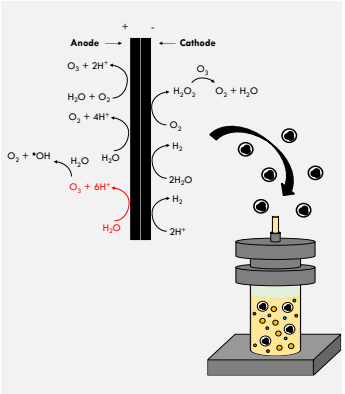
New Perspectives On Electro-ozonizers: Towards The Disinfection And Treatment Of Wastewater with O_3 (g)

POSTER
Ph.D. Student: Y
Journal: JECE

S. E. Correia[1], *Á. Moratalla*[1], *V. Pertegal*[2], *E. Lacasa*[2], *P. Cañizares, M. Rodrigo, C. Sáez. (1) Department of Chemical Engineering, Faculty of Chemical Sciences and Technologies, University of Castilla-La Mancha, Avenida Camilo José Cela, s/n. – 13071, Ciudad Real, Spain, Sergio.Corrreia@uclm.es. (2) Department of Chemical Engineering, Higher Technical School of Industrial Engineering, University of Castilla-La Mancha, Avenida de España, s/n. - 02071, Albacete, Spain*



In this research, the electrochemical generation of an ozone gas stream is evaluated using a Polymer Electrolyte Membrane (PEM) cell. The results indicate that ozone gas can be produced at rates of 0.058, 0.185, 0.263, and 0.574 mg O_3 min^{-1}, applying current densities of 25, 42, 50 and 75 mA cm^{-2}, respectively. Additionally, the oxidation capacity of ozone in the gas phase for the treatment of hospital effluents is evaluated. *Klebsiella pneumoniae (K. Pneumoniae)* has been used as a model bacteria, and Metamizole-MAA (MTZ-MAA), Meropenem (MRP), and Piperacillin (PIP) as pharmaceutical compounds. The results show that the ozone gas generated by the electro-ozonizer can be used to treat hospital urine. It is important to note that the ozone dose plays a crucial role in the process.

Introduction

Hospital effluents are considered a primary source of antibiotic resistance bacteria (ARB) due to the simultaneous presence of pharmaceuticals and pathogens stemming from the direct excretion of medications by patients through urine and/or feces [1,2].

Many chemicals have been tested for the disinfection of wastewater, such as hydrogen peroxide, hypochlorite, chloramines, ozone, chlorine dioxide, etc. Among them, ozone is a very powerful oxidant ($E° = 2.07$ V) that exhibits superior performance in the treatment of many parasites, bacteria and viruses compared to chlorine-based disinfectants Likewise, its use prevents the generation of disinfection by-products such as trihalomethane. In fact, ozone (O_3) is considered as an environmentally friendly oxidant and free from secondary pollution [3,4]

Commonly, ozone is generated by the conventional corona discharge method, but it requires high voltage and presents low electrical efficiency [5]. To address these limitations, electrochemical technology has emerged as a promising alternative for ozone generation as it allows the generation of high concentrations of ozone at low voltages.

In this context, the aim of this work is to evaluate the effectiveness of producing gaseous ozone by electrochemical technology and of using this gaseous oxidant stream to decrease the chemical and biological risk of sanitary effluents.

Material and Methods

The chemical composition of the synthetic hospital effluents used in the present investigation is reported in previous studies [4]. *Klebsiella pneumoniae (K. pneumoniae*) is used as target bacteria, and Metamizole-MAA (MTZ-MAA), Meropenem (MRP), and Piperacillin (PIP) as pharmaceutical compounds. The concentration of ozone in the liquid phase is determined by an ozone test, while ozone in gas phase was quantified using the iodometric titration technique. Regarding the experimental setup, this consists of two different systems: 1) the electro-ozonizer where the ozone is electro-generated using a Polymer Electrolyte Membrane (PEM) type cell; 2) the ozone dosing system in which the effluent (contaminated hospital urine) is treated using gaseous ozone. This gas stream is derived from the stripping of ozone contained in the reservoir tank through a Jet aerator.

Results and Discussion

Initially, the electro-generation of ozone by oxidation of water in liquid and gas phases through a PEM electrolyzer is evaluated. To accomplish this, the influence of the current density (25, 42, 50 and 75 mA cm^{-2}) in the electrolyte (liquid phase) was studied. In addition, the stripping of ozone contained in the electrolyte during the electrochemical process was evaluated. Figure 1 (principal axel) shows the steady-state values obtained for the mass flow of ozone gas (expressed in mg O_3 min^{-1}) as function of the current density applied. As expected, a direct correlation between the concentration of ozone in the liquid phase and the corresponding ozone concentrations in the gas phase is observed (according with Henry's law). The Coulombic efficiency is also shown in the figure, with values up to 6.5 %.

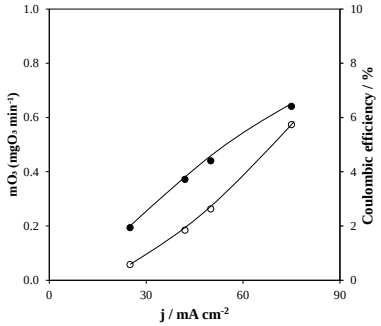


Figure 1. Influence of current density applied on the electro-generation of ozone concentration (mg O_3 min^{-1}) in the gas phase (principal axel), and Coulombic efficiency (secondary axel). Legend: ozone doses (white circle), and Coulombic efficiency (black circle).

Finally, the inactivation of antibiotic resistant bacteria (ARB) and the removal of pharmaceutical compounds in hospital effluents is evaluated by applying an absorption-based process. Figure 2 shows the removal of *K. Pneumoniae* (principal axel), and MTZ-MAA, MRP, and PIP (secondary axel). The results show that the required doses of ozone to attain the complete disinfection are lower than those required for the degradation of drugs. Furthermore, it can be observed that there is a competitive oxidation between pharmaceutical compounds: MTZ-MAA > MRP > PIP.

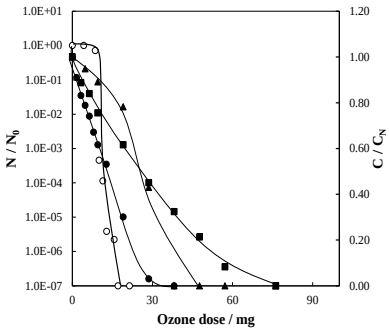


Figure 2. Evolution of bacteria and pharmaceutical compounds as a function of ozone dose. Legend: bacteria (white circle), MTZ-MAA (black circle), MRP (black triangle), and PIP (black square).Simulated liquid hospital effluents: urine. Target bacteria: 10^7 CFU mL^{-1} of *K. pneumoniae* ATCC BAA 1705.

Conclusions

- Higher current densities favour electrochemical ozone production in PEM cells.
- It is possible to valorize a gaseous current from the stripping of the ozone contained in the electrolyte for the treatment of hospital urine.
- The inactivation of *K. pneumoniae* and the removal of pharmaceutical compounds are related with the mass flow rates of the ozone. Full disinfection is achieved with ozone doses below 20 mg, while 75 mg O_3 are required for the treatment of polymedicated hospital effluents.

Acknowledgments

This research has been funded by the Junta de Comunidades de Castilla-La Mancha (JCCM) and the European Union (European Regional Development Fund) through the project SBPLY/21/180501/000035 and by the Ministry of Science and Innovation through of project PID2022-140113OB-I00.. Sergio E. Correia thanks the PRE2020-094608 scholarship funded by MCIN/AEI/10.13039/501100011033 and by "ESF Invest in your future ".

References

[1] M. Herraiz-Carboné, S. Cotillas, E. Lacasa, M. Vasileva, C. Sainz de Baranda, E. Riquelme, P. Cañizares, C. Sáez, *Journal of Hazardous Materials,* 426 (2022) 128028.

[2] S. Giannakis, B. Androulaki, C. Comninellis, C. Pulgarin, *Chemical Engineering Journal,* 343 (2018) 270.

[3] Á. Moratalla, S.E. Correia, E. Lacasa, P. Murillo, P. Cañizares, M.A. Rodrigo, C. Sáez, *Journal of Water Process Engineering*, 55 (2023) 104153.

[4] S.E. Correia, V. Pertegal, M. Herraiz-Carboné, E. Lacasa, P. Cañizares, M.A. Rodrigo, C. Sáez, *Journal of Water Process Engineering,* 57 (2024) 104732.

[5] I.F. Mena, M.A. Montiel, C. Sáez, M.A. Rodrigo, *Chemical Engineering Journal,* 464 (2023) 142688.