Proceedings of the 5th International Conference on Materials Chemistry and Environmental Engineering
DOI: 10.54254/2755-2721/2025.28062

Practical Application of MBR Combined with Advanced Oxidation Treatment Technology in Hospital Wastewater Treatment

Jun Zhang[1†], Zheyi Chen[2*†]

[1]*Department of Water Resources and Hydropower Engineering, North China University of Water Resources and Electric Power, Zhengzhou, China*
[2]*Department of Environmental Science and Engineering, Nanjing University of Information Science and Technology, Nanjing, China*
**Corresponding Author. Email: 202283280113@nuist.edu.cn*
[†]*These authors contributed equally to this work and should be considered as co-first author.*

Abstract. The new pollutants in hospital wastewater, represented by antibiotics and other micro pollutants, as well as drug-resistant bacteria, have posed new challenges to the hospital wastewater treatment system. This article proposes a new system that combines Advanced Oxidation Processes (AOPs) with ozone and Membrane Bioreactors (MBR) as the core to treat new pollutants in hospital wastewater. It details various catalytic technologies that can be used as references in the ozone oxidation process and their basic advantages and disadvantages. It also introduces the corresponding biofilm treatment process and its limitations and future prospects. This article evaluates the treatment efficiency of ozone oxidation and biofilm technology separately in the results section, compares AOPs with traditional technologies such as ozonation and chlorination disinfection, and provides more supplements to MBR. Finally, the technological advantages were summarized. This demonstrates the broad prospects of this system and proposes new solutions to the problem of treating hospital wastewater pollutants.

Keywords: hospital wastewater, AOPs, MBR, ozone

1. Introduction

Modern sewage treatment systems often treat sewage on a specific building or community basis [1]. Hospitals generate a huge volume of wastewater which poses a great threat to the environment and hence to human health [2]. The wastewater generated from hospital units such as pathology laboratories, infection wards and staff quarters is very complex as it contains pathogenic microorganisms, drug residues, and chemicals. Due to the special nature of the environment and treatment objects, inefficient or incomplete treatment of hospital sewage has shown adverse consequences in terms of environmental indicators and Antibiotics Resistance Genes (ARGs) quantities [3]. Some pollutants have been widely and efficiently treated, but there are still a considerable number of pollutants that have not been effectively degraded, and even more complex

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2025.28062

types of organic toxic substances have been generated due to incomplete degradation [4]. In order to overcome the low efficiency and incompleteness of traditional oxidation processes, advanced oxidation technologies have made significant progress in recent years. Reactive oxygen species (ROS) has been used as the core to form diversified comprehensive oxidation technologies, which have played a significant role in the treatment of various complex and difficult to degrade organic pollutants and micro pollutants.

Advanced Oxidation Processes (AOPs) is an oxidation technology that primarily utilizes hydroxyl radicals to oxidize pollutants in wastewater. Ozone can generate a large amount of ROS in the system through electrocatalysis or photocatalysis, thereby achieving efficient degradation of various pollutants in water [5].

The Membrane Bioreactor (MBR) process integrates membrane filtration with biological treatment for wastewater purification. This technology has proven to be particularly effective in treating hospital wastewater, offering several distinct advantages. MBR system can effectively remove organic pollutants and microorganisms, and the effluent water quality is excellent. By combining with advanced oxidation treatments (AOPs), the MBR system can greatly enhance the elimination of organic pollutants from hospital wastewater, ensuring that the treated effluent complies with strict discharge regulations.

Due to its compact design and high treatment capacity, MBR technology can effectively treat hospital wastewater in confined spaces [2]. This is particularly important for sites with tight land use such as hospitals. The MBR system has a high degree of automation and is easy to operate and manage, which achieves continuous and stable operation and reduces manual intervention and management costs. The MBR technology also has a good resistance to shock loading and treatment stability, and the study by when treating hospital wastewater with large fluctuations, the MBR system is able to maintain high treatment efficiency and effluent quality [3].

The AOPs with ozone as core has played an important role in hospital wastewater treatment. Through long-term practical application, it has been cross combined with other important technologies of AOPs such as photocatalysis and electrocatalysis, significantly improving the degradation spectrum of ozone oxidation, greatly enhancing the efficiency and safety of hospital wastewater treatment, and suppressing the growth of ARGs and other harmful substances in environmental water that cause widespread harm to human society. In addition to conducting a large number of experiments in the laboratory, multiple pilot experiments also provide important support for demonstrating the broad prospects of the new ozone oxidation technology.

The application of advanced oxidation technologies (AOPs) in hospital wastewater treatment has significant advantages, and AOPs can efficiently remove organic pollutants and pathogenic microorganisms from wastewater and improve effluent quality [5]. Secondly, AOPs can be combined with other treatment technologies, such as MBR, to further improve the treatment effect and system stability [3]. In addition, AOPs are relatively simple to operate and are suitable for the treatment of a variety of complex wastewaters. AOPs also have some challenges, such as high energy consumption and treatment costs. Future research should focus on optimizing the operating conditions of AOPs, developing efficient and low-cost catalysts, and improving the combined process to further improve treatment efficiency and economics.

Objective

1. Introduce the relevant technical methods of advanced oxidation technology using ozone
2. Comparing the characteristics of different technologies through efficiency comparison
3. By combining advanced ozone oxidation with biofilm technology, efficient treatment of micro pollutants and ARGs in hospital wastewater can be achieved.

DOI: 10.54254/2755-2721/2025.28062

2. Method

Due to limited conditions, this article cannot provide data on water samples personally taken by the author's team and can only use data on hospital wastewater pollutants from other countries. The following will introduce the measurement methods for pollutants. Subsequently, governance measures based on this will be introduced.

2.1. Pollution in hospital wastewater

This article cites sewage data from hospitals in Japan and Canada. The former obtained water samples directly from waterways under suitable weather conditions [3], while the latter used Liquid Chromatography coupled with Tandem Mass Spectroscopy after sampling to obtain more accurate data on water pollutants [2]. Due to the variability of drug concentration, existing methods are limited in accuracy, and several sample formulation may help improve analysis efficiency.Table 1 shows the basic water quality parameters of the hospital wastewater in some areas.

Table 1. The basic water quality parameters of the hospital wastewater [3]

Type	Parameter
pH	8.4
chemical oxygen demand (COD)	51 mg/L
biochemical oxygen demand (BOD)	74 mg/L
suspended solids (SS)	204 mg/L
NH_4-N	30 mg/L
PO_4^{3-}	2.3 mg/L
E. coli	2,600 CFU/mL
coliform bacteria	108,000 CFU/ mL

2.2. Catalytic ozone oxidation

Catalytic ozone oxidation is a key focus of AOPs centered around ozone. The ozone as an oxidizing agent has the advantage that can selectively react with organic compounds via direct oxidation with molecular ozone or by indirect reaction through the generation of hydroxyl radicals .This characteristic gives it a unique advantage in decomposing organic micro pollutants represented by antibiotics in hospital wastewater. However, the low solubility of ozone and the generation of toxic by-products limit the efficiency and application of ozonation.

2.2.1. Electrocatalytic(EC) oxidation

Basic principles of degradation in the EC process can be attributed to two oxidation processes. In addition to oxidizing pollutants such as contrast agents and antibiotics through the oxidation ability of ozone itself in the system, the formation of hydroxyl radicals or other intermediate oxides such as hydrogen peroxide through electron transfer is generally more representative. The reaction equations are shown below [6,7].

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$$

$$H_2O_2 + O_3 \rightarrow \cdot OH + \cdot O_2^- + H^+ + O_2$$

$$O_3 + H_2O + e^- \rightarrow \cdot OH + O_2 + OH^-$$

DOI: 10.54254/2755-2721/2025.28062

2.2.2. Photocatalytic oxidation

Photocatalysis is widely used due to its convenient conditions and low sustained operating costs, among which UV photocatalytic oxidation is researched as an important way to treat various antibiotics and other hospital wastewater pollutants [8]. During the photocatalysis process, organic pollutants can be mineralized into nontoxic low molecules such as CO_2 and H_2O. Currently, due to their stability and economic benefits, semiconductors and other substances are being researshed as photocatalysts.Fig.1.demonstrates the basic reaction of catalytic ozone oxidation.

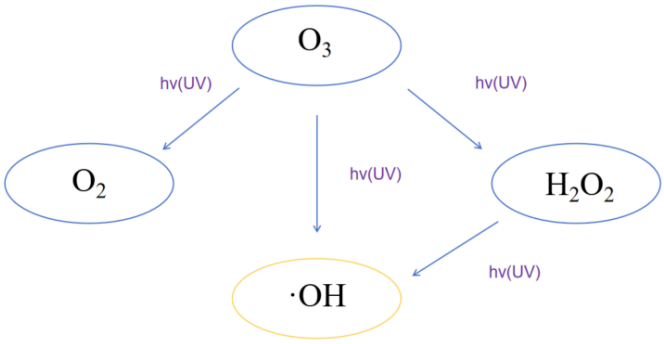

Figure 1. The basic reaction of photocatalytic ozonation

2.2.3. Membrane technology

Membrane technology provides new ideas for catalyzing ozone oxidation [9]. For example, ceramic membrane could provide an attachment carrier for the photocatalytic material TiO_2 and a reaction field for UV photocatalysis, thus replacing traditional bubble based oxidation designs, reducing structural complexity and energy consumption operating costs, and improving photocatalytic efficiency [10].Fig. 2. provides a brief demonstration of this process.

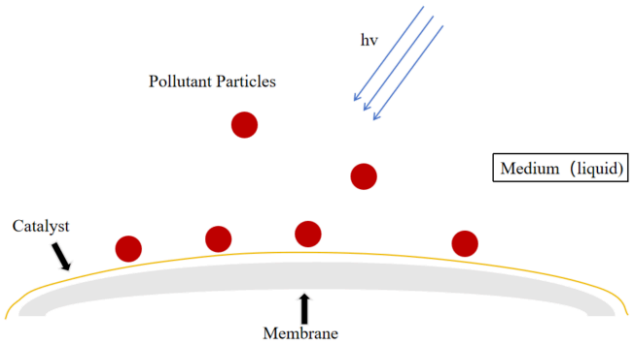

Figure 2. Schematic diagram of pollutant particles adsorbed onto membrane surface and reacting under the action of catalyst

DOI: 10.54254/2755-2721/2025.28062

2.2.4. Inorganic catalytic oxidation

Inorganic catalytic is the most traditional way of catalyzing ozone oxidation and sometimes serves as the basis for other catalytic technologies [11].

Taking catalytic ozonation using Y zeolite for example. Zeolite is an ozone catalyst suitable for treating organic micro pollutants in hospitals, rapidly inducing ozone decomposition to generate more active free radicals, enabling more efficient treatment for pollutants [12].

2.3. Working principle and advantages of MBR

The Membrane Bioreactor (MBR) process integrates membrane separation with biological treatment for wastewater purification. The core principle involves microorganisms in the bioreactor breaking down organic pollutants, and at the same time, solid-liquid separation is carried out through the membrane module, so as to realize highly efficient wastewater treatment. The MBR system usually consists of a bioreactor and a membrane module, and the wastewater firstly enters into the bioreactor, and the organic pollutants are degraded by microorganisms, and then the processed water is filtered through the membrane module to remove the suspended matters and bacteria.

It has demonstrated that by combining with advanced oxidation treatments (AOPs), the MBR system can significantly increase the efficiency of the organic pollutant removal from hospital wastewater, ensuring that the effluent meets stringent discharge standards [13]. MBR technology is useful in the treatment of hospital wastewater due to its compact design and efficient treatment capacity, it can achieve efficient wastewater treatment in a limited space [14].

MBR technology also has good shock load resistance and treatment stability, and the MBR system was able to maintain high treatment efficiency and effluent quality when treating hospital wastewater with high volatility [15]. The MBR system also performs well in the treatment of difficult-to-biodegrade organics, and by combining AOPs, the MBR system can effectively remove drug residues and other trace organic pollutants from wastewater (Mousel et al. 2020), further improving the effluent water quality [16]. Despite the significant advantages of MBR technology in hospital wastewater treatment, its membrane contamination still needs attention. Long-term operation of MBR systems can result in membrane fouling, which may reduce membrane flux and increase operating costs [17].

2.4. Advantages of combining MBR and AOPs

By integrating with Advanced Oxidation Processes (AOPs), the MBR system can substantially enhance the removal efficiency of organic pollutants when treating dye wastewater [18]. The MBR system removes most of the organic matter and suspended solids through biodegradation and membrane filtration, while the AOPs oxidize and degrade the residual difficult-to-degrade organics through the generation of highly active free radicals, which ensures that the effluent water quality is excellent. Membrane contamination can be effectively reduced and membrane service life can be prolonged through the introduction of electrochemical advanced oxidation treatment in MBR systems ([19].

The combination of advanced catalytic oxidation and biological treatment system can significantly improve the shock load resistance of the system, and showed good results in treating pesticide-contaminated water [20]. The combination of MBR and AOPs can also achieve deep treatment and resource recovery, and the combination of AOPs and MBR can achieve deep oxidation treatment in wastewater treatment, which not only removes the organic pollutants, but also

DOI: 10.54254/2755-2721/2025.28062

greatly reduces trace amounts of contaminants and pharmaceutical residues [21]. The combination of the partial anaerobic ammonia oxidation (ANAMMOX) technology and MBR can achieve advanced municipal wastewater nitrogen removal treatment [22].

3. Result and analysis

3.1. Evaluating the efficiency of ozone oxidation

During catalytic ozonation process, bromate may be produced as a byproduct due to insufficient oxidation, but methods such as increasing photocatalysts and catalytic contact surfaces can greatly reduce the production of by-products. Through catalytic ozonation, the treatment efficiency of micro pollutants such as CBX and SMX and the removal efficiency of drug-resistant bacteria are much higher than traditional ozone oxidation [10]. At the same time, this AOPs based on catalytic ozonation provides a relatively clean and efficient oxidation solution with a relatively low amount of by-products, which can meet the current needs of hospital sewage treatment [23]. Generally speaking, the comprehensive use of multiple technologies can achieve better processing results [24].

3.2. Efficiency analysis of MBR equipment combined with oxidation technology

Advanced ozonation treatment can produce more hydroxyl radicals to improve the decolorization rate (Sathya et al. 2019), increase the biodegradation index, and facilitate the simplified utilization of complex molecules to improve the degradation rate [25]. Fig 3 shows that ozone pretreatment improved the relative abundance of biodegradable organic matter and it can also improve the biodegradation of classical NAs, providing more material for microbial growth.The ozone-treated organic matter has a lower molecular weight and recyclability, which can be preferentially utilized by microorganisms [26].

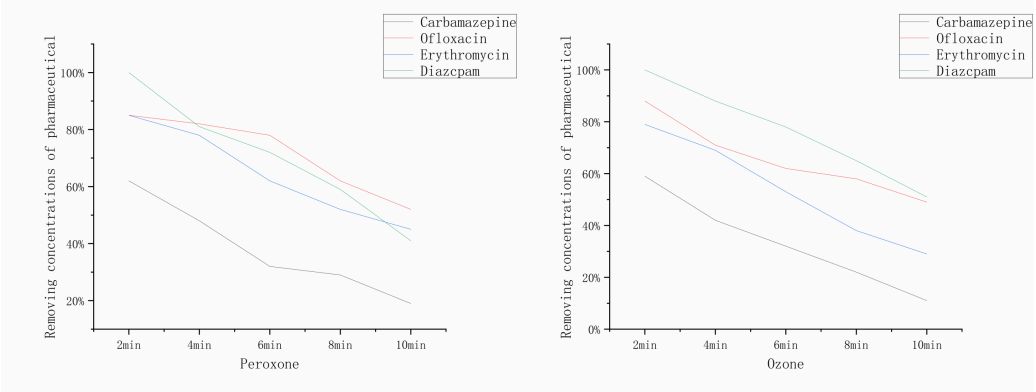

Figure 3. Relative removal of different antibiotics without ozone treatment and after ozone treatment

Photocatalytic oxidation uses ultraviolet light to irradiate the surface of catalysts (e.g., titanium dioxide) to generate hydroxyl radicals, which degrade organic pollutants through photochemical reactions. Photocatalytic oxidation combined with MBR can further improve the treatment effect [27]. Fig 4 demonstrates that when photocatalysts are exposed to appropriate light, they generate photoexcited electron-hole pairs, which produce reactive oxidizing substances (ROS). These ROS decompose antibiotic compounds into intermediates and damage bacterial cell membranes, leading to cell inactivation. The photocatalytic process can mineralize both cell walls and cellular contents, effectively preventing bacterial regeneration in the reactor [28].

DOI: 10.54254/2755-2721/2025.28062

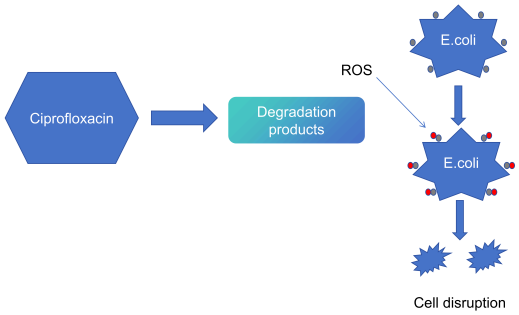

Figure 4. Schematic diagram of the basic principle of bacteria removal by photocatalytic oxidation technology

In combination with electrochemical techniques that can significantly reduce total nitrogen and phosphorus, applied current may facilitate denitrification by providing electrons from anodic oxidation.In addition,the conducting medium acts as a secondary electron provider and encourages electron conduction in the reactor. Fig 5 shows the basic parts of MBR combined with electrochemical techniques.The generated hydrogen molecules can be used as an electron donor by autotrophic denitrifying bacteria instead of a carbon source to complete the denitrification process. Through the electrochemical reaction, the TMP (Transmembrane Pressure Differential) and fouling resistance are significantly reduced [29].

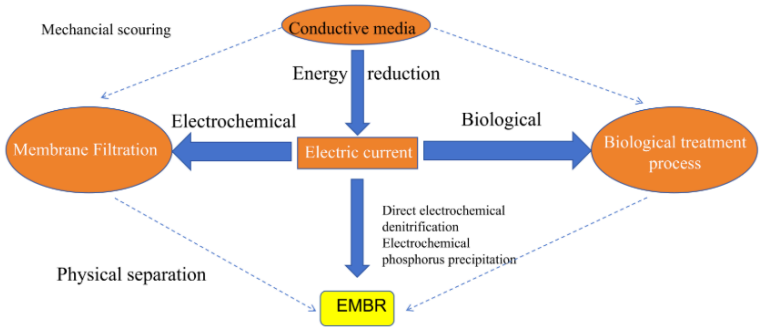

Figure 5. The basic components that make up an electrochemical biofilm system

Fenton oxidation disrupts cell walls, leading to plasma release and increased levels of soluble organic matter and nitrogen in the solution. Initially, it kills and oxidizes some activated sludge microorganisms, converting them into dissolved organic matter. This process causes organic matter to leach into the supernatant, raising soluble chemical oxygen demand (SCOD). While Fenton oxidation increases soluble organic matter, the elevated SCOD enhances reactions between the Fenton reagent and soluble compounds, ultimately reducing SCOD levels [30].

4. Discussion and prospect

This section will discuss the comparison between advanced oxidation technology and traditional technology, and list the advantages and future of combining biofilm with AOPs.Through a cleaner

DOI: 10.54254/2755-2721/2025.28062

and more efficient water pollution treatment design, this system has a broader application prospect compared to traditional solutions.

4.1. Comparison advanced ozonation process with traditional oxidation technology

The main advantage of advanced ozone oxidation is the utilization of ozone's high oxidation capacity and ability to generate free radicals, which enables traditional pollutants, micro pollutants, and microorganisms with ARGs to be more thoroughly oxidized, reducing the impact of antimicrobial resistance on people's healthy living environment.The advantages demonstrated by this technology include, but are not limited to, lower levels of pollutants after treatment, effective elimination of bacteria, and lower production of toxic by-products [10].

In contrast, traditional oxidation techniques such as chlorination disinfection have led to the production of more serious toxic by-products [31], and the treatment of these by-products is still under research and difficult to completely solve [32].Muammar Qadaf described the generation and toxicity of by-products (DBP) from chlorination disinfection, revealing the potential hazards of this widely used traditional technology [4].

The activated sludge process is also a widely used sewage treatment method,but it cannot replace the AOPs pathway of catalytic ozone oxidation due to the difficulties and principles encountered in practical application. The activated sludge process will produce a thick foam layer, which will seriously affect the oxidation efficiency and produce a large number of pollutant residues [33]. Even if the process of generating foam by anaerobic digestion of activated sludge process is optimized, it is still difficult to fundamentally solve the problem of pollutant residue [34]. On the other hand, the activated sludge process is extremely difficult to degrade antibiotics and other components in hospital wastewater, and even antibiotics can seriously affect the efficiency of the activated sludge process. Meanwhile, the activated sludge process is more suitable for pollutants with larger volumes and more uniform components, such as food degradation wastewater and urban domestic wastewater, and is not suitable for hospital wastewater, which has complex components and relatively smaller volumes [34].

In summary, catalytic ozone oxidation technology is superior to some traditional sewage treatment technologies in treating hospital wastewater in many aspects, and has great practical value and development prospects.

4.2. Limitations of MBR and possibilities for future development

The application of membrane bioreactor (MBR) technology in hospital wastewater treatment, although demonstrating significant advantages, faces some limitations. Hospital wastewater contains a large amount of organic matter and pathogenic microorganisms, which are prone to form a contamination layer on the surface of the membrane, affecting the filtration effect and the service life of the membrane [35].

MBR systems have high energy consumption, especially when treating highly concentrated organic wastewater, the combination of MBR and nanofiltration (NF) can significantly improve the wastewater treatment effect, but it also increases the energy consumption of the system [36]. The treatment efficiency of MBR systems is limited by the performance of the membrane modules and the stability of the bioreactor [37]. The membrane's anti-contamination performance and filtration efficiency can be significantly improved through the application of nanomaterials and composites [38]. Integrating multiple treatment technologies is an effective method to enhance the efficiency of MBR systems, particularly through the use of hybrid membrane technologies. (e.g., the combination

DOI: 10.54254/2755-2721/2025.28062

of MBR and advanced oxidation treatment technologies) can significantly improve the wastewater treatment effect, and reduce energy consumption and treatment costs [39].

5. Conclusion

From Table 2, as a material with broad prospects, ozone has a strong oxidizing capacity, but it has a high overhead, so it is more suitable for places such as hospitals where efficient removal of organic matter is required; electrochemical combinations have the advantage of being easy to regulate, for example, by varying the current level, but they require a large amount of energy, photocatalysis, although easy to achieve under milder conditions, has a weaker oxidizing capacity, and may oxidize incompletely, and is therefore only suitable for simple types of pollutants in wastewater treatment and Fenton reactions, although fast, produce a large amount of sludge. Photocatalysis is easy to realize under mild conditions, but its oxidizing ability is weak and may not oxidize completely, so it is only suitable for simple pollutant types in wastewater treatment, and the Fenton reaction is fast, but it will produce a large amount of sludge, and its subsequent treatment is still a problem worth thinking about.

Table 2. Comparison of different oxidation techniques combined with biofilm systems

Type	Advantage	Limitation	Cost	Location
Ozone-MBR	Strong oxidizing power No secondary pollution	Transfer efficiency Byproduct	1. High	Places where efficient removal of organic pollutants is required, such as hospitals
Electric-MBR	Control flexibility Less membrane contamination	High energy consumption Electrode aging	2. Appropriate	Some developed areas with complex pollutant types and large amounts of electrical energy
Photocatalysis-MBR	No need for harsh conditions No secondary contamination	Limited light penetration depth Incomplete oxidation	3. Appropriate	Where wastewater has a low concentration of organics and low turbidity
Fenton-MBR	high speed of reaction(combined with light) Easy to operate	Produces large amounts of iron sludge Poor oxidizing power	4. Low	Where low concentration difficult to degrade wastewater treatment

Totally the most suitable way of advanced oxidation combined with biofilm system in hospital wastewater treatment system should be combined with ozone, at the same time, the future should be focused on the material preparation about the new membrane, how to solve the problem of ozonation technology combined with biofilm system more efficiently, the design of a new type of system containing biofilm system and oxidation system is considered to be a possible direction of development, and at the same time, the intelligent control module can also be added.

Acknowledgement

Jun Zhang, Zheyi Chen contributed equally to this work and should be considered co-first authors.

References

[1] Bhandari, G.; Chaudhary, P.; Gangola, S.; Gupta, S.; Gupta, A.; Rafatullah, M.; Chen, S. A Review on Hospital Wastewater Treatment Technologies: Current Management Practices and Future Prospects. J. Water Process Eng. 2023, 56, 104516. https: //doi.org/10.1016/j.jwpe.2023.104516.

[2] Vaudreuil, M.-A.; Vo Duy, S.; Munoz, G.; Sauvé, S. Pharmaceutical Pollution of Hospital Effluents and Municipal Wastewaters of Eastern Canada. Sci. Total Environ. 2022, 846, 157353. https: //doi.org/10.1016/j.scitotenv.2022.157353.

DOI: 10.54254/2755-2721/2025.28062

[3] Azuma, T.; Usui, M.; Hayashi, T. Inactivation of Antibiotic-Resistant Bacteria in Hospital Wastewater by Ozone-Based Advanced Water Treatment Processes. Sci. Total Environ. 2024, 906, 167432. https: //doi.org/10.1016/j.scitotenv.2023.167432.
[4] Kali, S.; Khan, M.; Ghaffar, M. S.; Rasheed, S.; Waseem, A.; Iqbal, M. M.; Bilal Khan Niazi, M.; Zafar, M. I. Occurrence, Influencing Factors, Toxicity, Regulations, and Abatement Approaches for Disinfection by-Products in Chlorinated Drinking Water: A Comprehensive Review. Environ. Pollut. 2021, 281, 116950. https: //doi.org/10.1016/j.envpol.2021.116950.
[5] Dong, C.; Fang, W.; Yi, Q.; Zhang, J. A Comprehensive Review on Reactive Oxygen Species (ROS) in Advanced Oxidation Processes (AOPs). Chemosphere 2022, 308, 136205. https: //doi.org/10.1016/j.chemosphere.2022.136205.
[6] Li, H.; Wang, Z.; Geng, J.; Song, R.; Liu, X.; Fu, C.; Li, S. Current Advances in UV-Based Advanced Oxidation Processes for the Abatement of Fluoroquinolone Antibiotics in Wastewater. Chin. Chem. Lett. 2024, 110138. https: //doi.org/10.1016/j.cclet.2024.110138.
[7] Yu, S.-Y.; Xie, Z.-H.; Wu, X.; Zheng, Y.-Z.; Shi, Y.; Xiong, Z.-K.; Zhou, P.; Liu, Y.; He, C.-S.; Pan, Z.-C.; Wang, K.-J.; Lai, B. Review of Advanced Oxidation Processes for Treating Hospital Sewage to Achieve Decontamination and Disinfection. Chin. Chem. Lett. 2024, 35 (1), 108714. https: //doi.org/10.1016/j.cclet.2023.108714.
[8] Yang, Z.; Guo, S.; You, X.; Zhuo, Q.; Yang, B.; Huang, J.; Niu, J. Degradation of Hexafluoropropylene Oxide Tetrameric Acid (HFPO-TeA) Using Electrocatalytic Ozone Technique. Water Cycle 2022, 3, 106–111. https: //doi.org/10.1016/j.watcyc.2022.08.001.
[9] Herrmann, S.; Ullrich, F.; Tepper, M.; Wessling, M. On the Geometry and Material Stability of Tubular PVDF-TiO2 Static Mixer Membrane Contactors for Photocatalytic Ozonation of Micropollutants. J. Membr. Sci. 2024, 702, 122753. https: //doi.org/10.1016/j.memsci.2024.122753.
[10] Herrmann, S.; Dietz, K.; Wilms, L.; Wessling, M. Bubble-Less Photocatalytic Ozonation with Ceramic Membranes and Static Mixers Enhances the Total Organic Carbon Removal and Degradation of Iodinated X-Ray Contrast Agents. J. Environ. Chem. Eng. 2024, 12 (3), 112995. https: //doi.org/10.1016/j.jece.2024.112995.
[11] Zhu, L.; Zhou, S.; Cheng, H.; Komarneni, S.; Ma, J. In-Situ Growth of Mn-Ni3S2 on Nickel Foam for Catalytic Ozonation of p-Nitrophenol. Chemosphere 2024, 357, 142037. https: //doi.org/10.1016/j.chemosphere.2024.142037.
[12] Prada-Vásquez, M. A.; Simarro-Gimeno, C.; Vidal-Barreiro, I.; Cardona-Gallo, S. A.; Pitarch, E.; Hernández, F.; Torres-Palma, R. A.; Chica, A.; Navarro-Laboulais, J. Application of Catalytic Ozonation Using Y Zeolite in the Elimination of Pharmaceuticals in Effluents from Municipal Wastewater Treatment Plants. Sci. Total Environ. 2024, 925, 171625. https: //doi.org/10.1016/j.scitotenv.2024.171625.
[13] Khan, A., Khan, N., Ahmed, S., Dhingra, A., Singh, C. P., Khan, S., Mohammadi, A., Changani, F., Yousefi, M., Alam, S., Vambol, S., Vambol, V., Khursheed, A., & Ali, I. (2020). Application of advanced oxidation processes followed by different treatment technologies for hospital wastewater treatment. Journal of Cleaner Production, 269, 122411. doi: 10.1016/j.jclepro.2020.122411.
[14] Monteoliva-García, A.; Martín-Pascual, J.; Muñío, M. M.; Poyatos, J. M. Effects of Carrier Addition on Water Quality and Pharmaceutical Removal Capacity of a Membrane Bioreactor – Advanced Oxidation Process Combined Treatment. Sci. Total Environ. 2020, 708, 135104. https: //doi.org/10.1016/j.scitotenv.2019.135104.
[15] Vo, T.-K.-Q.; Bui, X.-T.; Chen, S.-S.; Nguyen, P.-D.; Cao, N.-D.-T.; Vo, T.-D.-H.; Nguyen, T.-T.; Nguyen, T.-B. Hospital Wastewater Treatment by Sponge Membrane Bioreactor Coupled with Ozonation Process. Chemosphere 2019, 230, 377–383. https: //doi.org/10.1016/j.chemosphere.2019.05.009.
[16] Mousel, D.; Bastian, D.; Firk, J.; Palmowski, L.; Pinnekamp, J. Removal of Pharmaceuticals from Wastewater of Health Care Facilities. Sci. Total Environ. 2021, 751, 141310. https: //doi.org/10.1016/j.scitotenv.2020.141310.
[17] Yacouba, Z. A., Mendret, J., Lesage, G., Zaviska, F., & Brosillon, S. (2021). Removal of organic micropollutants from domestic wastewater: The effect of ozone-based advanced oxidation process on nanofiltration. Journal of Water Process Engineering, 39, 101869. doi: 10.1016/j.jwpe.2020.101869.
[18] Li, Q.; Dong, K.; Tu, Y.; Jiang, L.; Li, X.; Li, H. Current Situation and Problems of MBR Treatment Process in Dye Wastewater. IOP Conf. Ser. Earth Environ. Sci. 2019, 358 (2), 022043. https: //doi.org/10.1088/1755-1315/358/2/022043.
[19] El Kateb, M.; Trellu, C.; Darwich, A.; Rivallin, M.; Bechelany, M.; Nagarajan, S.; Lacour, S.; Bellakhal, N.; Lesage, G.; Héran, M.; Cretin, M. Electrochemical Advanced Oxidation Processes Using Novel Electrode Materials for Mineralization and Biodegradability Enhancement of Nanofiltration Concentrate of Landfill Leachates. Water Res. 2019, 162, 446–455. https: //doi.org/10.1016/j.watres.2019.07.005.
[20] Soto-Verjel, J.; Maturana, A. Y.; Villamizar, S. E. Advanced Catalytic Oxidation Coupled to Biological Systems to Treat Pesticide-Contaminated Water: A Review on Technological Trends and Future Challenges. Water Sci.

DOI: 10.54254/2755-2721/2025.28062

Technol. 2022, 85 (4), 1263–1294. https: //doi.org/10.2166/wst.2021.642.
[21] Hilles, A., Abu Amr, S. S., Aziz, H. A., & Bashir, M. (2019). Advanced Oxidation Processes for Water and Wastewater Treatment. Advances in Environmental Engineering and Green Technologies. doi: 10.4018/978-1-5225-5766-1.CH003.
[22] Yang, L., Peng, Y., Li, J., Gao, R., Wang, M., & Li, X. (2019). Advanced Denitrification of Municipal Wastewater Achieved via Partial ANAMMOX in Anoxic MBBR. Huan jing ke xue= Huanjing kexue, 40(8), 3668-3674. doi: 10.13227/j.hjkx.201901015.
[23] Yao, W.; Yang, T.; Liu, D.; Liu, F.; Zhang, L.; Cheng, C.; Hu, J.; Huang, H. Preparation of LMO@FC Catalysts and Degradation of Tetracycline by Catalytic Ozonation. J. Alloys Compd. 2024, 1004, 175848. https: //doi.org/10.1016/j.jallcom.2024.175848.
[24] Palomares-Reyna, D.; Carrera-Crespo, J. E.; Sosa-Rodríguez, F. S.; García-Pérez, U. M.; Fuentes-Camargo, I.; Lartundo-Rojas, L.; Vazquez-Arenas, J. Photo-Electrochemical and Ozonation Process to Degrade Ciprofloxacin in Synthetic Municipal Wastewater, Using C, N-Codoped TiO2 with High Visible-Light Absorption. J. Environ. Chem. Eng. 2022, 10 (3), 107380. https: //doi.org/10.1016/j.jece.2022.107380.
[25] .Sathya, U., et al., Evaluation of advanced oxidation processes (AOPs) integrated membrane bioreactor (MBR) for the real textile wastewater treatment. J Environ Manage, 2019. 246: p. 768-775.
[26] Zhang, Y.; Xue, J.; Liu, Y.; Gamal El-Din, M. The Role of Ozone Pretreatment on Optimization of Membrane Bioreactor for Treatment of Oil Sands Process-Affected Water. J. Hazard. Mater. 2018, 347, 470–477. https: //doi.org/10.1016/j.jhazmat.2017.12.013.
[27] Xinyu, Z., et al., Advances in research of Anammox process in MBR. E3S Web of Conferences, 2023. 385: p. 2032.
[28] Sayanti Ghosh, N.V.M. Sri Harsha, Swatantra Pratap Singh, Amritanshu Shriwastav, Simultaneous removal of ciprofloxacin and disinfection from wastewater by combined photocatalytic reactor(PCR) and membrane bioreactor (MBR) system, Journal of Environmental Chemical Engineering, Volume11, ssue5, 2023, 110855, ISSN2213-3437, https: //doi.org/10.1016/j.jece.2023.110855.(https: //www.sciencedirect.com/science/article/pii/S2213343723015944)
[29] Udomkittayachai, N.; Xue, W.; Xiao, K.; Visvanathan, C.; Tabucanon, A. S. Electroconductive Moving Bed Membrane Bioreactor (EcMB-MBR) for Single-Step Decentralized Wastewater Treatment: Performance, Mechanisms, and Cost. Water Res. 2021, 188, 116547. https: //doi.org/10.1016/j.watres.2020.116547.
[30] He, M.; Wei, C. Performance of Membrane Bioreactor (MBR) System with Sludge Fenton Oxidation Process for Minimization of Excess Sludge Production. J. Hazard. Mater. 2010, 176 (1–3), 597–601. https: //doi.org/10.1016/j.jhazmat.2009.11.071.
[31] Qadafi, M.; Rosmalina, R. T.; Pitoi, M. M.; Wulan, D. R. Chlorination Disinfection By-Products in Southeast Asia: A Review on Potential Precursor, Formation, Toxicity Assessment, and Removal Technologies. Chemosphere 2023, 316, 137817. https: //doi.org/10.1016/j.chemosphere.2023.137817.
[32] Du, Y.; Lv, X.-T.; Wu, Q.-Y.; Zhang, D.-Y.; Zhou, Y.-T.; Peng, L.; Hu, H.-Y. Formation and Control of Disinfection Byproducts and Toxicity during Reclaimed Water Chlorination: A Review. J. Environ. Sci. 2017, 58, 51–63. https: //doi.org/10.1016/j.jes.2017.01.013.
[33] Zhou, B.; Wang, D.; Zhao, G.; Zhang, M.; Liu, X.; Zhang, D.; Liang, J.; Zhou, L. Effects of Food Waste Hydrolysate as an External Carbon Source on Defoaming in Wastewater Treatment with Activated Sludge Process. Bioresour. Technol. 2024, 404, 130900. https: //doi.org/10.1016/j.biortech.2024.130900.
[34] Zhou, B.; Wang, D.; Yan, C.; Zhao, G.; Liu, X.; Zhang, D.; Liang, J.; Zhou, Y.; Li, J.; Zhou, L. A Novel Approach for Purifying Food Waste Anaerobic Digestate through Bio-Conditioning Dewatering Followed by Activated Sludge Process: A Case Study. Environ. Pollut. 2024, 346, 123644. https: //doi.org/10.1016/j.envpol.2024.123644.
[35] Liu, A., Zhao, Y., Cai, Y., Kang, P., Huang, Y., Li, M., & Yang, A. (2023). Towards Effective, Sustainable Solution for Hospital Wastewater Treatment to Cope with the Post-Pandemic Era. International Journal of Environmental Research and Public Health, 20. doi: 10.3390/ijerph20042854.
[36] Tran, T., Nguyen, T., Ho, H. L., Le, D., Lam, T. D., Nguyen, D. C., Hoang, A., Do, T. S., Hoang, L., Nguyen, T., & Bach, L. (2019). Integration of Membrane Bioreactor and Nanofiltration for the Treatment Process of Real Hospital Wastewater in Ho Chi Minh City, Vietnam. Processes. doi: 10.3390/PR7030123.
[37] Wang, H.; Cheng, Z.; Sun, Z.; Zhu, N.; Yuan, H.; Lou, Z.; Chen, X. Molecular Insight into Variations of Dissolved Organic Matters in Leachates along China's Largest A/O-MBR-NF Process to Improve the Removal Efficiency. Chemosphere 2020, 243, 125354. https: //doi.org/10.1016/j.chemosphere.2019.125354.
[38] Ma, D.; Yi, H.; Lai, C.; Liu, X.; Huo, X.; An, Z.; Li, L.; Fu, Y.; Li, B.; Zhang, M.; Qin, L.; Liu, S.; Yang, L. Critical Review of Advanced Oxidation Processes in Organic Wastewater Treatment. Chemosphere 2021, 275, 130104. https: //doi.org/10.1016/j.chemosphere.2021.130104.

DOI: 10.54254/2755-2721/2025.28062

[39] Priyanka, M., Mohapatra, S., & Menon, N. (2021). Hybrid membrane technology: an alternative to industrial wastewater treatment. Membrane-Based Hybrid Processes for Wastewater Treatment. doi: 10.1016/b978-0-12-823804-2.00001-x.