlighted a significant enhancement in the degradation efficiency and reaction rate of pharmaceutical compounds when treated with ultrasound-assisted persulfate (as shown in Table I). Notably, the degradation efficiency varied widely, ranging from 51% to 100%. This variability can be attributed primarily to the diverse nature and properties of pollutants and the specific experimental parameters employed during the treatment process. The degradation of these compounds was primarily accomplished through pyrolysis and the action of free radicals, notably hydroxyl radicals ($^{\cdot}OH$) and sulfate radicals ($SO_4^{-\cdot}$), generated as a result of the cavitation process within the system. Ultrasound induces the cleavage of O–O bonds within persulfate, producing $SO_4^{-\cdot}$through cavitation, high temperature, and pressure within the solution. Furthermore, sulfate in the solution may undergo further reactions with OH^{-}, generating more hydroxyl radicals, or directly with the pollutant compounds. These processes collectively reinforce the degradation process [3].

Table1: *Ultrasound-assisted PS for the degradation of emerging contaminants*

Pollutant	Oxidant concentration	Reaction time(min)	Degradation rate	Degradation efficiency (%)	Refs
Carbamazepine (0.025 mM)	5.0 mM	120	/	89.4	[4]
Tetracycline (0.025 mM)	4 mM	120	0.0175	96.5	[5]
Ammonium perfluorooctanoate (46.4 μM)	10 mM	120	/	51.2	[6]
1,1,1-trichloroethane (20 mgL^{-1})	1.50 mM	240	$k=0.0336 min^{-}$	100	[2]
1,4-dioxane (1 mgL^{-1})	1.50 mM	240	$k = 0.0329\ L\ mg^{-1} min^{-1}$	100	[2]

4 Conclusions and recommendations

The synergistic effect of ultrasonic activation of persulfate technology has been investigated, revealing a strong synergy between ultrasound and persulfate when employed together. However, the efficiency of the process is dependent on various factors, such as the nature of pollutants and the specific experimental parameters applied. Moreover, the high energy consumption of the reaction, lengthy reaction times, and associated high economic costs may hinder its widespread application. Future research should aim to

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address these challenges and focus on large-scale applications in real wastewater systems to assess the true efficacy and feasibility of this technology in practical settings.

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