The Study and construction of a sustainable solar photocatalytic reactor : degradation of penicillin and indigo carmine blue food dye

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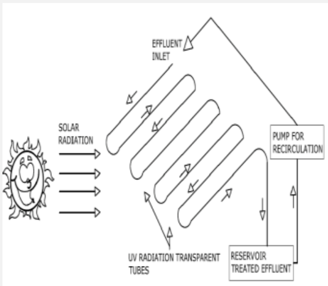

Antibiotics are consumed worldwide as a treatment for infectious diseases in humans or animals. The drug penicillin specifically has excellent bacterial action. The estimated daily consumption forecast is 126 billion doses by 2030 worldwide. However, there is an environmental problem generated by unrestrained consumption, metabolization and excretion of these drugs in effluents through urine and feces, or by criminal disposal directly into sewage collection systems. The problem is intensified by low mineralization through conventional treatments. Such substances are recalcitrant and reach bodies of water. They pose risks to ecosystems both through the emergence of resistant bacteria and by promoting changes in the behavior, reproduction and growth of aquatic species. The development of new technologies applied to wastewater treatment is a current demand. Heterogeneous photocatalysis is proposed in this work in order to mineralize this contaminant of emerging concern.

Introduction

The intense use of antibiotics is causing a huge environmental problem since some of the drugs consumed are metabolized by organisms and some are excreted into effluents through urine and faeces. Added to this is the illegal disposal into sewage systems of pharmaceutical industry waste from cleaning production lines and leftover substances removed from equipment, utensils and machinery. Because they are recalcitrant, antibiotic molecules reach rivers and lakes, do not degrade and remain, posing risks to aquatic health and the population. Their presence in receiving water bodies has worried the scientific community worldwide, both because of the contamination of ecosystems and because of the emergence of resistant bacteria [1]. In addition, antibiotics can promote changes in the behavior, reproduction and growth of aquatic species and organisms. In this context, the outlook calls for the improvement and development of new technologies applied to wastewater treatment. One possibility is the application of Advanced Oxidative Processes (AOP), through heterogeneous photocatalysis in a photocatalytic reactor that has the capacity to degrade these contaminants of emerging concern.

Material and Methods

In the experiments, tubes produced from quartz with 99.995% purity in SiO_2, an internal dimension of 16 mm and external dimension 20 mm, a length of 500 mm, manufactured and marketed by “Action - Scientific Technology” were used. The chemical reagents used were: titanium dioxide TiO_2 P25 produced and distributed by Degussa Evonik Brasil, composed of 75% anatase, 25% rutile, Penicillin G Potassium ($C_{16}H_{18}N_2O_4S$) produced by Alamar Tecno Científica Ltda and indigo carmine blue food dye, produced by Adicel, ($C_{16}H_8N_2Na2O_8S_2$). For the degradation and quantification analyses, analytical penicillin and indigo carmine blue food dye solutions were prepared in the laboratory, both at an initial concentration of 30 mg/L, pH (4, 7 and 10) and dosage of titanium dioxide TiO2 degussa P25 30 mg/L, with the kinetics being carried out in triplicate (Table 1). The analyzes were carried out using high-performance liquid chromatography (HPLC), using the following chromatographic conditions: zorbax eclipse XDB C-18 4.6 x 50 mm phase column; mobile phase containing water and acetonitrile in a 50:50 v/v ratio; flow of 0.3 mL/min; injection volume of 10 µL; detection wavelength of 210 nm.

Results and Discussion

The degradation kinetic curves by AOP UV/TiO_2 were obtained by graphically representing the final effluent concentration (mg/L) as a function of time (minutes) acording to [2].

The analyses showed that the effluent was degraded in the six kinetics carried out, but the pH variable had a considerable impact on the treatment.

The results (Table 2 and Figure 1) show that for the dye, on a scale of 4 to 10, the higher the pH, the more efficient the treatment, but for the effluent containing penicillin, the greatest degradation occurs at acidic pH.

The pH of the effluent to be treated is the most important variable in the photocatalytic degradation process. This is justified, as pH influences the ionic species of the solution and the physical-chemical properties of the photocatalyst, a fact that provides an increase or reduction in the efficiency of the discoloration process (LIMA et al., 2020). [3].

However, according to Konstantinou and Albanis (2004), interpreting the effects of pH on photodegradation is not simple, as it has multiple roles, starting with its relationship with the surface ionization state of the catalyst (Equation 1 and 2), as well as for the substrate containing dye, amines and acids.

$TiOH + H^+ \Leftrightarrow TiOH_2^+$ (Equation 1)

$TiOH + OH^- \Leftrightarrow TiO^- + H_2O$ (Equation 2)

Also according to Jawad et al, (2016), in acidic environments, contaminants in solutions absorb UV radiation, competing with (TiO2), which is why fewer photons will be absorbed by the photocatalyst and consequently there will be less generation of hydroxyl radicals to promote the reactions

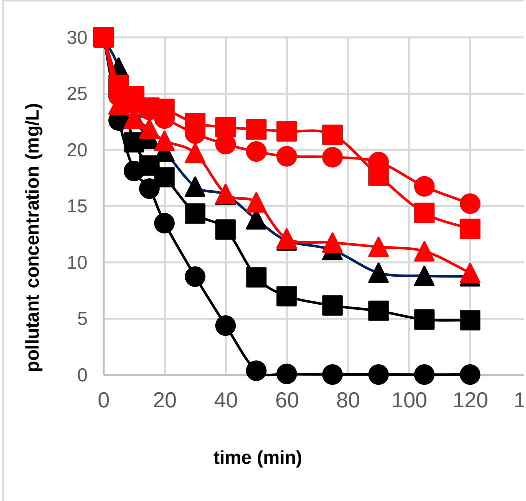

Figure 1. Comparison between decay curves of Penicillin and indigotine blue dye as a function of time: indigo blue: C1 (●) pH 10,0 , C2 (■) pH 7,0, C3 (▲) pH 4,0; penicillin: C4 (●) pH 10,0 , C5 (■) pH 7,0, C6 (▲) pH 4,0.

Tabela 1. Values applied to the experimental design and Results obtained with 120 minutes of treatment

Kinetics	TiO2 concentration (mg/L)	Pollutant concentration (mg/L)	pH	Pollutant elimination rate (%)
C1 - indigo blue	30	30	10	99.84
C2 - indigo blue	30	30	7	83.80
C3 - indigo blue	30	30	4	70.81
C4 - penicillin	30	30	10	49.29
C5 - penicillin	30	30	7	56.78
C6 - penicillin	30	30	4	69.78

Conclusions

The experiments demonstrated that the reactor proposed and developed in this project is a sustainable treatment alternative, according to the evidence given by the high degradation rates pollutants. From the results obtained by the decontamination of the effluent treated in this study, it is possible to conclude that the Advanced Oxidative Process (AOP - UV/ TiO_2), using solar energy, presented itself as a strategic alternative for the removal of contaminants, including recalcitrants, such as synthetic dyes. In addition, it is an economically viable, sustainable treatment as it does not require energy expenditure. This research also provides strategies and indicators for the development of a new photocatalysis and TiO_2 coupling technology for wastewater treatment.

Acknowledgments

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