Synthesis, characterization and photocatalytic activity of carbon dots from coffee waste

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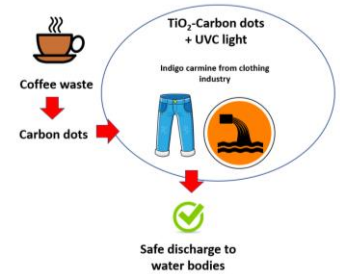

In this work, we present the synthesis of TiO_2-Carbon dots materials and the evaluation of its photocatalytic activity in the removal of indigo carmine dye. Coffee waste was employed as raw material for the synthesis of carbon dots by an easy hydrothermal method. XRD and SEM characterization was performed. Indigo carmine dye is extensively used in clothing industry and when is released to the water bodies without the proper treatment, its degradation products are responsible for damage to aquatic species. Two samples of TiO_2-Carbon dots materials were tested under UVC light and both exhibited a better photocatalytic performance against pristine TiO_2. In 30 min it was possible to remove 97% of the original parent compound with the sample containing 4 wt% of carbon dots.

Introduction

During the last decades there have been developed different technologies for wastewater treatment. Among the advances in the area, AOP's have contributed with different approaches and specifically, photocatalysis have gained attention because it is attractive the utilization of the abundant sunlight to performs and accelerate chemical reactions [1, 2]. One of the main challenges for the implementation in large scale of photocatalytic processes for the treatment of real effluents, is the elevated cost, long-term stability and limited light response of the photocatalysts. Carbon dots are a category of materials which are interesting for photocatalytic purposes due to its potential biocompatibility and low toxicity, in addition to its nano-scale size and a expected good photoluminescence performance [3, 4]. Carbon dots can be synthesized from organic waste reducing costs and environmental impact. Considerable amounts of coffee waste are generated every day around the world. This makes coffee a suitable raw material for the synthesis of active photocatalysts for water purification.
In central Mexico, the intense industrial activity leads to important damage to water bodies due to the unsafe discharge of effluents. Specifically, indigo carmine is a pollutant commonly present in industrial discharges, particularly which is related to jeans manufacturing [5]. Our contribution presents the photocatalytic degradation of indigo carmine with carbon dots supported on TiO_2 looking for the valorization of organic waste.

Material and Methods

Carbon dots supported on TiO_2, were prepared by an hydrothermal method adapted from Rajapandi [3] in two steps: 1) Coffee waste were collected from a coffee shop and dried at 100 ºC prior to the catalytic synthesis. Afterwards 0.5 g of coffee and 3 mL of distilled water were placed in the autoclave and then, heated during 14 h at 195 ºC. The synthesized carbon dots were filtered, washed, dried and finally milled for the upcoming step. 2) Different amounts of carbon dots were placed in the autoclave with 0.5 g of commercial TiO_2 and 3 mL of water to obtain the final photocatalyst. This sample was heated at 195 ºC for 8 h. The final material was then characterized by XRD and SEM.
100 mL of an indigo carmine ($C_{16}H_8N_2Na_2O_8S_2$) aqueous solution with an initial concentration of 30 ppm was placed in a discontinuous reactor. 25 mg of catalyst were added to the reactor and stirred at 800 rpm to facilitate the dispersion of the catalytic sample. The reaction was performed under UV light (254 nm) supplied by a T-5 G8T5 lamp. After 30 min, the system was turned off and the final samples of treated water were filtered and analyzed by UV-vis spectroscopy, following the absorbance at 612 nm, and by TOC analyses, to determine the degree of mineralization.

Results and Discussion

Carbon dots soported on TiO_2 were succesfully synthesized. XRD pattern of several samples are presented in Figure 1: Blue pattern corresponds to a 4 wt% of Carbon dots while red patter coresponds to a 6 wt% sample. It can be observed the characteristic pattern of TiO_2 and only a slighly variation in intensity was found in 2Θ=23 since this response is related to the content of carbon dots. This is verified in the inset in Figure 1, where the XRD pattern of pristine carbon dots is included. About morphology of the catalysts TiO_2-Carbon dots, in Figure 1 it can be distinguised spherical shapes on the surface. The EDS analysis confirmed the presence of C, Ti and O in our samples.

Regarding to the photocatalytic activity of the catalysts, Table 1 summarizes the results of the degradation of indigo carmin catalyzed with the prepared materials. Both samples (4 and 6 wt%) were able to catalyze the degradation of the parent compound but at different rate. The sample with less amount of carbon dots allowed to reach a higher removal of the dye. Likely the recombination of electron-holes pairs ocurred at higher rate when the TiO_2 is doped with a higher amount of carbon dots. For comparison purposes, an experiment with pure TiO_2 was performed and it was found a slower removal rate since in 30 min only 70% of the original molecule was removed. In addition, a photolysis experiment was also conducted and in this case, no removal of indigo carmine was registered.

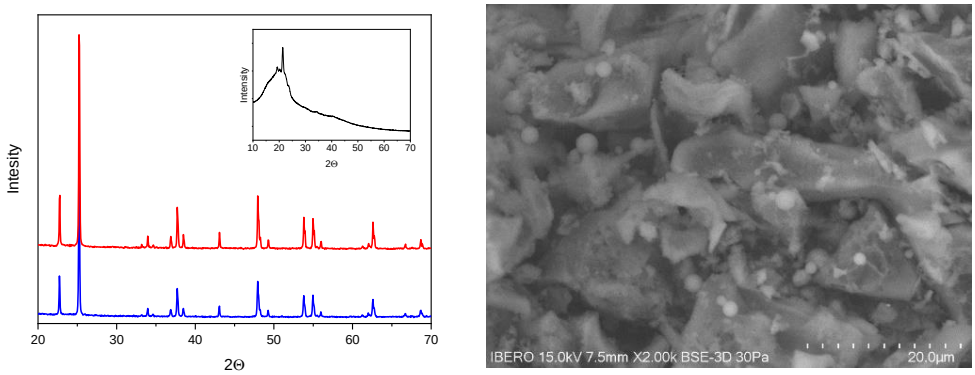

Figure 1. Left: XRD patterns of Carbon dots supported on TiO_2 and pristine Carbon dots (inset). Right: SEM image of synthezised photocatalysts.

Table 1. Indigo carmine removal rate with different photocatalysts

Catalyst	% Indigo carmin removal	$-r_A \times 10^6$ (mol $g_{cat}^{-1} * s^{-1}$)
TiO_2	70.3	1.01
TiO_2-Carbon dots 4 wt%	97.3	1.40
TiO_2-Carbon dots 6 wt%	95.6	1.37

Conclusions

Carbon dots were synthesized by means of a hydrothermal method and starting from coffee waste collected from our main campus. Two TiO_2-Carbon dots photocatalysts were prepared (4 and 6 wt% of carbon dots) and its photocatalytic activity were assessed in the degradation of indigo carmine molecule. Both samples overperformed the activity of pristine TiO_2 in more than 20%. The sample with less amount of carbon dots (4 wt%) leaded to the higher degradation (97.3%) in only 30 minutes. This results are promising looking for environmentally friendly solution for the utilization of organic waste and alternatives for water purification.

Acknowledgments

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