19th International Conference on Environmental Science and Technology

Kos, Greece, 3 to 6 September 2025

Catalytic activation of peracetic acid to decompose micropollutants in water

Suyeon Jeon[1], Chaejin Choi[1], Ayoung Choi[1], Haesung Lee[1], Changseok Han[1,2,*]

[1]Program in Environmental and Polymer Engineering, Graduate School of INHA University, Incheon, Korea 22212

[2]Department of Environmental Engineering, INHA University, Incheon, Korea 22212

*corresponding author: hanck@inha.ac.kr

e-mail: chlcowls@gmail.com

Abstract

Acetaminophen (APAP), a widely used pharmaceutical, is frequently detected in aquatic environments due to its persistence and limited removal by conventional wastewater treatment processes. In this study, a peracetic acid (PAA) based advanced oxidation system was developed using magnetically recoverable tungsten modified iron oxides (TI) as heterogeneous catalysts to degrade APAP without external energy. TI catalysts were synthesized via a combustion method in the presence of polyvinyl alcohol for providing their magnetic properties for easy recovery after their use. The catalytic performance of the TI/PAA system was evaluated under various conditions, showing efficient APAP degradation. Radical scavenging experiments revealed the generation of hydroxyl, acetyloxy, and acetylperoxyl radicals as dominant reactive species in the system. Degradation intermediates were identified to propose a possible APAP degradation pathway. The findings demonstrate the effectiveness of tungsten modification in enhancing the catalytic performance of iron oxides for PAA activation. This study highlights a green, energy-free, and reusable catalytic system with strong potential for the treatment of pharmaceutical micropollutants in water.

Keywords: Acetaminophen, AOPs, Peracetic acid, Catalyst, radicals

1. Introduction

Pharmaceuticals and personal care products (PPCPs) are frequently identified in aquatic ecosystems due to their widespread use and persistence in the environment [1, 2]. Municipal, hospital, and industrial discharges serve as major entry routes into surface waters, where these bioactive substances accumulate and pose toxicological threats to organisms across trophic levels [2]. Among PPCPs, acetaminophen is widely consumed and commonly detected in surface waterbodies [3]. As reported in previous studies, APAP demonstrated hepatotoxicity and endocrine-disrupting effects for different species with concentrations of several hundred μg/L [4]. Its resistance to biodegradation and poor removal in conventional wastewater treatment systems highlights the urgent need for developing reliable technologies to remove APAP in water [5].

Advanced oxidation processes (AOPs) are effective for removing different recalcitrant contaminants by generating reactive oxygen species (ROS) for readily mineralizing organic molecules [6]. Among various oxidants, peracetic acid (PAA) is emerging as a safer and sustainable alternative. PAA can be easily synthesized on-site, degrade into benign by-products, and has broad working pH ranges [7]. Its ability to generate ROS, including hydroxyl, acetyloxy, and peracetyl radicals, makes it attractive for water treatment, especially when activated by transition metal catalysts [8, 9].

Heterogeneous metal oxides are widely applied in AOPs due to their stability, reusability, and broad working range of solution pH [10]. Magnetic iron oxides, such as magnetite and maghemite, enable easy recovery after their use [11]. While transition metals (e.g., Co, Cu, Mn) incorporation into magnetic iron oxides enhances catalytic activity, tungsten, a redox-active and structurally stable metal, has received limited attention. Tungsten oxides (e.g., WO_3) themselves exhibit excellent pollutant degradation performance owing to their favorable electronic properties [12].

In this study, tungsten modified iron oxides (TI) were synthesized with a combustion method and used as heterogeneous catalysts to activate PAA for APAP degradation. Catalytic performance of TI was assessed without external energy for PAA activation. Radical scavenging and intermediate analyses identified key ROS and proposed the APAP degradation pathway, respectively. This magnetically recoverable, energy-free treatment system may offer a sustainable and environmentally bening approach for effective treatment of pharamceutical polluted water.

2. Results

Fig. 1 (a) shows the adsorption behavior of the catalysts (i.e., TI 0, TI 1 and TI 2) in the absence of oxidants, aiming to assess their intrinsic affinity toward APAP. APAP adsorption by all samples could be negligible due to their minimal adsorption capacity. The result confirmed that APAP removal resulted from oxidation by radicals produced via a reaction with catalysts and PAA.

Figs. 1 (b) and (c) demonstrated that APAP degradation was significantly improved with tungsten incorporation and the efficiency was proportional to catalyst loadings for the treatment. Notably, the complete removal of APAP was obtained with TI 2 of 2.0 g/L within 10 min of the treatment. In Fig. 1 (d), a higher APAP degradation was observed with high PAA dosages while the degradation was inversely proportional to initial APAP concentrations due to the limited availability of ROS.

In summary, these results demonstrate that the TI/PAA system effectively degrades APAP with no external energy. This highlights the potential of tungsten modified iron oxides as sustainable and energy-efficient catalysts for water and wastewater treatment, especially for pharmaceutical removal.

Acknowledgement

This work was supported by Korea Environmental Industry & Technology Institute (KEITI) grant funded by the Korea Government (Ministry of Environment) (The Knowledge-based Environmental Service Specialized Graduate School Program).

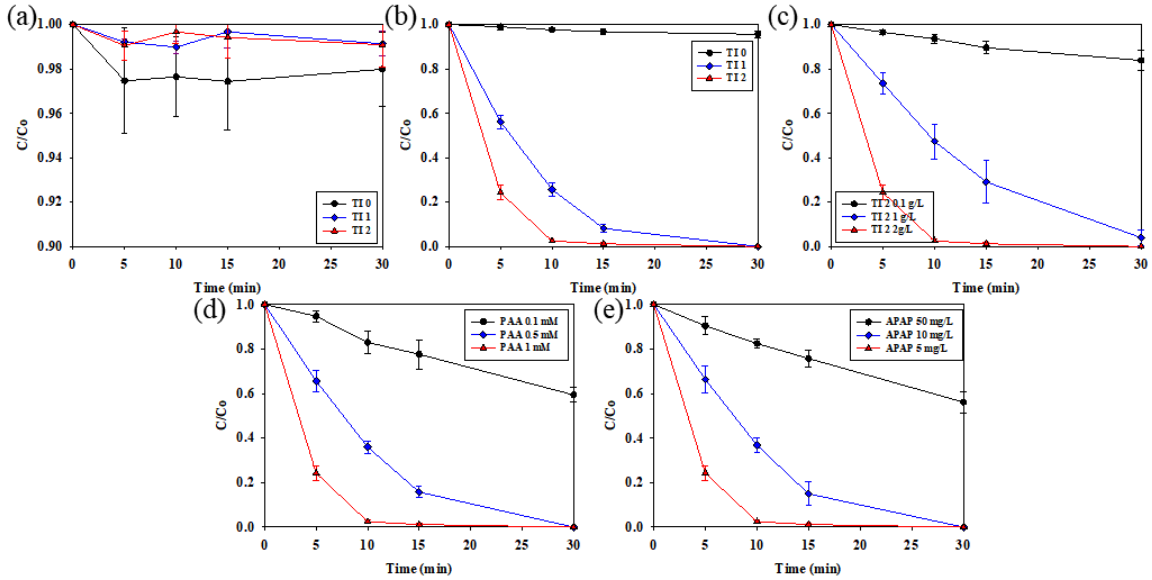

Figure 1. APAP degradation by the TI/PAA system: (a) APAP adsorption by TIs, (b) effect of tungsten in TI, (c) effect of TI 2.0 loading, (d) effect of PAA concentration and (e) effect of initial APAP concentration. Experimental conditions (unless stated otherwise): 5 mg/L APAP, 2 g/L TI 2.0, 1 mM PAA, pH 4, and room temperature.

References

1. Boxall, A.B., et al., *Pharmaceuticals and personal care products in the environment: what are the big questions?* Environmental health perspectives, 2012. **120**(9): p. 1221-1229.
2. Wang, J. and L. Chu, *Irradiation treatment of pharmaceutical and personal care products (PPCPs) in water and wastewater: an overview.* Radiation Physics and Chemistry, 2016. **125**: p. 56-64.
3. Wu, J.-l., et al., *Occurrence, removal and risk evaluation of ibuprofen and acetaminophen in municipal wastewater treatment plants: A critical review.* Science of the Total Environment, 2023. **891**: p. 164600.
4. Gotostos, M.J.N., et al., *Kinetic study of acetaminophen degradation by visible light photocatalysis.* Journal of Environmental Science and Health, Part A, 2014. **49**(8): p. 892-899.
5. de Luna, M.D.G., et al., *Kinetics of acetaminophen degradation by Fenton oxidation in a fluidized-bed reactor.* Chemosphere, 2013. **90**(4): p. 1444-1448.
6. Fernández-Castro, P., et al., *Insight on the fundamentals of advanced oxidation processes. Role and review of the determination methods of reactive oxygen species.* Journal of Chemical Technology & Biotechnology, 2015. **90**(5): p. 796-820.
7. Pedersen, L.-F., T. Meinelt, and D.L. Straus, *Peracetic acid degradation in freshwater aquaculture systems and possible practical implications.* Aquacultural Engineering, 2013. **53**: p. 65-71.
8. Wu, W., et al., *Degradation of organic compounds by peracetic acid activated with Co3O4: a novel advanced oxidation process and organic radical contribution.* Chemical Engineering Journal, 2020. **394**: p. 124938.
9. Gasim, M.F., et al., *Peracetic acid activation using heterogeneous catalysts for environmental decontamination: A review.* Catalysis Communications, 2023. **180**: p. 106702.
10. Wacławek, S., et al., *Chemistry of persulfates in water and wastewater treatment: A review.* Chemical Engineering Journal, 2017. **330**: p. 44-62.
11. Sin, A., et al., *Development of tungsten-modified iron oxides to decompose an over-the-counter painkiller, Acetaminophen by activating peroxymonosulfate.* Science of The Total Environment, 2024. **951**: p. 175472.
12. Dominguez, S., et al., *Magnetically recoverable TiO 2-WO 3 photocatalyst to oxidize bisphenol A from model wastewater under simulated solar light.* Environmental Science and Pollution Research, 2017. **24**: p. 12589-12598.