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# Solar photocatalysis for detoxification and disinfection of water: Different types of suspended and fixed $TiO_2$ catalysts study

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**Abstract**

Photocatalysis by titanium dioxide ($TiO_2$), operational in the UV-A domain with a potential use of solar radiation, could be an alternative to conventional water detoxification and disinfection technologies. However, employing the photocatalyst as a suspension or slurry makes the scaling-up of the process difficult, as the $TiO_2$ has to be removed from the decontaminated water to be reused several times. In this work the photocatalytic activity of different types of $TiO_2$ catalyst (Degussa P-25, Millennium PC-100 and PC-500, Tayca AMT-100 and AMT-600) in suspension or coated on fibrous web were studied in both decontamination and disinfection experiments at laboratory scale. Gallic acid was chosen as the model pollutant for detoxification experiments and *Escherichia coli* as the model microorganism for disinfection experiments. The influence of the surface area and other characteristics of $TiO_2$ are discussed concerning the photocatalytic properties of $TiO_2$. The role of adsorption is suggested, indicating that the reaction occurs at the $TiO_2$ surface and not in the solution. Gallic acid degradation kinetics were found to be of the same extent for both $TiO_2$ suspended and fixed, whereas for the bacterial inactivation efficiency was significantly less important with coated than with suspended $TiO_2$.


*Keywords:* Solar water disinfection and detoxification; Photocatalysis; $TiO_2$; *Escherichia coli*; Gallic acid

## 1. Introduction

Photocatalytic oxidation is a promising technology for the disinfection and detoxification of water and wastewater. When catalytic semiconductor powders, such as the titanium dioxide ($TiO_2$), are suspended in water and irradiated with near UV ($\lambda < 385$ nm), hydroxyl radicals ($OH^{\bullet}$) and other oxidative species like $H_2O_2$ and superoxide radicals ($O_2^{\bullet}$) are generated. The $OH^{\cdot}$ radical is highly toxic towards microorganisms and very reactive in the oxidation of organic substances. Photocatalytic inactivation of bacteria such as *Escherichia coli*, *Bacillus pumilus* and several others, as well as several Phage have been investigated (Block and Goswami, 1997; Matsunaga et al., 1985; Wei et al., 1994;

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Matsunaga and Okochi, 1999; Rincón et al., 2001; Rincón and Pulgarin, 2003).

The type of $TiO_2$ used plays an important role during the photocatalytic abatement of bacteria and organic pollutants since the rate of formation of surface species like $H_2O_2$ and oxidative radicals is a function of the titania size, BET area, crystalline phase, uniformity, etc. (Mills and Le Hunte, 1997; Blake et al., 1999).

The use of $TiO_2$ in suspension is efficient due to the large surface area of catalyst available for the reaction. Nevertheless, the catalyst must be removed following the treatment. Post-treatment removal requires a solid liquid separation stage which adds to the overall capital and running costs of the plant. Alternatively, the catalyst may be immobilized onto a suitable solid support which would eliminate the need of post-treatment removal, but which would also create a decrease in the surface area available for photocatalytic reaction (Robert et al., 1999).

In the present study, we have tested the photoactivities of several types of suspended $TiO_2$, in both decontamination and disinfection experiments. Their structures were varied to follow their influence upon activity. Gallic acid, one of the most frequent phenolic compounds in wastewater, was chosen as the model pollutant for detoxification experiments. *E. coli*, a classical bacterial indicator of fecal pollution, was chosen as the model microorganism for disinfection experiments. One of the catalysts was also coated on a nonwoven web (both natural and synthetic fiber) prepared by Ahlstrom (Research & Services, ZI de l'Abbaye, 38780 Pont-Evêque, France) to evaluate the effect of the fixation on *E. coli* and gallic acid abatement. The set of the results and its potential application for water disinfection are studied within the frame of the SOLWATER (EU-DGXII, contract: ICA4-CT-2002-10001) and AQUACAT (EU-DGXII, contract: ICA3-CT2002-10016) INCO projects.

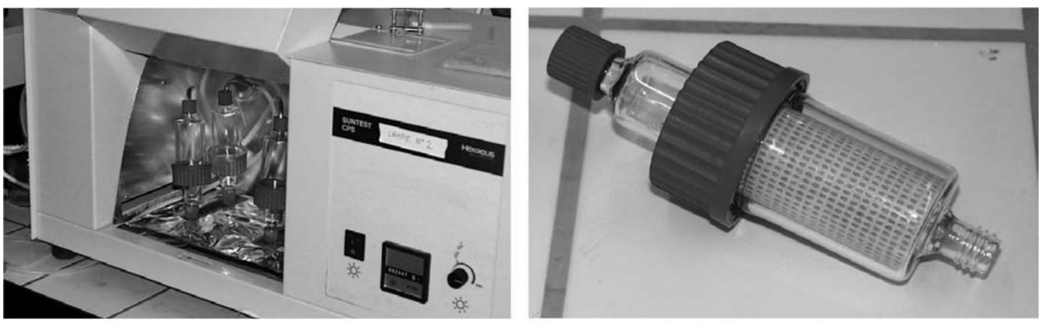
## 2. Experimental section

### 2.1. Photoreactors and light sources

All the experiments were carried out under artificial light using thin film Pyrex glass reactors with an illuminated volume of 25 ml (Fig. 1(a)). A peristaltic pump recirculated the water from a glass bottle, acting like a recirculation tank, to the reactors with a flow rate of 150 ml/min. The total volume of the system (100 ml) is considered in two parts: the 25 ml irradiated volume and the dead volume (recirculation tank + connecting tubing). Internal PVC supports were put in the reactors to carry the nonwoven web with coated $TiO_2$ (Fig. 1(b)). The reactor was illuminated from the outside with a solar lamp (Hanau Suntest AM1). This lamp has a light spectral distribution of about 0.5% of the emitted photons at wavelengths shorter than 300 nm and about 7% between 300 and 400 nm. The emission spectrum between 400 and 800 nm follows the solar spectrum. Four reactors could be placed in parallel inside the solar lamp (Fig. 1(a)).

### 2.2. Catalysts

The experiments with suspended $TiO_2$ were performed with Degussa P-25, two $TiO_2$ catalysts prepared by Millennium Inorganic Chemicals (Millennium PC-100 and PC-500) and two catalysts prepared by Tayca Corporation (Tayca AMT-100 and AMT-600) at concentrations of 0.2, 0.6 or 1 $g l^{-1}$. Their characteristics are given in Table 1.



(a) (b)

Fig. 1. (a) Photograph of thin film reactors in solar lamp. (b) Photograph of thin film reactor with nonwoven web fixed on an intern PVC support.