Study of the photocatalytic degradation of an emerging pollutant in the presence of zinc oxide

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Abstract

The heterogeneous photocatalysis is an advanced oxidation technology (POA), which relies on the activation of a semiconductor in the presence of UV radiation. Semiconductors such as TiO2, ZnO, CdS, SnO2 have proven their activity under the effect of an appropriate wavelength radiation and are considered among the best photocatalysts.
However, the research carried out so far has all shown that zinc oxide is a very interesting material because of its high photocatalytic activity, its stability under the conditions of use, and its relatively low cost. This has motivated the test of this semiconductor, i.e. zinc oxide, in the present study, in order to degrade an endocrine disrupter (BPA) by means of solar photocatalysis. A degradation rate of 93% was obtained after 90 minutes confirming the performance of the solar ZnO/UV system.

Keywords: ZnO, Solar, Photocatalysts, UV, BPA, Semiconductor, Degradation, POA.

I. Introduction

Zinc oxide is a semiconductor material from the transparent and conductive oxide (TCO) family. It is an inorganic compound, transparent in the visible.

For many years, the main applications of zinc oxide have been in the chemical and pharmaceutical industries. New research applications in optoelectronics, particularly in the field of photovoltaics, are currently attracting very strong interest to this material because of its multiple properties such as: high photocatalytic activity, its stability under conditions of use, non toxicity, high thermal conductivity, low water absorption and relatively low cost [1].

In the field of water treatment, new processes such as advanced oxidation processes have been dedicated to the removal of pollutants that appear to be refractory to conventional treatments. These processes are an efficient and clean solution that is consistent with the objectives of green chemistry and sustainable development, given their non-pollutant nature and low application costs. They aim for the complete mineralization of pollutants in CO_2, H_2O and other mineral compounds such as Cl^-, SO_4^{2-}, NH_4^+, etc. Advanced oxidation processes are based on in situ generation of radical species with strong oxidative power, such as hydroxyl radicals that can be produced by different processes among which heterogeneous photocatalysis appears to be a first choice method for this type of application [2, 3]. This technique relies on the activation of a semiconductor in the presence of UV radiation allowing complete oxidation of most biorecalcitrant organic pollutants.

In this sense, given Algeria's privileged geographical position which offers a very important

solar potential, Semiconductor-based solar photocatalysis, zinc oxide was the process chosen in this study to degrade an endocrine disrupter (BPA).

II. *Materials and methods*

The study of photocatalysis was carried out on an endocrine disruptor in the presence of zinc oxide (ZnO). The semiconductor used in this study was a marketed product. Its hexagonal wurtzite structure is confirmed according to the ASTM data sheet.

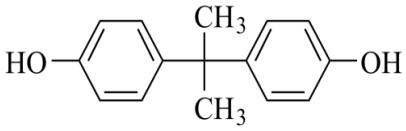

Fig.1 Chemical structure of Bisphenol A.

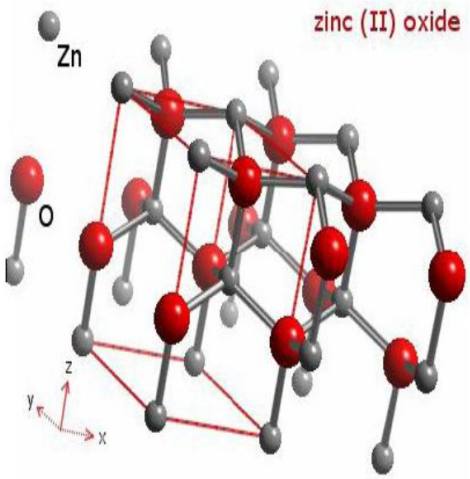

Figure 2. Crystallographic structure of the ZnO (Würtzite).

III. Results and discussion

In this work the photocatalytic degradation of an endocrine disruptor, bisphenol A was considered in presence of zinc oxide (ZnO) under solar irradiation. In order to study the influence of zinc oxide on the degradation kinetics, the effect of different removal processes had been studied, the operating conditions of which are given in Table. 1.

Table 1. Operating conditions for the different processes.

Initial concentration BPA ($mg.L^{-1}$)	20
Concentration in catalyst ($g.L^{-1}$)	0.2
Free pH	7.14

III. 1. Spectral evolution of Bisphenol A

Figure 4 shows the spectral evolution of an aqueous solution of bisphenol A when photo-oxidized by UV/ZnO.

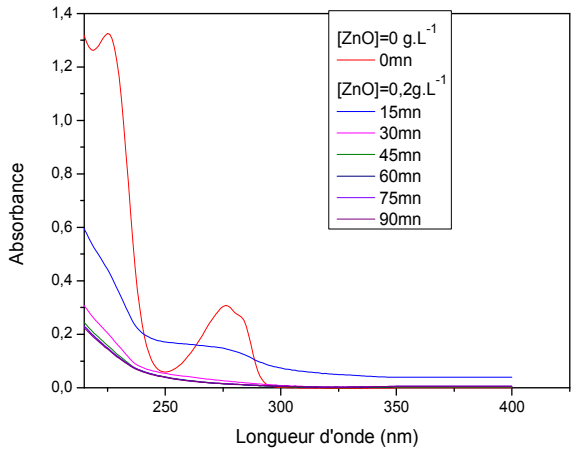

Figure 3. Spectral evolution of Bisphenol A during photodegradation.

It is clear from this figure that the photocatalytic process was linked to a gradual disappearance of the absorption bands indicating the destruction of the essential bands, characterising transitions in cycles and oxygen connections.

III.2. Effect of different processes on Bisphenol A removal

To study the effectiveness of heterogeneous photocatalysis in the presence of ZnO, a comparative study was conducted between

different BPA removal processes such as an adsorption in which the solution was brought into contact with the catalyst acting as an adsorbent without any input from the photons, a photolysis where the pollutant was brought into contact with a light source in the absence of a catalyst and a Photocatalysis in the presence of the catalyst and the U.V. (solar) radiation-source.

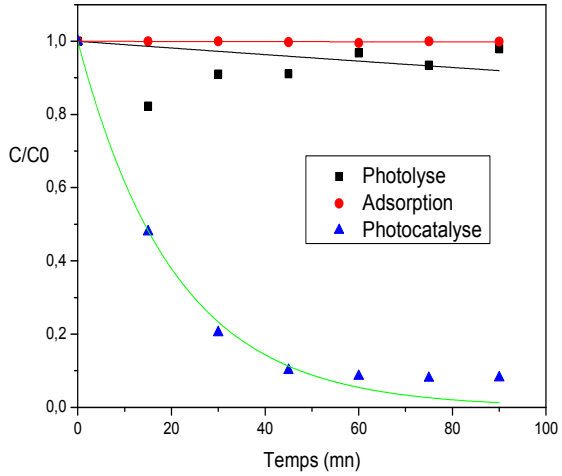

Figure 4. Temporal evolution of reduced Bisphenol A concentration for different processes.

From figure.4 it can be seen that during adsorption, which is a physical phenomenon, BPA was not greatly adsorbed and the elimination rate by means of this process was less than 1%. The presence of only UV sunlight, shows that the rate of degradation of BPA was also negligible. Indeed, the rate obtained was less than 8%. These results are in agreement with the work carried out by [4] which showed that after 2 hours of photolysis, the elimination of bisphenol A was not significant.
However Photocatalysis, in the presence of zinc oxide and radiation from solar sources, significantly increased the BPA removal rate to 92% after 90 min of irradiation.

III.3. Influence of catalyst concentration

Several studies on heterogeneous Photocatalysis [5] have shown that there is an optimal catalyst concentration for the effective removal of a pollutant. For this purpose, the influence of this parameter on the photodegradation of BPA was investigated using concentrations of ZnO ranging from 0.05 to 0.5 $g.L^{-1}$. The experiments were carried out according to the operating conditions.

Figures 5 show that the effect of ZnO concentration on bisphenol A removal was significant, confirming the importance of active sites in the photocatalytic process and degradation of the organic pollutant. Photocatalytic degradation increased with the dose of ZnO up to 93% using 0.1 g.L-1 catalyst under solar irradiation and decreased below this value. This behaviour is explained by the fact that, below the optimum concentration of ZnO, these particles caused a screen effect between them, thereby reducing the formation of hydroxyl radicals, responsible for the oxidation reaction of Pollutant [6].

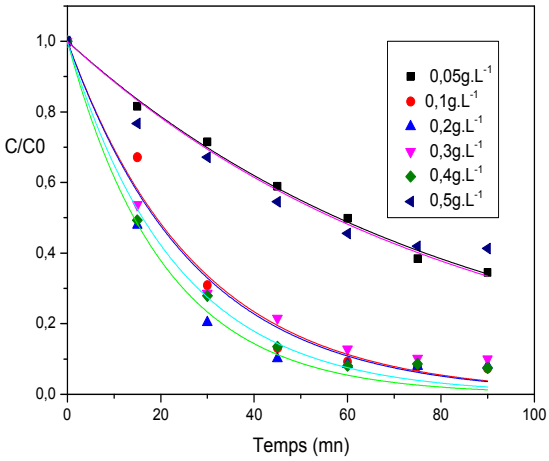

Figure 5. Evolution temporelle C/C_0= f([ZnO]).

IV. Conclusion

The objective of this study was to evaluate the photocatalytic activity of a commercial catalyst (ZnO) under natural irradiation with an endocrine disruptor (bisphenol A) as a model pollutant. A comparative study of the different processes of removal of the considered emerging pollutant, namely adsorption, photolysis and Photocatalysis, showed that:

- The UV/ZnO process proved to be the most effective for the elimination of bisphenol A by an oxidation phenomenon in the presence of hydroxyl radicals.
- The rate of pollution degradation increased with the increase in zinc oxide concentration. However, the increase in

concentration could not be carried out indefinitely because below a certain concentration considered as an optimal value, the particles of ZnO caused a reduction in the formation of hydroxyl radicals which were responsible for the oxidation reaction of the pollutant.

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