HELLENIC REPUBLIC
ARISTOTLE UNIVERSITY OF THESSALONIKI

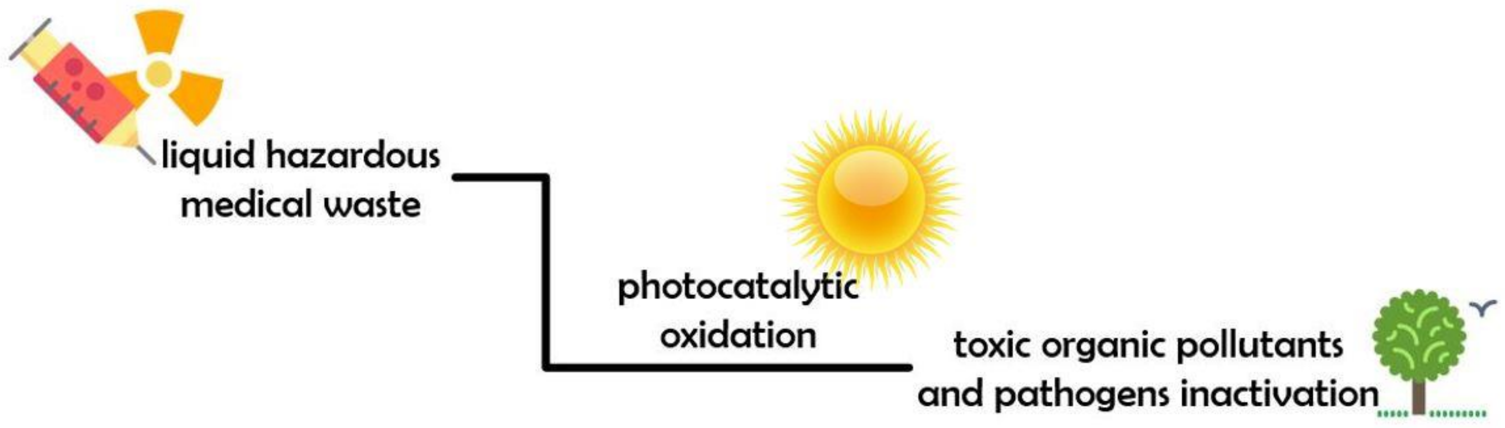
Photocatalytic mineralization of non-ionic surfactant Polysorbate 20 contained in liquid hazardous medical waste

Sophia Tsoumachidou*, Crysanthi Berberidou, Vasiliki Kitsiou, Ioannis Poulios

Laboratory of Physical Chemistry, Department of Chemistry,

Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece

***Correspondence: stsoumac@chem.auth.gr**



Problem, definition and objectives

Health units such as medical, biochemical and molecular laboratories produce liquid hazardous medical waste (LHMW). Depending on its composition, LHMW may be classified as toxic (LHMW-TC), infectious (LHMW-IN), or mixed (infectious and toxic, LHMW-MC). LHMW is heterogeneous regarding its constitution, a property that hampers the use of a universal processing method that would effectively deactivate any kind of pollutant and pathogen. Furthermore, application of currently available, traditional, liquid waste processing methods entails several intermediate processing steps that require expensive equipment, which results in high processing costs. Moreover, available methods are not fully effective at several cases, as they are unable to completely inactivate the abovementioned pollutants.

In this work is presented the application of heterogeneous and homogeneous photocatalytic oxidation at the degradation of the nonionic surfactant Polysorbate 20 (Tween 20) contained in LHMW, in order to provide a further insight to oxidation kinetics and estimate mineralization degree towards the corresponding oxidation process. Polysorbate 20 is a polysorbate-type nonionic surfactant. Its stability allows it to be used as a detergent and emulsifier in a number of scientific and pharmacological applications, among which it is used:

- as a washing agent in immunoassays, such as Western blots and ELISAs. It helps to prevent non-specific antibody binding.
- to saturate binding sites on surfaces (i.e., to coat polystyrene microplates, generally combined with proteins such as BSA).
- to stabilize proteins purified protein derivative (PPD) solution used in skin testing for tuberculosis exposure.
- as a solubilizing agent of membrane proteins.
- for lysing mammalian cells, generally combined with other detergents, salts and additives.

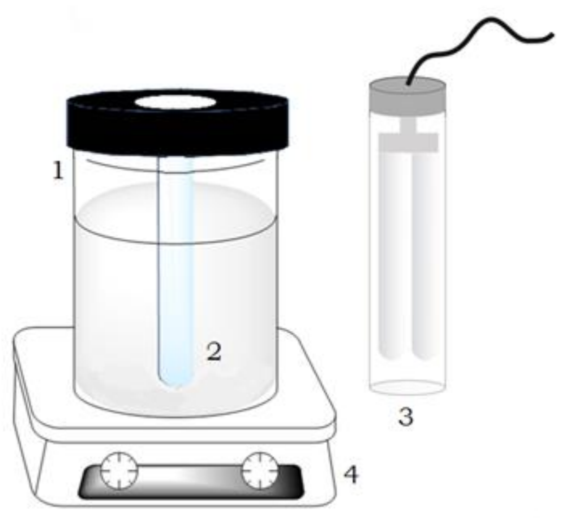


Figure 1. Schematic representation of UV-A-induced photocatalytic reactor1 thermostated pyrex cell of 500 mL capacity, 2 cylindrical sleeve where lamp (3) is inserted, 3 lamp, 4 magnetic stirrer

Strategy and methods

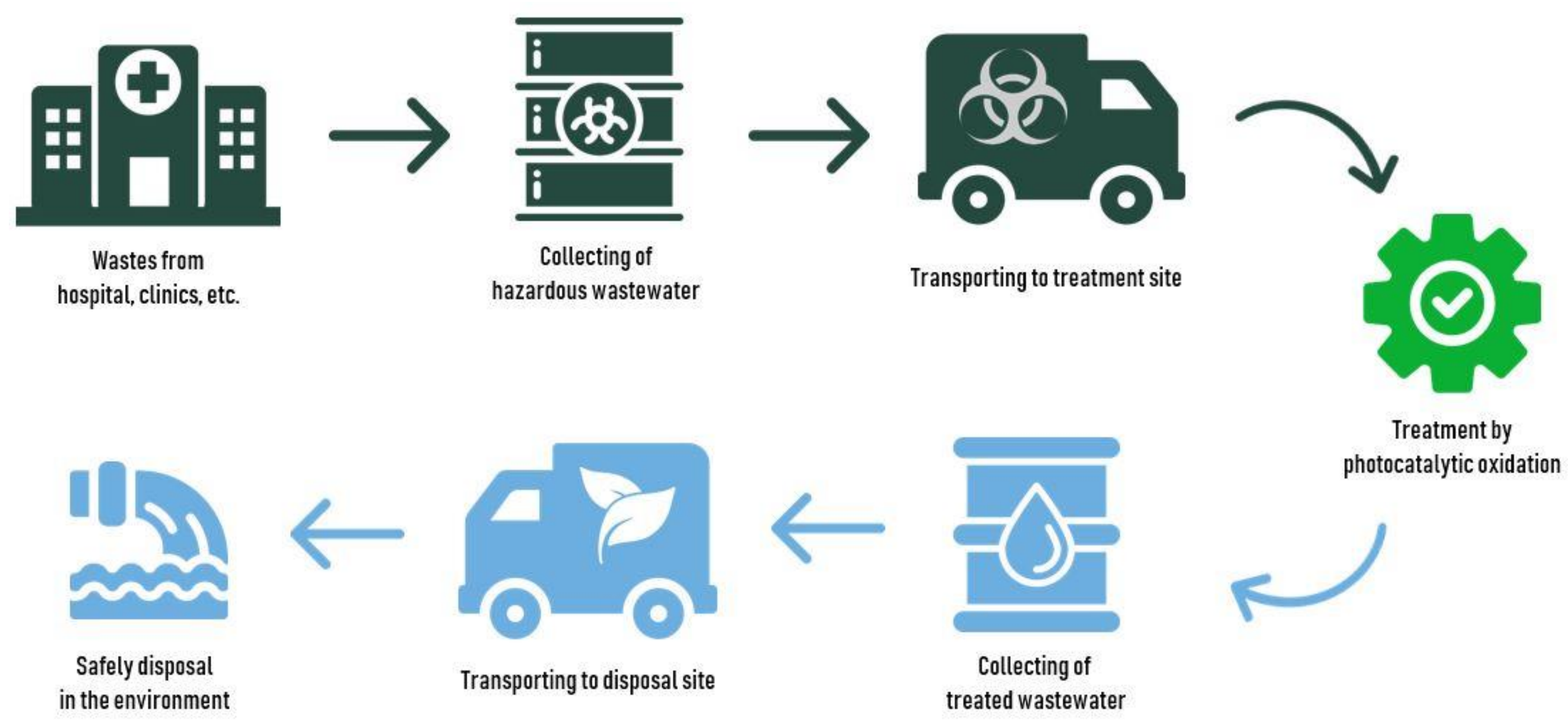
•*Photocatalytic experiments*

All photocatalytic experiments were conducted in a thermostated pyrex reaction cell of 0.5 L capacity (Figure 1), with an Osram Dulux® S blue UV-A lamp (9W/78, 350−400 nm) fitted centrally and a black cloth on it in order to avoid any interaction with ambient light (Figure 1). The radiation intensity was determined, using potassium ferrioxalate $[K_3Fe(C_2O_4)_3{\cdot}3H_2O]$ actinometry, at $1.116{\cdot}10^{-4}$ Einstein min^{-1}.

Tween 20 aliquots were sampled at frequent time intervals and filtered through a 0.45 μm syringe filter in order to remove any catalyst particle before any further analysis. Total volume of the withdrawn samples was not exceeded 2% of the initial suspension volume. The results shown in this paper is the mean values, since all photocatalytic runs were conducted in duplicate and, occasionally, in triplicate; standard deviation never exceeded 10%.

• *Analytical methods*

A Shimadzu V_{CSH} Total Organic Carbon Analyzer was used to measure the dissolved organic carbon (DOC) as a monitoring indicator of mineralization, while pH was determined with a Mettler Toledo S20 SevenEasy pH meter. Colorimetric determination with MQuant™ Peroxide test strips and spectrophotometric detection (Shimadzu UV-1700, 410 nm, glass cuvettes, 1 cm path length) with titanium (IV) oxysulfate-sulfuric acid solution according to DIN 38409 H15 were used for residual H_2O_2 measurement.



Results and conclusions

• The effect of TiO_2 loading on the mineralization of Tween 20 was studied under varying amounts of TiO_2 i.e. 0.25, 0.5, 0.75 and 1 g L^{-1}. In all experimental runs more than 85% of Tween 20 organic load was mineralized within 180 min of illumination.

• The effect of hydrogen peroxide addition on the mineralization of Tween 20 by TiO_2-mediated photocatalytic oxidation was studied under varying amounts of H_2O_2 i.e. 0.05, 0.1 and 0.2 g L^{-1} at TiO_2 loading 0.5 g L^{-1}. In all experimental runs with H_2O_2 more than 80% of Tween 20 organic load was mineralized within 180 min of illumination. Furthermore, the aforementioned runs exhibit similar mineralization percentage notwithstanding the different conditions employed.

• Testing the influence of the initial concentration of Tween 20, it was observed that increasing the substance concentration from 0.01 up to 0.05 g L^{-1} the mineralization percentage was decreased (Figure 2).

•Solution pH holds a decisive role in the effectiveness of the heterogeneous photocatalytic process not only because it strongly affects the physicochemical properties of the organic load but also because it is responsible for altering the surface properties of the catalyst thus directly influencing its activity. As shown in Figure 3 the highest mineralization, i.e. ca. 90%, was achieved at natural pH (~7.5), that is near the point of zero charge of TiO_2 P25. The amphoteric character of TiO_2 P25 dictates that either a positive or a negative charge can be developed on its surface. As the point of zero charge (pzc) for TiO_2 P25 is at $pH_{pzc}\approx6$, solution pH values directly affect the particles' surface charge; that is, above and below the pH_{pzc} the TiO_2 surface becomes negatively and positively charged, respectively.

• In the case of photo-Fenton, the increment of ferric ions from 0.0035 to 0.014 g L^{-1} did not led to an increase on the mineralization percentage of Tween 20. On the other hand, the use of extra H_2O_2 dosage led to a remarkable improvement (i.e. from 34 to 71.3%) in UV-A-irradiated process efficiency of Tween 20 photo-Fenton mineralization, with 0.007 g L^{-1} Fe^{3+} loaded in the reaction solution (Figure 4).

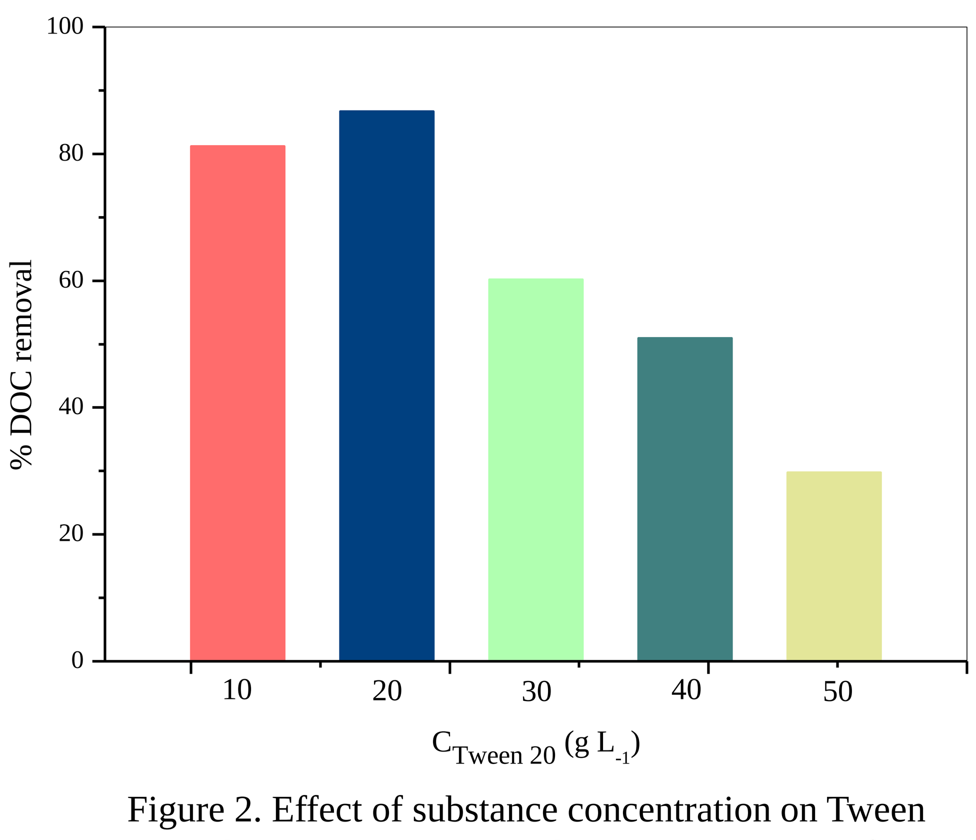


Figure 2. Effect of substance concentration on Tween 20 heterogeneous mineralization at 180 min of photocatalytic process (initial conditions: 0.02 g L^{-1} Tween 20, 0.5 g L^{-1} TiO_2, UV-A illumination).

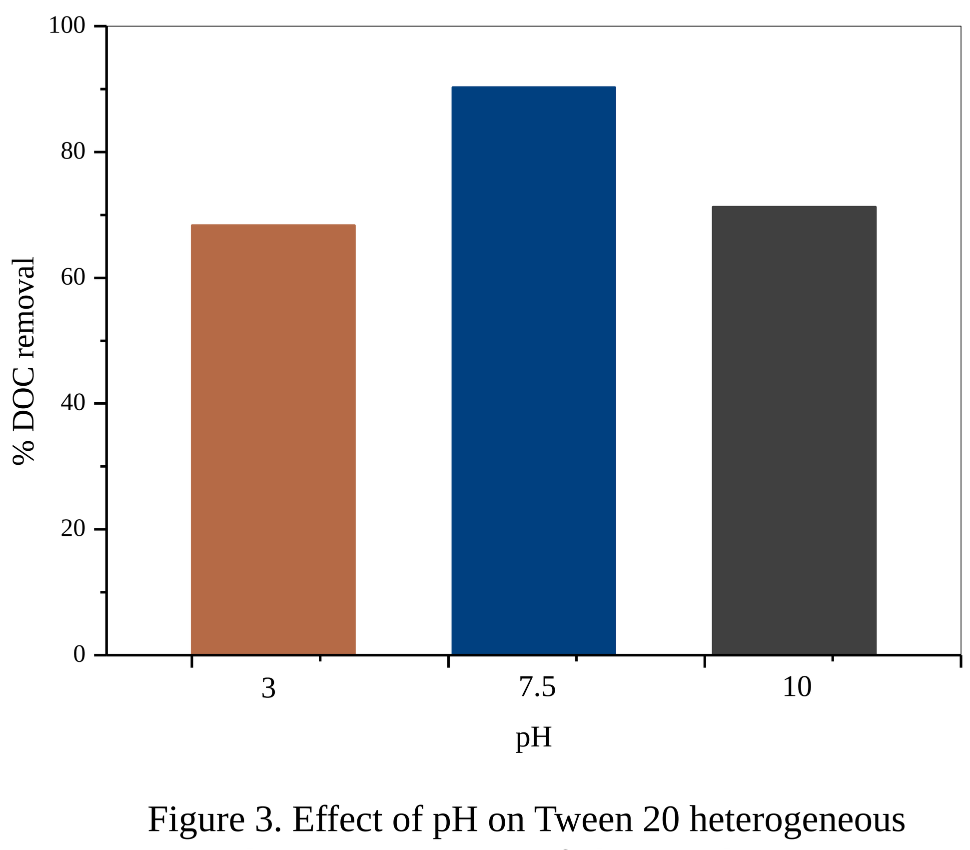


Figure 3. Effect of pH on Tween 20 heterogeneous mineralization at 180 min of photocatalytic process (initial conditions: 0.02 g L^{-1} Tween 20, 0.5 g L^{-1} TiO_2, UV-A illumination).

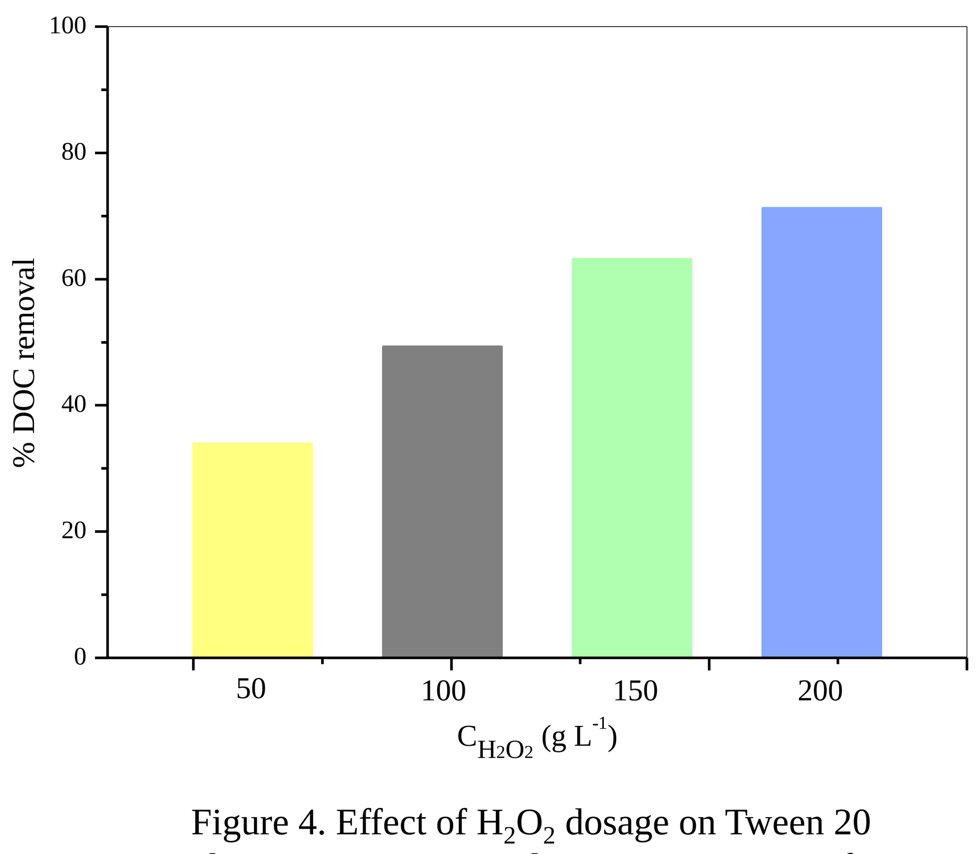


Figure 4. Effect of H_2O_2 dosage on Tween 20 homogeneous mineralization at 180 min of photocatalytic process (initial conditions: 0.02 g L^{-1} Tween 20, 0.007 g L^{-1} Fe^{3+}, UV-A illumination).

Acknowledgments

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).

6th European Conference on
Environmental Applications of Advanced Oxidation Processes
26-30 June 2019, Portorož-Portorose, Slovenia