Comparison of ceramic and polymeric membrane permeability and fouling by surface water

Introduction

Ceramic membranes are often stated to have several advantages when compared to polymeric membranes, like higher chemical and mechanical stability and higher hydrophilicity. The chemical and mechanical differences between ceramic and polymeric membranes may be the cause of a difference fouling behaviour as was suggested by previous research (see Techneau deliverables D2.3.2.2 and D2.3.2.7).

Importance

In order to understand which ceramic microfiltration membrane has the best fouling properties and can be expected to have the best performance, one has to first compare the available options. Thus, we compared four types of ceramic membranes (Al_2O_3, TiO_2, ZrO_2, SiC) and one polymeric membrane with similar pore sizes, by characterizing the membrane properties (mean flow pore size, elemental composition) and the fouling behaviour by direct filtration of surface water.
This in principle allows us to identify the best membrane material, with respect to performance and fouling.

Approach

First, the membranes were characterized by porometry and X-ray photoelectron spectroscopy (XPS). We also attempted to measure the zeta-potential of the membranes. A comparison of the obtained properties of the membranes and supplier information was made.
Second, we compare the membrane properties with respect to trans membrane pressure (TMP) increase due to both reversible and irreversible fouling. In practice, in full scale application, the membranes would be used under different operational conditions than in this study. However, since we want to compare the membrane properties on the level of the membranes rather than different operational conditions, we decided to fix the flux and backwash procedure.
The TMP increase due to fouling was determined at constant flux for all the membranes in a small scale setup in experiments with a five hour duration. Additionally, the non-purgeable organic compound (NPOC) content, turbidity and UV extinction of the feed water, backwash water, permeate and cleaning solutions were measured in order to be able to make a NPOC mass balance and determine the performance of the membranes with respect to removal.

Result

We compared the permeability and fouling of four different ceramic membranes and one polymeric membrane using surface water.

- Pore size measurements by permporometry showed that the pore size of the Al_2O_3 and ZrO_2 were similar to the values given by the supplier. The measured pore size for the TiO_2 and SiC membrane deviated by a factor of 5 and 24 from those given by the supplier, respectively. The properties of the membranes may cause deviations in the used method; the SiC membrane is exceptionally hydrophilic.
- XPS measurements confirmed the membrane compositions as documented by the suppliers, although the measurements showed that all membrane samples were contaminated with carbon and oxygen.
- The TiO_2 and especially the SiC membrane showed a low TMP increase due to low reversible and irreversible fouling, compared to the Al_2O_3, ZrO_2 and polymeric membranes. For the polymeric membrane the differences can probably be attributed to differences in the V/A ratio between the membrane modules. The TMP increase due to fouling increases with decreasing measured pore size.
- Removal of NOM and UV was lowest for the polymeric membrane (13-25%) and higher and comparable (around 30%) for the different ceramic membranes. The removal of turbidity was >95% for all membranes except the SiC membrane.
- The reversible fouling load decreases in the following order: (Al_2O_3>(ZrO_2≈TiO_2))≈SiC>polymeric and the irreversible fouling load after 5 hrs of operation decreases in the order; $Al_2O_3 \approx ZrO_2 > TiO_2 \approx$ SiC. The load of reversible and irreversible NPOC fouling, however, was not very different for the Al_2O_3, TiO_2, ZrO_2, and SiC membranes, suggesting that these parameters cannot be used as an indicator of TMP increase.
- Mass balance analysis of the NPOC load on the membranes and in the backwash, showed that 85±8% of the expected NPOC could be accounted for. Probably, the soaking at pH 12 did not remove some of the fouling materials from the membranes. This is especially true for the ZrO_2 membrane where only 59% of the NPOC was accounted for. This suggests that a more aggressive CIP is necessary for the complete removal of irreversible fouling.

Concluding; looking at the performance and fouling, the SiC and TiO_2 membranes seem to be the best choice.

More information

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