FOULING STUDIES ON ULTRAFILTRATION / MICROFILTRATION USING SINGLE MEMBRANE CAPILLARIES: FOCUS ON FOULING BY NATURAL ORGANIC MATTER

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Abstract

Membrane fouling studies would pave way for the modification or removal of problematic organic fraction(s) so as to minimize fouling. Coagulation prior to membrane filtration is used to transform the dispersed particles and other inorganic and/or organic water contaminants in stable suspension into a preferable form for retention, aimed at minimizing particulate and NOM fouling. The intended presentation talks on the background, idea, methods used and results of experiments on the fouling characteristics of different membrane configurations and that of the NOM-fractions as well as the optimisation of the coupling of coagulation+membrane processes to reduce NOM fouling. Out-In membranes with different pore sizes and material composition supplied by the German company Puron AG are used for the experiments. They are all made of standard PES and mixture of PES and another polymer, with pore sizes ranging from MF to UF. Bulk surface water from a reservoir at Roetgen, near Aachen, which is supposed to have a relatively high organic content is to be used as the model water. Ground waters from deep-well filtration, which are normally particle-free and those containing high NOM are also considered as alternative model waters. The laboratory setup used for the coagulation+membrane filtration experiments is a simple modified "jar-test" apparatus, with three feed-tanks followed by a membrane that could be used to test different coagulation and filtration conditions.

Key words: Fouling Minimization, NOM, Model Solutions, Membrane Capillaries, Hybrid Coagulation-UF/MF process

I. INTRORDUCTION

Studies on NOM fouling of UF/MF membrane processes, operated both in in-out and out-in modes, are based on earlier studies by Lerch et. al. and Panglisch et. al., and experiments in a project on fouling minimisation studies using single membrane capillaries.

II. OBJECTIVES

Objectives of this study are to find solutions to minimise the problem of NOM fouling. The focus is on studying the fouling characteristics of organic/inorganic substances present in surface waters. This can be done by characterising the more fouling-causing components in water, and then to find ways by which such components can either be removed or modified to minimise fouling. Characterising the more fouling-causing components can be done by two different ways – (1) by using single or mixture of model solutions, representing physical/chemical characters of real NOM/Humics in surface waters, (2) by starting with sample surface waters and gradually extracting the different components in steps to find out the more fouling-causing component(s).

III. INSIGHT INTO FOULING OF POLYMERIC MEMBRANES BY NATURAL ORGANIC MATTER

Fouling of polymeric membranes used for water treatment is a major blockade that stands in the way of this technology becoming more widely used and more economic. Among the fouling mechanisms, pore blocking is thought to be more irreversible. Use of delivered DOC/TOC (DOCd/TOCd) instead of time, while plotting flux or permeability curves, is recommended, in order to accommodate the differences in the initial pure water permeability of different membrane samples. Among the different components of NOM, the macromolecular portion consists of polysaccharides and proteins, while the organic colloidal portion consists of peptidoglycans and aminosugars.

A negative membrane surface charge is said to reduce UF fouling, while in low pressure membrane processes, MF is more fouling than UF. Among the membrane properties influencing fouling, membrane surface roughness plays a greater role than hydrophobicity. High fouling waters are characterised by,

- Low SUVA
- High hydrophilicity, and
- High molecular weight

The colloidal proportion of NOM are said to be more problematic in MF fouling. Humic substances are believed to lie in the size range of 1000-2000Da. In the absence of Ca2+ ions and conditions that don't favour aggregation at the concentration polarization zone, humic substances are said to cause no major fouling. Among the various analytical techniques available, FT-IR and SEM/SEC are more revealing in the case of fouling phenomena.

Organic matter seems to play probably a minor role in NF/RO fouling. Impressive program are available these days for analysing organic compounds in different natural waters. Work on water quality parameters that predict reliably the rate of fouling of MF/UF and NF/RO, due to organic matter; seem to be missing out in depth.

Fouling problems related to proteins are due to its precipitation, aggregation and adsorption. Cellulose acetate membranes exhibit a negative surface charge in the pH range of 4-12 and positive between 1-4. While using hybrid coagulation + UF/MF systems, the coagulation/flocculation time should be long enough to prevent any floc formation inside the pores. One fundamental way to control fouling is by increasing mass transfer. Air-sparging (air-liquid two phase flow) decreases concentration polarisation.

IV. MATERIALS & METHODS

We use "single" membrane capillary test units (both in-out and out-in) for our studies. The units can be fully automatically controlled and operated, with data processing and retrieval through adaptable and programmable tools. Backwashing and chemical cleaning possibilities (can also be automated) are the key features. The units are well suited to test a variety of natural and model waters, UF/MF membrane capillaries of different material composition, pore size and porosity, and different operating modes like constant feed pressure, constant flux, dead-end and cross-flow. The in-out systems are currently being used for studies on fouling minimization through coupling of coagulation step prior to membrane filtration, and the out-in system (shown in Figure 1) is used for NOM fouling studies using natural and model waters.

The key to our approach on NOM fouling studies is an understanding on the interactions

(1) between the different organic components in water and the membrane surface/pores,

(2) between the organic and inorganic groups in water

(3) the combined effect of such interactions on the membrane performance.

Two-phase flow in UF/MF capillary systems is very promising in controlling membrane fouling. Higher fluxes, controlled concentration polarization and scaling can be achieved by using two-phase flow in capillary NF systems. Cost of introducing air-sparging/flushing is less when compared to that of increasing the fluid cross-flow velocity. A group in Holland is believed to have developed a method to measure the streaming potential of capillaries. Its recommended to use a back wash velocity that is twice that of permeation velocity.

It's recommended to maintain constant ionic strength and pH conditions during the fractionation of NOM. In the study of NOM fouling, filtration through XAD 4 – XAD 8 resins prior to UF is a potential tool to predict fouling due to different types of organic compounds. NOM fouling is a greater problem in low pressure membranes (UF/MF) than high pressure membranes (NF/RO).

NOM measurement and characterization can be done by measuring,

- DOC,
- UVA254, SUVA (=UVA254/DOC),
- Molecular weight distribution by size exclusion chromatography (SEC),
- Polarity measurements using XAD-4/8 resin adsorption chromatography,
- Fluorescence excitation-emission matrix (EEM),
- Infrared spectroscopy (FT-IR)
- Pyrolysis gas chromatography/mass spectroscopy (P-GC/MS)

V. RESULTS

Results from many experiments show that coagulation prior to membrane filtration is a good alternative process for the direct treatment of surface waters, using UF/MF membranes, for the production of drinking water. It also gives the impression that the presence or addition of inorganic particulate matter in the feed water minimizes NOM fouling considerably (as shown in Figure 1 and 2).

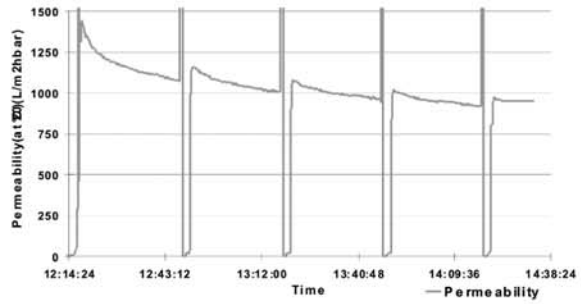

Fig. 1. OUT-IN MF of 2mg/ l DOC at 55l / m2h for about 2h

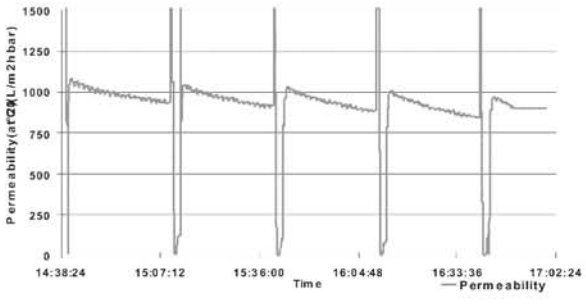

Fig. 2. OUT-IN MF of 2mg /l DOC + 500mg / l silica particles at 55l/m2h for about 2h

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