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Advanced systems for the enhancement of the environmental performance of wineries – wastewater purification combining biological, advanced chemical and reverse osmosis treatment

ABSTRACT

The presence of high organic and inorganic compounds, and the spatio-temporal dynamics of winery wastewater among and within wineries, makes the treatment of winery wastewater challenging. The various wine processing systems applied at each winery, generate wastewater with specific properties, and therefore, establishing a general agreement on the most suitable cost-effective technology for the treatment of this wastewater stream does not seem feasible. Several winery wastewater treatment technologies are available, but the development of alternative ones is essential, in order to increase their efficiency and decrease the investment and operational costs.

Five underlying objectives were set to fulfill the overall target of this dissertation. The first was to investigate and identify the environmental impacts related to the wine production process, using Cyprus wineries as a case study, and the various actions that could be implemented by wineries, in order to minimize or eliminate these impacts. The second objective was to investigate the application of an advanced chemical oxidation process (AOP), and specifically the solar photo-Fenton process, as post-treatment, for the removal and the possible mineralization of the organic content of winery effluents, which have been pretreated by a biological process, i.e. (a) a Sequencing Batch Reactor (SBR), and (b) a Membrane Bioreactor (MBR), at a bench- and a pilot-scale setup. The results obtained by the bench- and the pilot-scale experiments indicated that solar photo-Fenton is very efficient for the treatment of both biologically pretreated flows, yielding, after the end of the treatment, high removal of the organic content, as well as complete reduction of the toxicity towards D. magna, and significant reduction of the phytotoxicity towards the three plant species examined. The combined MBR + solar Fenton process seems to be a more effective technology for winery wastewater treatment than the combined SBR + solar Fenton, since the first one can reduce the organic pollutants in the winery effluent to values well below those included in the Cypriot discharge limits (residual COD< 30 mg L-1, TN< 1.6 mg L-1, TP< 0.4 mg L-1 and TSS< 10 mg L-1).

The third objective was the monitoring of the efficiency of the solar Fenton as post-treatment of the most efficient biological treatment (i.e. MBR) at an industrial scale, which led to the conclusion that no significant differences with regard to the organic content removal, as well as toxicity reduction should be expected, when upscaling the process from the pilot to industrial level. The fourth objective of this thesis was to investigate the efficiency of a membrane separation process, and specifically reverse osmosis (RO), for the treatment of raw winery wastewater, as an alternative to the biological and advanced treatment. RO achieved high levels of purification of the winery wastewater, and resulted in a water fraction (permeate), which can be discharged in aquatic systems or to be reused in winery cleaning processes. Taking into consideration that the RO does not really

destroy the pollutants, but merely concentrates them into smaller volumes of wastewater, i.e. concentrate, solar photo-Fenton oxidation was applied for its treatment before its disposal to the environment. This resulted in a COD reduction of 75±2.5%, while the toxicity towards all species examined was significantly reduced.

The last objective of this thesis was to establish the overall ownership cost of an MBR, a solar Fenton system, and an RO system, the combination of which (MBR + solar Fenton and RO + solar Fenton) may represent an integrated system for complete management of winery wastewater, based on a typical medium-size winery that produces an average of 50 m3 of wastewater per day. The total cost of the full-scale MBR unit was estimated to be 2.1 € m-3, of the solar Fenton unit was 1.83 € m-3 and of the integrated RO system was 2.55 € m-3.