Summary of doctoral dissertation "The application of ceramic MF and UF membranes in photocatalytic membrane reactors" by Kacper Szymański

The main objective of this study was to determine the effect of process parameters on fouling and stability of micro- and ultrafiltration (MF and UF) ceramic membranes during exploitation in a photocatalytic membrane reactor (PMR). Moreover, the effectiveness of organic compounds removal from model solution containing humic acids (HAs), surface water and secondary effluent was determined. The influence of feed cross flow velocity (CFV) and transmembrane pressure (TMP), as well as a photocatalyst loading and type, on membrane fouling and stability were particularly examined. The resistance to abrasion by photocatalyst particles of membranes with separation layer made of two different materials (TiO_2, ZrO_2) during long – term operations in the PMR was assessed. Additionally, the detailed analysis of influence of different feed water composition on effectiveness of organic compounds removal in the PMR was investigated. Photocatalytic membrane reactor was compared with other hybrid systems such as UVC/H_2O_2-UF and photolysis UVC-UF in terms of organic compounds removal, ecotoxicity and membrane fouling.

Commercially available asymmetric ceramic membranes (TAMI Industries, France) with separation layer made of TiO_2 (Filtanium™) or ZrO_2 (INSIDE CéRAM™) with different cut off and pores diameter has been applied in the experiments. Commercial TiO_2 (AEROXIDE® TiO_2 P25, Evonik, Germany and ST-01, Ishihara Sangyo, Japan) and laboratory fabricated TiO_2 (A700 and A800) were used as photocatalysts. The photocatalysts exhibited different phase composition and particle size.

It was found that the loading of photocatalyst TiO_2 P25 amounted from 0.5 to 1.5 g/dm^3 had no significant influence on permeate flux during experiments with the usage of Filtanium™ membrane with cut off of 5 000 and 100 000 g/mol and the permeate fluxes were higher than permeate fluxes measured during ultrafiltration of ultrapure water. That was caused by the abrasion of separation layer of membranes by TiO_2 particles and formed pores with larger diameters or new pores. Filtanium™ membrane with cut off of 100 000 g/mol exhibited the highest resistance to abrasion by TiO_2 particles. Moreover, it was found that between membranes with cut off of 5 000 g/mol, the membrane with separation layer made of ZrO_2 exhibited higher resistance to abrasion than the one made of TiO_2.

In case of UF membranes, the influence of feed cross flow velocity ranged 3 – 6 m/s on permeate flux was not observed. Additionally, the linearly correlation between transmembrane pressure and permeate flux during filtration of P25 in ultrapure water was noted.

For microfiltration membrane with nominal pores diameter equal to 0.2 μm, significant influence of feed cross flow velocity on permeate fluxes during microfiltration of TiO_2 P25 in ultrapure water was observed. In case of feed cross flow velocity of 3 m/s, photocatalyst particles were deposited within membrane pores causing significant decline of permeate flux. The research revealed that application of back-flushing is less effective method of limiting MF membrane fouling than increasing feed cross flow velocity.

A significant influence of pH and feed water composition during ultrafiltration of humic acid solution in the PMR was observed. The highest decrease in permeate flux was noted in alkaline conditions. In the presence of inorganic anions (HCO_3^-, SO_4^{2-}, HPO_4^{2-}), both in the absence or in the presence of Ca^{2+} and Mg^{2+} cations, decrease of the flux just at the beginning of the process was noticed and this phenomenon was attributed to the deposition of HAs and/or HA/TiO_2 on a membrane surface. However, the Ca^{2+} and Mg^{2+} cations led to the reduction of fouling under alkaline conditions as a result of higher adsorption of HAs on photocatalyst particles.

The research of surface water from Miedwie Lake treatment in the PMR exhibited no influence of photocatalyst concentration on permeate flux via INSIDE CéRAM™ membrane. However, the influence of photocatalyst loading on the effectiveness of Total Organic Carbon (TOC) removal was observed, with the highest value noted for TiO_2 P25 (1 g/dm^3). Comparing the data collected from the PMR and the UVC/H_2O_2-UF system, it was concluded that the second above mentioned method offers better solution for treatment of lake water. Application of appropriate doses of H_2O_2 enabled higher TOC removal than in the PMR, with simultaneous maintaining of high permeate flux.

In the last part of the study the investigations with application of secondary effluent were carried out. Based on the comparison of permeate quality collected in the PMR and the UVC/H_2O_2-UF system, it was noticed that both systems exhibited similar effectiveness of compounds removal. Slightly smaller decrease of permeate flux noted in case of the PMR indicates that the presence of TiO_2 has positive influence on the limiting of membranes fouling. However, taking into consideration the ecotoxicity of treated solutions, the UVC/H_2O_2-UF system is considered as more favourable than the PMR.

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