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## **Photo-Fenton and slow sand filtration coupling for hydroponics water reuse**

### **ABSTRACT**

This thesis is framed in the collaboration between the Chemical Engineering Department, from the University of Barcelona, and the R+D Department from the company Acciona Agua S.A.U., under the umbrella of CENIT-MEDIODIA Project. This initiative, founded by CDTI-Spanish Ministry of Science and Innovation comprised a consortium of companies and research centers that focused their innovative efforts in the development of a new concept of Advanced Hydroponics Greenhouses.

The collaboration between the University of Barcelona and Acciona Agua was focused on optimizing greenhouses hydric resources. The functionality of a combined treatment had to be assessed, when applied to the discard stream of a recycling system of the Advanced Greenhouse leachates. The coupling consisted on an Advanced Oxidation Processes (AOP), photo-Fenton, based on hydroxyl radical oxidative potential, produced by the interaction between  $\text{Fe}^{2+}$  and  $\text{H}_2\text{O}_2$ , and a slow sand filtration column acting as a bioreactor. The recycling system will require the synergy of chemical and biological processes to be able to work efficiently with the particular characteristics of greenhouses effluents: high salinity content and the presence of pesticides.

Two recycling strategies proposed by the project defined two conductivity thresholds that the coupled system should be able to cope with. The first strategy proposed a simple semi-closed system that recycled nutrient solution from the hydroponics crops until a maximum value of 11  $\text{mS}\cdot\text{cm}^{-1}$ , phytotoxicity limit. Part of the current was then diverted to be treated by the integrated system. The second strategy introduced reverse osmosis membrane technology that concentrated that diverted stream, sending the permeate for its reuse directly to the greenhouse, while the brine had to be treated by the coupled process. In this case the maximum level of salinity in the effluents could reach conductivities close to those for seawater, around 50  $\text{mS}\cdot\text{cm}^{-1}$ .

The performance of photo-Fenton reaction was essayed in order to improve the knowledge regarding this treatment technique. On the first place, this AOP and the ozonation process were compared. Results shown that increasing toxicity of ozonation effluents confirmed the choice of photo-Fenton as the most adequate treatment for pesticide polluted effluents. Experimental design criteria allowed then to determine optimal working conditions depending on the content of the reaction media, and enabled to prove the existence of endogenous catalyst inhibition in the presence of fosetyl-Al. Salinity essays were finally performed, yielding positive results even for highest conductivity effluents. Those positive results were also reflected in the increase of the biodegradability of the treated effluents, what led to the next step of the research.

Biocompatibility of pretreated effluents was essayed by means of sequencing batch reactors (SBR). These devices were used to show how photo-Fenton indeed increased biodegradability of the effluents, and how it grown until a certain point when more hydrogen peroxide did not lead to better results. They were also utilized to assess the biocompatibility of high salinity pretreated effluents, as

a first step towards the coupling with the slow sand filtration at high conductivities. Results obtained were extremely encouraging, given that even for the highest salinity concentrations (10 and 50 mS·cm<sup>-1</sup>), the performance of the bioreactor achieved an organic content reduction for more than 80% of the loaded concentration, which compared to the 10-20% removal achieved by photo-Fenton, justifies the need of combining both treatments.

Guided by those positive results, the load of the slow sand filtration column with different salinity pretreated effluents was performed. Also positive results were obtained. The achieved elimination of the organic content was more than 75% when loaded with 10 mS·cm<sup>-1</sup> effluent, and the refractory fraction (the remaining organic matter that cannot be oxidized either by photo-Fenton reaction or by the biomass metabolism) was the lowest also for this high conductivity.

Molecular biology tools, MTBs, used in this thesis were based on cloning and sequencing techniques of 16S rRNA genes. They allowed characterizing the bacterial population of one of the assessed SBRs and of the different loading stages of the slow sand filtration column. They showed how with the increase of salinity, the population in the slow sand filtration column loosed diversity, despite the fact that the performance of the column was still proficient. This fact stated how a very different microbial consortium could be developing the same functions as others.

According to obtained results, it could be finally concluded that the coupling between photo-Fenton reaction and slow sand filtration column could be an effective treatment alternative for implementing the recycling strategies of hydroponics greenhouse leachates proposed by CENIT-MEDIODIA Project. For its part, MBTs were revealed as powerful tools to characterize microbial population and increase the understanding of the bioreactions taking part in bioremediation.