UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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PhD in Textile Engineering

Assessment of novel Advanced Oxidation Processes for the simultaneous disinfection and decontamination of water

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SUMMARY

It is well recognized that the world is facing a water crisis and the reuse of urban wastewater (UWW) in agriculture, has been gaining attention as a reliable solution to address this problem. It is mandatory to promote the safe water reuse and minimum water quality limits could be achieved by upgrading the Urban Wastewater Treatment Plants, through the addition of an efficient tertiary treatment. In the last decades, Advanced Oxidation Processes (AOPs), relying on the potential generation of highly oxidant, reactive and non-selective Reactive Oxygen Species (ROS), have been raised as alternative to conventional treatments for both water disinfection and decontamination. The general aim of this study is the assessment of novel AOPs for the simultaneous disinfection and decontamination of water, investigating (*i*) solar heterogeneous photocatalysis, involving modified ZnO with Ce, Yb and Fe and the benchmark TiO_2-P25, (*ii*) peroxymonosulfate (PMS) under natural solar radiation (PMS/Solar), (*iii*) Sulfate radical-based AOPs (SR-AOPs) involving PMS and UV-C radiation (PMS/UV-C) and (*iv*) combination of the best-performing photocatalytic material with PMS (PMS/modified ZnO). The involved biological and chemical targets in this study were: three human health impact pathogens (two gram-negative bacteria *Escherichia coli*, *Pseudomonas* spp. and the gram-positive *Enterococcus* spp.) and three Contaminants of Emerging Concern (CECs, Diclofenac-DCF, Sulfamethoxazole-SMX and Trimethoprim-TMP).

Photoactivity of modified ZnO with Ce, Yb or Fe was assessed in 200-mL vessel reactors, attaining good target's removal kinetic rates. Best performing material was ZnO-Ce, but its feasibility for a further up-scaling was discarded both as photocatalyst alone, considering the similar performances obtained, compared to TiO_2-P25 and the high treatment cost, and in combination with PMS, due to the release of high amount of Zn^{2+}. PMS alone has been proven to be an effective oxidant agent for water and UWW treatment, increasing its effectiveness when illuminated with photons from UV-C lamps and natural sunlight. Nevertheless, different inactivation and CECs degradation mechanisms have been postulated for each type of irradiation, and according to the activation of PMS (with UV-C photons) or non-activation (under natural sunlight).

The capability of PMS/Solar and PMS/UV-C processes were evaluated in actual UWW at pilot plant scale in 10-L Compound Parabolic Collector and in 80L UV-C pilot plant, respectively. Optimal load of PMS was found to be 1 mM in both cases, achieving successful inactivation of natural occurring bacteria and their antibiotic resistant

counterparts, without observing bacterial regrowth after 48h and efficiently eliminating CECs. Efficient removal of antibiotic resistant genes (ARGs) and transformation products (TPs) was obtained by PMS/UV-C, while their elimination is still a challenge to be addressed in PMS/Solar process. Reclaimed UWW obtained by both PMS/Solar and PMS/UV-C process showed no toxicity towards *Aliivibrio fischeri,* excluding a harmful effect towards the receiving aquatic environment after effluent discharge, and a very slightly phytotoxic effect for growth of two out of the three tested seeds (*L. sativum* and *S. alba*), indicating the suitability of this water for its subsequent reuse for agriculture. The analysis of the treatment cost revealed that this key factor could be an important barrier for implementation of PMS/Solar process in large centralized UWW treatment plants. Nevertheless, its consideration as decentralized systems associated to small volume of water in areas with a high solar radiation incidence, saving energy costs by using natural solar radiation, could be a real and affordable option.