Dominika Darowna

Application of photocatalytic membrane reactors for the treatment of water and wastewater

Abstract

The main objective of this study was the determination of the effect of process parameters on fouling and stability of micro- and ultrafiltration (MF and UF) membranes in photocatalytic membrane reactor (PMR). The influence of membrane properties, the type and concentration of a photocatalyst, the presence of oxidative species (H_2O_2), the hydraulic conditions in a membrane module as well as the composition of a feed was thoroughly examined. The effectiveness of the contaminants removal during the treatment of model solutions and effluents from a municipal wastewater treatment plant in PMR was also investigated.

In the experiments a series of commercially available polymeric membranes made of polyethersulfone (PES) and polyvinylidene fluoride (PVDF) with different separation and transport characteristics was applied. Four different TiO_2 powders were used in the study: two commercially available photocatalysts: TiO_2 Aeroxide® P25 (Evonik, Germany) and ST-01 (Ishihara Sangyo, Japan) and two samples obtained in the laboratory: A700 and A800. The photocatalysts exhibited different phase composition and particle size.

During the experiments with the use of TiO_2 P25 suspension it was found that the feed cross-flow velocity (v) and transmembrane pressure (ΔP) had a significant effect on the membrane fouling in PMR. No deposition of photocatalyst particles on the membrane surface was observed when the parameters such as $v = 0{,}8$ m/s and $\Delta P = 1$ bar were used. The decrease of the feed cross-flow velocity and the increase of the transmembrane pressure resulted in formation of a thick and dense fouling cake on the membrane surface and a decrease of the permeate flux. The presence of HCO_3^-, SO_4^{2-} and HPO_4^{2-} ions and humic acids had a negative impact on the permeate flux, however, these substances had a positive influence on the stability of the membrane. The deterioration of the separation properties was observed after the filtration of the TiO_2 suspension in clean water, but the changes were negligible when a mixture of inorganic salts and humic acids was used as a feed. The combination of photocatalysis and UF during treatment of effluents from a municipal wastewater treatment plant resulted in membrane fouling mitigation.

Membranes made of PVDF were more prone to fouling by TiO_2 particles than PES membranes. The susceptibility to fouling depended on the membrane structure, pore size and water permeability. Membranes with a denser structure and smaller pores had lower resistance to the damage due to the abrasive action of the photocatalyst than the samples having larger pores and thicker separation layer. It was further found that the membrane fouling and the decrease of the separation properties was significantly affected by the shape and size of the TiO_2 particles. The commercial TiO_2 P25 caused the most severe decrease of the permeate flux due to the smallest particles, however, TiO_2 ST-01, having the particles with the sharpest edges, contributed to the most significant decrease of the separation properties. The presence of oxidative species such as H_2O_2 had only small effect on the changes of the separation properties of the examined membranes.

The studies on the municipal wastewater treatment in PMR showed high efficiency of removal of micro-contaminants. The concentration of ibuprofen decreased for 59% when the primary effluents, containing high concentration of organic pollutants and high turbidity, were used as a feed, while in secondary effluents it was decomposed completely.

Taking into consideration the present research it was concluded that PMR with UF/MF membranes could supplement the conventional wastewater treatment methods, especially when the removal of micro-contaminants, such as pharmaceuticals is necessary. However, special attention should be paid to the selection of membranes, especially in respect of their resistance to the abrasio

Dominika Dudziak