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ADVANCED PROCESSES FOR THE REMOVAL OF ORGANIC MICROPOLLUTANTS FROM WASTEWATER BY THE ADDITION OF POWDERED ACTIVATED CARBON TO MEMBRANE BIOREACTOR / NAPREDNI PROCESI ZA UKLANJANJE ORGANSKIH MIKROZAGAĐIVALA IZ OTPADNIH VODA DODATKOM PRAŠKASTOGA AKTIVNOGA UGLJENA U MEMBRANSKI BIOREAKTOR

Cotutelle de these

Activated carbon coupled to a membrane bioreactor (MBR) is a novel hybrid system able to potentially enhance the removal of organic micropollutants (OMPs) in wastewater. In a context in which wastewater treatment plants (WWTPs) have been declared as the major sources of OMPs into the aquatic environment, hospital wastewater is a growing concern as a point source of these contaminants, especially of pharmaceuticals. The combination of the great adsorption capacity of the activated carbon with the biological degradation and membrane separation of the MBR results in a promising option to obtain a high-quality effluent. That being said, the numerous influencing factors and mechanisms by which OMP removal is enhanced are yet not fully understood. In addition, few research studies in full-scale hybrid MBRs have been reported in literature.

In this thesis, an in-situ hybrid MBR coupled to powdered activated carbon (PAC) has been proposed to remove OMPs from wastewater and reduce the impact of the effluent on the receiving water body. The experiments were conducted in a full-scale MBR treating mainly hospital wastewater with 0.1 and 0.2 g/L of PAC added inside the biological reactor. The occurrence and removal efficiencies of a vast selection of OMPs (232) were reported, compared and discussed in a MBR and a hybrid MBR over a year time. Based on the results obtained, PAC addition was proved to enhance the removal of several OMPs, especially antibiotics and psychiatric drugs. The increase of the PAC concentration from 0.1 g/L to 0.2 g/L showed to further improve the quality of the effluent by reducing the total OMP loads and the environmental risk in the receiving water body.

In addition to that, a systematic review and a meta-analysis were conducted about the state-of-the-art of MBRs coupled to activated carbon to treat urban and domestic wastewater. Collected data on the removal efficiencies, the effluent concentrations, the physicochemical properties of the OMPs, the system configuration and the operational conditions applied were discussed and subjected to statistical analysis. Consequently, a detailed assessment of the factors affecting the removal of the OMPs in presence of activated carbon was carried out.

Finally, the adsorption of three pharmaceuticals (i.e., diclofenac, sulfamethoxazole and trimethoprim) onto PAC was studied using mathematical models applied to batch experiments at laboratory-scale. The PAC adsorption capacity, mechanisms and kinetics were investigated

under controlled conditions. In particular, four water matrices of increasing complexity were used: Milli-Q water, humic acid solution, permeate and mixed liquor of an MBR. The adsorption was proved to be an overall fast kinetic process dependent on the initial concentration of the pharmaceutical and the adsorbent. A competitive effect was observed when compounds occur in a mixture, causing a decrease in the overall PAC adsorption capacity. Additionally, the composition of the water matrix proved to have a major effect on the adsorption of the selected compounds. Decreased adsorption was found in the mixed liquor for all tested pharmaceuticals, whereas the humic acids were proven to enhance the adsorption of certain compounds, namely diclofenac and sulfamethoxazole.

Keywords: activated carbon, adsorption, membrane bioreactor, organic micropollutants, wastewater treatment