BiOCl as a Beneficial Photocatalyst for Pharmaceutical Wastewater

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Introduction

Aim of the study

The goal of this work was to study the degradation of *Sulfamethoxazole (SMX)* by using simulated solar radiation and BiOCl semiconductor as a photocatalyst. The structure and properties of the prepared material were determined in detail. Experiments were carried out to examine the effect of critical parameters on SMX degradation, the catalyst stability, the applicability of process in real water matrices, as well the photocatalytic mechanism.

Background

Pharmaceuticals could be considered as the main group of emerging contaminants, making them a cause of concern due to their excessive use globally [1,2]. The irrational use of antibiotics, a group of pharmaceuticals that are used both in human and veterinary medicine, have led to the transformation of microbes to multi-drug resistant forms [1,2]. *SMX*, which belongs to antibiotics, is one of the most commonly detected substances in effluent wastewater [1]. Since conventional wastewater treatment processes have failed to completely remove antibiotics from wastewater, and thus *advanced oxidations processes (AOPs)* have been widely tested against these persistent contaminants [3,4]. Generally, AOPs are known by the formation and utilization of radical species mainly hydroxyl radical and they have been successfully used in the case of the non-biodegradable organic compounds [3,4]. Solar heterogeneous photocatalysis emerged as a promising and green technology for wastewater treatment due to its versatile and inexpensive process that can be implemented for the treatment of different organic pollutants [5-6].

Study Protocol

Photocatalytic system

Experiments were conducted in batch mode using a cylindrical glass vessel of 100 mL capacity, as a photoreactor. The reactor was filled with 60 mL of an SMX aqueous solution at various initial concentrations and an appropriate amount of catalyst. Solar irradiation was emitted by an Oriel LCS - 100 Watt solar simulator system.

Analysis

An HPLC system (Waters Alliance 2695) was used for the determination of SMX equipped with a diode array detector (Waters 2996). The stationary phase was a reversed-phase Kinetex C18 column, 150mm×3 mm, i.d. 2.6μm, purchased from Waters (Milford, MA, USA). The mobile phase consisted of ACN and 0.1% H_3PO_4, using an isocratic elution program. The flow rate was 200 μL/min and the overall analysis time was 6 min. DAD was set at 270 nm.

Results

BiOCl was characterized by employing X-ray diffraction (XRD), UV–vis diffuse reflectance spectroscopy (DRS), and the Brunauer–Emmett–Teller (BET) method. The obtained results are shown in figures 2-3.

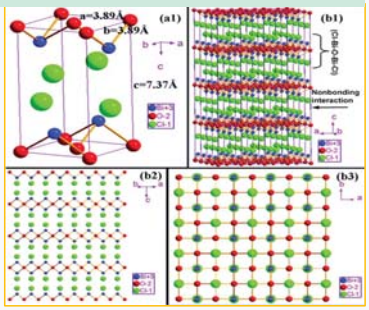

Figure 1. Schematic structure model of BiOCl crystal [(a) unit cell, (b) 4 6 4 6 4 cells] viewed from (1) three-dimensional projection, (2) [110] projection, (3) [001] projection.

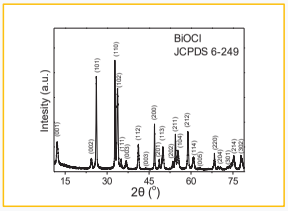

Figure 2. XRD pattern.

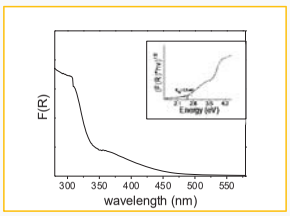

Figure 3. DRS spectra. Inset: Tauc plot

Representative results regarding the influence of operating conditions on SMX degradation are shown in figure 4. The performance of the process in actual water matrices (bottled water; BW and wastewater; WW) and ultrapure water (UPW) spiked with humic acid (HA), bicarbonate ions (BIC), and chlorides are depicted in figure 5. SMX degradation in all reactions followed the pseudo-first-order kinetic model. Last, results by trapping experiments and catalyst reusability are shown in figures 6 and 7, respectively.

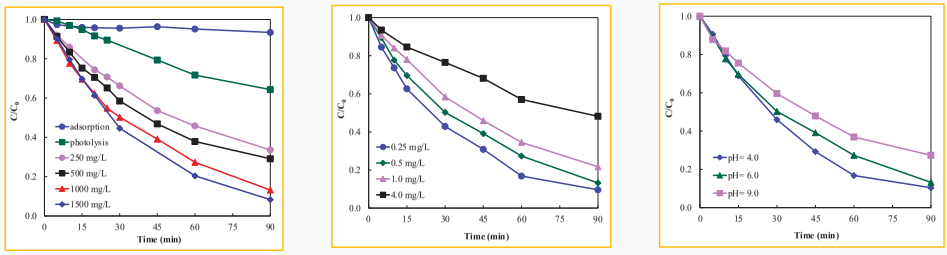

Figure 4. Influence of catalyst and SMX concentration, as well as pH solution.

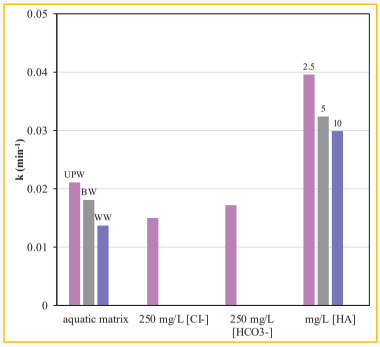

Figure 5. Rate constants in several water matrices and their constituents.

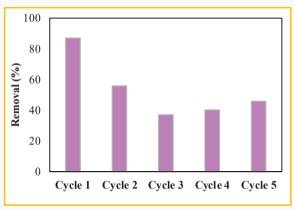

Figure 6. Catalyst 's stability.

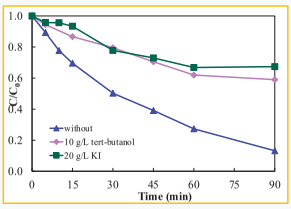

Figure 7. Mechanism reaction.

Conclusions

In this study, the photocatalytic degradation of SMX was investigated with BiOCl as a photocatalyst, under simulated solar irradiation, and the main conclusions are summarized as follows :

- A low dose of catalyst is capable of degrading SMX at the relevant environmental levels.
- pH values did not affect the performance of the process.
- The complexity of the environmental matrices slightly hindered the efficiency of the process, which possibly associates to the presence of organic and inorganic ions in existence within actual waters matrices.
- Trapping experiments revealed that the photogenerated holes (h^+) played a leading role in the degradation of SMX.

References

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