

Membrane fouling and chemical cleaning in three full-scale reverse osmosis plants producing demineralized water

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## Supplementary data S1 – RO plant design and pre-treatment

### Location I (Sas van Gent, The Netherlands):

The plant (Figure S1.1) produces demineralized water, with conductivity less than  $10 \mu\text{S cm}^{-1}$ , from secondary wastewater effluent from the food industry. First, the secondary wastewater effluent is pre-treated with coagulation, flocculation, sedimentation process with ferric chloride ( $\text{FeCl}_3$ ) ( $2.5 \text{ mg L}^{-1}$ ), prior to ultrafiltration (UF). Hydrochloric acid (HCl) (pH 7.2) and antiscalant (Genesys LF) ( $1.78 \text{ mg L}^{-1} - 3.68 \text{ mg L}^{-1}$ ) are dosed to the UF permeate to prevent scaling in the RO membrane elements. Between the first and second stage of the RO membrane system, the water is degassed.

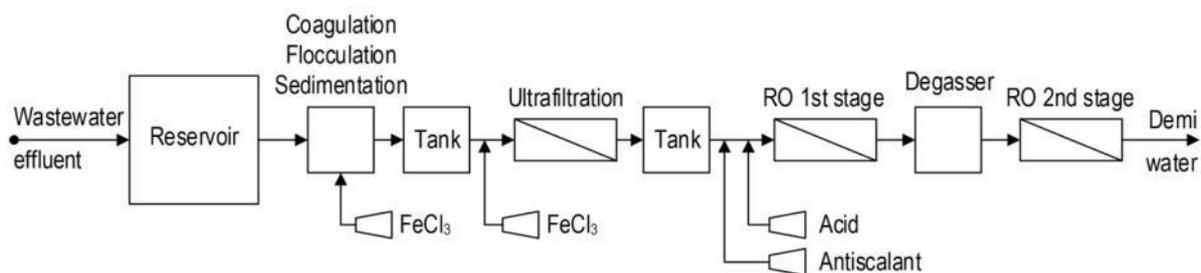


FIGURE S1.1: Schematic representation of RO plant location I (Sas van Gent, The Netherlands).

### Location II (Dordrecht, The Netherlands):

The plant (Figure S1.2) produces demineralized water, with conductivity less than  $0.2 \mu\text{S cm}^{-1}$ , from river water. First, river water is pumped through a 100 micron strainer, then ferric chloride ( $\text{FeCl}_3$ ) ( $1 \text{ mg L}^{-1}$ ) coagulant is dosed before UF. Antiscalant (PermaTreat® PC-191T) ( $1.5 \text{ mg L}^{-1}$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ) (pH 7.5) is dosed to the UF permeate in order to prevent scaling in the RO membrane elements. RO permeate is then degassed and fed to a mixed-bed ion exchanger.

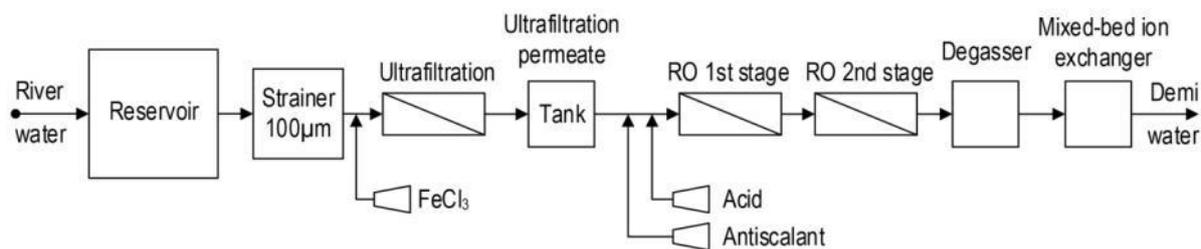


FIGURE S1.2: Schematic representation of RO plant location II (Dordrecht, The Netherlands).

**Location III** (Veendam, The Netherlands):

The plant (Figure S1.3) produces demineralized water from surface water (channel water). First river water is pumped through a coarse screen, and is then is pre-treated with coagulation, flocculation, sedimentation process with ferric chloride ( $\text{FeCl}_3$ ) ( $18 - 28 \text{ mg L}^{-1}$ ), prior to UF. The UF permeate then passes the two stage RO system before degasification.

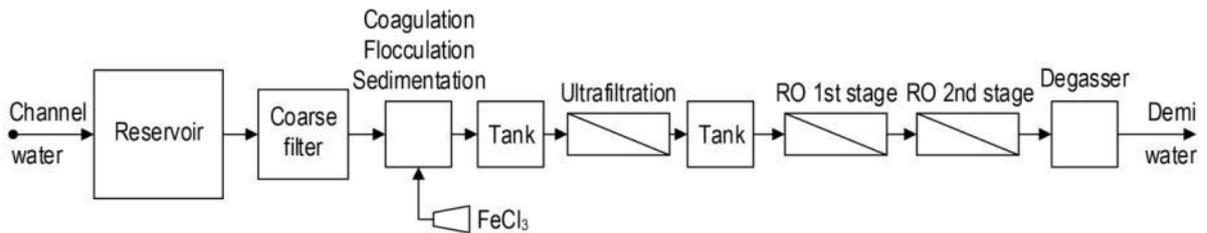


FIGURE S1.3: Schematic representation of RO plant location III (Veendam, The Netherlands).

**Supplementary data S2 – Schematic representation of high-pressure setup for cleaning studies and cleaning setup**

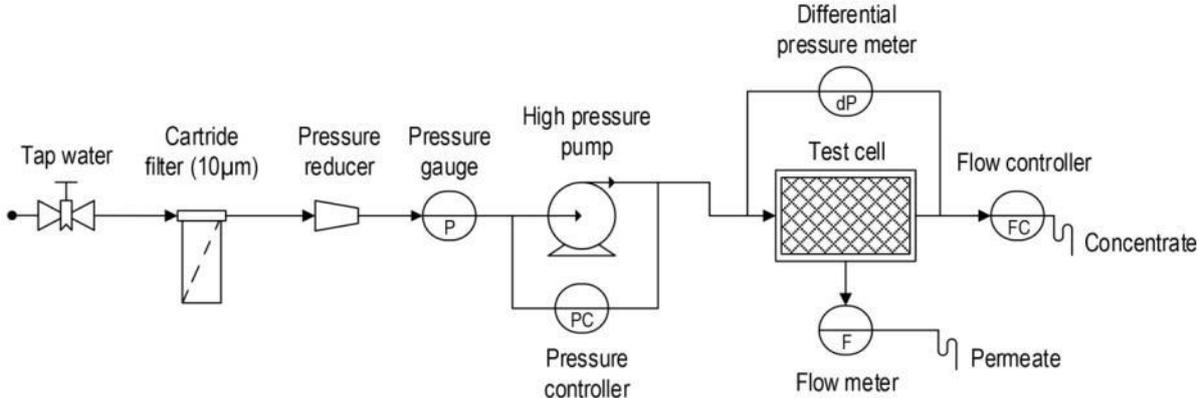


FIGURE S2.1: Schematic representation of high-pressure setup for cleaning studies.

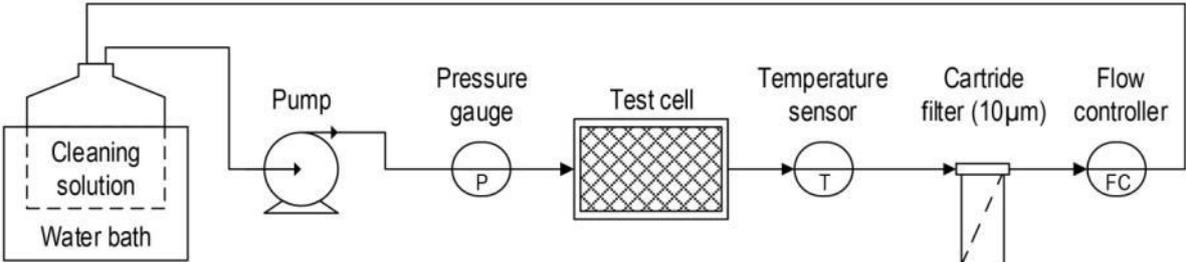
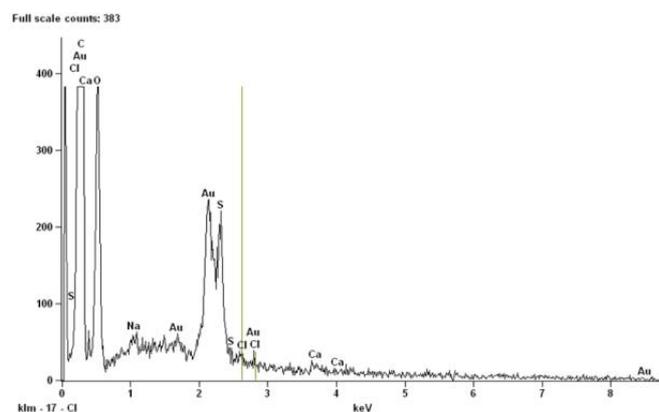


FIGURE S2.2: Schematic representation of chemical cleaning setup for cleaning studies.

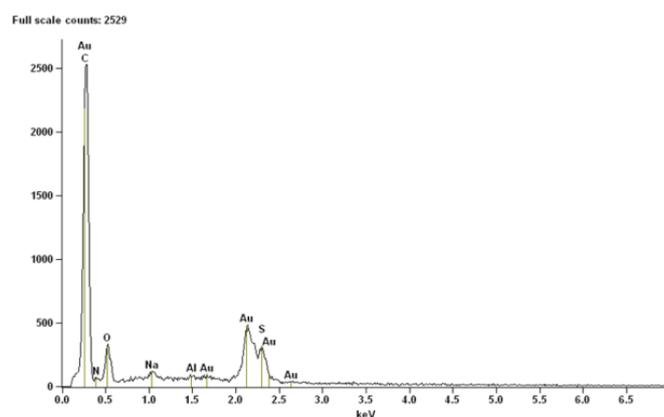
## Supplementary data S3 – Energy dispersive X-Ray spectroscopy (EDS) spectra and related elemental analysis

### Location I (*Sas van Gent, The Netherlands*):



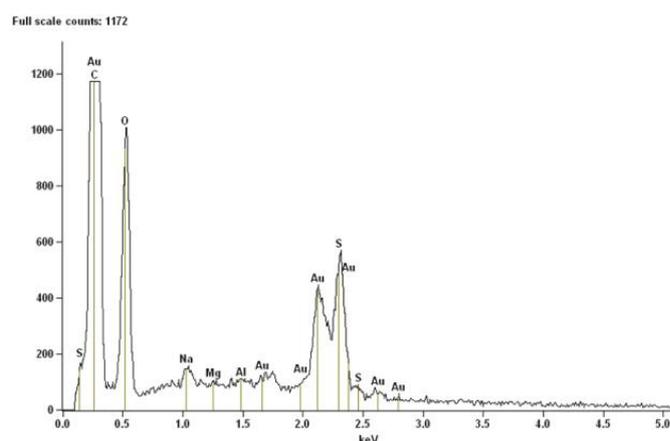
Element	Net	Weight %	Atom %
Line	Counts		
C K	10531	51.3	70.17
O K	2323	24	24.65
Na K	130	0.37	0.27
S K	1827	5.79	2.97
S L	0	---	---
Cl K	126	0.51	0.24
Cl L	0	---	---
Ca K	100	0.66	0.27
Ca L	0	---	---
Au L	6	---	---
Au M	3022	17.36	1.45
Total		100	100

### Location II (*Dordrecht, The Netherlands*):



Element	Net	Weight %	Atom %
Line	Counts		
C K	14989	53.84	78.89
N K	0	0	0
O K	1719	13.28	14.61
Na K	381	0.75	0.58
Al K	185	0.3	0.19
S K	2780	6.27	3.44
S L	775	---	---
Au L	4	---	---
Au M	6443	25.55	2.28
Total		100	100

### Location III (*Veendam, The Netherlands*):



Element	Net	Weight %	Atom %
Line	Counts		
C K	19856	55.38	71.69
O K	3980	24.26	23.58
Na K	323	0.54	0.37
Mg K	0	0	0
Al K	169	0.23	0.13
S K	3602	6.61	3.21
S L	771	---	---
Au L	1	---	---
Au M	3838	12.98	1.02
Total		100	100

FIGURE S3: Selected EDS spectra and elemental analysis of the location I (*Sas van Gent, The Netherlands*), location II (*Dordrecht, The Netherlands*) and location III (*Veendam, The Netherlands*) during autopsies of the full-scale membrane elements (before chemical cleaning in the laboratory cleaning setup). The spectra presented were selected from multiple spectra per element ( $\geq 5$ ). The trends observed during multiple measurements are discussed in the manuscript.

## Supplementary data S4 – Operational and cleaning limitations of the membranes used in this study

TABLE S4: Operational and cleaning limitations of the membrane elements used in the three RO locations investigated in this study. FCP = feed-channel pressure drop.

DOW FILMTEC™ LE-440i and BW30XFR-400/34i	
Operational limits	
Max temperature	45 °C <sup>a</sup>
Max. working pressure	41 bar
Max. FCP (single element)	1 bar
Max. FCP (multielement vessel)	3.4 bar
pH Range (continuous)	2 - 11
pH Range (CIP, max. 30min)	1 - 13
Free chlorine tolerance	< 0.1 ppm

<sup>a</sup>) Max. temperature above pH 10 is 35°C for continuous operation