Photocatalytic purification of hazardous liquid medical waste containing toxic pollutants: TiO_2 mediated decomposition of light green SF Y in aqueous suspensions

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Problem definition and objectives

Medical, including biochemical, molecular and histopathological laboratories operating in Greek health care units produce liquid hazardous medical wastewater (LHMW), containing toxic compounds and/or infectious agents. Heterogeneous composition of LHMW hampers the use of a universal treatment method that would effectively inactivate any kind of pollutant and pathogen in this type of wastewater. Furthermore, application of currently available, traditional, wastewater processing technologies requires several intermediate steps and expensive equipment, resulting in high operating costs, while, these methods in several cases, are unable to effectively purify LHMW.

This study is part of a research project aiming to the development and application of a prototype for the photocatalytic inactivation of LHMW containing toxic pollutants and/or pathogens. Biological stains are among the most common components of LHMW. Although the volume of the staining solutions used in these kind of laboratories is relatively small, the high concentration of dyes in them and the presence of harmful additives, results in the formation of wastewater of high toxicity, low light transparency and high organic carbon content. In this context, Light Green SF Yellowish (LGSFY), a triarymethane dye commonly used in a wide range of histologal applications, including collagen staining, as a counterstain in Masson's trichrome and as a critical component of Papanicolaou stains together with Eosin Y and Bismarck Brown Y, has been studied regarding its potential to be decomposed in the presense of TiO_2 and UV-A irradiation. LGSFY is a triarymethane dye known for its chronic toxicity and along with its metabolites is capable of severely affecting the metabolic system, while it induces carcinogenic effects and severe blood disorders in living organisms.

Strategy and methods

Experiments were performed in laboratory scale employing a closed Pyrex cell of 500 ml capacity. The reaction vessel was fitted with a central 9 W lamp and had inlet and outlet ports for bubbling CO_2 free air during the photocatalytic process. The spectral response of the UV-A irradiation source ranged between 350-400 (max: 366 nm), while that of the visible irradiation source ranged between 400-520 nm (max: 450 nm). Experiments were conducted under constant magnetic stirring. The reaction temperature was kept constant at 25°C. The catalysts employed during heterogeneous photocatalytic oxidation of LGSFY in the presence of UV-A irradiation are presented in Table 1.

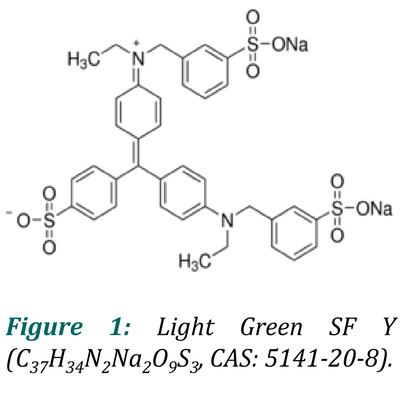

Figure 1: *Light Green SF Y ($C_{37}H_{34}N_2Na_2O_9S_3$, CAS: 5141-20-8).*

Table 1: *Main physical-chemical properties of the catalysts employed during heterogeneous photocatalytic oxidation of LGSFY in the presence of UV-A irradiation.*

Catalyst	Composition	Surface area (BET)	Crystallite size	E_g	Company
TiO_2 P25	70% anatase-30% rutile	55 ± 15 $m^2 g^{-1}$	21 nm	3.2-3.0	Evonik
TiO_2 P90	-	90 ± 20 $m^2 g^{-1}$	-	3.2	Evonik
ZnO	-	10 $m^2 g^{-1}$	-	3.2	Merck
TiO_2 uvlp 7500	100% anatase	>250 $m^2 g^{-1}$	~15 nm	3.2	Kronos Worldwide, Inc.

Acknowledgements

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH–CREATE–INNOVATE (project code: T1EDK-02678).

Results

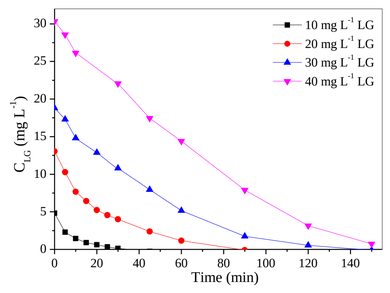

Figure 2: *Effect of LGSFY initial concentration on the photocatalytic degradation of the dye in the presence of 0.5 g L^{-1} TiO_2 P25 and UV-A.*

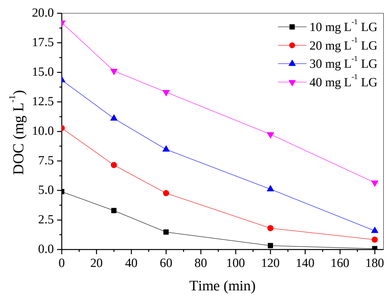

Figure 3: *Effect of LGSFY initial concentration on the photocatalytic mineralization of the dye in the presence of 0.5 g L^{-1} TiO_2 P25 and UV-A.*

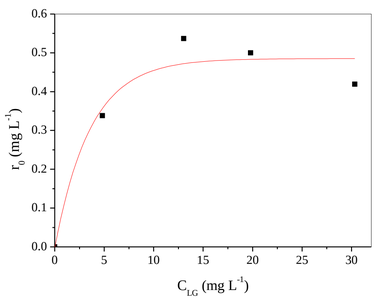

Figure 4: *Effect of the initial LGSFY concentration on the initial degradation rates in the presence of 0.5 g L^{-1} TiO_2 P25 and UV-A.*

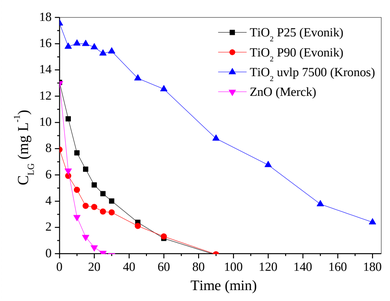

Figure 5: *Effect of various commercial TiO_2 on the photocatalytic degradation of LGSFY in the presence of UV-A. Catalyst concentration: 0.5 g L^{-1} .*

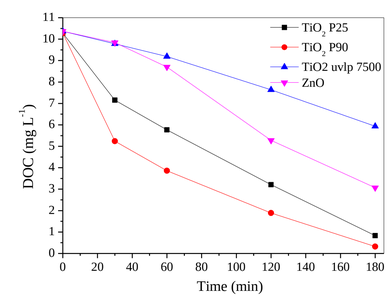

Figure 6: *Effect of various commercial TiO_2 on the photocatalytic mineralization of LGSFY in the presence of UV-A. Catalyst concentration: 0.5 g L^{-1} .*

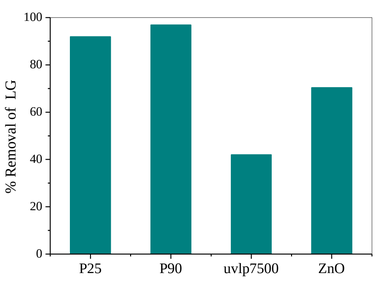

Figure 7: *Effect of various commercial TiO_2 on the photocatalytic degradation of LGSFY in the presence of UV-A. Catalyst concentration: 0.5 g L^{-1} .*

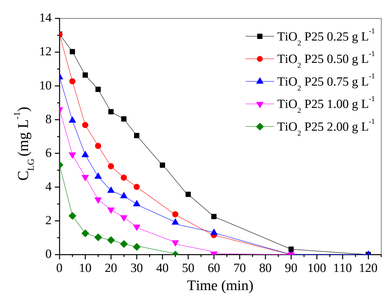

Figure 7: *Effect of initial concentration of TiO_2 P25 on the photocatalytic degradation of 20 mg L^{-1} LGSY in the presence of UV-A.*

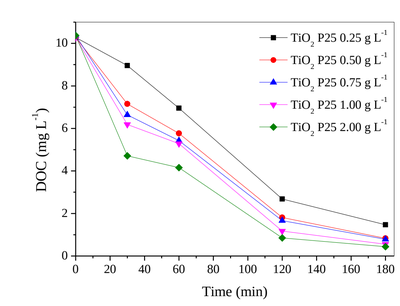

Figure 8: *Effect of initial concentration of TiO_2 P25 on the photocatalytic mineralization of 20 mg L^{-1} LGSY in the presence of UV-A.*

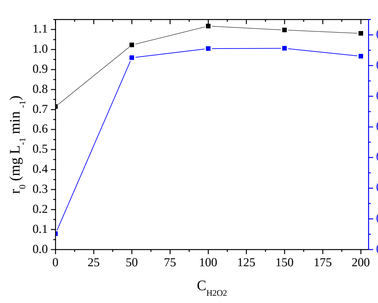

Figure 9: *Effect of H_2O_2 concentration on the initial degradation and mineralization rates during photocatalytic oxidation of 20 mg L^{-1} LGSY in the presence of TiO_2 P25 and UV-A.*

Conclusions

- Photocatalytic degradation of LGSFY by TiO_2 P25/UV-A follows pseudo first order kinetics. Among the various commercial titania tested regarding their efficiency in the decomposition of the dye, TiO_2 P90 followed by P25 (Evonik), resulted in the highest initial degradation and mineralization rates (Figs. 5-6). %Removal efficiency after 180 min of UV-A illumination follows a similar trend (Fig. 7).
- Addition of H_2O_2 into the TiO_2 P25 slurry clearly enhances both photo-degradation as well as photo-mineralization of 20 mg L^{-1} of LGSFY in the presence of UV-A. More specifically, 100 mg L^{-1} of H_2O_2 achieve the maximum increase in the r_0 and r_{DOC} values (Fig. 9).
- Acute toxicity tests using marine bacteria *Vibrio fischeri* along with phytotoxicity tests employing three eukaryotic plant species (*Sorghum saccharatum, Sinapis alba and Lepidium sativum*) will be performed to provide interesting information regarding the potential of the optimal photocatalytic process to reduce or eliminate the toxicity of LGSFY.