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New prototype pre-filter for seawater RO
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Summary

A simple testing procedure is presented to evaluate performance of particle filtration. The test method applies to a newly developed cross-flow filter for prefiltration of seawater ahead of RO membranes in spiralwound configuration.

Contents

1 Introduction

Pre-treatment ahead of seawater reverse osmosis (SWRO) aims at providing a stable feed water quality that allows continuous operation of the membrane unit at a stable flux. Depending on seawater characteristics, RO productivity may decline due to various fouling mechanisms:

- *Adsorptive fouling*. Organic matter may adsorb to the membrane surface or within the pores and reduce permeability. The characteristics of organic materials that determine their relative propensity to foul a membrane include their affinity for the membrane, molecular weight, functionality and conformation.
- *Colloidal fouling*. Particles in the colloidal range (operationally defined between 5 nm and 1 µm) are transported towards the membrane by the permeation drag. Such particles will deposit on the membrane if the permeation drag force exceeds all back transport forces due to Brownian diffusion, shear-induced diffusion, and inertial lift. Particles in the range of 0.1-3 µm have the lowest back transport velocities and thus are prone to foul the membrane.
- *Biological fouling (biofouling)*. Microorganisms may actively colonize the membrane surface and form a biofilm that imparts a resistance to filtration. Bacteria accumulate on surfaces by adhesion and growth and feed on easily assimilable organics. Extracellular polymeric substances (EPS) excreted by the cells have been found to contribute to the fouling layer. Although more prevalent in freshwater systems, biofouling may also occur in RO desalination plants.
- *Precipitative fouling (scaling)*. Precipitation or scale formation on the membrane occurs when solubility limits of salts are exceeded on the feed side. Concentration of scale forming species is most critical in the concentration polarization layer.

Prefiltration aims primarily at reducing the load of particulate and colloidal matter to the RO spirals, which may clog spacer channels. Biofouling can be reduced to some extent depending on the method used.

Several methods have been developed to assess fouling potential for a given raw water, including silt density index (SDI), modified fouling index based on UF membranes (MFI-UF), and direct particle analysis. Some of these methods will be used for monitoring the performance of the filter with respect to fouling potential in the pilot-scale experiments.

In the development phase of the new prefilter, a simple screening technique is required to estimate filtrate quality and detect internal leakages in the filter unit before incorporating it in the pilot plant.

2 Screening technique

The technique described in the following represents a simple integrity test of the filter unit to detect internal leakages.

2.1 Model particle suspensions

A model particle suspension is prepared containing particles that are slightly larger than the nominal cut-off of the screening material (filter cloth). Tests with Bentonite and Kaolinite suspensions proved unsuccessful due to the large amount of submicron particles. To reduce the influence of submicron particles a (nearly) isodisperse particle suspension was prepared from 4-µm acrylate particles (obtained from SINTEF Materials and Chemistry). Fig. 1 shows the particle size distributions of this suspension. The number percentage distribution reveals to principal peaks at about 1 µm and 4 µm, respectively, which coincide with the volume percentage distribution. Some larger particles are detected in the higher particle size range, which may have been caused by insufficient disaggregation. Isodispersity not a requirement for the test suspension as long as the particle size is larger than the nominal mesh opening of the screening material.

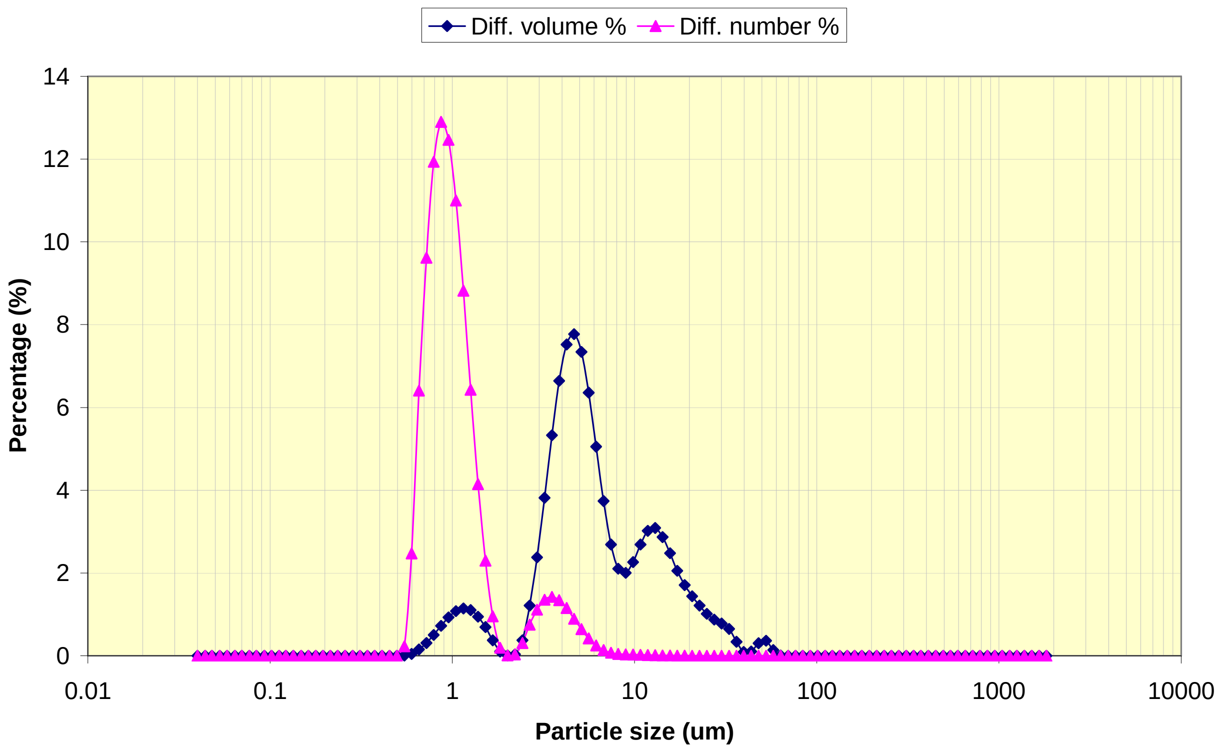

Fig. 1. Particle size distributions of 4-µm arcrylate suspension, expressed as differential volume and number percentage, respectively.

2.2 Dead-end filtration

For later comparison with the filter unit, the theoretical filtrate quality is assessed by simple dead-end filtration using the same filtration apparatus as for determining suspended solids (Fig. 2). All glassware is washed thoroughly before use to avoid contamination of the filtrate. Instead of a membrane disc, the apparatus is fitted with an unused sample of the respective filter cloth to be tested. The cloth is wetted by filtering small batches of distilled water through it. Excess water is expelled from the system.

A 100-mL sample volume is filtered at low suction pressure. Larger filtrate volumes may lead to increased cake filtration, particularly at high particle concentration, and may thus overestimate filtration performance. The filtrate is withdrawn from the filtration flask and analysed for turbidity, evt. other suitable parameters.

Figure 2. Filtration apparatus (Photo: Millipore)

2.3 Experimental setup

The inlets and outlets of the filter unit are fitted with hand valves and connected to a small circulation pump and a small water reservoir. The filter unit is operated in total-recycle-mode (Fig. 2) at low cross-flow velocities without flow or pressure monitoring. Samples are withdrawn from the filtrate line and analyzed for turbidity.

The same setup may be used to obtain actual filtrate quality and performance figures. In this case, however, the flow through the filter unit must be monitored with respect to cross-flow velocity and flux.

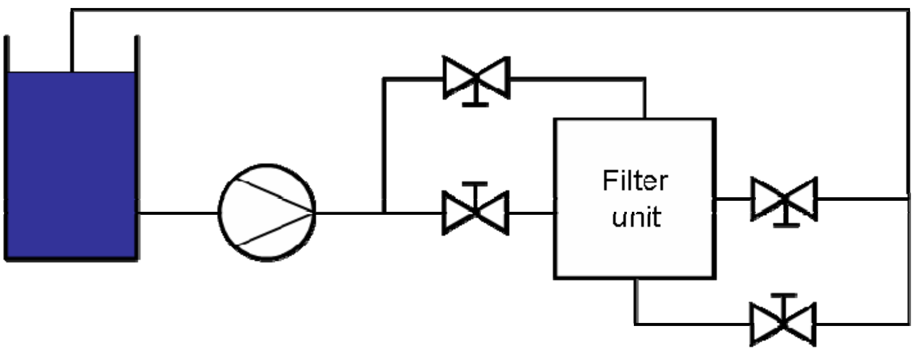

Fig. 3. Test loop (total-recycle mode)

3 Example of results

3.1 Theoretical filtrate quality

The theoretical retention of acrylate particles was assessed using the dead-end filtration equipment as described in the section 2.3. Two suspensions with different particle concentrations were filter through 4 different filter media. The average particle retention in terms of turbidity is given in Tab. 1.

Both needle felt cloths allowed a significant particle passage, even the tighter one. However, ripening effects are significant with needle felt cloth and were not assessed. The relatively high filtrate turbidity value obtained at with the 3-um felt at lower raw water turbidity may be attributed to high filtration velocities as these were not controlled during the batch tests. Filtration using the screening fabric 1 resulted in the same filtrate quality (0.35 NTU) for both raw water concentrations, which was close to tap water turbidity. Hence, this fabric removed practically all particles. The filtrate quality obtained with the screening fabric 2 was poorer and particle passage was evident for both raw water concentrations.

Tab. 1. Assessment of theoretical filtrate quality according to section 2.2

#	Filter medium	Filtrate turbidity (NTU)	Filtrate turbidity (NTU)
	None (raw water)	72.5	6.7
1	5 um needle felt	33.5	1.7
2	3 um needle felt	7.4	2.4
3	Screening fabric 1	0.35	0.34
4	Screening fabric 2	1.76	1.40

3.2 Particle retention of filter unit

A volume of approximately 4 L of the isodisperse acrylate suspension with a concentration of 0.2 g/L was pumped through the system shown in Fig. 3. The particle concentration in the holding tank was relatively unstable and decreased from an initial 29 NTU to about 11 NTU due to particle deposition in the feed channel. Particle retention averaged at 32 ± 5%, i.e. significantly lower than the values obtained in dead-end filtration. This result can only be explained by internal leakages of feed into filtrate.