Micro- and Ultra-Filtration as a Pretreatment for Reverse Osmosis Plants: Summary of Test Results and Comparative Analysis

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Abstract

The MF and UF membrane pilot installations were tested in a regime of prolonged operation as a pretreatment alternative to sand filtration for RO plants. Both MF and UF installations, being mobile units, demonstrated a good potential for an autonomous prolonged operation. This justifies a MF/UF application to RO pretreatment in future plants.

The effect of feed flow variability slows down the rate of membrane fouling. This effect promises 10-13% enhancement of flux permeate and prolongation of operation within commercially justified parametric range of at least by 30%, comparing to that done with constant feed flow rate. This was confirmed both by literature data and by tests reported herein.

1. Introduction

Currently desalination is focusing on RO technology, implying a stage of pretreatment that is known as one of the most important issues. Fouling of the membranes of the RO plant is undesirable and cleaning is harmful to the membranes and should be done as little as possible.

The conventional pretreatment for RO plants based on sand filters gives good results for the low contaminated seawater. On the other hand, the conventional pretreatment is known as rather cumbersome one. This might result in the variability of the filtrate quality, causing the membrane fouling.

Using MF and UF membranes as an alternative for conventional RO pretreatment could save, in principle, the large area of the sand filters and the chemicals required for pretreatment. The other benefits are:

- better feed quality to the RO section which should elongate lifetime and improve performance of the RO membranes
- reduction of biological fouling which will improve the performance of the RO section
- for highly contaminated feed sea water, sand filtration is not sufficient and better pretreatment is required.

The current paper summarizes results of test programs related to MF and UF pilot units. These activities were carried out since September 1999 to November 2001.

2. Previous Work

Previous activities might be classified according to the chronological order:

Year 1999

- Literature survey on micro- and ultra-filtration [1].

- Design and mounting of the MF and UF pilot installation [2] in cooperation with the Technion Chemical Engineering Department.

Year 2000

- Carrying-out of MF tests performed on the base of the K00320 Memtec micro compact filtration unit [3,4]. The seawater was delivered to facilities of the Technion Chemical Engineering Department.

- The literature review on seawater contamination effect on membrane operation [5].

- Carrying-out of UF tests performed on the base of the 13PE Stork membrane module on boat "Tirza" at Ashkelon [6].

- Mounting of the new test site at the Hadera. Delivering of the MF and UF pilot installations to the new test site. Start of MF and UF comparative tests. Start of the resistor controlled cathodic protection (RCP) tests.

Year 2001

- Reporting on the first results of MF and UF tests performed at Hadera [7]

- Reporting on the corrosion tests of the stainless steel protected by RCP method [8]

- Continuation of MF and UF tests at Hadera and reporting [9]

- Literature survey on improvement of MF and UF performance [10]

2. Objective of the Research

The objective was defined as evaluation of the following operating characteristics of the MF and UF pilot installations:

- Permeate flux and quality

- Backwash interval and duration

- Trans-membrane pressure (TMP) and feed flow rate

- Kind of coagulant and dosing

- Chlorine dosing at backwash and cross flow prior to backwash

- Feed flow rate variability

Long-term duration of the tests was caused by the objective to prolong operating time interval between procedures of chemical cleaning of membranes.

3. Experimental

3.1 Description of the Experimental Equipment

Testing was performed on the base of the following equipment:

a) MF installation: K00320 Memtec micro compact filtration unit: area=4m^2; mean pore size=0.2µ.

b) UF installation: 13PE UF Stork membrane modules: area=2.1 m^2 or 3.6 m^2, depending on the fiber diameter of 1.5 mm or 0.7 mm, respectively; mean pore size=0.01µ.

The principle flow diagrams of the UF installation are shown in Figure 1.

3.2 Experimental Procedure

The following measurements were performed in order to evaluate operating parameters:

a) Filtration mode:

Permeate flow rate

Pressure drops in the feed, permeate and concentrate lines

Temperature in the feed line

Rate of pulsating feed flow

Flow rate of coagulant dosing

b) Backwash mode:

Backwash flow rate and pressure drop

Flow rate of chlorine dosing

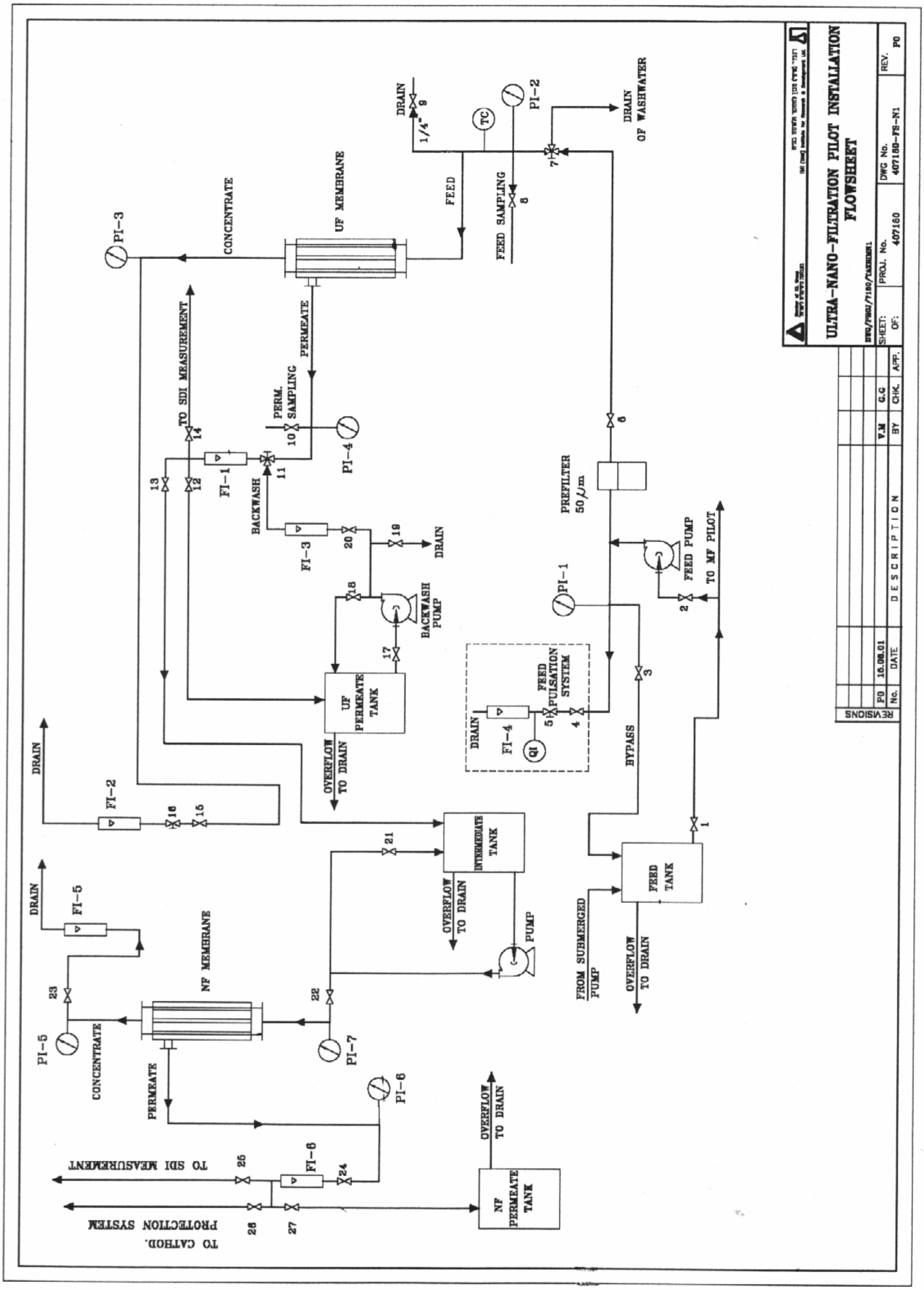


Figure 1. Flow sheet of the mobile UF pilot installation.

3.3 Analytical Methods

Evaluation of the permeate quality was performed on the following base:

a) Standard SDI measurement procedure evaluating an amount of solid particles

b) Reduction of amount of microorganisms in permeate, comparing to that in feed. This estimate was done by the following means:

- "Hy-labs" sticks sampled from permeate and feed lines. This gave a first indication of the amount of microorganisms.

- Direct microbiological counting performed periodically. This confirmed the indications made when using sticks.

4. Operating Conditions

4.1 Boat "Tirza" off shore Ashkelon coast

Feed:	sea water
Location:	opposite the port entrance at Ashkelon power station vicinity
Distance from the coast:	around 300 m
Sea depth:	11 m
Intake depth:	6 m
Feed temperature:	30-33°C
TMP:	0.6-1 bar
Backwash interval:	30 min
Backwash duration:	2 min
Operation mode:	dead end

4.2 Hadera site

Feed:	sea water
Location:	North of Hadera power station site
Distance from the coast line:	around 4 m
Sea depth:	2-3 m
Intake depth:	1.5 m
Feed temperature:	23-29°C
TMP:	0.1-1 bar and 0.1-1.5 bar for MF and UF, respectively
Backwash interval:	30 min
Backwash duration:	2 min
Operation mode:	dead end

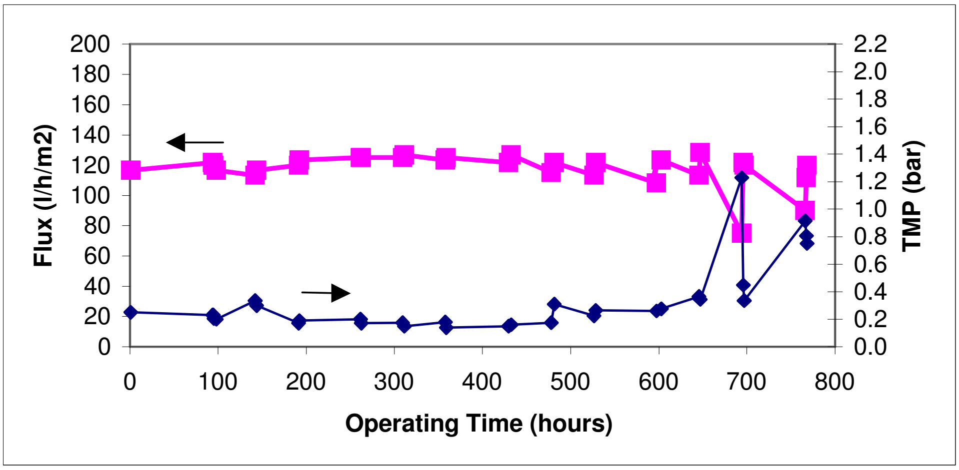
5. Main Results

a) The following effects were studied:

- efficiency of backwash procedure
- effect of cross flow
- effect of coagulant dosing
- effect of feed flow rate variability.

ii) The operating parameters of the MF and UF installations (3 kinds of membranes) were measured under various real conditions during the prolonged operation (up to 960 hours/run, see Figure 2):

- the potential to prolong a continuos commercially justified operation (J_v=80-120 l/h/m^2; TMP=0.1-1.2 bar) was demonstrated
- the SDI values were measured within the range of 1.5-2.5
- amount of microorganisms in permeate was kept 10^{1-2} cfu/ml for all tests
- a base for a comparative analysis of MF and UF pretreatment to a conventional pretreatment was obtained



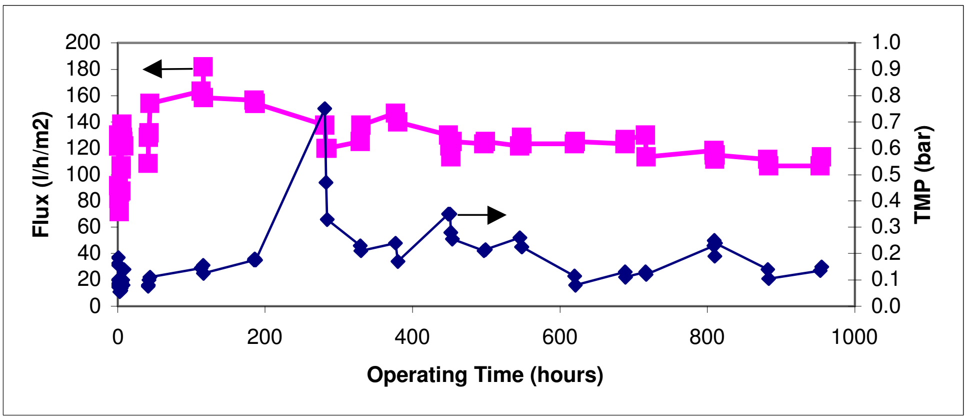


Figure 2. Examples of UF prolonged tests performed under pulsating feed flow rate.

6. Feed Flow Rate Variability

First information regarding the positive effect of feed flow rate variability was obtained from the paper [11]. Being considered in literature review [1], this material was served as a basis for the first MF tests done at the Technion [4]. That testing confirmed the positive role of the feed flow rate variability. In parallel, the rational to increase the frequency of pulses from 1 to 10 per second has been demonstrated.

Further to paper [11], papers [12,13] confirmed the flux improvement due to feed flow rate variability realized in a form of liquid pulses or by application of various electromagnetic field (EMF) devices [14,15]. The flow rate variability causes a higher diffusion of the solute away from the membrane surface. The diffusion reduces the amount of solids (for MF/UF) or salt concentration (for RO) near the membrane wall, comparing to that in the bulk of the liquid. Indirectly, this was confirmed also due to wide implementation of various energy recovery devices [16-18], applying liquid pulses on RO membranes due to pressure recovery operation.

In view of the above, both test the UF and MF installations [2,19] were equipped by an appropriate Electro-mechanical device developed by *Mr. E. Dafny* of IMI. This device developed frequent pulses of 0.1 second period. The amplitude of the pulsating component was adjusted manually and was chosen up to 25-30% of the average feed flow rate. Due to hydraulic reasons, a location of this device was chosen rather remote from the membrane module (around 1-1.5 m).

Therefore, due to the hydraulic resistance of the piping configuration, the feed pressure drop was observed being pulsated under low amplitude of 1-2% and with the given frequency. This ensured that the mechanical damage to membrane will be avoided. To confirm the membrane integrity, periodical appropriate tests recommended by manufacturers of membranes have been carried out.

To estimate the effect of the feed flow rate variability, prolonged MF and UF tests [9] have been performed with variable feed flow rate. The results were compared to those obtained under similar conditions but with a constant feed rate [7,9]. The commercial justified duration of the tests (the operations under commercial values of flux permeate and TMP without stops for chemical cleaning) was studied.

It was demonstrated (both for MF and UF membranes [9]) that with a variable feed flow rate the operation within commercially justified parametric range is longer at least by 30%, comparing to that done with constant feed flow rate. Actually the effect of feed flow rate variability slows down the rate of membrane fouling.

This result corresponds to that of paper [11], mentioning that a variable feed flow rate results in a longer time (by 30-40%) before reaching a limiting TMP. As it was also mentioned [11], to restore the membrane performance, the constant feed flow rate operation requires a more frequent chemical cleaning, in comparison to the variable one. Similar results were obtained in papers [12,13], reporting on flux improvement by 10-13% due to effect of variable feed flow rate. A positive role of feed flow rate variability was confirmed also in papers [20-23]. A similar positive effect, based on vibrating technology, was reported in the paper [24].

7. Conclusions.

1. The MF and UF membrane pilot installations were tested in a regime of prolonged operation as a pretreatment alternative to sand filtration for RO plants. Both MF and UF installations, being mobile units, demonstrated a good potential for an autonomous prolonged operation. This enabled to conclude the reasoning of MF/UF application to RO pretreatment in future plants.

2. The effect of feed flow variability slows down the rate of membrane fouling. This effect promises 10-13% enhancement of flux permeate and prolongation of operation within commercially justified parametric range of at least by 30%, comparing to that done with constant feed flow rate. This was confirmed both by literature data and by these experiments.

3. The next step implies discussion regarding combined implementation of effects mentioned in this work and in accordance to the plans of IDE applications in view of the forthcoming desalination and wastewater recovery plant tenders.

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