Photocatalytic mineralization and disinfection of simulated medical wastewater

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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. Application of 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 (*PhotoInact*) aiming to the development and application of a prototype for the photocatalytic inactivation of LHMW containing toxic pollutants and/or pathogens. For this purpose, simulated medical wastewater containing chemicals commonly found in LHMW as well as microbial species highly resistant to inactivation processes, were prepared and subjected to heterogeneous (TiO_2/UV-A) oxidation in laboratory scale. In this context, a mixture of biological stains (Eosin Y, Light Green SF Y and Bismarck Brown Y), all with the potential to be employed independently or combined as components of Papanicolaou stains, together with the nonionic surfactant Tween 20 and endospores of the *Bacillus stearothermophilus* species has been studied regarding its potential to be decomposed in the presense of TiO_2/UV-A.

Strategy and methods

Photocatalytic purification and disinfection of simulated LHMW was performed in lidded sterile polystyrene 6 well plates, under magnetic stirring, at room temperature. Each well served as a cylindrical 12 mL photocatalytic reactor. The appropriate amount of the chemical components (Eosin Y, Light Green SF Y, Bismark Brown Y, Tween 20, Fig. 1) and of the stock suspension of *B. stearothermophilus* endospores (ATCC 7953, Fluka, see preparation in Fig. 2A, $4 \cdot 10^7$ cfu mL^{-1}) was diluted in sterile distilled H_2O and was added to a single well of the plate. The catalyst (TiO_2 P25) was then added at the desired concentration, resulting to a 10 ml working volume. The plate was illuminated by a system of 4 parallel blacklight lamps (length: 45 cm, Blacklight blue, F15W/BLB-T8, Silvania), connected with a voltage regulator, placed 10 cm above the surface of the suspension. The intensity of the incident UV-A irradiation at this distance measured by a PMA 2100 radiometer was 4.4±0.2 mW cm^{-2}. Samples collected in duplicates at various time intervals in sterile Eppendorf tubes, were diluted with sterile PBS and were enumerated by direct counting of the colonies on tryptic soy broth (TSB) plates (Fig. 2B).

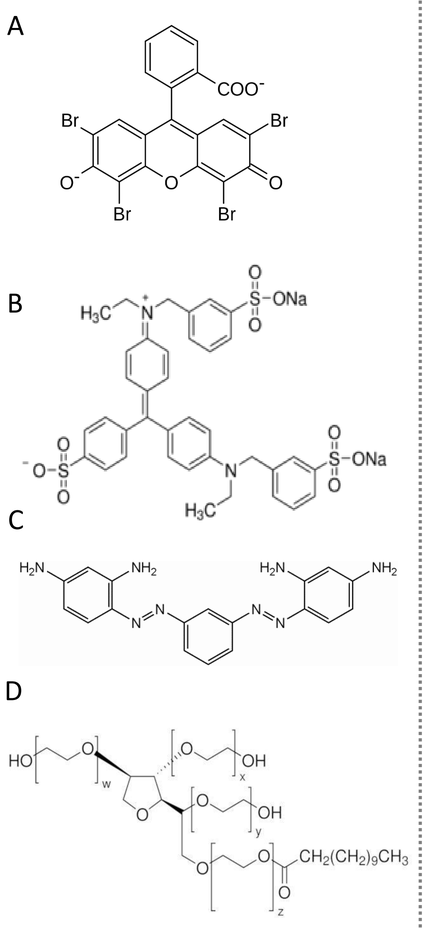

Figure 1: *Chemical components of the LHMW. A. Eosin Y ($C_{20}H_6Br_4Na_2O_5$), B. Light Green SF Y ($C_{37}H_{34}N_2Na_2O_9S_3$), C. Bismarck Brown Y ($C_{18}H_{18}N_8 \cdot 2HCl$), D. Tween 20 ($C_{58}H_{114}O_{26}$).*

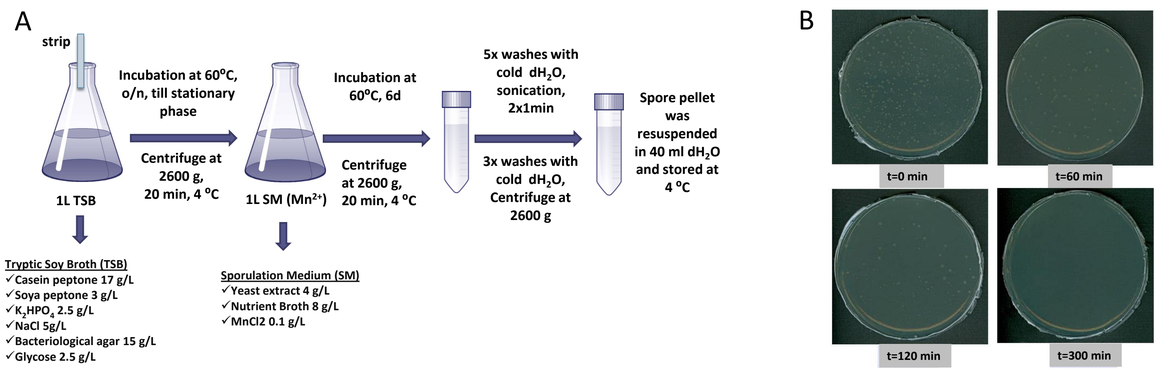

Figure 2*: A. Preparation of the B. stearothermophilus endospore stock suspension from strips with 10^6 cfu immobilized endospores. B. Photocatalytic inactivation of B. stearothermophilus endospores with 0.5 g L^{-1} TiO_2 P25 under UV-A irradiation. $N_0 = 10^6$ cfu ml^{-1}.*

Results

LHMW	TOC_0, mg L^{-1}	TOC_{300}, mg L^{-1}	C_0 (T20), mg L^{-1}	C_0 (EY/LG/BB), mg L^{-1}	C_{300} (EY/LG/BB), mg L^{-1}
1	226.7	204.2	20	100/100/100	34.4/42.3/41.1
2	103.7	89.2	20	50/50/50	5.4/23/16.8
3	103.5	80.8	100	20/20/20	0/0/0

Table 1: *Main parameters investigated during TiO_2/UV-A photocatalytic treatment of the simulated liquid hazardous medical wastewater-LHMW containing biological stains (Eosin Y-EY, Light Green SF Y-LG, and Bismarck Brown Y-BB), a nonionic surfactant (Tween 20-T20) and endospores of the species of Bacillus stearothermophilus.*

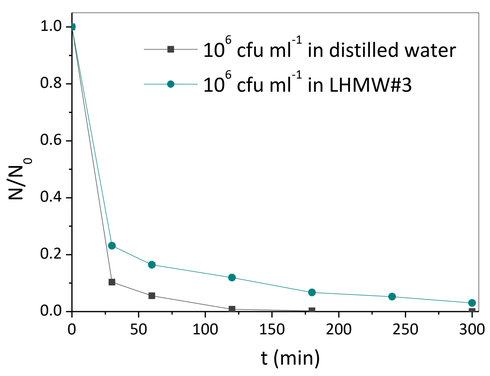

Figure 3: *Effect of the presence of chemicals during photocatalytic inactivation of B. stearothermophilus endospores of LHMW#3 in the presence of 0.5 g L^{-1} TiO_2 P25 and UV-A.*

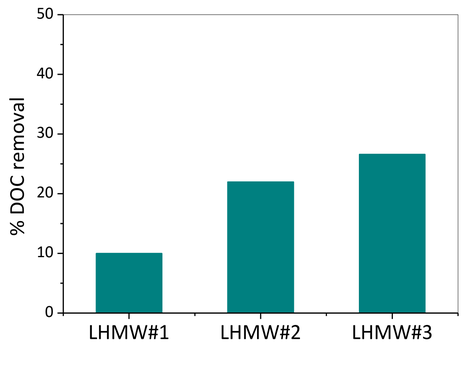

Figure 4: *Percent DOC removal during 300 min of photocatalytic oxidation of three different LHMW containing biological stains, Tween 20 and B. stearothermophilus endospores in the presence of 0.5 g L^{-1} TiO_2 P25 and UV-A.*

Conclusions

- Photocatalytic decolorization, mineralization and disinfection of three different LHMW has been investigated (Table 1).
- As expected, increase in the concentration of the biological stains present in the LHMW resulted in reduction of the efficiency of the TiO_2 P25/UV-A system. Illumination for 300 min in the presence of 0.5 g L^{-1} P25 and 20 mg L^{-1} of Eosin Y, Light Green SF Y, Bismark Brown Y, 100 mg L^{-1} Tween 20 and 10^6 cfu mL^{-1} of *B. stearothermophilus* endospores led to the following results:
  - complete decolorization of the three biological stains
  - approximately 30% DOC removal
  - more than 3 logs cfu reduction of the *B. stearothermophilus* species
- On-going experiments aiming in the enhancement of the photocatalytic process (use of electron scavengers, application of homogeneous photocatalysis, etc) will enable the determination of optimal conditions necessary for the mineralization and inactivation of pathogens present in LHMW in the prototype of the *PhotoInact* project.

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