Photodegradation of amoxicillin using titanium nanocatalysts synthesized via green route

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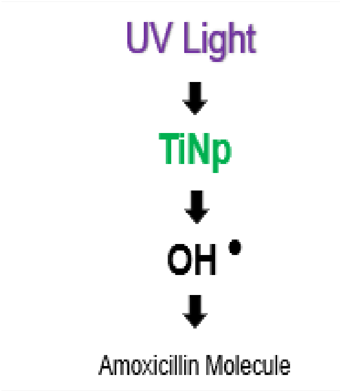

Antibiotics exhibit resistance to oxidation during conventional effluent treatment processes, resulting in substantial discharge into aquatic ecosystems, where they become present in soils and various water bodies. This emphasizes the necessity of exploring novel degradation techniques for these compounds. Photodegradation, an advanced oxidation process, proves effective in breaking down antibiotics. Titanium nanoparticles are instrumental in this aspect, acting as photocatalysts with stability in photocatalytic processes. In this context, this study utilized titanium nanoparticles synthesized via the green route to evaluate the effects of nanoparticle concentration, antibiotic concentration, and reaction time The degradation efficiency of amoxicillin was 28% for 1 g L^{-1} of titanium nanoparticles. Additionally, this work identified the radical responsible for amoxicillin degradation.

Introduction

Titanium nanoparticles have been widely used in recent years as photocatalysts due to their high photocatalytic activity, non-toxicity, and high stability. These characteristics make them effective in the photodegradation of recalcitrant compounds, such as the antibiotic amoxicillin [1]. The degradation of antibiotics in the presence of photocatalysts at the nano scale becomes more attractive due to the advantages that this scale provides. Chemical, optical, and physical properties are some of the key factors that are significantly influenced by the nano scale [1, 2]. Furthermore, nanostructures synthesized via green synthesis offer enhanced properties, including reduced agglomeration and greater stability, when compared to those produced through conventional synthesis methods [3]. In this context, this study utilized titanium nanoparticles (TiNp) synthesized with pumpkin peel extract and photodegraded the antibiotic amoxicillin under UV light.

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Material and Methods

Previously synthesized titanium nanoparticles were used for the degradation of amoxicillin. The characterization of these nanoparticles has been published in the Proceedings of the 14th Brazilian Meeting on Adsorption, under the title: "Green synthesis and characterization of titanium nanoparticles for the adsorption of amoxicillin." Titanium nanoparticles, in concentrations ranging from 1-3 g L^{-1}, were introduced into aqueous solutions containing the antibiotic, with concentrations between 10 and 40 mg L^{-1}. The UV-Vis Spectroline lamp, model EA-160, from the USA, emitting at 365 nm with 20 amps, was strategically placed using a stand to irradiate the center of a 100 ml borosilicate reactor. This reactor was subjected to magnetic stirring, and the process temperature was maintained at 25°C.

Results and Discussion

Fgure 1 shows the influence of TiNp dosage on the photodegradation of amoxicillin. It was observed that concentrations of 1.0, 2.0, 2.5, and 3.0 g L^{-1} resulted in photodegradation percentages of 28.3, 27, 22.4, and 21.6%, respectively. A decline in degradation efficiency is noted as the TiNp dosage increases. According to a previous study [3], the catalyst dosage can affect the photodegradation process either positively or negatively. Positively, by increasing the number of active sites and consequently producing more reactive species, such as hydroxyl radicals. And negatively, due to an excess of nanoparticles in the medium, which can hinder UV light from penetrating the solution and reaching the nanomaterials surface to produce hydroxyl radicals.

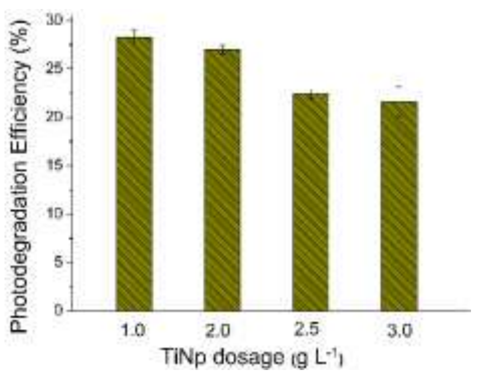

Figure 1 - Effect of TiNp dosage on amoxicillin photodegradation (TiNp = 1-3 g L^{-1}; [amoxicillin] = 10 mg L^{-1}; 60 minutes; pH = 5.6)

Figure 2 shows the effect of amoxicillin concentration on its photodegradation by TiNp. As shown in Figure 2, at concentrations of 10 – 20 mg L^{-1}, degradation remained constant at approximately 28% for both dosages. At concentrations of 30 and 40 mg L^{-1}, the degradation percentages were 18.4 and 7.1%, respectively. As observed in previous studies [3], lower concentrations of amoxicillin exhibited higher percentages of degradation, which is attributed to the saturation of TiNp's active sites by the amoxicillin molecule and its fragments, hindering the production of hydroxyl radicals. Furthermore, increased contact between TiNp and amoxicillin (at lower dosages) is advantageous for photodegradation [4].

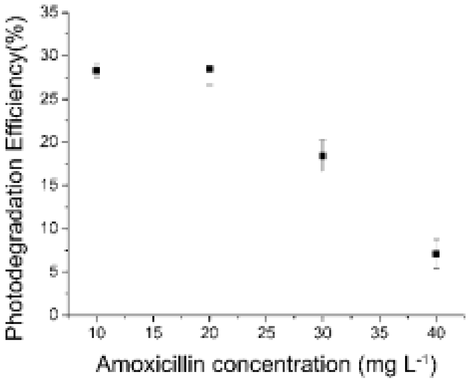

Figure 2. Effect of amoxicillin concentration on photodegradation (TiNp = 1 g L^{-1}; [amoxicillin] = 10 - 40 mg L^{-1}; 60 minutes; pH = 5.6)

Figure 3 shows the effect of time on the irradiation of amoxicillin by TiNp. According to Figure 3, it can be observed that time has a positive effect on degradation. The longer the reaction time, the higher the observed degradation, which can be attributed to the production of reactive species being directly proportional to the reaction time. Besides, 60 minutes of reaction achieved a 28.3% degradation of amoxicillin. Krakowiak *et a*l. (2022) [5] degraded ibuprofen using titanium in the anatase phase and achieved 86% removal. However, the time required to reach this percentage was 360 minutes.

Figure 4 shows the effect of isopropanol on the photodegradation of amoxicillin by TiNp. As can be seen, without the radical scavenger, the photodegradation is 28.3%, and with the scavenger, the photodegradation percentage decreases to 7.5%. This suggests that the hydroxyl radical is primarily responsible for the oxidation of amoxicillin.

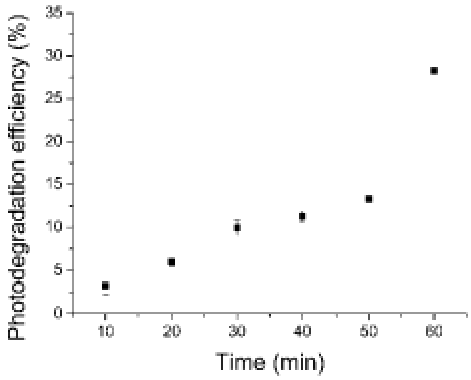

Figure 3. Effect of TiNp irradiation time on the photodegradation of amoxicillin (reaction time = 10 - 60 minutes; TiNp = 1 g L^{-1}; [amoxicillin] = 10 mg L^{-1}; pH = 5.6)

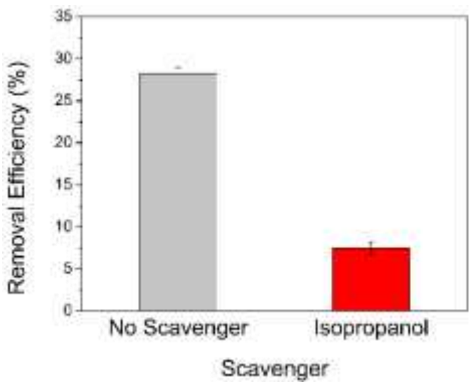

Figure 4. Effect of addition of reactive species scavenger on amoxicillin photodegradation (pH = 5.6; TiNp = 1 g L^{-1}; [amoxicillin] = 10 mg L^{-1}; 60 minutes)

Conclusions

The TiNps in the anatase phase demonstrated catalytic activity in the photodegradation of amoxicillin. Considering this property, it can be inferred that the anatase phase is important in this degradation process, suggesting that the crystalline structure of the TiNps may significantly influence their catalytic capacity. Therefore, optimizing the synthesis and reaction conditions to promote the formation and stability of the anatase phase may be essential for improving the efficiency of amoxicillin photodegradation.

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References

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