1-step RO

Controlling RO fouling after minimal pretreatment

Emile Cornelissen, Bastiaan Blankert, Danny Harmsen, Peter Wessels en Walter van der Meer

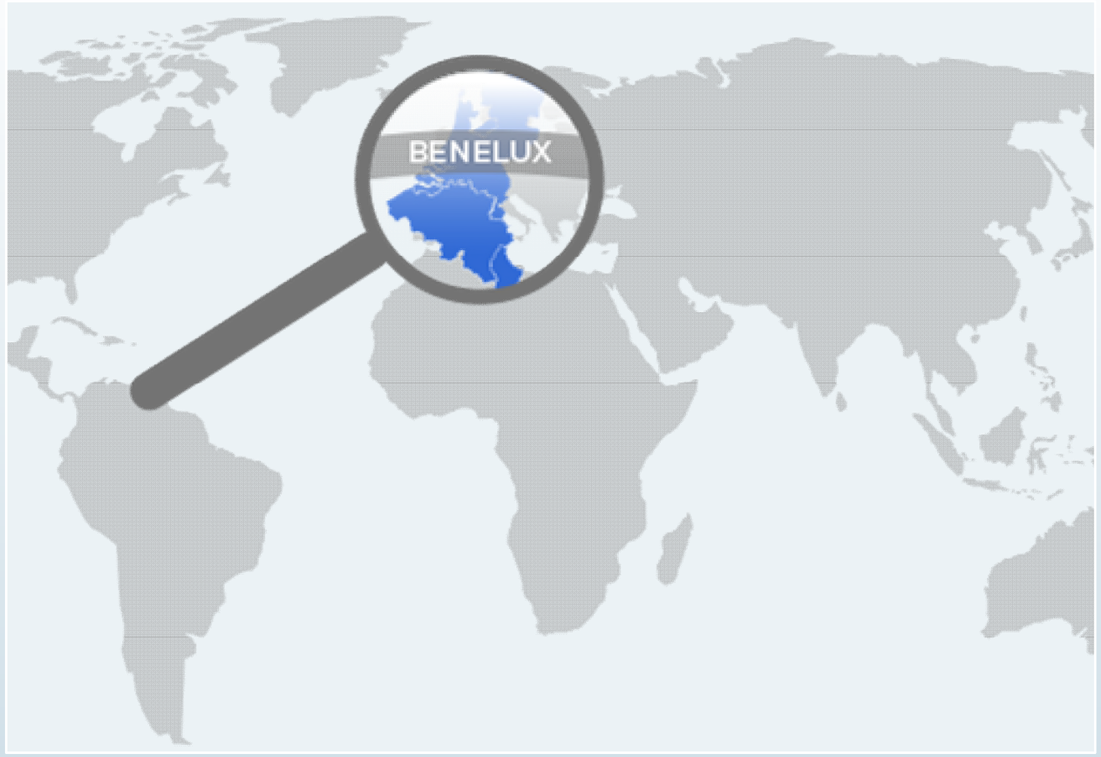
11th International Symposium on Water Supply Technology, 9-11th July, Yokohama, Japan

KWR Watercycle Research Institute
GHENT UNIVERSITY

Introduction

Where are the Low Lands ?

BELGIUM AND THE NETHERLANDS

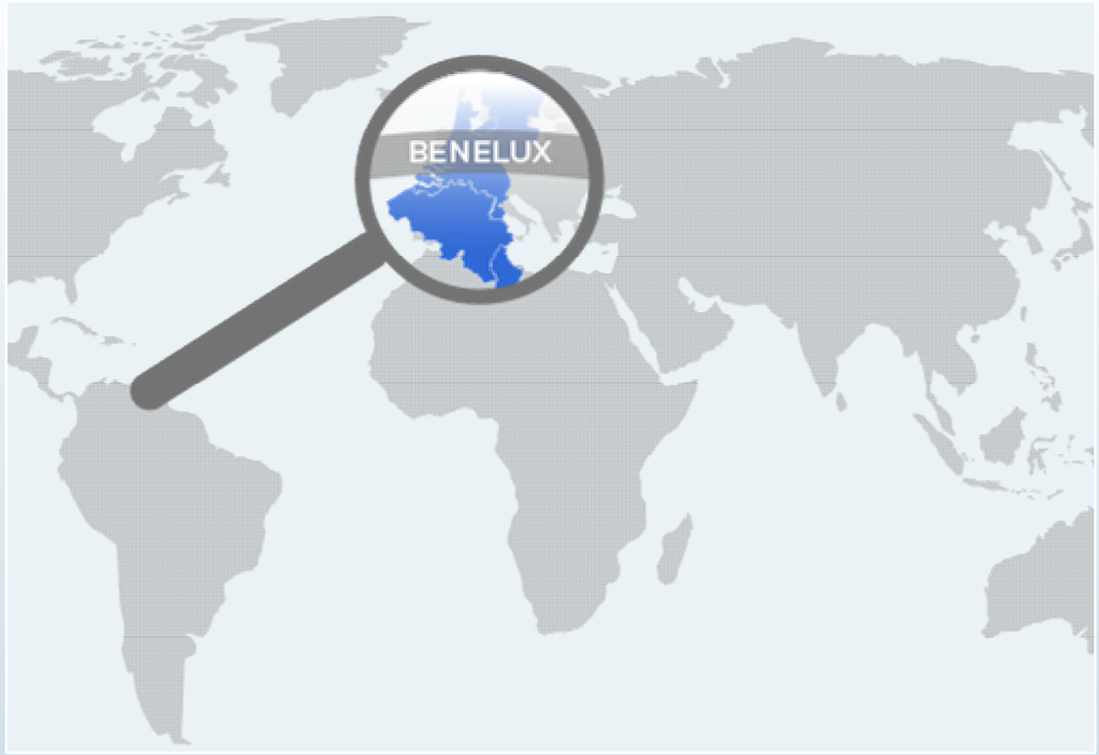


GHENT AND NIEUWEGEIN

Introduction

Where are the Low Lands ?

BELGIUM AND THE NETHERLANDS

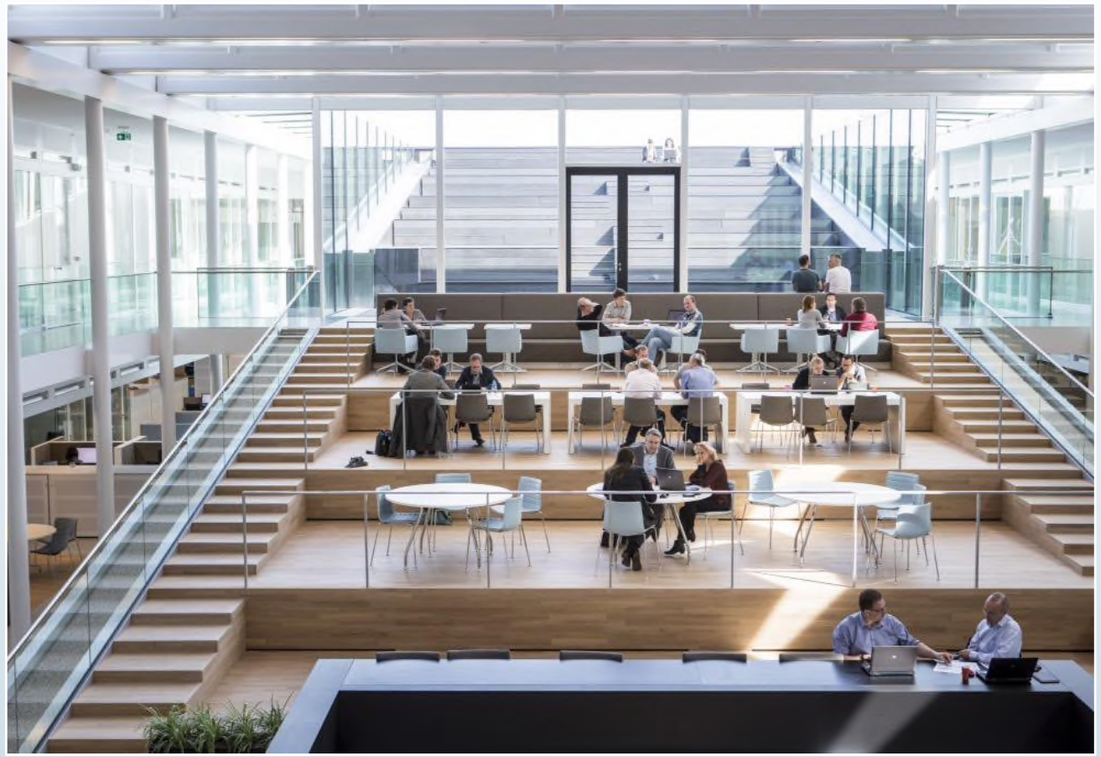


GHENT AND NIEUWEGEIN

Introduction

Two buildings – One mission

KWR – NIEUWEGEIN (THE NETHERLANDS)



GHENT UNIVERSITY – GHENT (BELGIUM)

Introduction
Some figures

KWR – Nieuwegein (the Netherlands) (60%)

- Water Research Institute

180 employees

- 3 departments → Water Systems & Technology
- 12 in drinking water treatment group

Ghent University – Ghent (Belgium) (40%)

- Ranked 61st (Shanghai Ranking Index)

44 k students and 9k staff

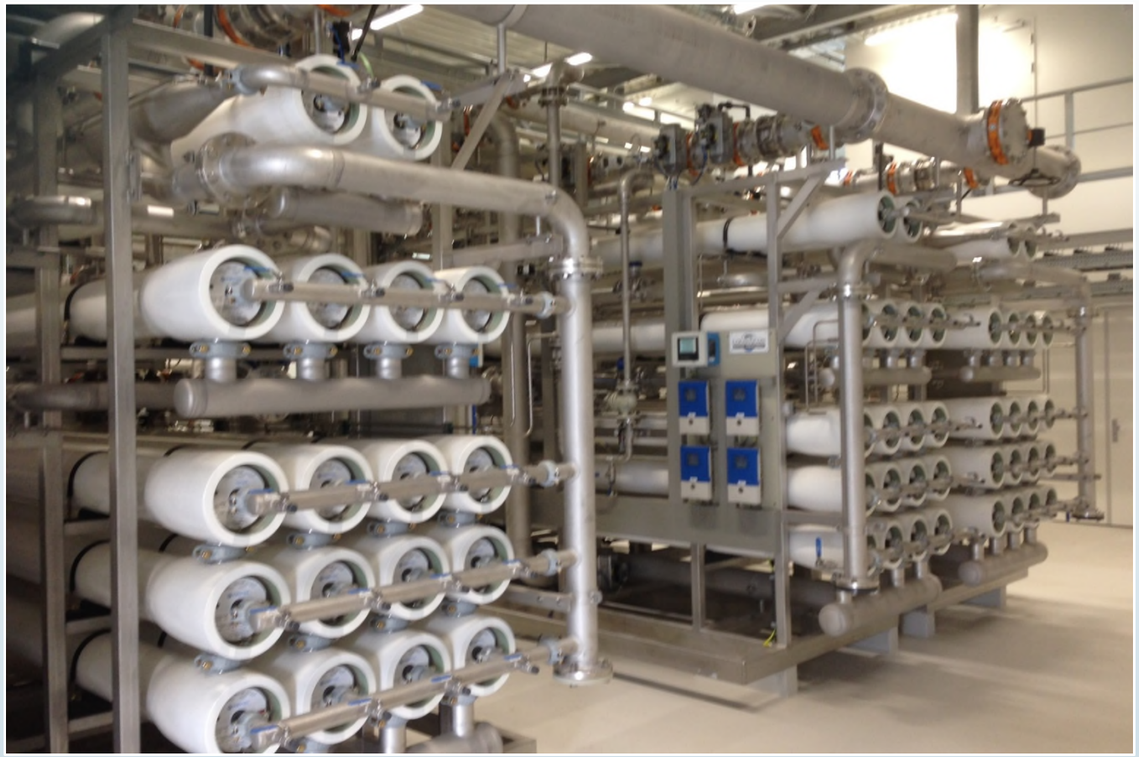
- 11 Faculties → Bioengineering
- 40 in Particle and Interfacial Technology Group

Bridging Science to Practice

Background
Reverse Osmosis

A robust barrier

- Pathogens removal
- Rejection of salts (incl. softening)
- Rejection of organic micro-pollutants
- Biological stable permeate water
- Rejection of particles



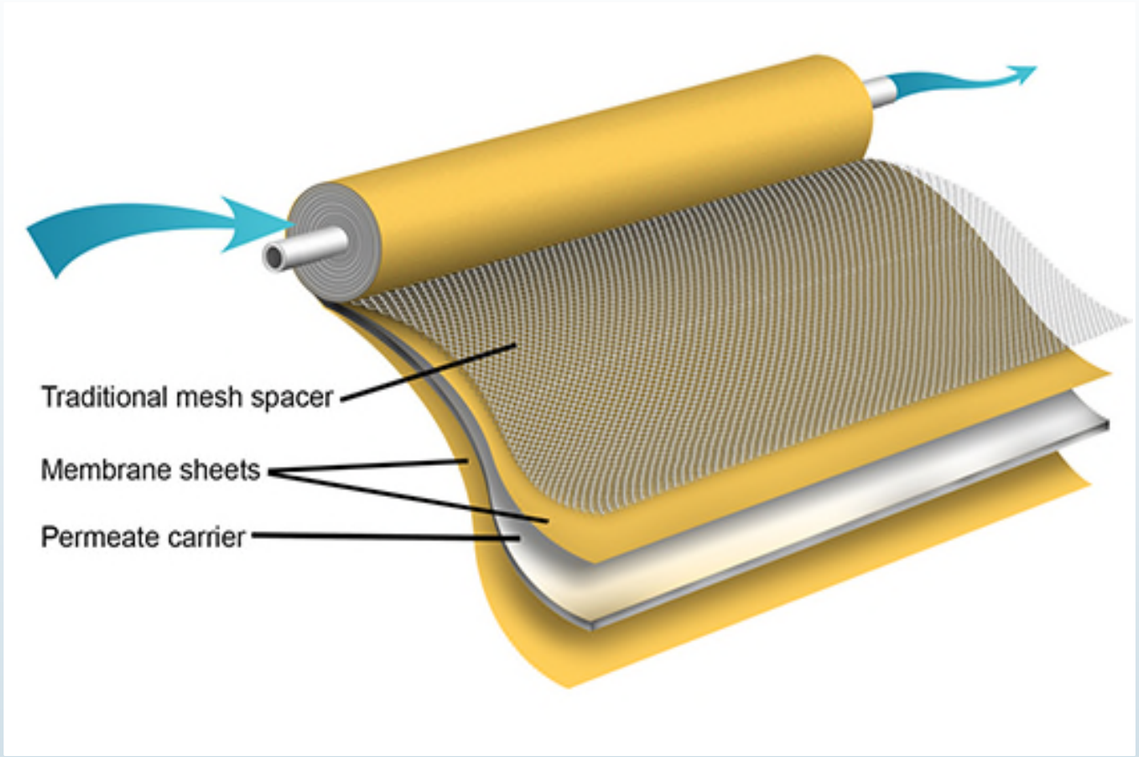
RO ON RIVERBANK FILTRATE AT OASEN

oaseo drinkwater

Background
Reverse Osmosis

A robust barrier

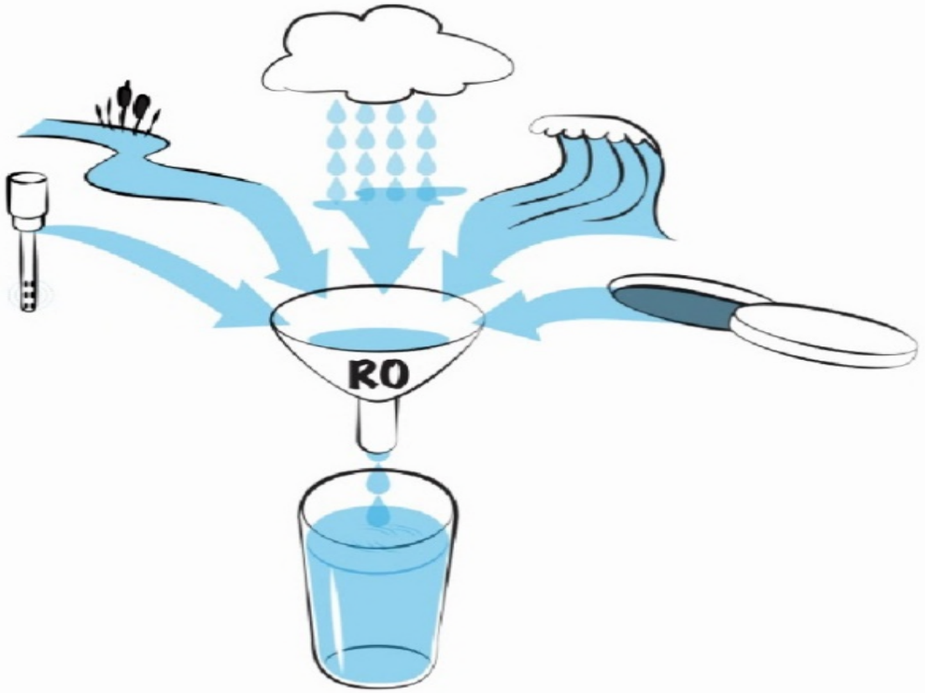
- **Pathogens removal**
- **Rejection of salts (incl. softening)**
- **Rejection of organic micro-pollutants**
- **Biological stable permeate water**
- **Rejection of particles**



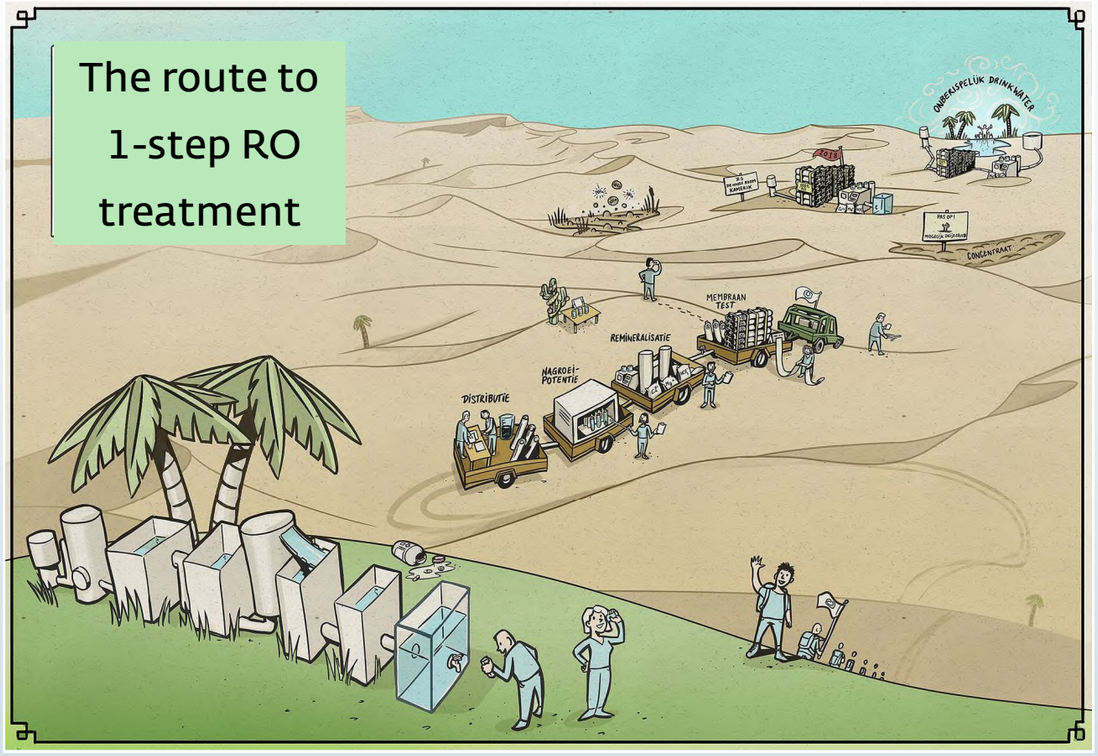
SPIRAL WOUND MEMBRANE MODULE

Background
Reverse Osmosis

MULTI SOURCE



1-STEP RO



Background & aim

Many questions

- Re-mineralization permeate
- Biological stability
- Rejection organic micro-pollutants
- Pathogen removal
- Membrane integrity

Focus today on

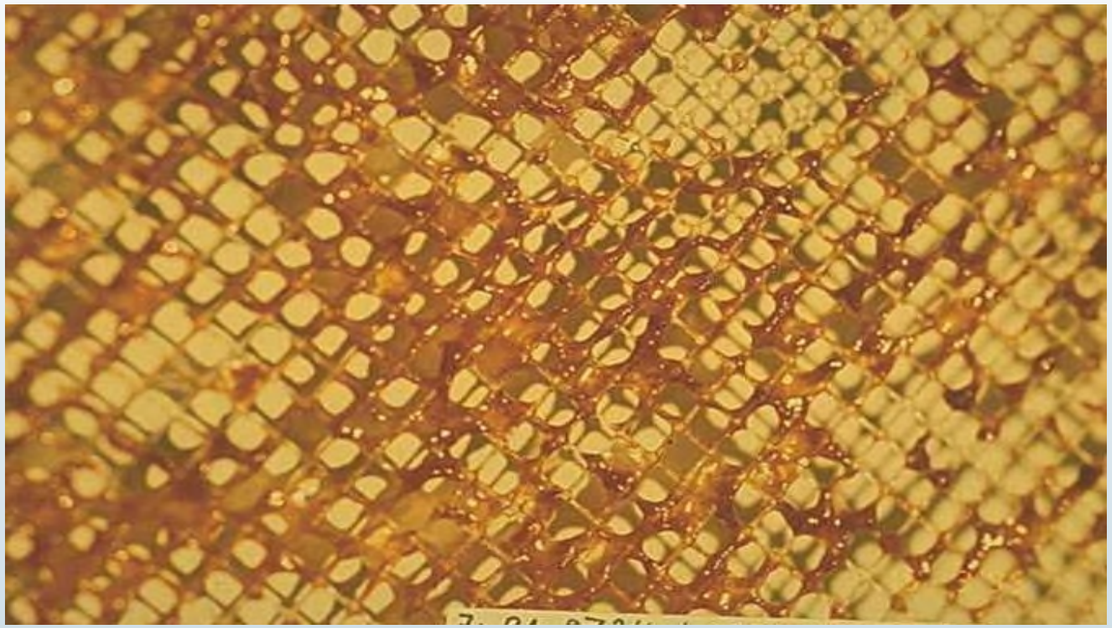
- **(Minimal) pre-treatment**
- **Control membrane fouling**
- **Technical economic evaluation**

RE-MINERALIZATION

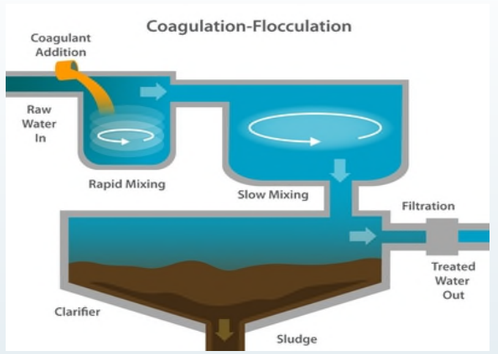
Background & aim

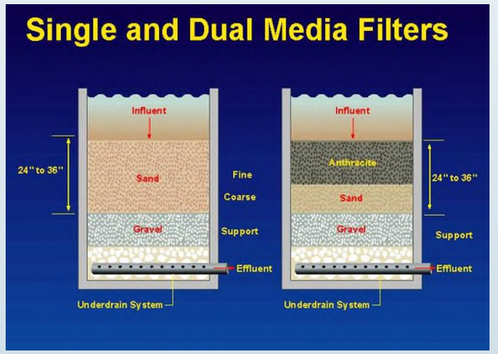
Fouling and pre-treatment

Example of spacer clogging



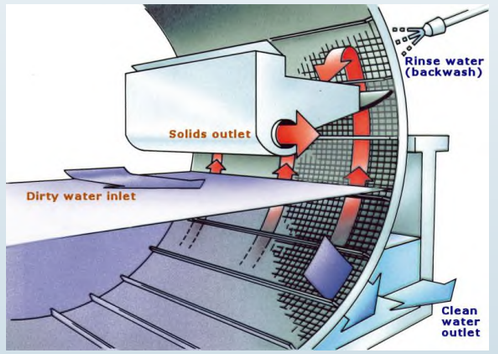
COAG./FLOC./SED.





SAND FILTRATION

ULTRAFILTRATION



(MICRO) SIEVES

Materials and methods

Source water

Dissolved organic carbon : 6.1 mg-C/l

Predominantly humic acids : 65-75%

Biopolymers : 13% of 0.7 mg-C/l

Seasonal variations (March-November)

LOCALLY AVAILABLE LAKE WATER

Materials and methods

Pre-treatment

ULTRAFILTRATION PENTAIR XIGA-46 (AFTER 250 UM)

25UM SCREEN FILTRATION (AFTER 250 UM)

Materials and methods

Reverse Osmosis

Six 2,5-inch ESPA2 SWM elements

- **Ultrafiltration (2) & screens (4)**
- **With (3) & without (3) air/water cleaning[1]**
- **High (4) & low (2) flux[2]**

Focusing on:

- **Fouling resistance increase (fouling)**
- **Pressure drop increase (clogging)**

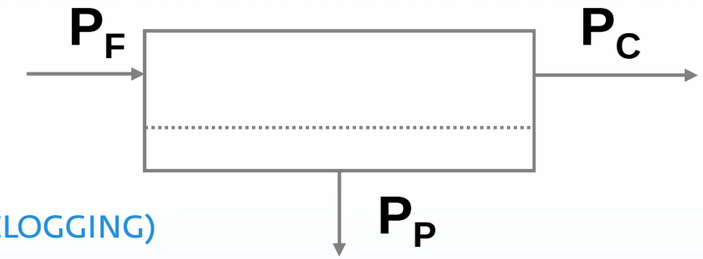
[1] Daily 5 min @ air/water ratio = 4:1

[2] Respectively 25 LMH and 10 LMH

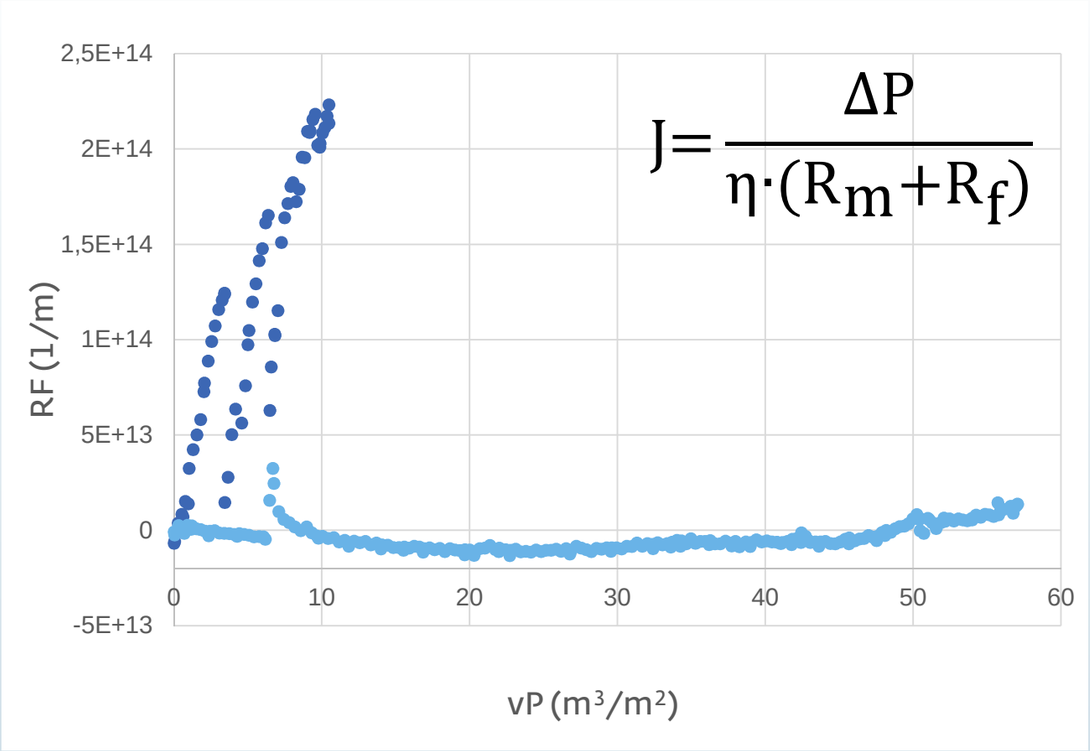
RO SET-UP WITH 6 PARALLEL ELEMENTS

Results

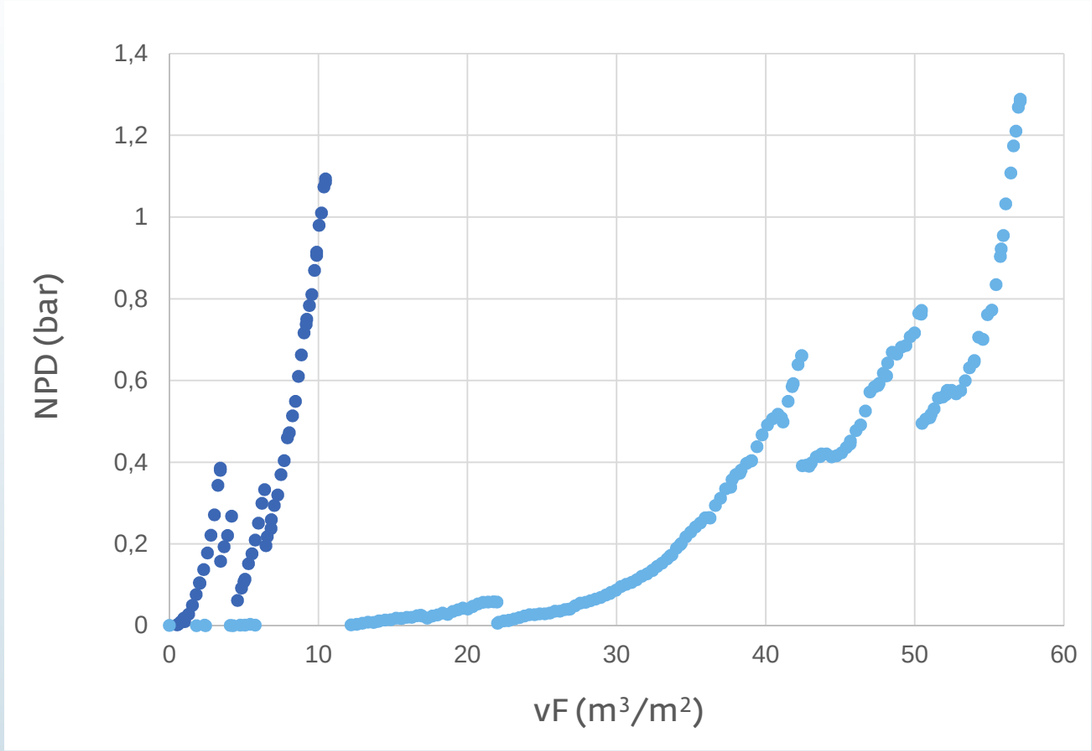
Effect of pre-treatment (UF versus screen)



FOULING RESISTANCE



PRESSURE DROP (CLOGGING)

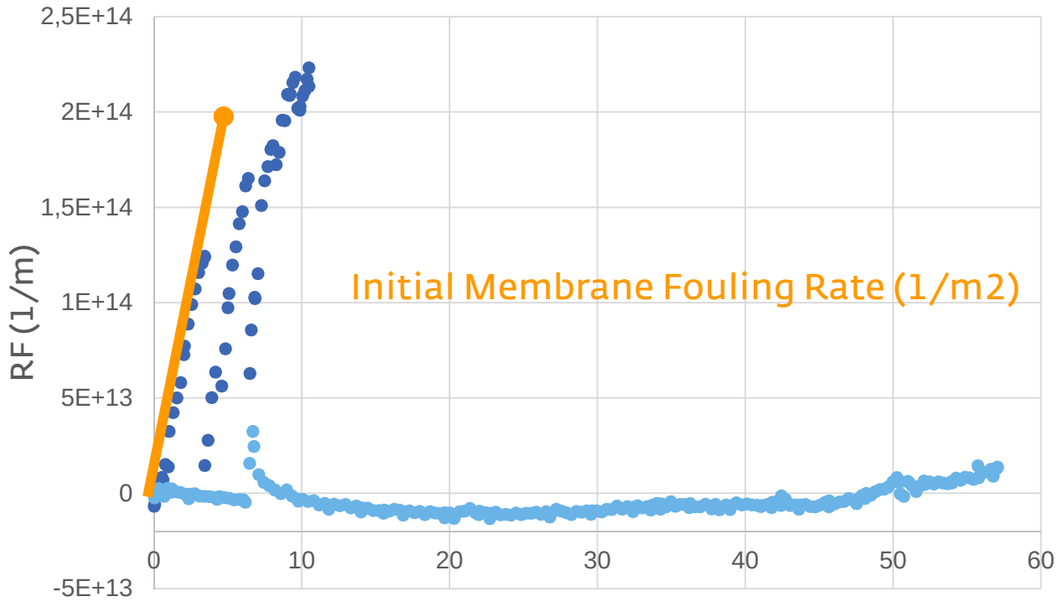


UF operated at 20 LMH

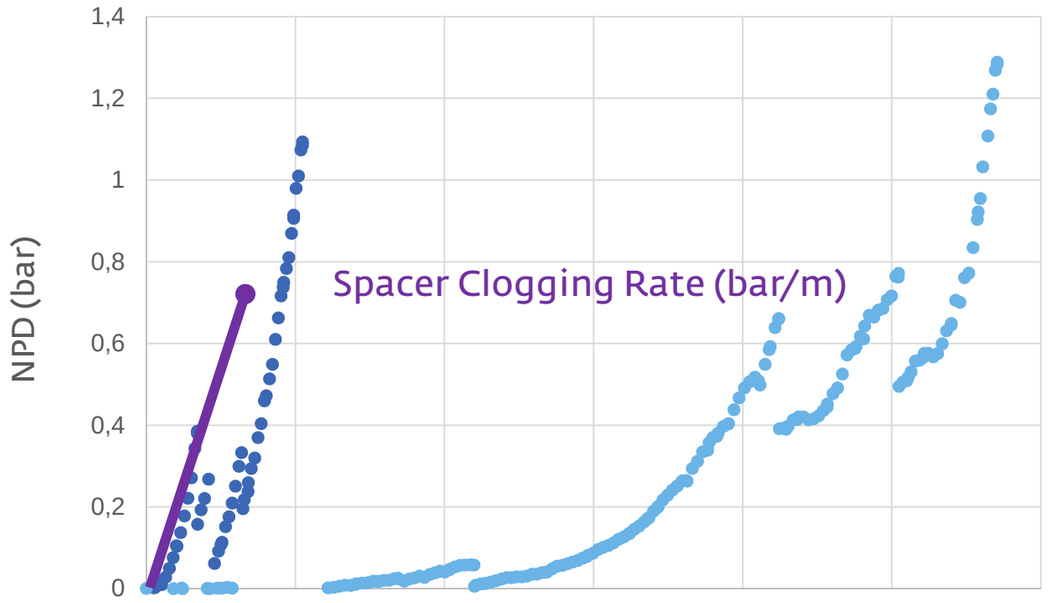
Results

Effect of pre-treatment (UF versus screen)

FOULING RESISTANCE



PRESSURE DROP (CLOGGING)



Results

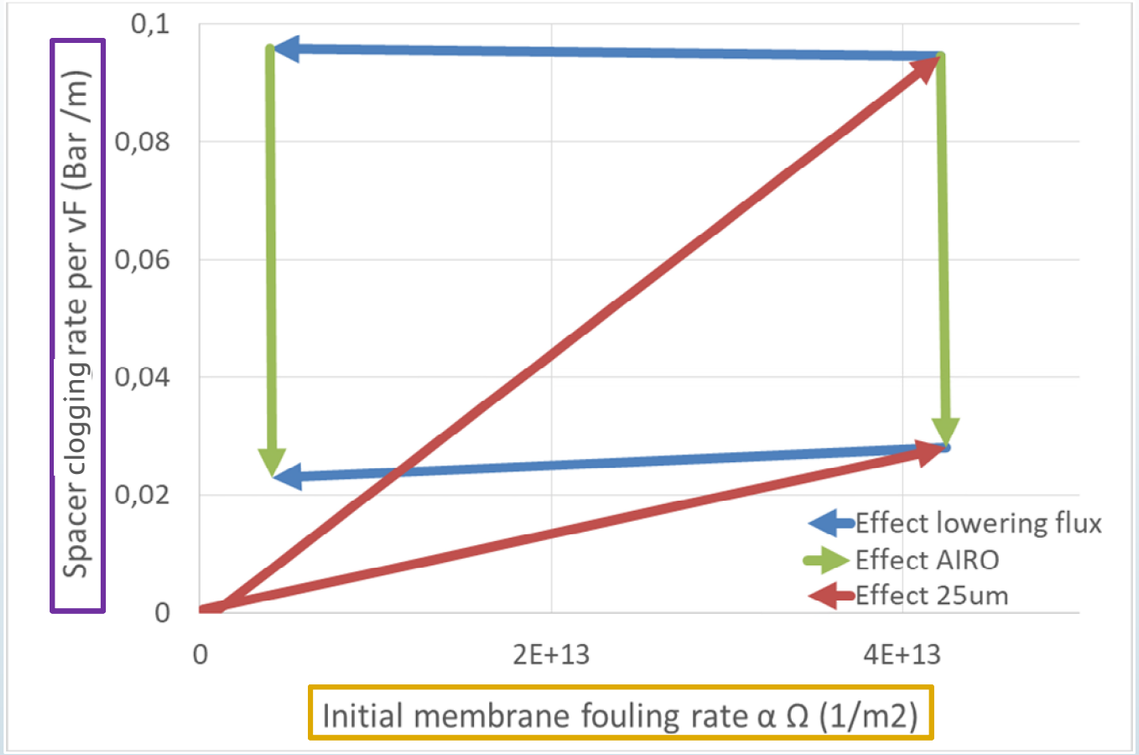
Effect of pre-treatment, air/water cleaning and flux

Initial UF operation at 0

Substantial fouling and clogging after screen

Air/water cleaning only impacts clogging

Flux only impacts fouling



IMPACT FOULING AND CLOGGING

Business Case 1-step RO

ULTRAFILTRATION

REVERSE OSMOSE

Two scenario's

1. Ultrafiltration followed by RO_{25} (state-of-the art)
2. Screens followed by RO (1-step RO_{10})

Aim

Determine technical economic feasibility 1-step RO scenario

Business Case 1-step RO

Approach

Excel spreadsheet cost calculations (± 30%) for the 2 scenario's

RHDHV cost calculation (for small projects)

- **From 2000**
- **Indexation over 15 year : 1,5% averaged**
- **Installations with a capacity of approx. < 200 m^3/h**
- **Industrial installations (skids construction costs)**

SCREENS FOR RO PRETREATMENT

COSTS ?

Business Case 1-step RO

Assumptions design

Ultrafiltration (state of the art scenario)

- Flux 60 LMH @ 0,5 bar
- 85% recovery (backwash losses)
- 20 mg/L chemicals (NaOH, NaOCl,…)

Reverse Osmosis

- Flux 25 LMH @ 12 bar (UF-RO scenario)
- Flux 10 LMH @ 8 bar (1-step RO scenario)
- 75% recovery
- 5x chemicals in 1-step scenario

PILOT TRIALS USING SWM ELEMENTS (2016)

Business Case 1-step RO

Assumptions financial

RHDHV cost calculations

- **Interest 3% within 20 year**
- **Depreciation installation & membranes respectively 20 & 6 years**
- **Investment factor (building, services)**

- **UF cost = 60 €/m²**
- **RO cost = 15 €/m²**
- **Energy = 0,08 €/kWh**
- **Chemical cost = 0,002 €/ (mg/L)**

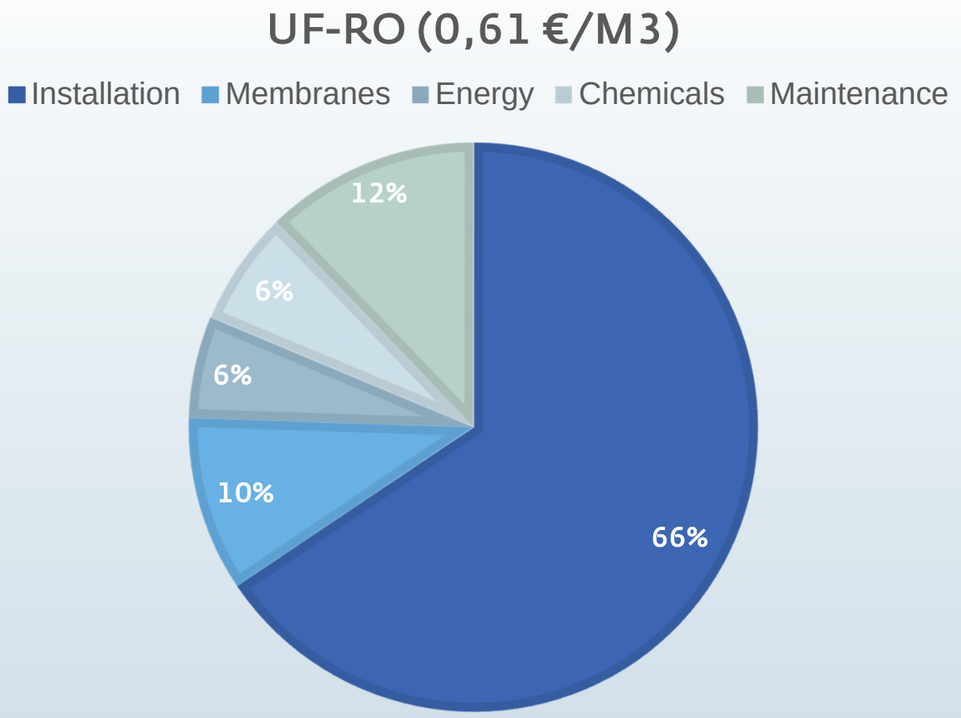
Kleinschalige kostenberekening										
Naam	Emile Cornelissen									
Datum	2-feb-17									
Capaciteit	150	m3/h	876000	m3/jaar	Investeringsfactor		1,6	klein (1,6x) - groot (2x)		
					Rente installatie		3%			
					Afschr.duur installatie		20	jaar		
					Afschr.duur membranen		6	jaar		
					UF kost		60	€/m2		
RO flux	10	LMH			RO kost		15	€/m2		
RO recovery	75%				Energiekost		0,08	€/kWh		
RO druk	8	bar			Chemiekost		0,002	€/ mg/L		
RO chemie	25	mg/L			Onderhoud		2%			

					Afschrijving					
	Capaciteit	Membraan	Bouwkosten	Investering	Installatie	Membranen	Energie	Chemicaliën	Onderhoud	
	[m3/h]	[m2]	[€]	[€]	[€/jaar]	[€/jaar]	[€/jaar]	[€/jaar]	[€/jaar]	
Screen	200	-	€ 27.000	€ 43.200	€ 2.904	€ -	€ 701	€ -	€ 540	
RO	150	15000	€ 2.520.000	€ 4.032.000	€ 271.014	€ 41.534	€ 19.467	€ 43.800	€ 50.400	
Screen					€ 0,003	€ -	€ 0,001	€ -	€ 0,001	€ 0,005
RO					€ 0,309	€ 0,047	€ 0,022	€ 0,050	€ 0,058	€ 0,487
				TOTAAL	€ 0,313	€ 0,047	€ 0,023	€ 0,050	€ 0,058	€ 0,491

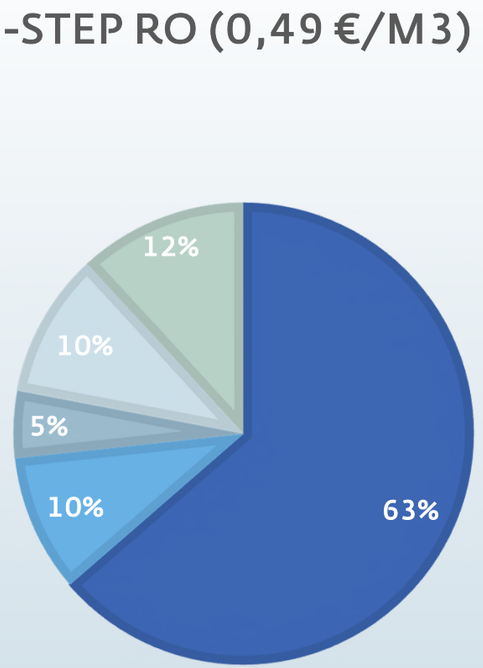
SPREADSHEET COST CALCULATIONS RHDHV (1-STEP RO)

Business Case 1-step RO

CAPEX/OPEX UF-RO (STATE OF THE ART)

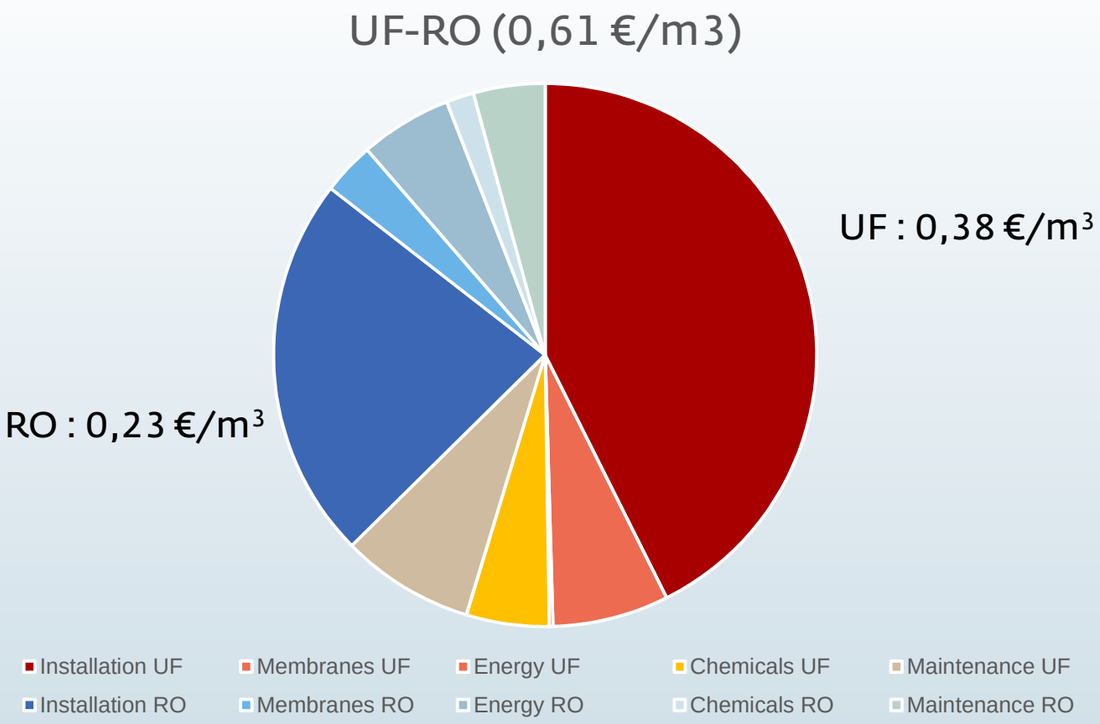


CAPEX/OPEX SCREENS-RO (1-STEP RO)

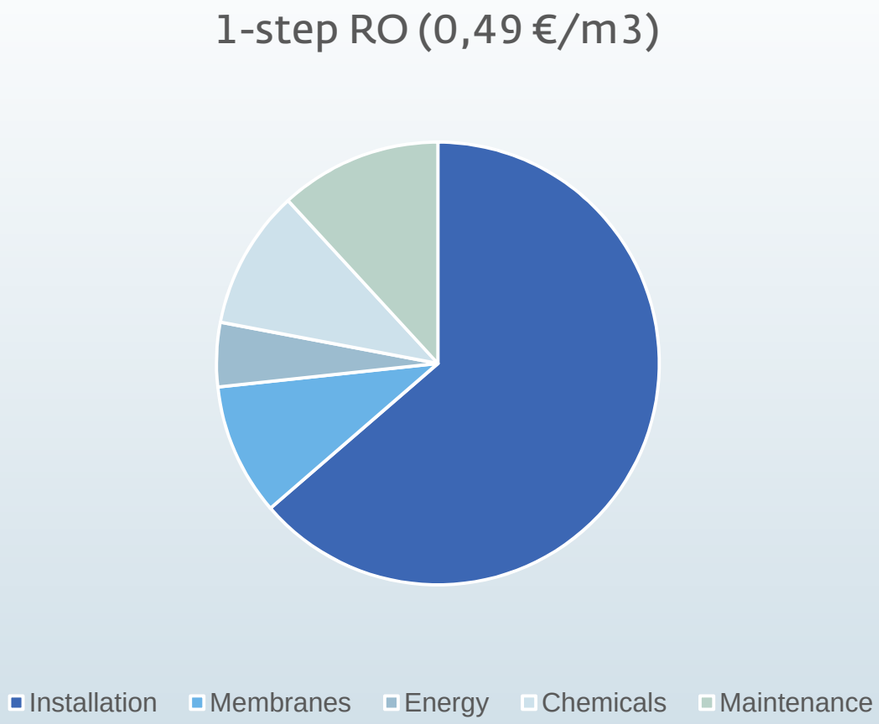


Business Case 1-step RO

CAPEX/OPEX UF-RO (STATE OF THE ART)



CAPEX/OPEX SCREENS-RO (1-STEP RO)



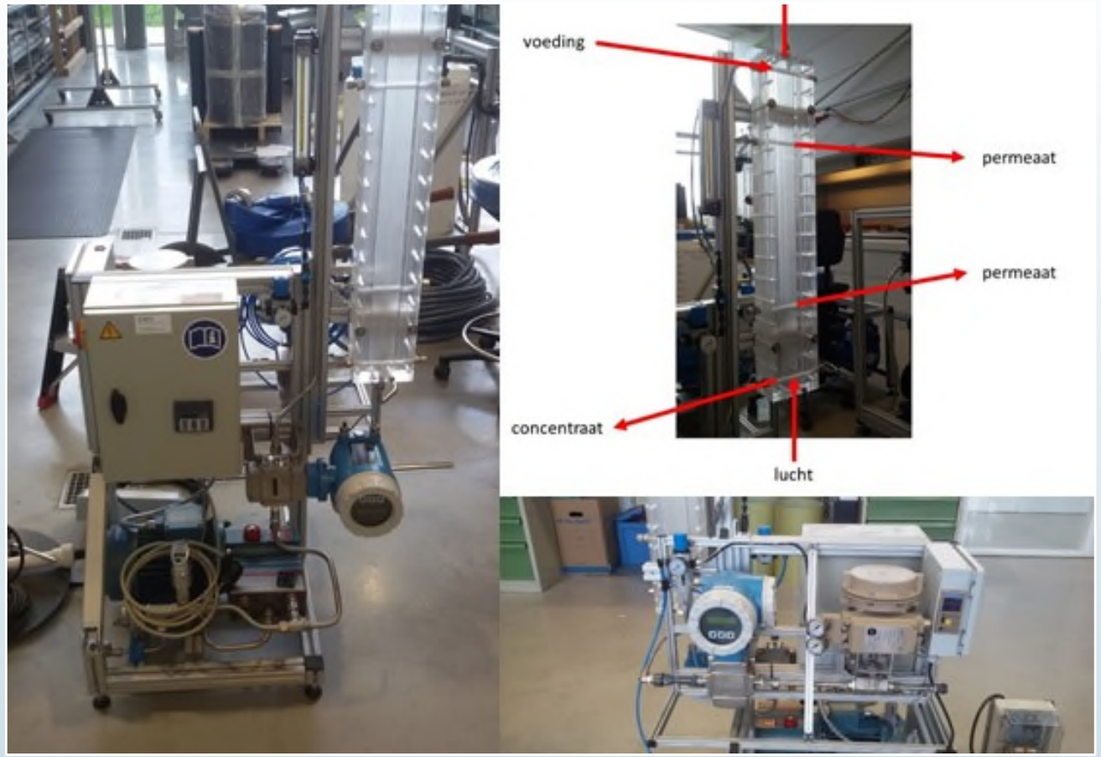
1-step RO

Innovative RO concepts

Innovative RO concepts

Photo's of the test set-up

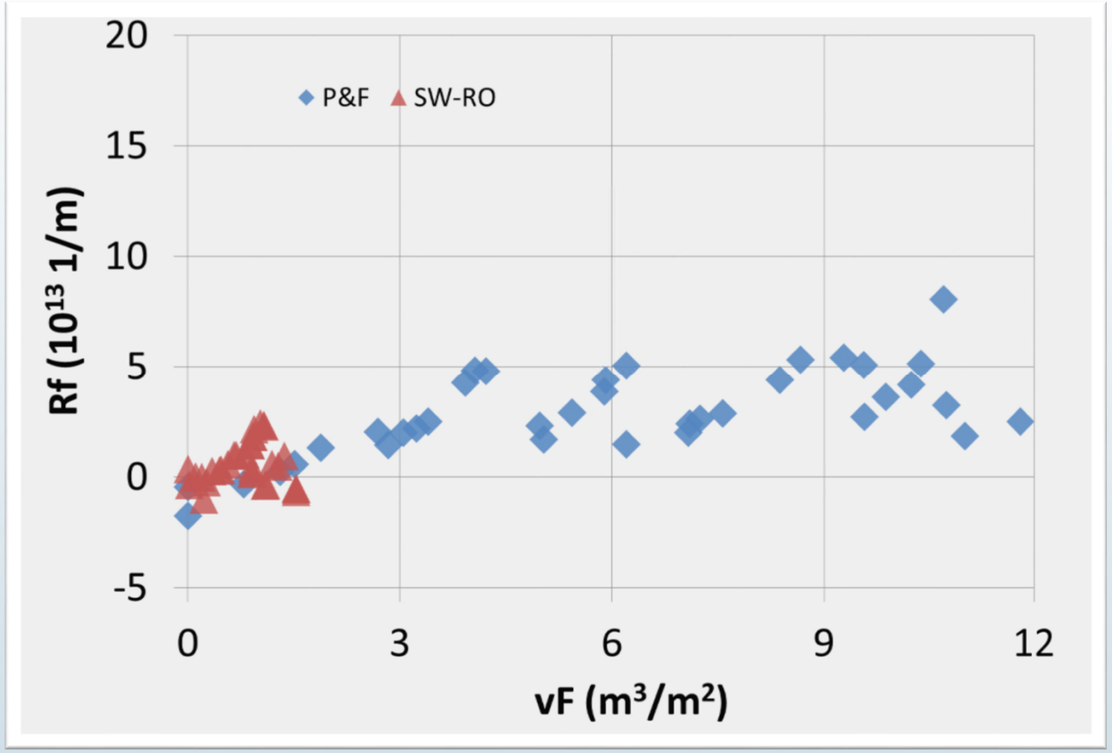
CONSTRUCTION



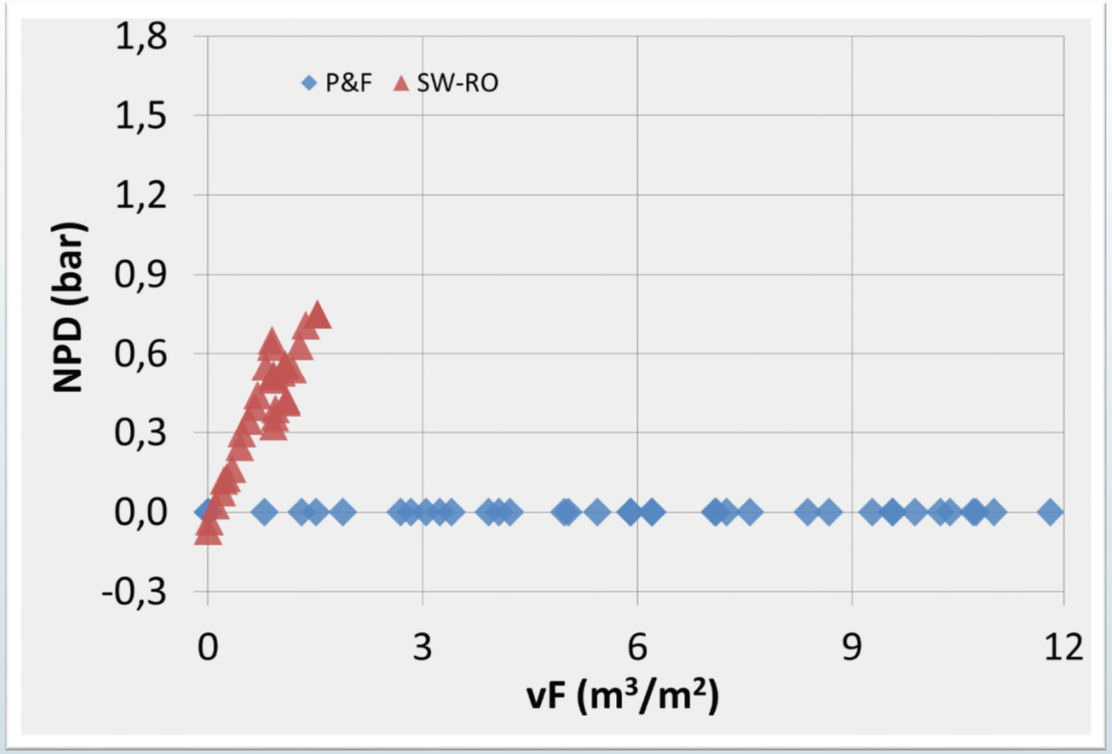
IN OPERATION

2. New system designs / hybrid processes

FOULING



CLOGGING



New Modules without Feed Spacers

Conclusion / Take Home Message

Ultrafiltration is a more robust pre-treatment for RO, but very expensive

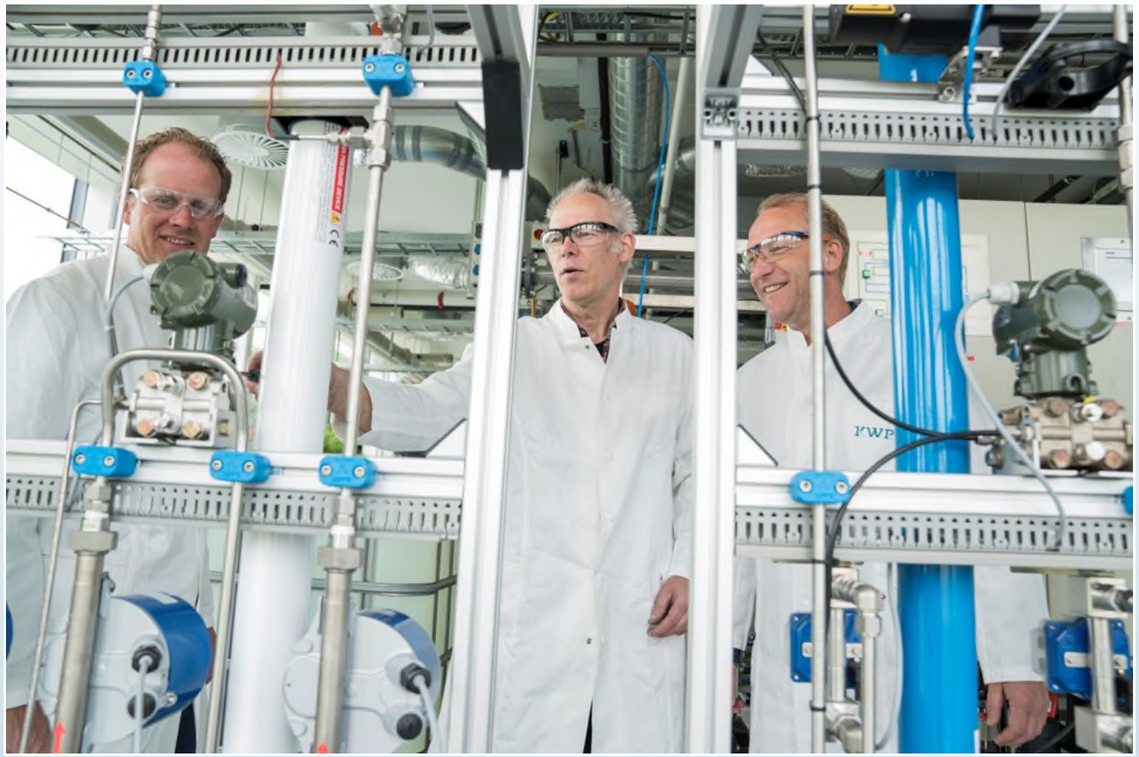
Innovative spacer-free RO concepts are the key to affordable 1-step RO

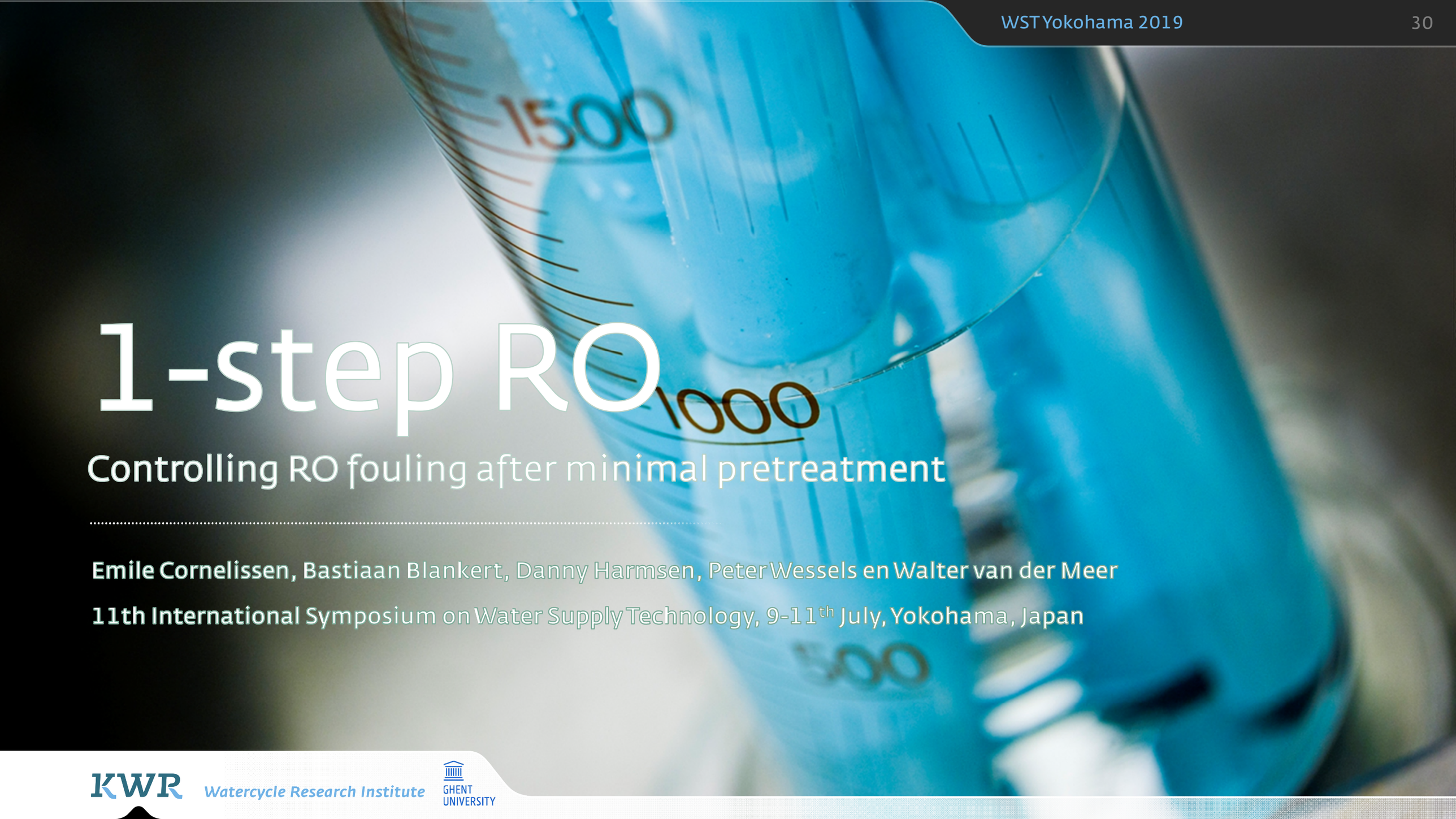
Acknowledgements

- Co-financed with TKI-funding of the Dutch Ministry of Economic Affairs
- Drinking Water company Oasen

THANK YOU FOR YOUR ATTENTION

emile.cornelissen@kwrwater.nl





1-step RO

Controlling RO fouling after minimal pretreatment

Emile Cornelissen, Bastiaan Blankert, Danny Harmsen, Peter Wessels en Walter van der Meer

11th International Symposium on Water Supply Technology, 9-11th July, Yokohama, Japan

KWR *Watercycle Research Institute*

GHENT UNIVERSITY