Forward osmosis – nanofiltration system applied for the production of high quality water from contaminated water

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Groundwater Remediation
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www.remtechexpo.com

Syndial - Overview

Syndial is Eni's company that provides an integrated service in the field of environmental remediation through procurement, engineering and project implementation, and waste logistics.

~ 1000
People

> 80
Managed sites

~ 200
Worksites

~ 800 mln€
Budget 2019

Advanced and sustainable technologies to manage and treat industrial **waste** and **water**, paying close attention to the specificities of the territories in which we operate.

Circular Economy initiatives: Eni Waste-to-Fuel (W2F) proprietary technology to convert ***Organic Fraction of Municipal Solid Waste*** into bio-oil and biomethane, as well as the recovery of industrial ***waste***, the reuse of ***water*** and the enhancement of ***soils*** for their reindustrialization.

REMEDIATION

WASTE MANAGEMENT

RECOVERY – i.e. W2F

Syndial - Overview

Technical-scientific skills and innovative thoughts come into play as a key element for experimenting new techniques.

This activity is carried out by the ***Research Center for Renewable Energy and the Environment (Novara)*** and by the ***Oil & Gas Laboratory (San Donato Milanese)***.

Furthermore, Eni and Syndial collaborate with the most important research centers and universities, inspired by the values of technological innovation, internationalization and excellence. From the ***Polytechnics of Milan*** and ***Polytechnics of Turin*** to the ***University of Bologna***, from the ***National Research Council*** to the ***Massachusetts Institute of Technology – MIT***.

Eni's commitment to ***sustainability*** and ***circular economy***.

Syndial is directing its operating models for environmental rehabilitation measures towards ***eco-compatible processes***, while ***maximizing the effectiveness and efficiency of the processes themselves***.

CASE STUDY

Forward osmosis and ***nanofiltration***, for reduction of energy consumption and management optimization of **contaminated groundwater treatment plants**.

A. CENGIO

The **National Interest Site** of Cengio (law 426/98) is located in the valley of the Bormida River, in the province of Savona, and extends over an area of *77 ha* (~ *67 ha* Syndial property).

- **1882**: born to produce explosives for the war, managed by *Societé Continentale Glicerynes et Dynamites.*
- **1925**: production of pharmaceutical products, managed by *ACNA*.
- **1999**: **stop** of all production lines. *Eni* come in 1989.
- **2003**: *Syndial* remediation workload (soil - groundwater).

AERIAL IMAGE OF ENI SITE, *CENGIO*

B. MANFREDONIA

The **National Interest Site** of Monte Sant'Angelo-Manfredonia (law 426/98) is located in the province of Foggia (Puglia), and extends over an area of *216 ha* (~ *96 ha* Syndial property).

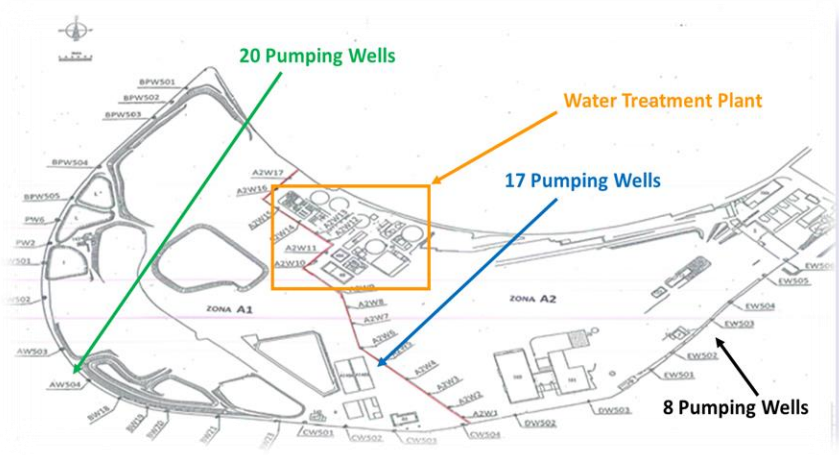
- **1968**: born to produce fertilizers and caprolactam.
- **1988:** stop of caprolactam line.
- **1994: stop** of all production lines.
- **2003**: *Syndial* remediation workload (soil).
- **2006**: Contaminated groundwater treatment plant.

AERIAL IMAGE OF ENI SITE, *MANFREDONIA*

CASE STUDY - Cengio

As part of the site's environmental remediation activities, the **ITAR** plant (Waste Water Treatment Plant) is active, delegated to purify:

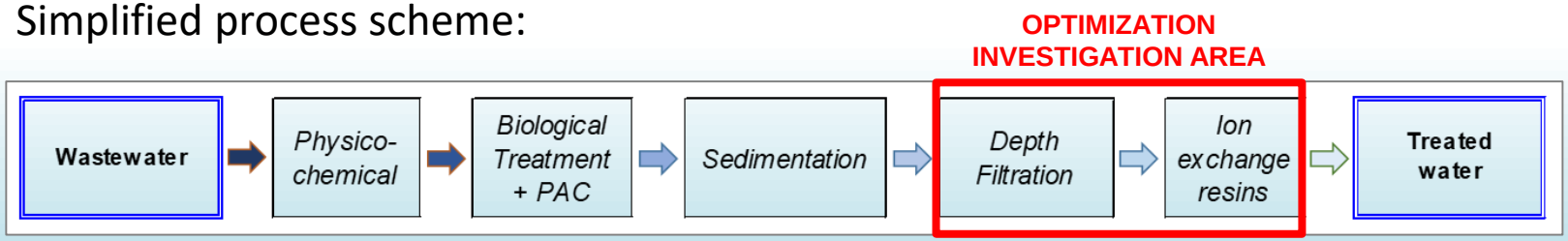
- *leachate* (subsoil of the site);
- *service waters* and *urban waters.*



n. 45 *pumping wells*
along a draining trench.

The plant built in **1985**, at current conditions treats about **130 m³/h**.

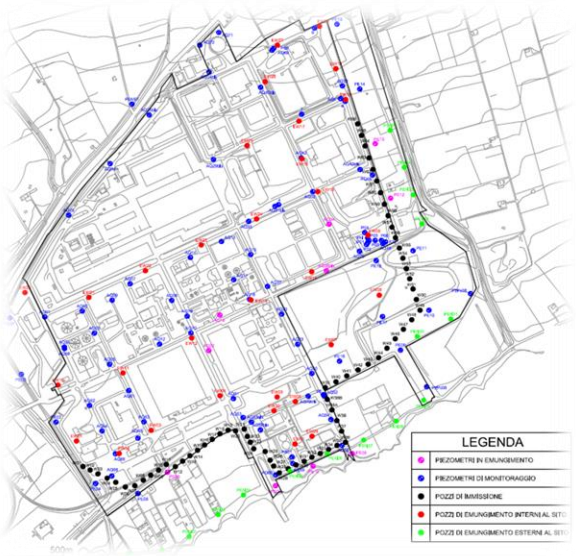
Simplified process scheme:



Quality requirements for treated water:
Tabella 3 - Allegato 5 - Parte III Titolo V - D.Lgs. 152/06

CASE STUDY - Manfredonia

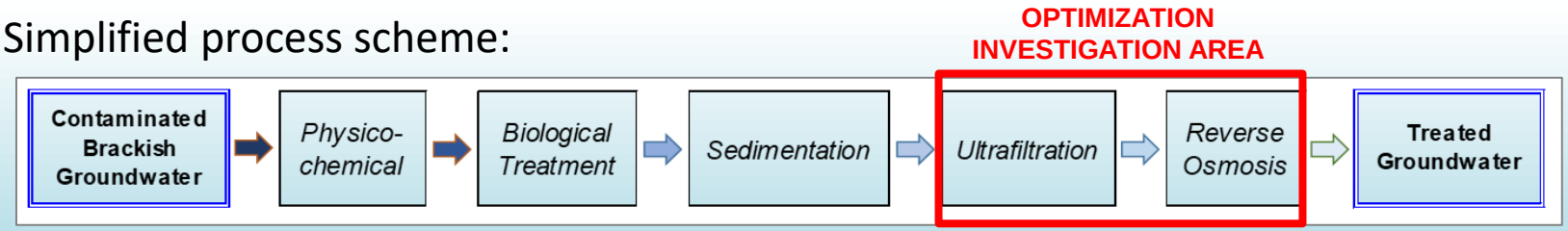
The *groundwater remediation* operates through extraction, treatment and injection in compliance with "*Decreto Interministeriale 28/10/2003*". Salt water intrusion and interface fresh/salt water *(Regional law on groundwater withdrawal)*.



n. 61 *pumping wells*
n. 68 *reinjection wells*

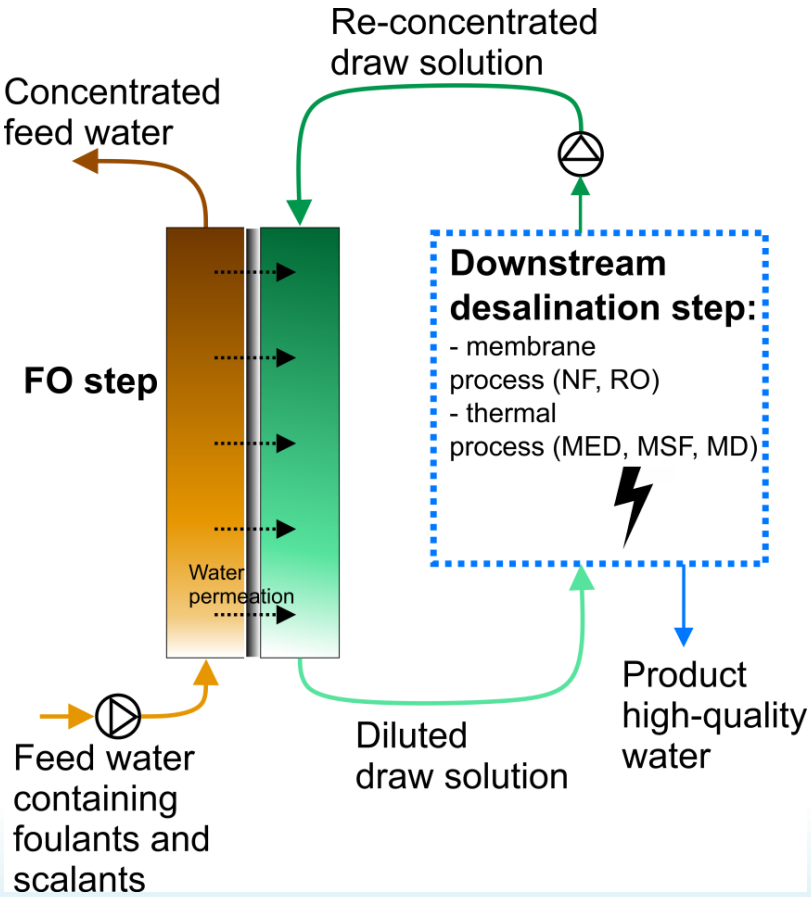
The groundwater treatment plant built in **2006** has a nominal treatment capacity of **150 m³/h**, to be increased up to **230 m³/h** within **2020**, in accordance to "*Decreto MATTM 10/04/19*".

Simplified process scheme:



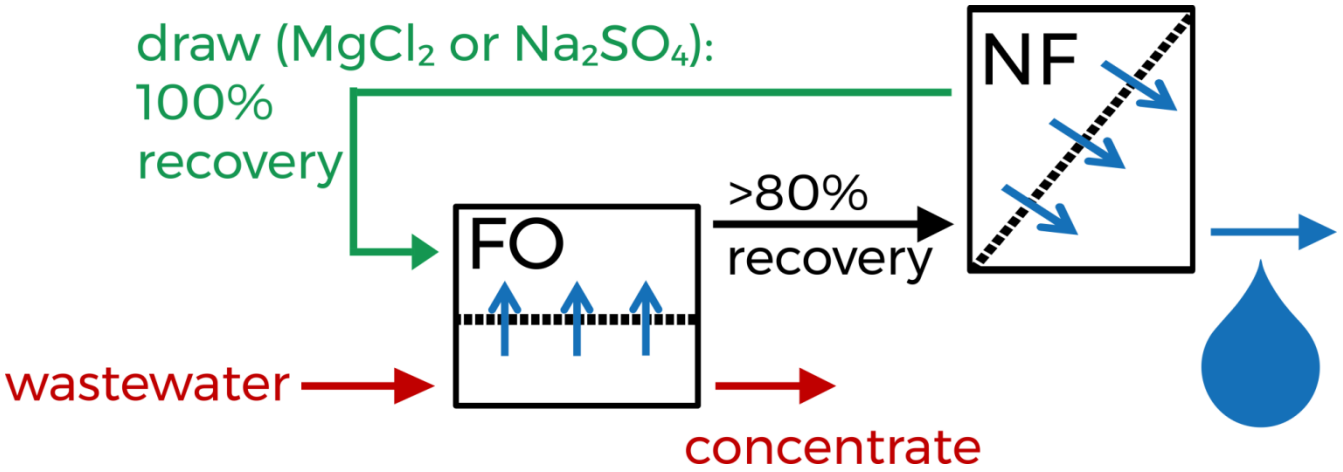
Quality requirements for treated water:
Tabella 2 - D.M. 471/1999

What is forward osmosis (FO)



- Operates at low or no hydraulic pressures: cheap materials and equipment
- Has high rejection of a wide range of contaminants (same as RO)
- Has lower membrane fouling propensity than pressure-driven membrane processes
- May be driven by low grade energy streams

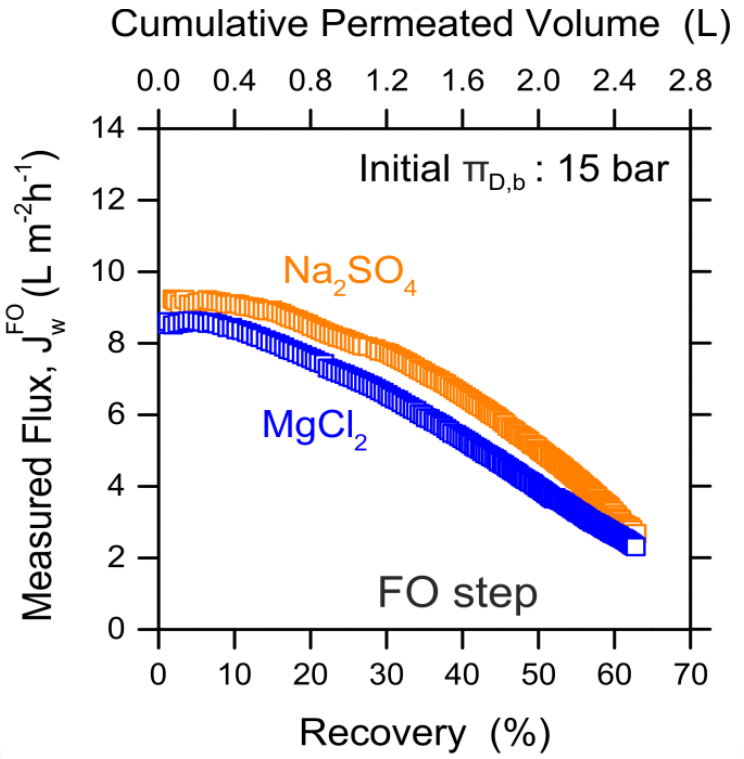
Application for the two case studies with different feed waters

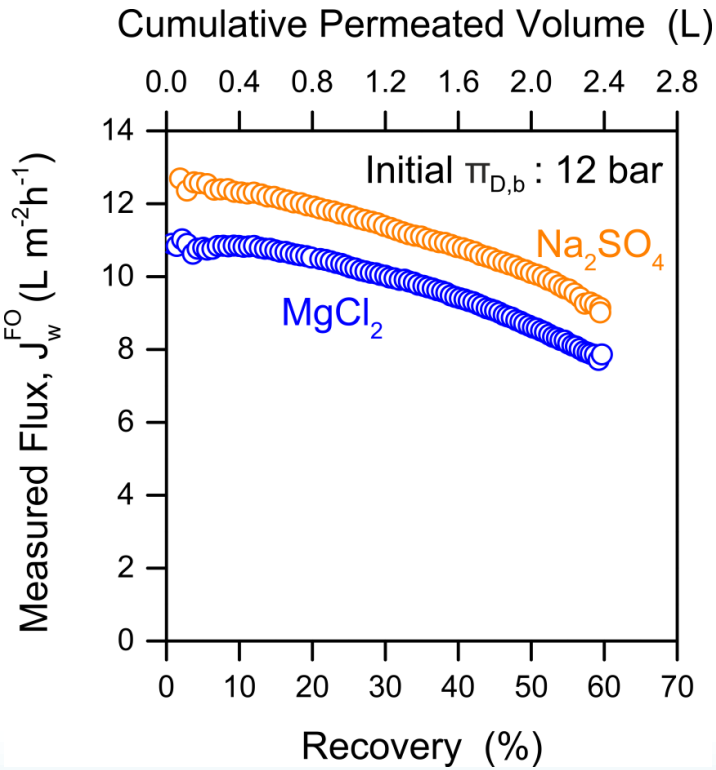


Manfredonia	
Dissolved organic carbon (mg/L)	**4.4**
pH	7.8
Conductivity (µS/cm)	6400
TDS (mg/L)	3900
Osmotic pressure (bar)	**3.0**

Cengio	
Dissolved organic carbon (mg/L)	**22**
pH	8.0
Conductivity (µS/cm)	1100
TDS (mg/L)	540
Osmotic pressure (bar)	**0.5**

Limiting factor: water flux in the FO step (productivity); site A not feasible



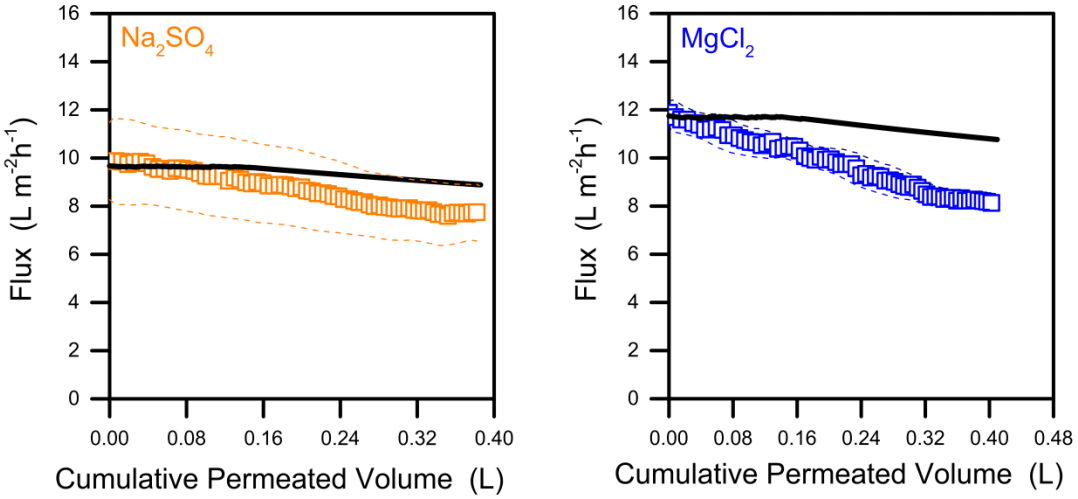


Manfredonia:
~ 65% recovery
AVG flux ~ 6 LMH
Relatively low flux: not feasible

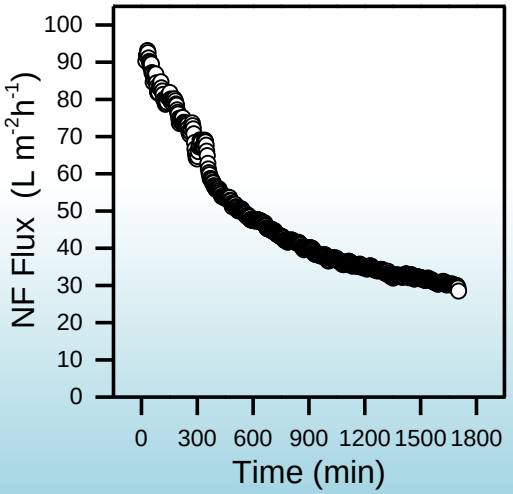
Cengio:
~ 65% recovery
AVG flux ~ 10 LMH
Relatively high flux: feasible

Advantages in fouling behavior with FO with respect to NF (Cengio)

FO



NF @ 15 bar



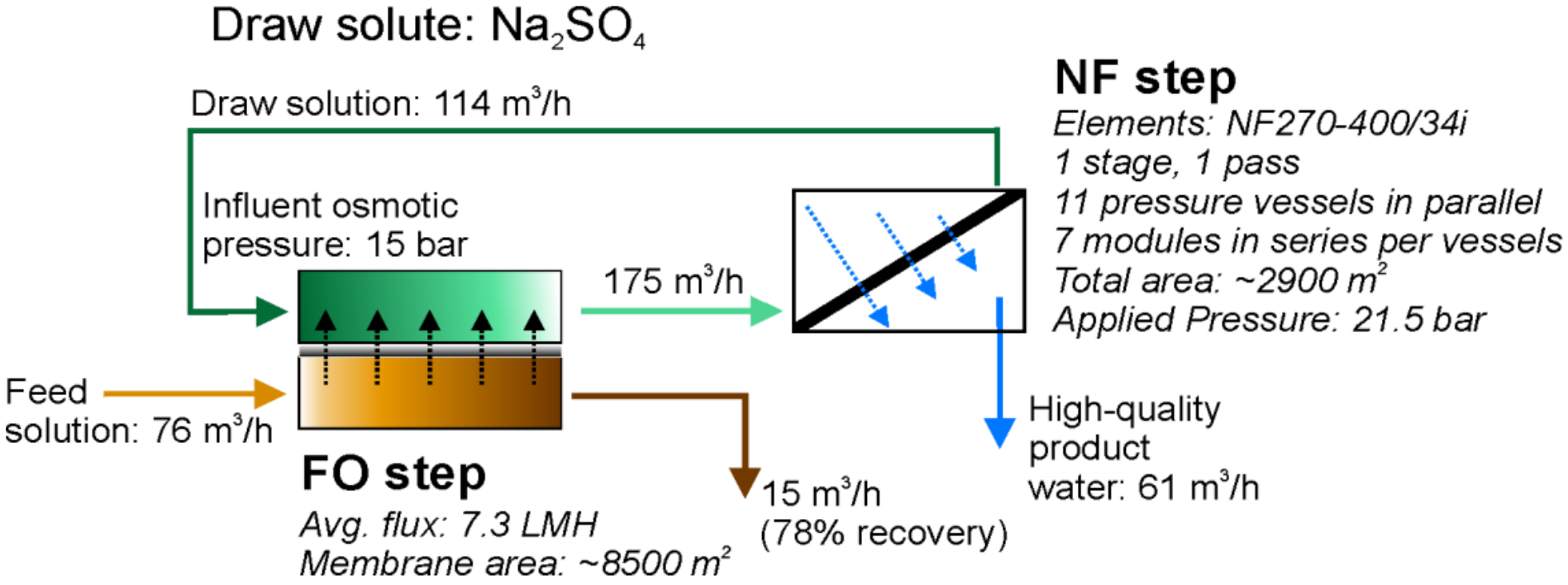
As expected, FO shows **much lower flux decline** due to fouling compared to a comparable pressure-driven process

Final Water Product (Cengio)

Parameter	Draw Solution Na_2SO_4	Draw Solution $MgCl_2$	Limits for use as irrigation water	Limits for use as drinking water
TOC (mg/L)	**1.1**	**0.33**		**10**
pH	**9.8**	**7.2**	**5.5 – 9**	**6.5 – 9.5**
Cl^- (mg/L)	7.4	55	**200**	**250**
F^- (mg/L)	n.d.	n.d.	**1**	**1.5**
PO_4^{3-} (mg/L)	n.d.	n.d.	**30**	
NO_3^- (mg/L)	0.24	n.d.	**50**	**50**
SO_4^{2-} (mg/L)	110	0.21	**2500**	**250**
N-NH_4 (mg/L)	0.022	0.0024		**0.5**
Ca^{2+} (mg/L)	0.7	3.5	**150**	
Mg^{2+} (mg/L)	0.065	16	**35**	
K^+ (mg/L)	0.16	2.5		
Na^+ (mg/L)	75	3.7	**180**	**200**
Conductivity (µS/cm)	350	190	**2500**	**2500**
TDS (mg/L)	**190**	**80**	**2000**	
Hardness (mg $CaCO_3$/L)	**43**	**83**		**500**
Alkalinity (mg/L)	**40**	**8.0**		
Aggressive Index	**12.3**	**9.3**		**>10**
SAR of irrigation water	**23**	**0.2**	**Crop-dependent**	

Quality of final product is of high-quality: **re-use** for irrigation
It respects the **limits for drinking water** as well

Design calculations for optimized full-scale plant



The optimized design would guarantee high recovery rates (~80%), with relatively high flux, compact systems, and possibility to beneficially re-use the final product.

THANKS FOR THE ATTENTION,

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