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Performance of Reverse Osmosis for the treatment of hazardous wastewater containing various concentrations and types of PFAS

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As this document is based on the state of the Veolia group's scientific, technical, and regulatory knowledge at the time of its publication, the completeness and accuracy of the information contained herein cannot be guaranteed.

Descriptions contained herein apply exclusively to those examples and/or to the general situations specifically referenced, and in no event should be considered to apply to specific scenarios without prior review and validation.

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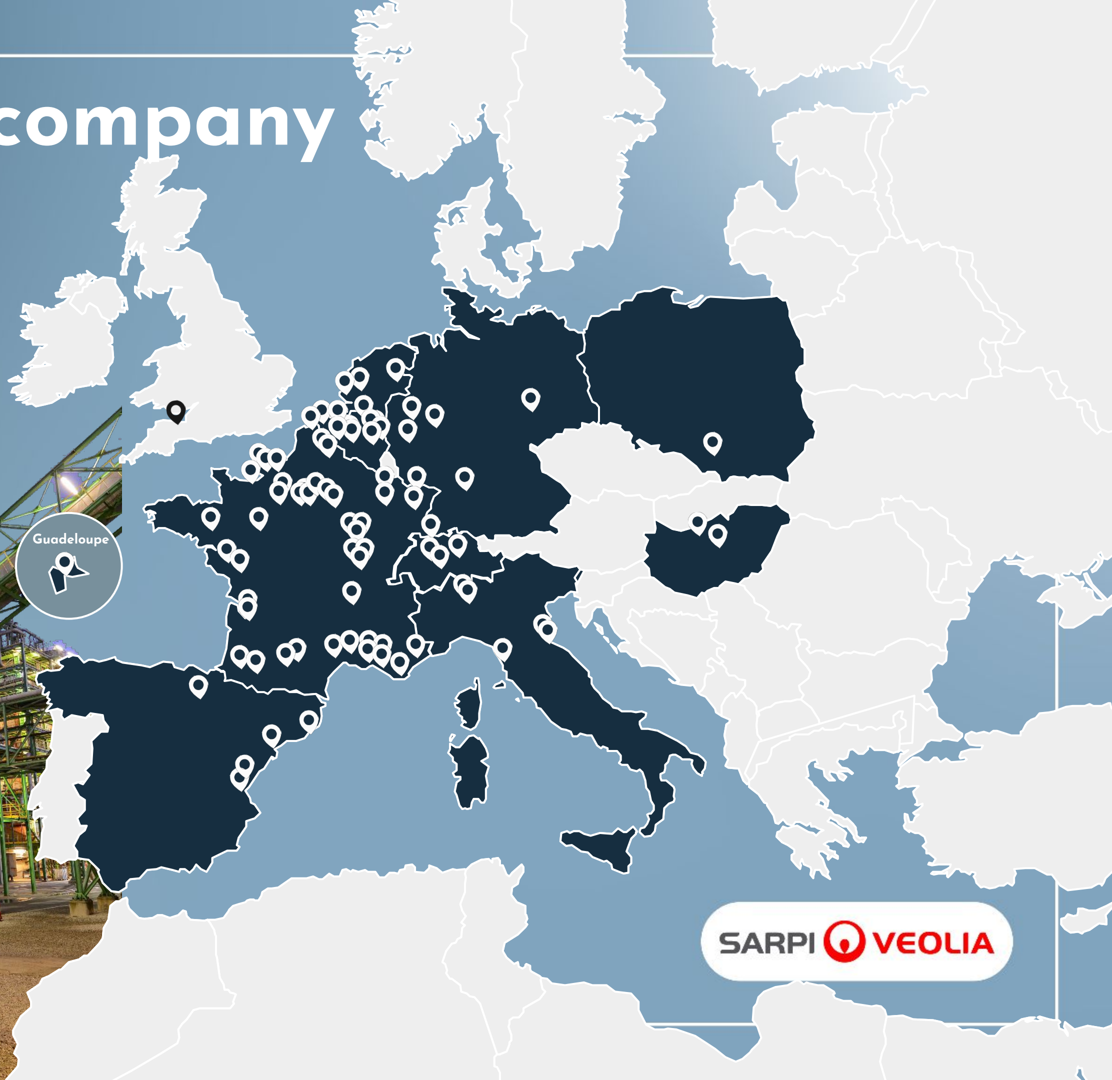
SARPI : a leading company in Europe

Treatment & valorization of hazardous waste

10 states in Europe

+ than 110 industrials sites

+ than 10 MT treated / year



High variety of wastewaters

High variety of origins

Heavy industry

Chemical industry

Collectors sector

Aircraft industry

Oil & gas

Pharmaceutical industry

High variety of matrices and pollutants

Water

Sludges

Suspended particles

Colloidal particles

Oils

Soluble matter

Organic pollutants

Inorganic substances

Challenge for the treatment of emergent pollutants by conventional technologies

Case of **PFAS**

Technologies for PFAS retention

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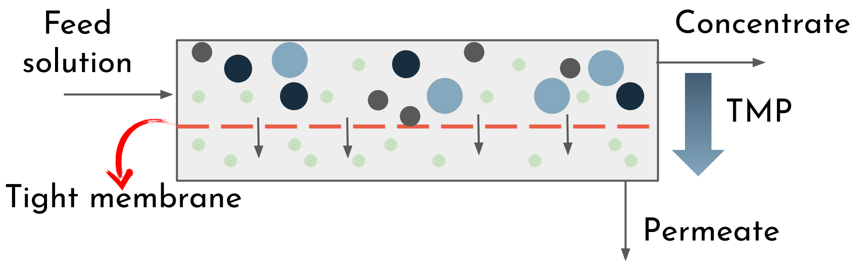
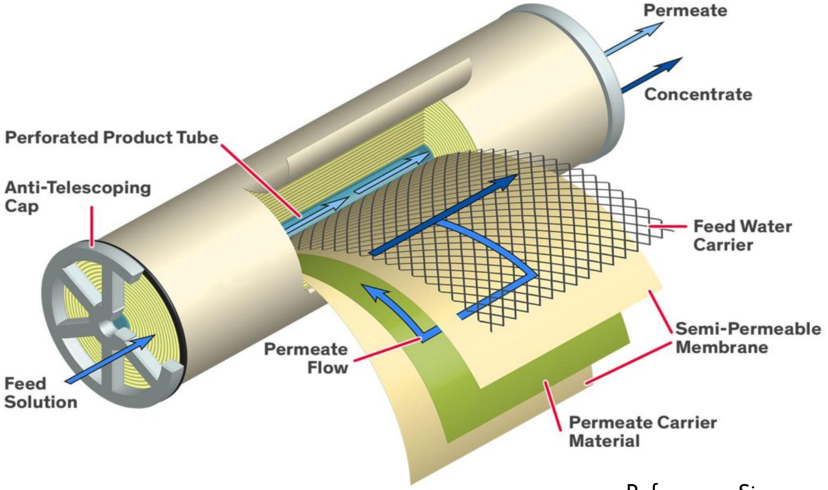
Conventional wastewater treatment technologies are insufficient in effectively treating short-chain PFAS

	Activated carbon	IE Resin	NF	RO
Organic pollutants reduction	++	+	+++	++++
Long-chain PFAS *reduction*	++	++	+	++++
Short-chain PFAS *reduction*	-	-	-	++++
Monovalent ions reduction	-	+	-	+
Polyvalent ions reduction	-	+	++	+++
Metal load reduction	+	+	-	++

Reverse Osmosis technology





Reference : Simpec

Driving force :

Pressure gradient = **TransMembrane Pressure**

$$Retention\ a_j = \left(1 - \frac{[a_j]_p}{[a_j]_c}\right) \times 100$$

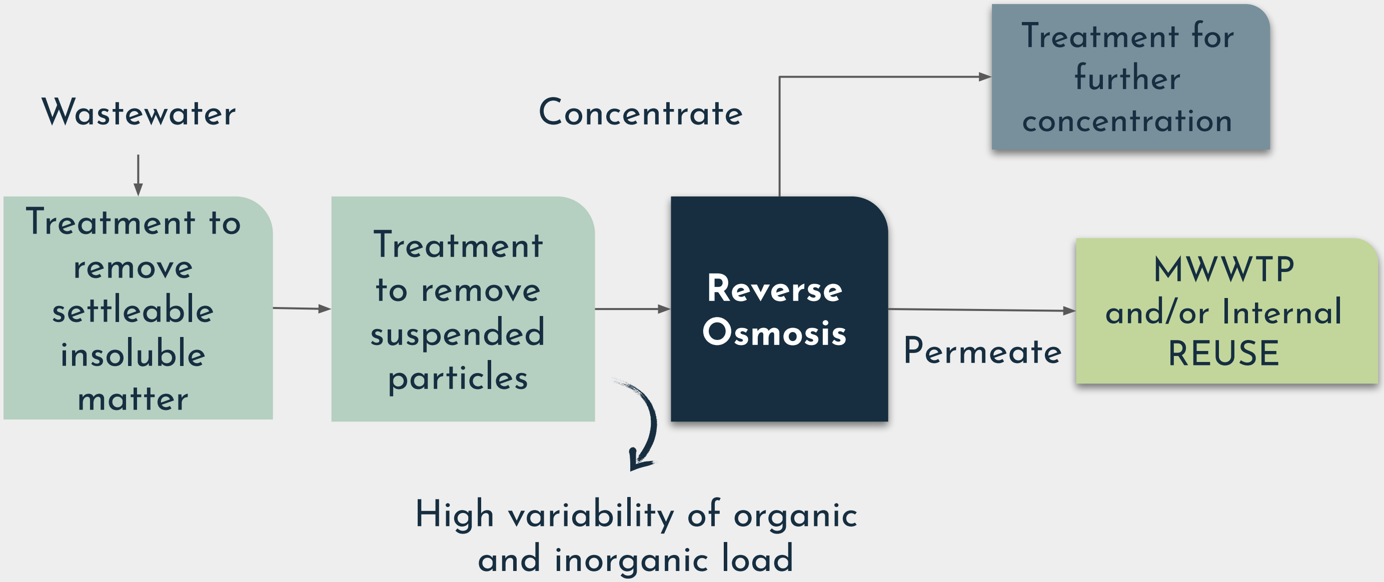
$[a_j]_p$ concentration of molecule a_j in permeate ($ng \cdot L^{-1}$)
$[a_j]_c$ concentration of molecule a_j in concentrate ($ng \cdot L^{-1}$)

$$Recovery = \frac{Q_p}{Q_f} \times 100$$

Q_p flow rate of permeate ($L \cdot h^{-1}$)
Q_f flow rate of feed solution ($L \cdot h^{-1}$)

Can we run RO with a high recovery rate to remove PFAS from pretreated hazardous wastewaters ?

Strategy



Objective :

To maximize the global recovery rate during RO

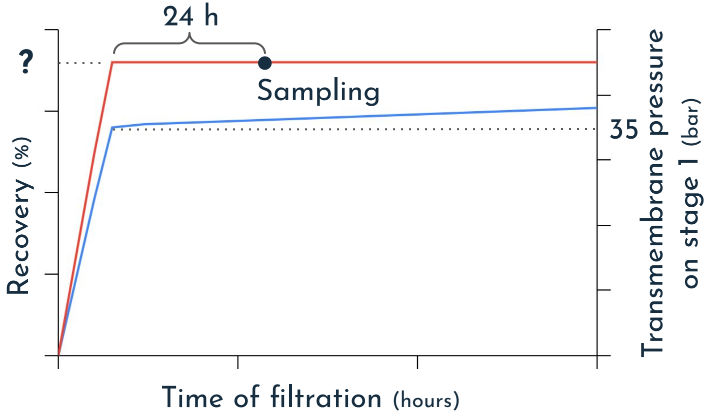
Material & methods

Mobile processing unit designed by **SEMEO**

47 polymeric spiral-wound membranes for RO

2 or 3 stages
Feed-and-bleed mode

6.8 +/- 0.2 $m^3 \cdot h^{-1}$ of feed flow rate
Ambiente temperature



Analysis

Total organic carbon
internal lab

Conductivity
internal lab

30 PFAS
external lab

Composition of feed solutions

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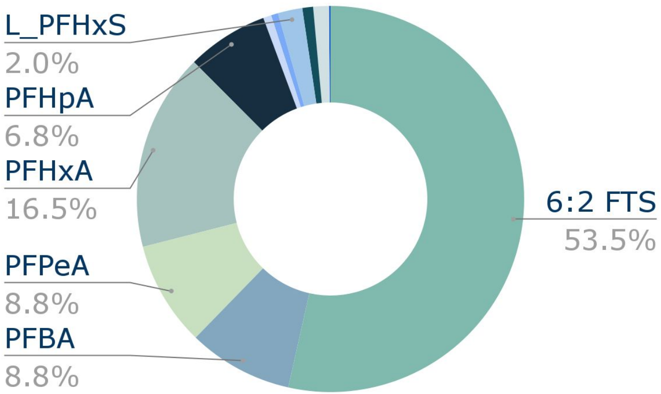
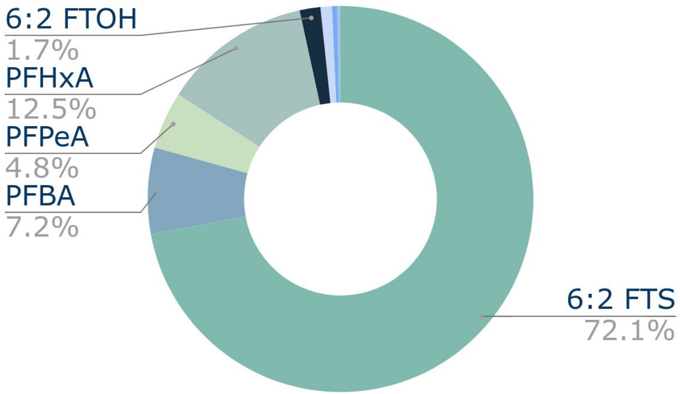
Low-organic load

TOC	280 mg·L^{-1}
Conductivity	10 202 µS·cm^{-1}
Total PFAS	20 560 ng·L^{-1}



High-organic load

TOC	1 157 mg·L^{-1}
Conductivity	10 189 µS·cm^{-1}
Total PFAS	20 810 ng·L^{-1}



Hydraulic performances

Low-organic load

7.0 $m^3 \cdot h^{-1}$ feed solution flow rate	**32.1 bar** transmembrane pressure at 1st stage	**87 % of Global Recovery**
6.5 $m^3 \cdot h^{-1}$ 1^{st} stage permeate flow rate	**93 %** recovery at 1^{st} stage	
6.2 $m^3 \cdot h^{-1}$ 2^{nd} stage permeate flow rate	**95 %** recovery at 2^{nd} stage	
6.1 $m^3 \cdot h^{-1}$ 3^{rd} stage permeate flow rate	**98 %** recovery at 3^{rd} stage	

High-organic load

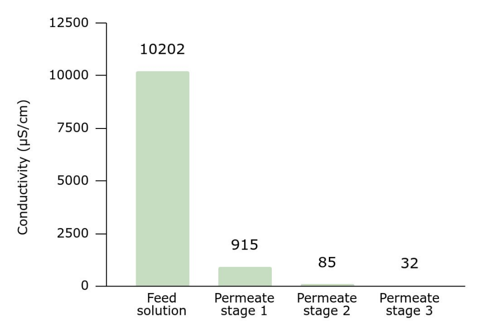
6.6 $m^3 \cdot h^{-1}$ feed solution flow rate	**35.4 bar** transmembrane pressure at 1st stage	**86 % of Global Recovery**
5.8 $m^3 \cdot h^{-1}$ 1^{st} stage permeate flow rate	**88 %** recovery at 1^{st} stage	
5.7 $m^3 \cdot h^{-1}$ 2^{nd} stage permeate flow rate	**98 %** recovery at 2^{nd} stage	

$$Recovery = \frac{Q_p}{Q_f} \times 100$$

Q_p flow rate of permeate ($L \cdot h^{-1}$)
Q_f flow rate of feed solution ($L \cdot h^{-1}$)

Quality of the permeates

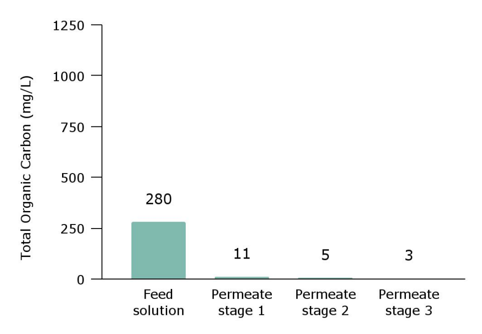
Low-organic load



1 9.0 % remaining

2 0.8 % remaining

3 0.3 % remaining

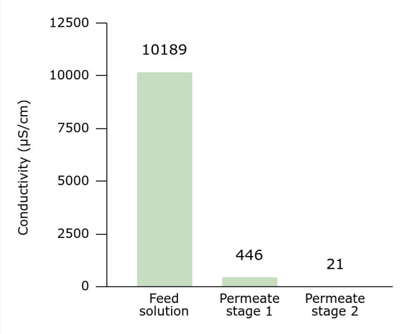


1 3.9 % remaining

2 1.8 % remaining

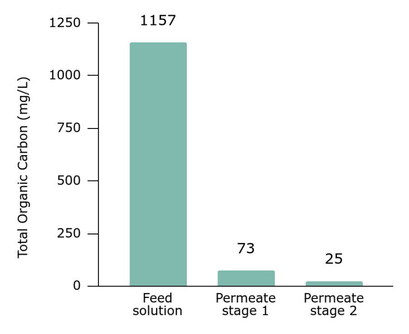
3 1.1 % remaining

High-organic load



1 4.4 % remaining

2 0.2 % remaining



1 6.3 % remaining

2 2.2 % remaining

Quality of the permeates

Low-organic load

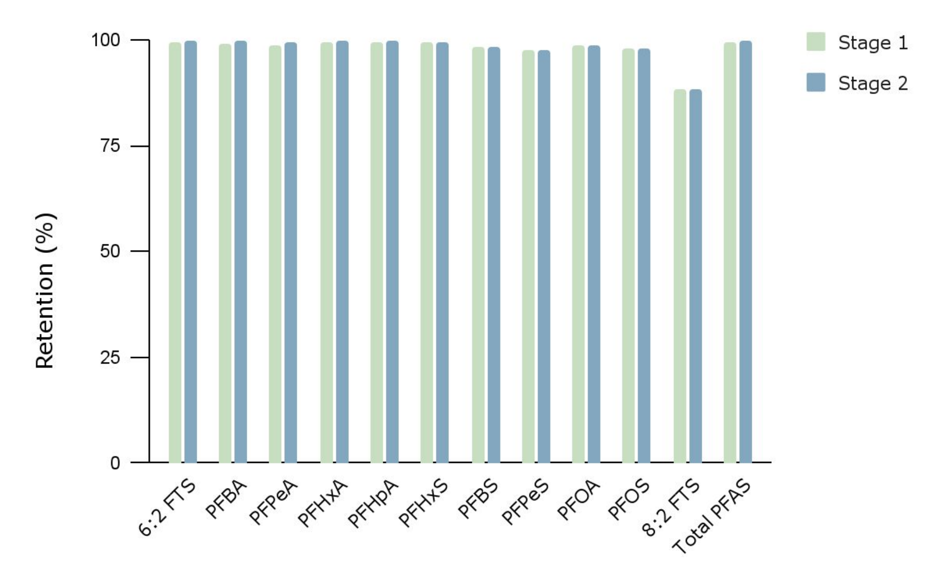
	Feed Solution ng·L^{-1}	Permeate Stage 1 ng·L^{-1}	Permeate Stage 2 ng·L^{-1}
6:2 FTS	11 000	450	< 20
PFHxA	3 400	130	< 20
PFBA	1 800	66	< 20
PFPeA	1 800	66	< 20
PFHpA	1 400	57	< 20
PFHxS	420	22	< 20
PFOS	270	< 20	< 20
PFOA	185	< 20	< 20
PFBS	140	< 20	< 20
PFPeS	120	< 20	< 20
8:2 FTS	25	< 20	< 20
Total	**20 560**	**791**	**< LOQ**

High-organic load

	Feed Solution ng·L^{-1}	Permeate Stage 1 ng·L^{-1}	Permeate Stage 2 ng·L^{-1}
6:2 FTS	15 000	180	< 20
PFHxA	2 600	34	< 20
PFBA	1 500	< 20	< 20
PFPeA	1 000	< 20	< 20
PFHpA	200	< 20	< 20
PFOS	56	< 20	< 20
PFOA	93	< 20	< 20
6:2 FTOH	361	< 10	n.d
Total	**20 810**	**214**	**< LOQ**

PFAS retention

Low-organic load



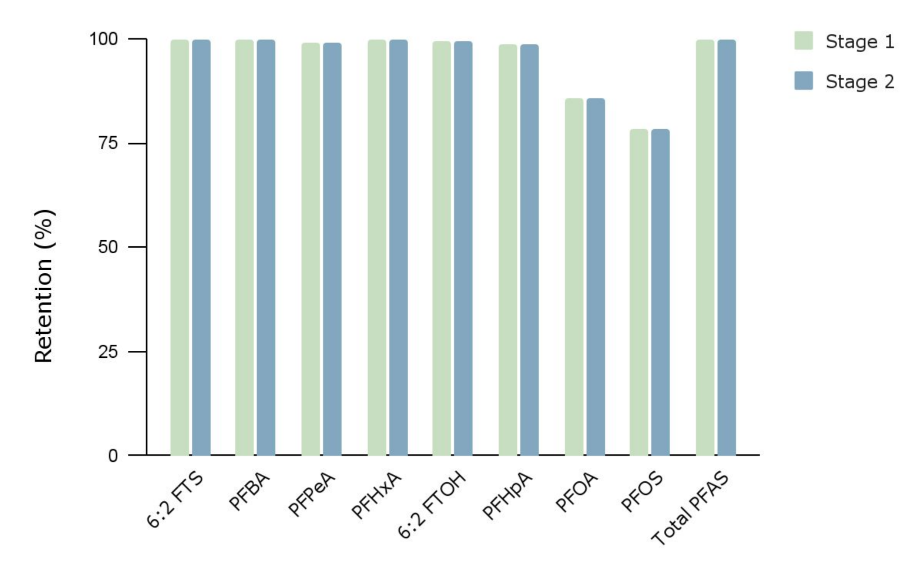
$$Retention\ a_j = \left(1 - \frac{[a_j]_p}{[a_j]_c}\right) \times 100$$

$[a_j]_p$ concentration of a_j in permeate ($ng \cdot L^{-1}$)
$[a_j]_c$ concentration of a_j in concentrate ($ng \cdot L^{-1}$)

	Retention (%)	
	Stage 1	Stage 2
6:2 FTS	99.5	> 99.9
PFHxA	99.5	> 99.9
PFBA	99.1	> 99.7
PFPeA	98.6	> 99.6
PFHpA	99.6	> 99.8
PFHxS	99.3	> 99.4
PFOS	> 98.2	> 98.2
PFOA	> 98.7	> 98.7
PFBS	> 98.2	> 98.2
PFPeS	> 97.6	> 97.6
8:2 FTS	> 88.2	> 88.2
Total	**> 99.4**	**> 99.9**

PFAS retention

High-organic load



$$Retention\ a_j = \left(1 - \frac{[a_j]_p}{[a_j]_c}\right) \times 100$$

$[a_j]_p$ concentration of a_j in permeate ($ng \cdot L^{-1}$)
$[a_j]_c$ concentration of a_j in concentrate ($ng \cdot L^{-1}$)

	Retention (%)	
	Stage 1	Stage 2
6:2 FTS	99.7	> 99.9
PFHxA	99.8	> 99.9
PFBA	> 99.8	> 99.8
PFPeA	> 99.1	> 99.1
PFHpA	> 98.7	> 98.7
PFOS	> 78.5	> 78.5
PFOA	> 85.7	> 85.7
6:2 FTOH	> 99.3	> 99.3
Total	**> 97.7**	**> 99.9**

Quality of the permeates

Metals ($\mu g \cdot L^{-1}$)	NF	RO
Mn	200	< 5
Cu	6.1	< 5
Al	31	6.3
Fe	68	19
Zn	34.5	7.8

Volatile compounds ($\mu g \cdot L^{-1}$)	NF	RO
$CHCl_3$	21	< 1
Xylène	3	< 1

Micropollutants ($\mu g \cdot L^{-1}$)	NF	RO
C5-C9	82	< 25
AMPA	1.2	< 0.1
Phenol	0.01	< 0.01
Diuron	0.258	< 0.05
Atrazine	0.359	< 0.025
Isoproturon	0.146	< 0.05
Glyphosate	1.1	< 0.1
Tributylphosphate	0.1	< 0.1

Take-away messages

Reverse Osmosis with a high recovery rate can be run to efficiently remove PFAS from hazardous wastewaters

Hydraulic performances

A Global Recovery up to 87 % was successfully applied on pretreated wastewater

Wastewater with a 10mS·cm^{-1}-conductivity and a total organic carbon concentration of 1100 mg·L^{-1} could be treated by RO

The concentrates were able to be further treated

Quality of the permeates

Both short-chain and long-chain PFAS were successfully treated

Total PFAS concentration below the limit of quantification was obtained after 2 stages of RO

In addition of PFAS, a wide range of organic micropollutants were removed

Inorganic pollutants concentration were reduced

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Merci pour votre attention.

Thanks for your attention.