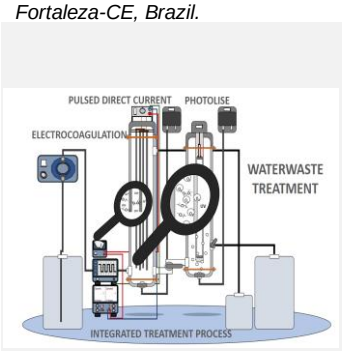
Removal of Drugs from Sewage Treatment Plant Effluents by Electrocoagulation Coupled to Photolysis With Aeration

SHORT-ORAL
Ph.D. Student: Y
Journal: CEJ

L. T. V. Silva[1], *J. T. Oliveira*[1], *T. R. Nogueira*[1], *O. S. Campos*[2], *E. F. Abdla Neto*[3], *R. F. Nascimento*[1]. *(1) Federal University of Ceará, Street Humberto Monte 940, Campus do Pici, Fortaleza, Brazil, thiago97@alu.ufc.br. (2) Federal University of Espírito Santo, Street Alto Universitário S/N, Alegre, Brazil. (3) Christus University Center, Fortaleza-CE, Brazil.*



The widespread usage of pharmaceuticals results in their discharge into wastewater treatment plant effluents. Even in reduced concentrations, these compounds can significantly impact the environment and human health. AIn this work, a comparative study was carried out between electrocoagulation (EC) and photolysis treatments with aeration (PA). Electrocoagulation demonstrated greater effectiveness in removing drugs and TOC compared to aeration photolysis. Therefore, electrocoagulation was selected as the primary method for this removal, while photolysis with aeration served as a supplementary step. There was a substantial increase in the removal of drugs and TOC through the combined processes, achieving the following: TMP increased from 43.03% to 75.95%, PAR from 45.75% to 71.78%, IBP from 78.79% to 96.01%, and COT from 56.77% to 78.72%.

Introduction

The increasing use of pharmaceuticals, both in veterinary and human medicine, is a global challenge. Unfortunately, wastewater treatment plants are not always able to effectively remove these drugs, resulting in the release of effluents with high concentrations of pharmaceuticals into the environment [1].

Many research efforts are being devoted to the development of alternative techniques for the total removal of pharmaceuticals and their by-products. Among them, we can mention the electrocoagulation (EC) process, which consists of an electrolytic treatment, where the oxidation of metal electrodes forms metal ions in solution, and insoluble compounds are later formed in the form of hydroxides via hydrolysis [2, 3].

Advanced Oxidative Processes (AOPs) also represent alternative techniques for the treatment of organic pollutants. These decontamination methods use highly reactive species, such as hydroxyl radicals, to degrade pollutants [4].

In this work, a comparative study will be carried out between the processes of electrocoagulation and photolysis with aeration (AOP) for the removal of drugs from an effluent of a domestic sewage plant, in addition to the evaluation of the association of these two processes.

Material and Methods

The standards of acetaminophen (PAR) 99%, ibuprofen (IBP) 99% and trimethoprim (TMP) 99% were acquired from Sigma-Aldrich. The actual samples were collected at the Aracapé III Sewage Treatment Plant in Fortaleza, Ceará, Brazil.

The electrocoagulation (EC) treatment system used a cylindrical acrylic reactor with a capacity of 4 liters, containing four aluminum electrodes. These were connected to a circuit controlled by a Minipa MPL33-03 DC power supply, with the duty cycle monitored by a Minipa MVB-DSO oscilloscope.

The direct photolysis treatment with aeration (PA) was performed in a PVC reactor of 105 cm in length, 33.90 mm in internal diameter and volume of 1.82 L. Internally, the reactor had a quartz shell with an external diameter of 22.25 mm, where a 40 W UV-C lamp, with a wavelength of 185 nm (model OZONE 762/T5 4, Phillips), was centralized. Aeration was done through a porous stone connected to a Master aquarium pump.

The experimental conditions included pH 5.45 and current density of 12.14 A m^{-2} for EC, and pH 7.03 and flow rate of 99.14 mL min^{-1} for photolysis with aeration. Initially, 3.00 L of WWTP effluent, containing 30.00 mg L^{-1} of each drug, were treated by the EC process for 30 minutes. The resulting supernatant in the EC reactor was collected and transferred to a reservoir before proceeding to the PA reactor. Samples of 25.00 mL were collected after the EC and PA processes and stored in conical tubes for drug and TOC analysis.

The chromatographic method was developed in a Shimadzu high-performance liquid chromatograph (20A Prominence), equipped with a diode array detector (SPDM20A) and reading range from 190 to 800 nm. A Shimadzu CLC-ODS column (4.6 x 250 mm, 5 µm) and an isocratic condition of 70:30 (acetonitrile:H_2O pH 3) were used. The sample, prepared according to the QuEChERs methodology, was injected in a volume of 20 µL.

Results and Discussion

A comparative evaluation was performed between the treatments by electrocoagulation and photolysis

with aeration, using the F and t statistical tests. The results obtained are presented in Table 1.

The data presented in Table 1 indicate that, for the removal of TMP, PAR, IBP and TOC, the Fcal values were higher than the Ftab ($F_{cal} > F_{crit}$), and the tcal values were higher than the ttab ($t_{cal} > t_{crit}$). This highlights a significant difference between the two treatments studied. The electrocoagulation process has been shown to be more effective in removing drugs and TOC compared to the photolysis process with aeration. Therefore, the electrocoagulation method was adopted as the main method for the removal of drugs and TOC, while the process of photolysis with aeration was used as a complementary polishing step.

Figure 1 shows the results of the removal of TMP, PAR, IBP and TOC obtained from the EC process followed by photolysis with aeration. A significant increase was observed in the removal of drugs and TOC, from 43.03% to 75.95% (TMP), from 45.75% to 71.78% (PAR), from 78.79% to 96.01% (IBP) and from 56.77% to 78.72% (TOC).

The exclusive use of the EC process as a treatment method can face serious practical limitations, especially when wastewater is highly polluted. Therefore, the need for effective and relatively affordable treatment processes is fundamental. In this sense, the adoption of a pre- or post-treatment process with EC can considerably improve its performance. Several studies have described combined treatment systems that demonstrate a good cost-benefit ratio when integrating EC with other methods, as reported in the literature [5, 6, 7].

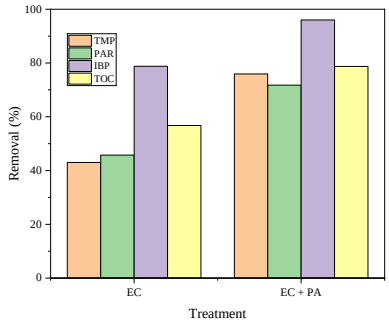


Figure 1. Removal of TMP, PAR, IBP and TOC after EC process associated with PA.

Table 1. Percentage of removal and F and t tests of EC and PA treatments.

	Treatment		$Value_{obs}$		$Value_{crit}$	
	EC	**PA**	F_{cal}	t_{cal}	F_{crit}	t_{crit}
TMP removal (%)	42.90 %	34.71 %	148.71	16.94	4.96	2.01
PAR removal (%)	45.22 %	41.37 %	30.92	5.78		
IBP removal (%)	78.64 %	44.95 %	1557.85	83.24		
TOC removal (%)	57.19 %	28.61 %	3585.42	130.92		

Conclusions

The electrocoagulation process has been shown to be more effective in removing drugs and TOC compared to the photolysis process with aeration. Therefore, the electrocoagulation method was adopted as the main method for the removal of drugs and TOC, while the process of photolysis with aeration was used as a complementary polishing step. A significant increase in the removal of drugs and TOC was observed with the association of electrocoagulation and photolysis processes with aeration.

Acknowledgments

We would like to thank the Federal University of Ceará and the funding agencies CAPES, CNPq and FUNCAP.

References

[1] Y. XIANG, H. WU, L. LI, M. REN, H. QIE, A. LIN, Ecotoxicology and Environmental Safety, 213 (2021) 112044.
[2] B. K. ZAIED, M. RASHID, M. NASRULLAH, A. W. ZULLARISAM, D. PANT, L. A. SINGH, Science of The Total Environmental, 726 (2020) 138095.
[3] S. M. ISLAM, Sustainable Water Resources Management, 5 (2019) 359.
[4] A. KULISTAKOVÁ, Journal of Water Process Engineering, 53 (2023),103727**.**
[5] Z. AL-QODAH, M. AL-SHANNAG, Separation Science and Technology, 52 (2017) 2649.
[6] E. GILPAVAS, I. DOBROSZ-GÓMEZ, M. GÓMEZ-GARCÍA, Science of The Total Environment, 651 (2019) 551.
[7] Z. AL-QODAH, M. TAWALBEH, M. AL-SHANNAG, Z. AL-ANBER, K. BANI-MELHEM, Science of The Total Environment, 744 (2020) 140806.