Photoelectrocatalysis of Stainless Steel Electrodes Electrodeposited with Polypyrrole in the Degradation of Antibiotic Tetracycline

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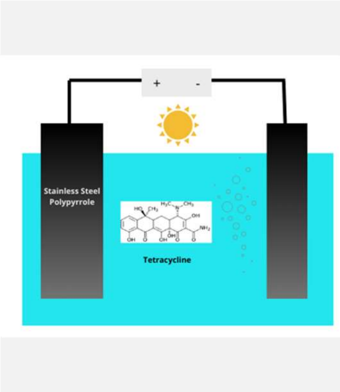

The worldwide challenge of reducing emerging contaminants (ECs) in water sources is a significant environmental concern. This study concentrates on improving the degradation of ECs, in specific the antibiotic tetracycline, through photoelectrocatalysis processes in conjunction with polypyrrole. Our primary goal is to optimize the efficiency of the degradation process, thereby improving water quality standards. We plan to create stainless steel electrodes coated with polypyrrole via potentiostatic electrodeposition, which will facilitate EC degradation through photoelectrocatalysis. The findings indicated a 12,23% removal rate in the process at a potential of 0,9 V and an electrolysis time of 60 minutes.

Introduction

The rise of emerging compounds (ECs), like tetracycline, is becoming an increasingly concerning global issue that poses a threat to both aquatic and terrestrial biodiversity. This worrisome trend is largely due to the overuse of this antibiotic in aquaculture, livestock farming, and human disease prevention. The widespread presence of tetracycline in water can result in severe consequences, jeopardizing the stability of both aquatic and terrestrial ecosystems.[1].

Prolonged exposure to elevated levels of tetracycline in water can pose significant health hazards, such as bacterial resistance, allergic reactions, and negative impacts on the gastrointestinal system. In some cases, it can even lead to the transmission of diseases. Unfortunately, conventional treatment methods may not be sufficient in entirely eliminating these harmful compounds, necessitating the development of new and innovative solutions. One promising technology that aims to ensure water quality is photoelectrocatalysis.

Photoelectrocatalysis involves the use of an anode composed of a conductive substrate coated with a semiconductor material. When this material is exposed to light, electrons are excited from the valence band to the conduction band of the semiconductor material, creating positively charged vacancies (holes) in the valence band. These generated vacancies can react with chemical species on the electrode surface [2]. Therefore, this study aims to develop modified electrodes, using stainless steel as a conductive substrate and polypyrrole as a coating. These electrodes will be used to degrade tetracycline in aqueous solution through the photoelectrocatalysis process.

Material and Methods

For the development of the electrodes, physically and chemically cleaned stainless steel sheets, pyrrole electrodeposition (PPI) experiments were carried out in an electrochemical cell composed of three electrodes: a working electrode made of AISI 316 stainless steel, a counter- electrode made of platinum and a reference electrode using saturated calomel. The electrodes were prepared by covering them with double-sided adhesive tape, leaving only a circular area of approximately 0.20 cm² exposed to interact with the electrolyte solution. The glass cell used has a total volume of 100 mL, but only 50 mL of solution will be added, ensuring adequate coating of the electrodes during cyclic voltammetry and chronoamperometry studies. Two concentrations of pyrrole were used, 0.1M and 0.3M. Cyclic voltammetry was carried out for these two concentrations, where two best potentials for deposition were found: 0.7 and 0.8 V, totaling 4 modified electrodes, with a deposition time of 15 seconds. After film formation, the electrodes were washed with ultrapure water and stored in a desiccator at room temperature and low oxygen concentration, free from moisture for preservation.

The tetracycline degradation experiments were conducted using the chronoamperometry technique with a fixed potential of 0.9V, sodium sulfate as electrolytic agent, and the effect of ultraviolet (UV) radiation with an 80 W mercury vapor lamp, with quartz bulb, which has a characteristic wavelength of 254 nm, for a total of 60 minutes. A 20 ppm tetracycline solution was used, and to measure the initial and final concentration of tetracycline in the solution, a Uv-Vis spectrophotometer will be used, with a wavelength of 357 nm [3].

Results and Discussion

Polypyrrole films were fabricated by means of polymerization and electrochemical deposition, capitalizing on the convenience of regulating reaction parameters and film width. The potentials linked to the formation of the polymer film from the pyrrole solution were detectable with the application of cyclic voltammetry technique. Figure 1 showcases the corresponding voltammogram.

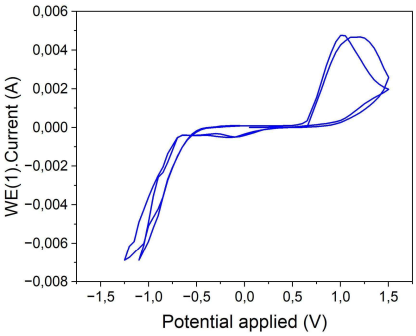

Figure 1. Voltametria ciclica.

The use of potentials above 0.6 V is intended to facilitate polymerization and promote efficient charge transfer, resulting in the electrochemical removal of electrons. This leads to the production of an electrically conductive material by introducing positive charge carriers [4], [5].

The results revealed that electrode 3, prepared with a 0.3 M pyrrole solution and subjected to a deposition potential of 0.7 V, showed a degradation of 12.23% of tetracycline in 60 minutes. Then, electrode 4, produced with a pyrrole concentration of 0.3 M and a deposition potential of 0.8V, achieved a degradation of 11.60%. Electrode 1, prepared with a 0.1 M pyrrole solution and subjected to a deposition potential of 0.7V, showed a degradation of 10.89%. Finally, electrode 2, deposited with a pyrrole concentration of 0.1 M and a deposition potential of 0.8 V, demonstrated the lowest degradation rate, this observation is illustrated in Figure 2.

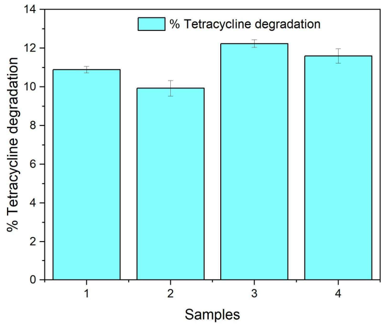

Figure 2. Tetracycline removal for differents tests.

The difference in the degradation rate between the electrodes can be attributed to a combination of factors related to the deposition conditions, the efficiency in generating reactive species and the properties of the polypyrrole films formed. These aspects highlight the importance of optimizing experimental conditions to maximize the effectiveness of the tetracycline degradation process.

Conclusions

In summary, it is imperative to conduct further research to increase the degradation rate in electrochemical photocatalysis. One promising avenue for improving this process is the integration of carbon nanotubes into the pyrrole matrix. This method is expected to boost the efficiency of photocatalysis, resulting in a more effective reduction of pollutants' environmental impact.

Acknowledgments

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