A multibarrier treatment by ozonation, coagulation and ceramic membrane filtration

Wastewater reuse in the Netherlands

- Municipal waste water part of the fresh water source
- In the Dutch delta, unintended/partial reuse
- Current focus legislation on removal of selected pharmaceuticals
- Additional priority pollutants: other pharmaceuticals, pesticides, microplastics, antibiotic resistance, protozoa/bacteria/virusses

Development reuse scenarios by an integrated multi barrier treatment approach

Case

HHNK

WWTP Wervershoof

296.000 i.e.

13 Mm^3/year DWA

Hotspot medicines
Microplastics
Antibiotic resistance

PWN

WTP Andijk, WTP WRK

Drink- & industry water

75 Mm^3/year

Source protection
CeC's
Drought -> Chloride

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hoogheemraadschap Hollands Noorderkwartier

PWN

Ambition

Wastewater treatment for high quality reuse application

Problem statement

- Watercycle – broad range of emerging contaminants
- Previous TKI study: combination ozonation and CMF promising concept
- Water quality assessment:
  - ❖ Organic micropollutants (pharmaceuticals)
  - ❖ Byproducts (bromate)
  - ❖ Biological parameters (antibiotic resistant genes, viruses)
- Main focus: Ozone – coagulation – CMF
- Additionally: High-end reuse (RO post-treatment)

Source and process selection

Effluent WWTP Wervershoof	Source for re-use
O_3 Treatment	Degradation micropollutants and flux enhancement
In-line Coagulation	Removal suspended matter and flux enhancement
Ceramic Microfiltration	Removal suspended matter, microplastics and bacteria

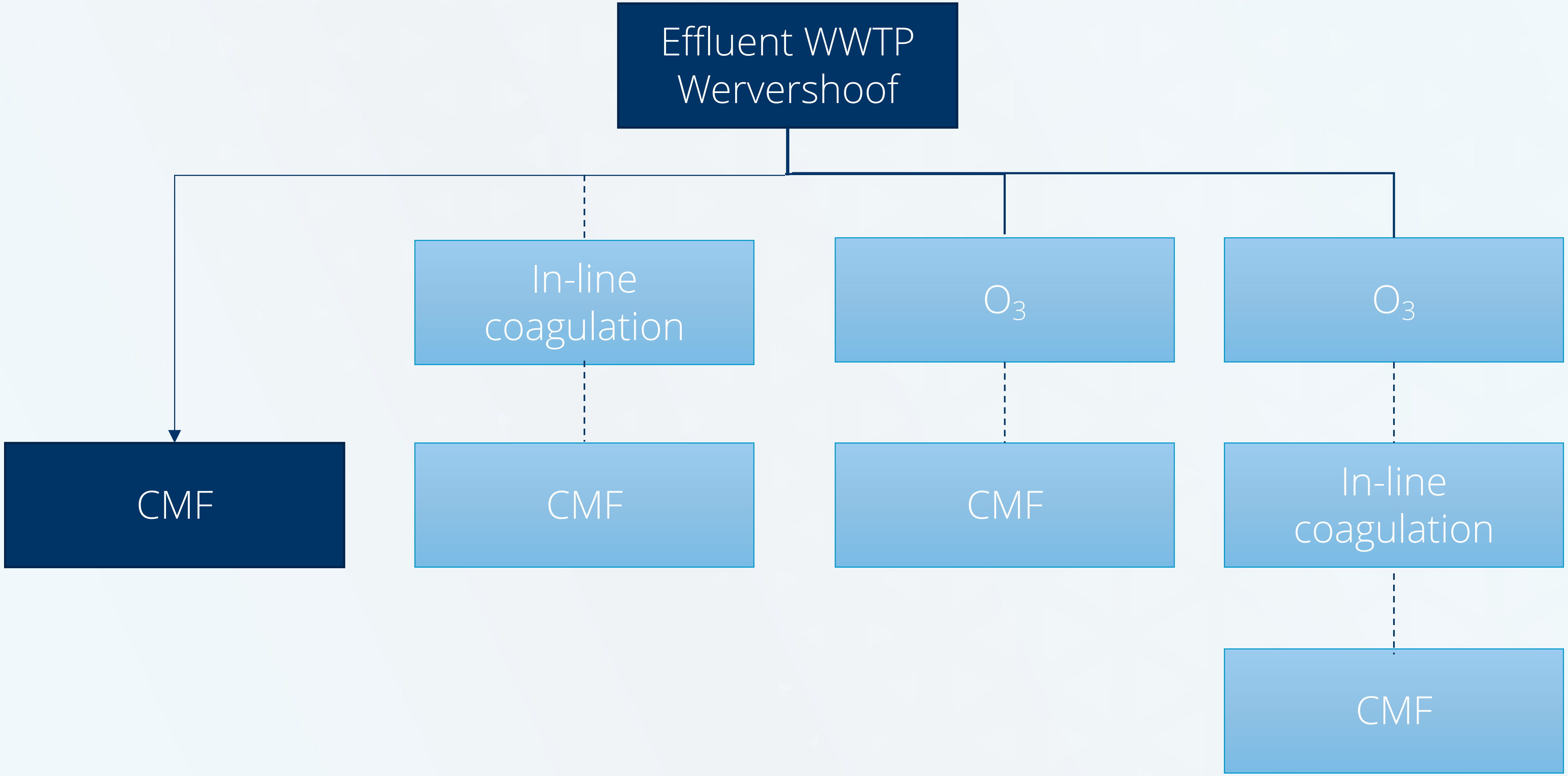
Objective: develop re-use scenario

This Part: optimization CMF

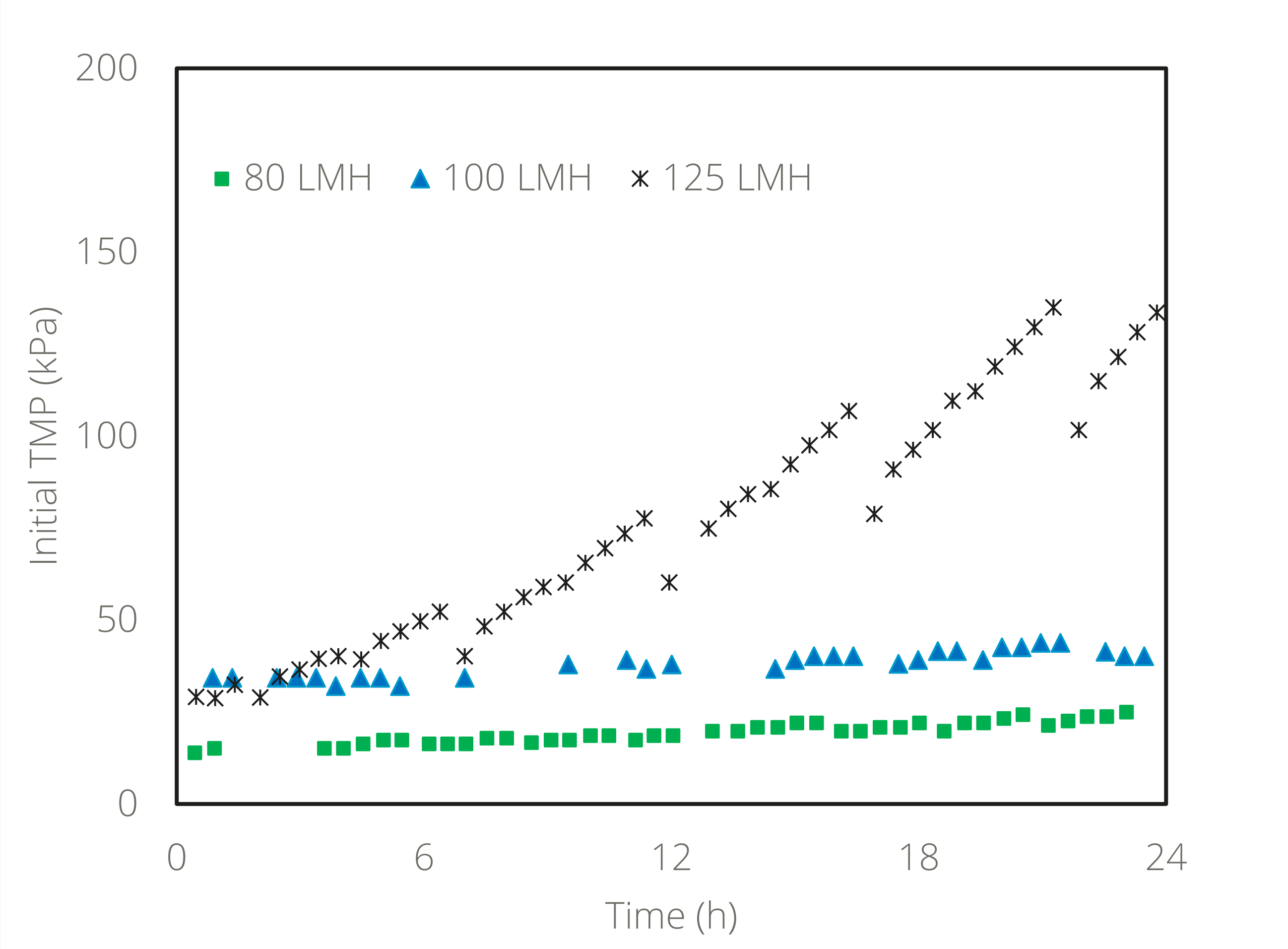
Materials & methods

- Membrane module
  - Pore size = 0.1 μm
  - Surface area = 0.4m^2
  - Maximum TMP = 200kPa
- Coagulation
  - a) 10 mg Fe^{3+}/L at pH 6.8
  - b) 10mg Fe^{3+}/L at pH 8.3
- Ozonation (bubble column)
  - a) 0.9/1 O_3/DOC
  - b) 1.9/1 O_3/DOC
- Coagulation+Ozonation

Experimental set-up

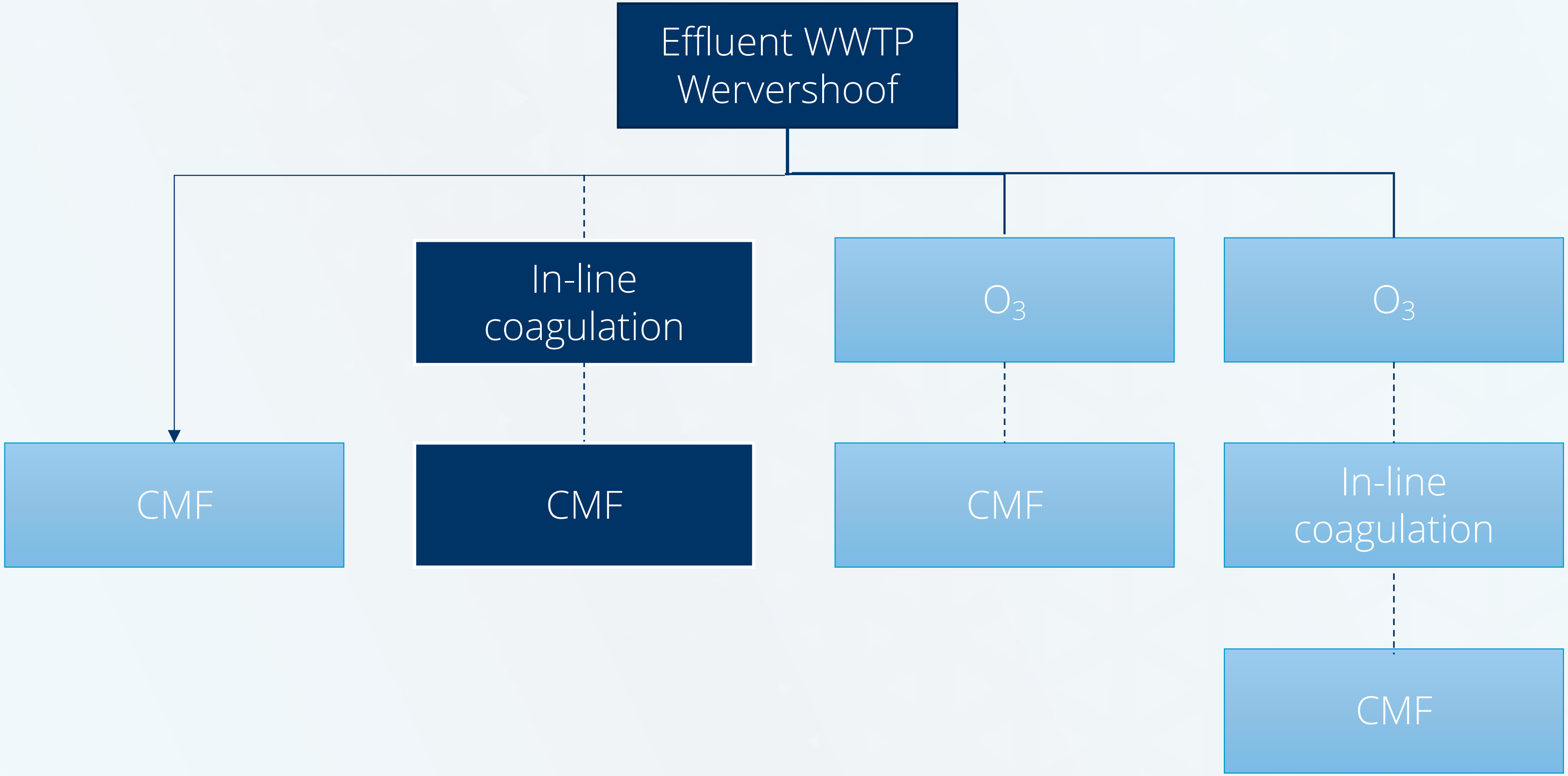


No Pretreatment



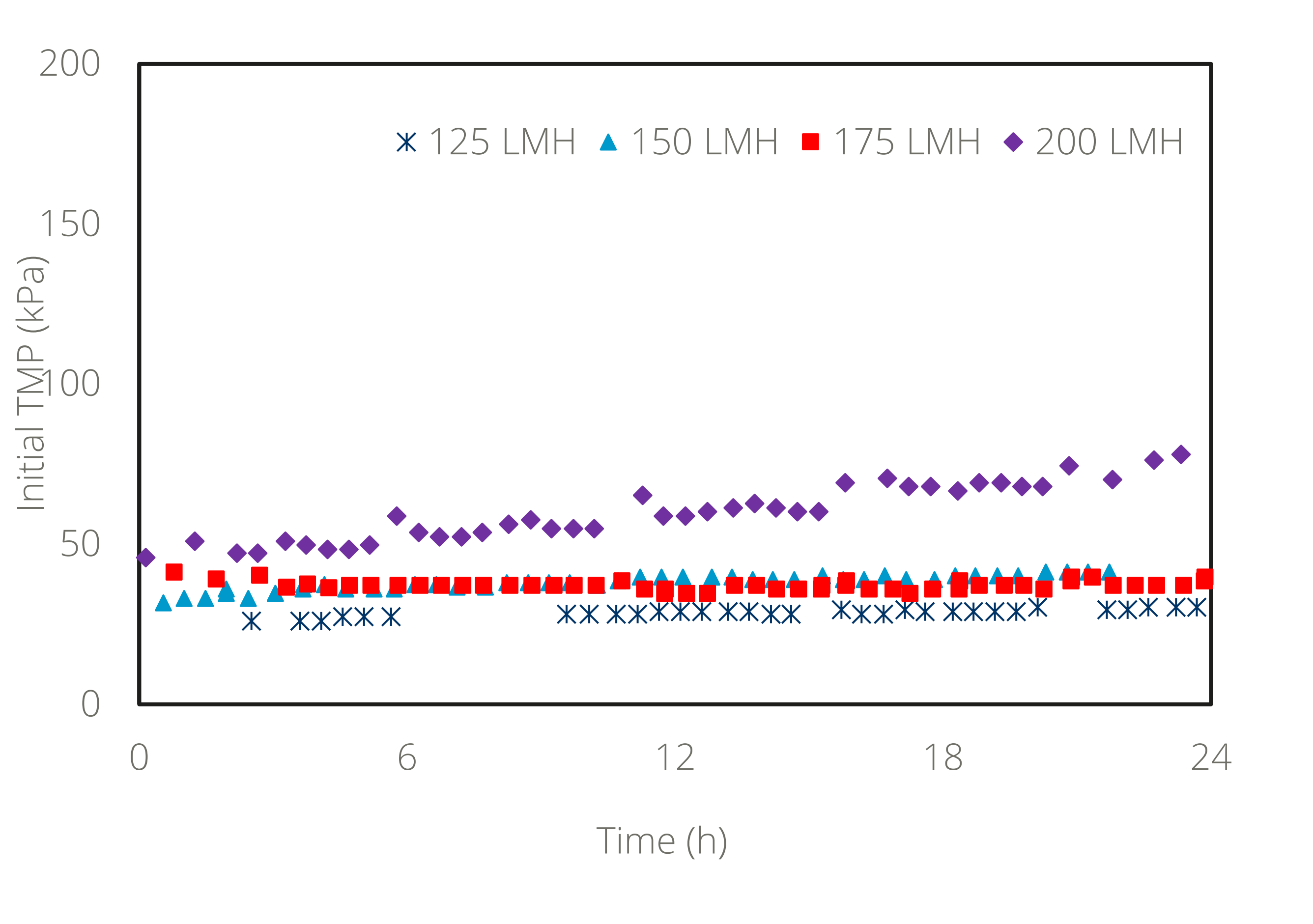
Flux (LMH)	Fouling rate (kPa/day)
80	10.05
100	9.90
125	109.58

Experimental set-up



Coagulation pretreatment at pH 6.8

10 mg Fe^{3+}/L at pH 6.8



Flux (LMH)	Fouling rate (kPa/day)
125	3.97
150	8.09
175	~ 0
200	30.58

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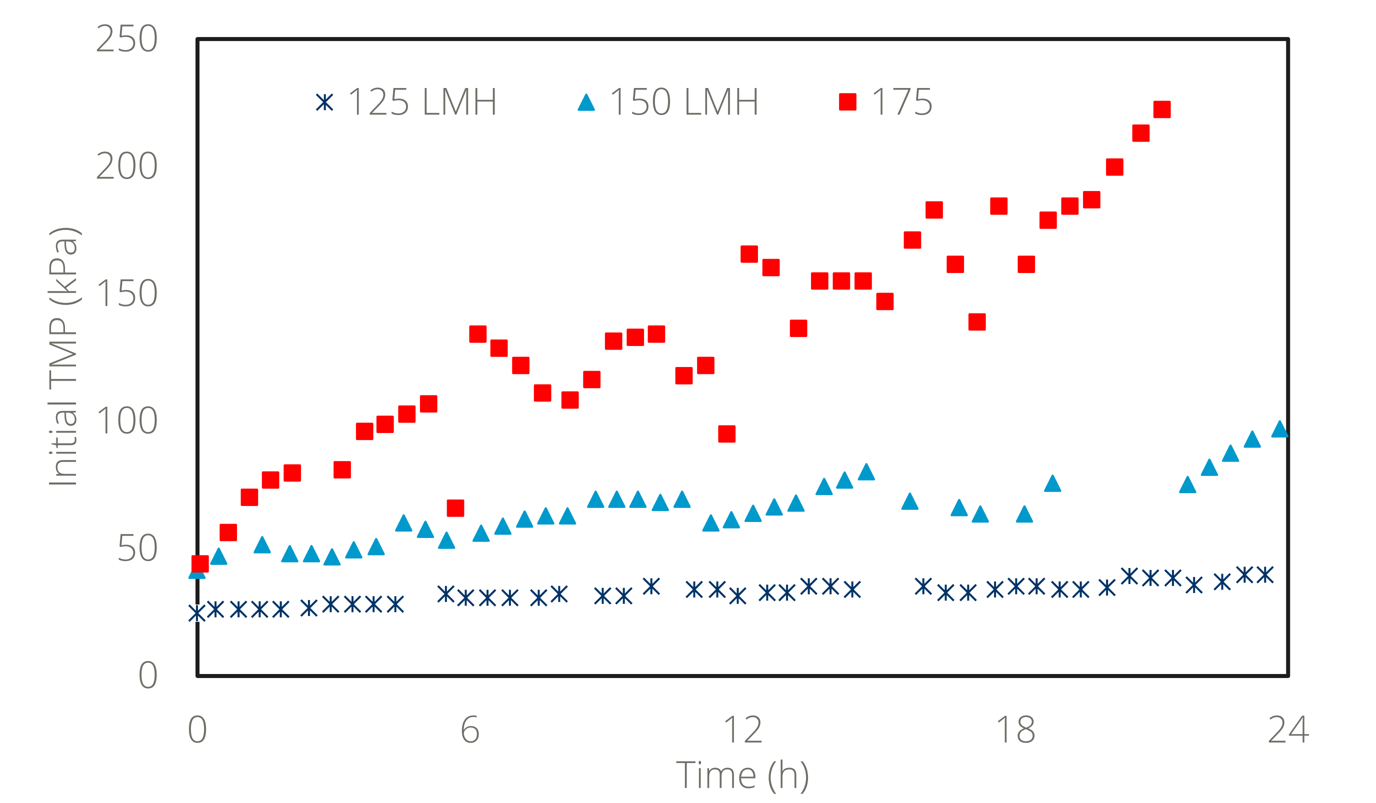
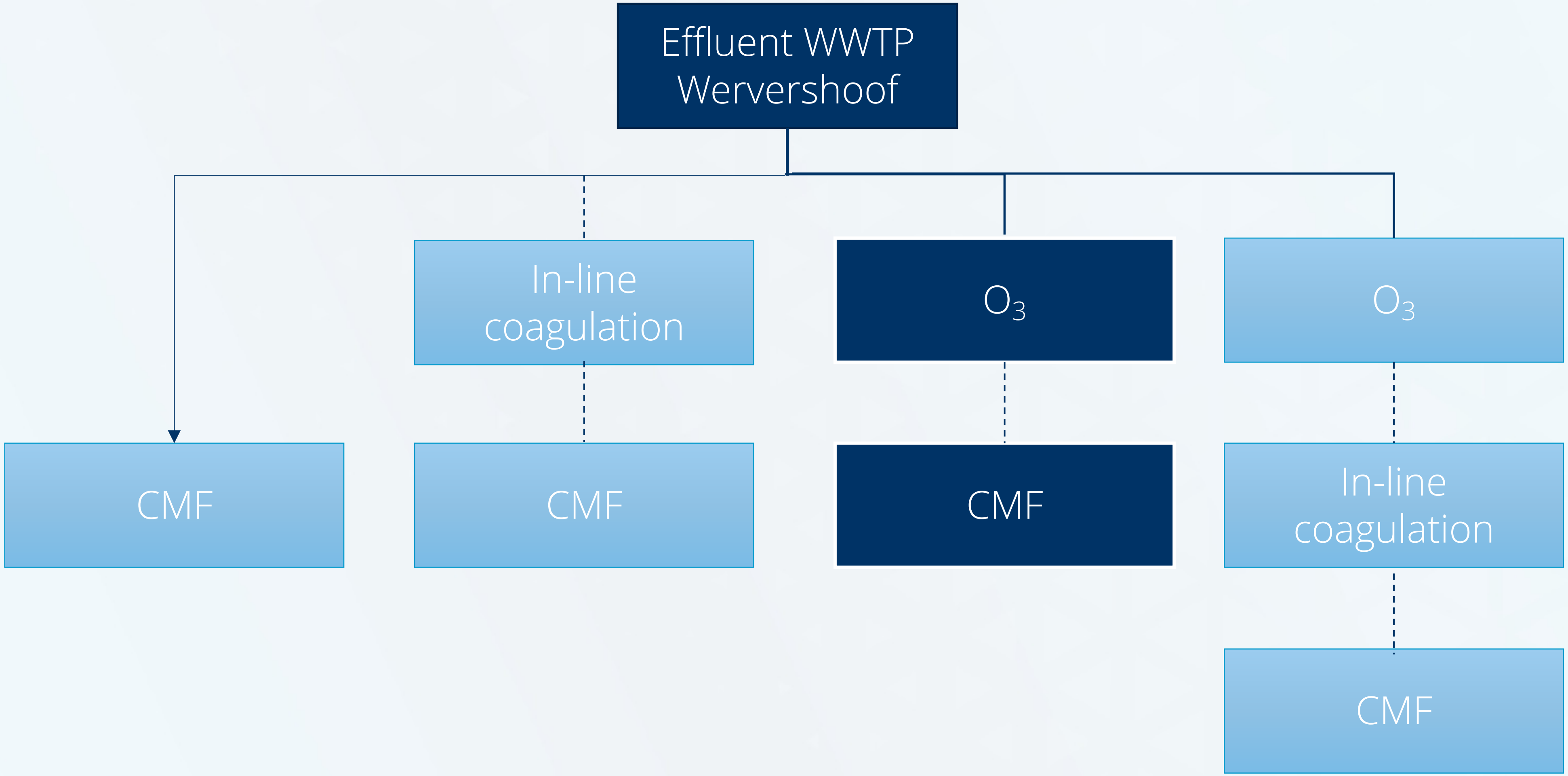
Coagulation pretreatment at pH 8.3

10mg Fe^{3+}/L at pH 8.3

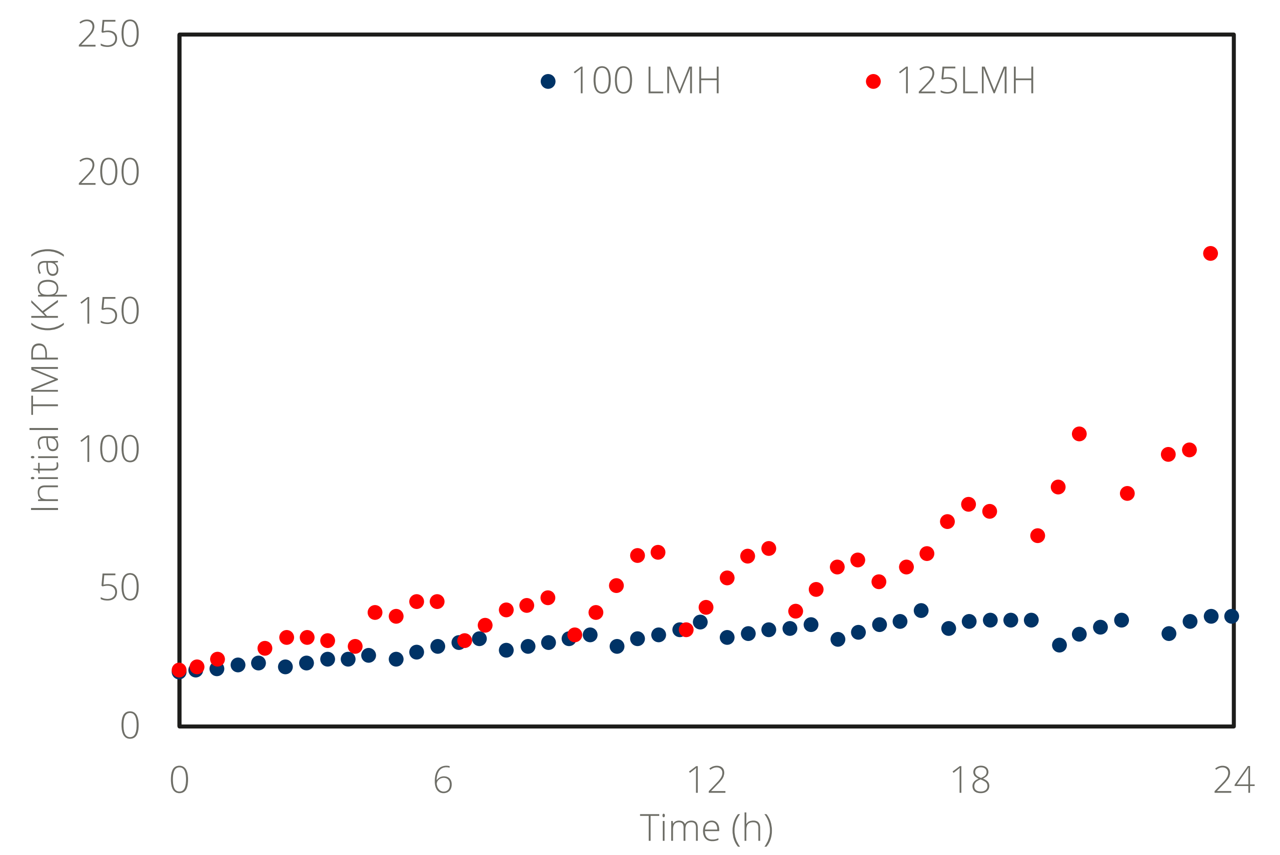


Flux (LMH)	Fouling rate (kPa/day)
125	12.07
150	40.02
175	153.13

Experimental set-up



Ozonation pretreatment – 0.9 O_3/DOC



Flux (LMH)	Fouling rate (kPa/day)
100	18.01
125	84.12

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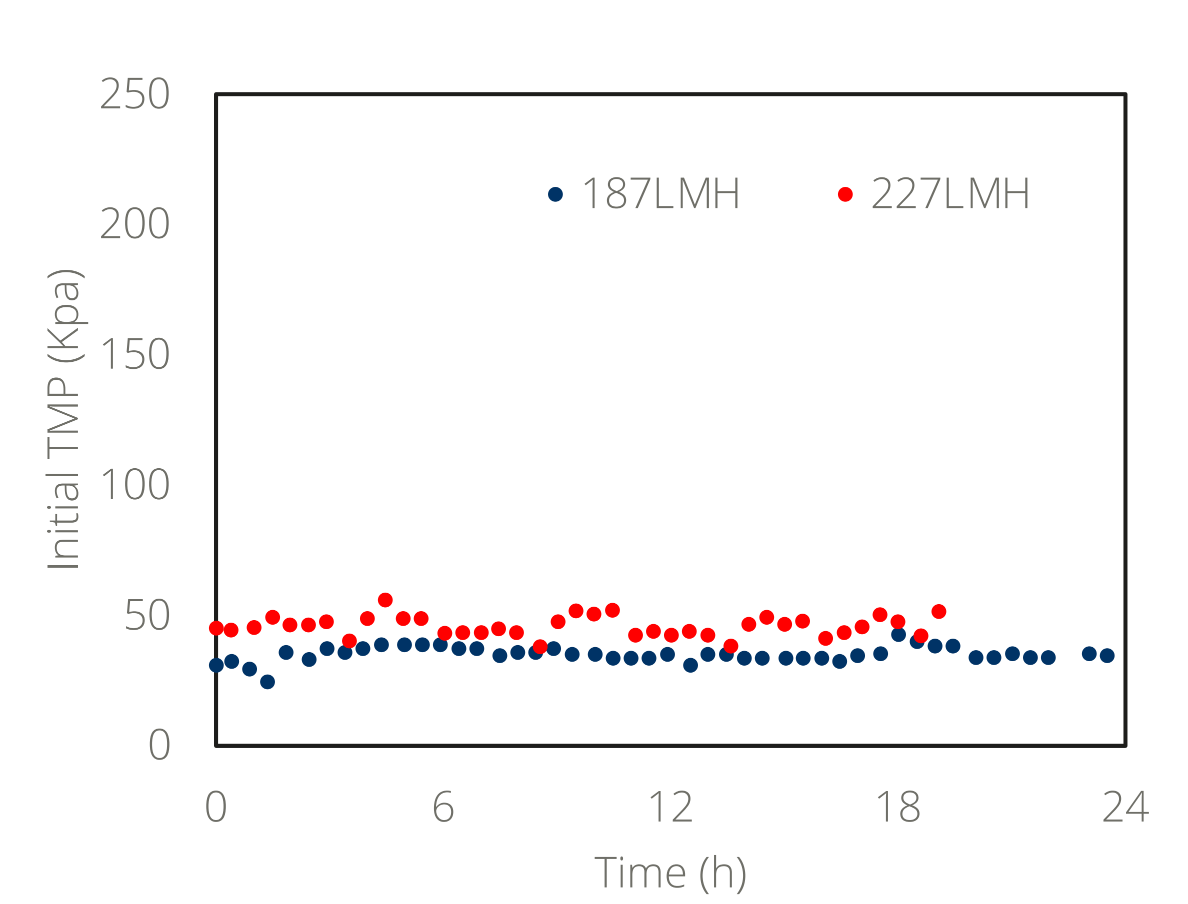
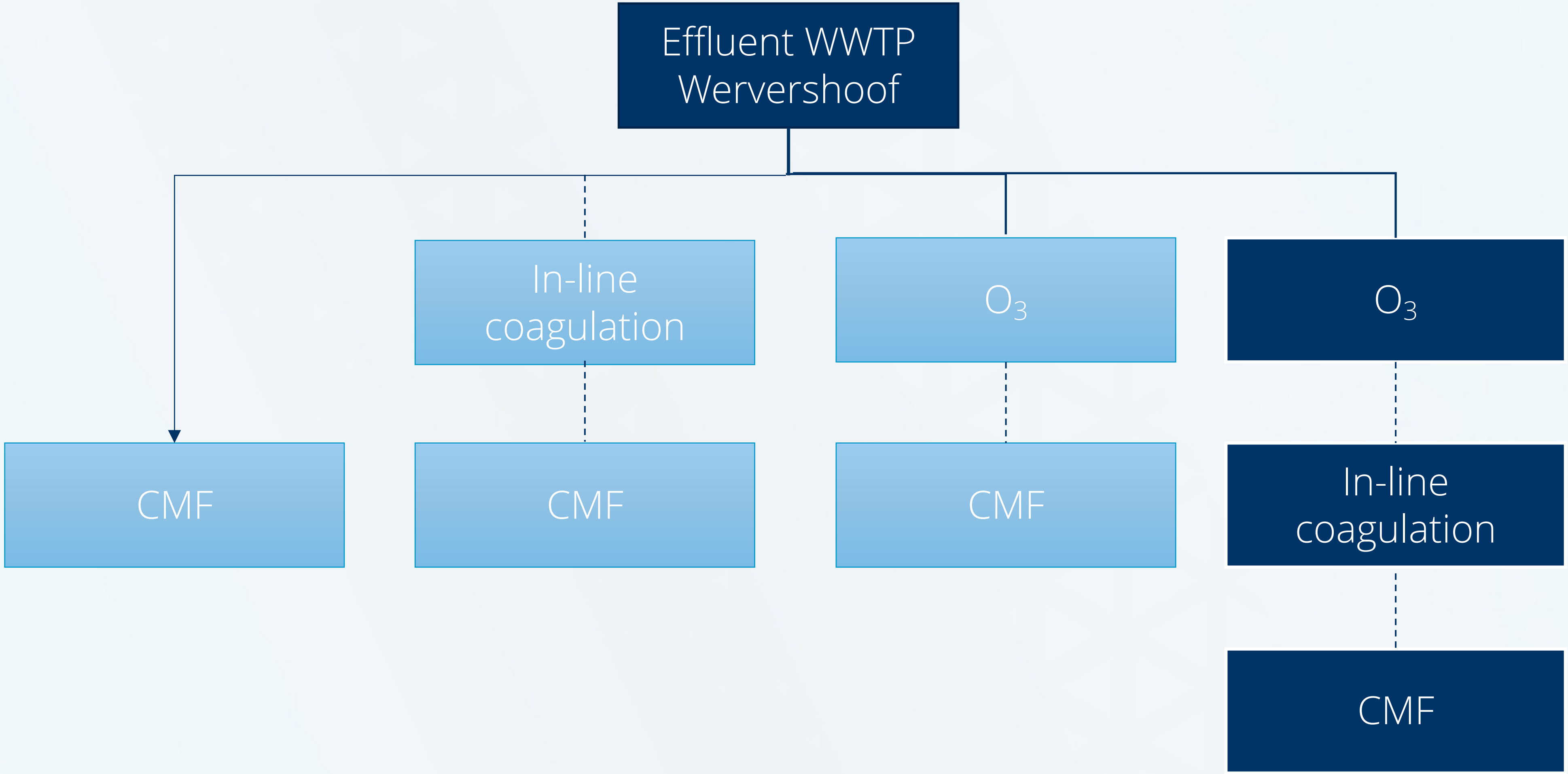
Ozonation pretreatment – 1.9 O_3/DOC



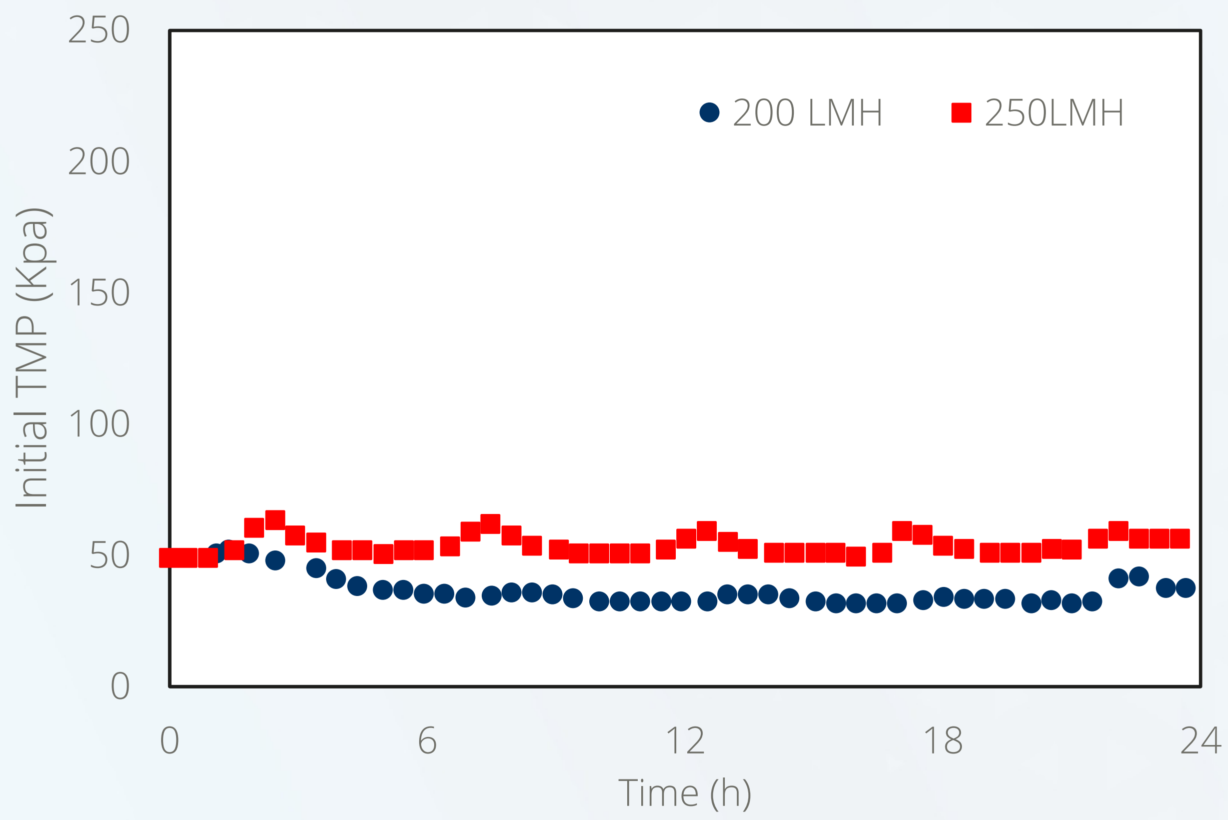
Flux (LMH)	Fouling rate (kPa/day)
187 LMH	~ 0
227 LMH	~ 0

Experimental set-up



Ozonation followed by coagulation pretreatment

10mgFe^{3+}/L at pH 6.8   1.9 O_3/DOC



Flux (LMH)	Fouling rate (kPa/day)
200	~ 0
250	~ 0

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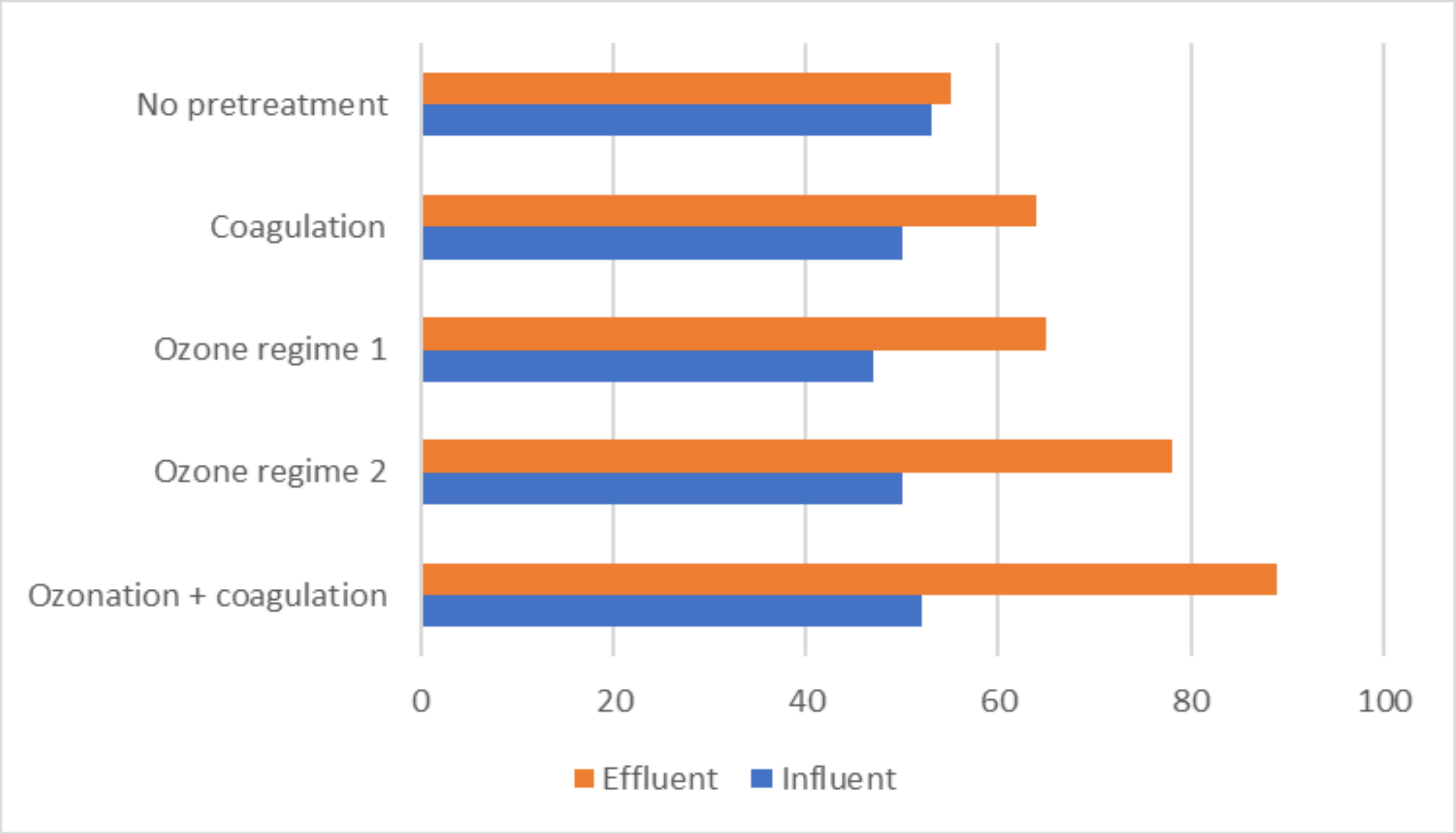
CMF Performance: conclusions

- Sustainable CMF flux enhanced by coagulation at pH 6.8
- Sustainable CMF flux enhanced by ozonation pretreatment (residual ozone)
- Ozonation followed by coagulation pretreatment resulted in highest CMF flux enhancement

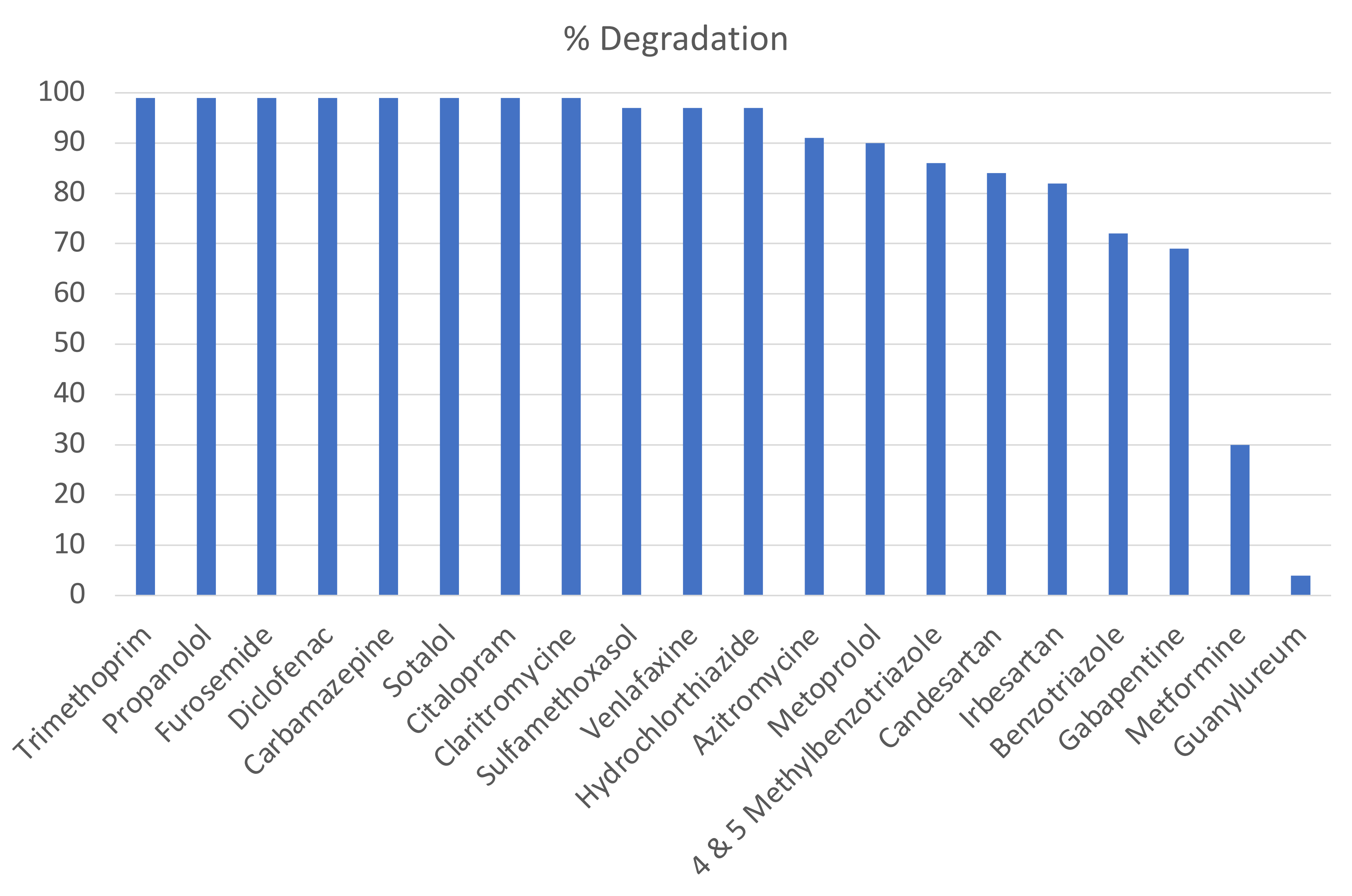
For optimal conditions ozonation/CMF, water quality examined within the context of reuse

Effect treatment on water quality: %UVT_{254}



%UVT_{254} WRK: 82 – 89%

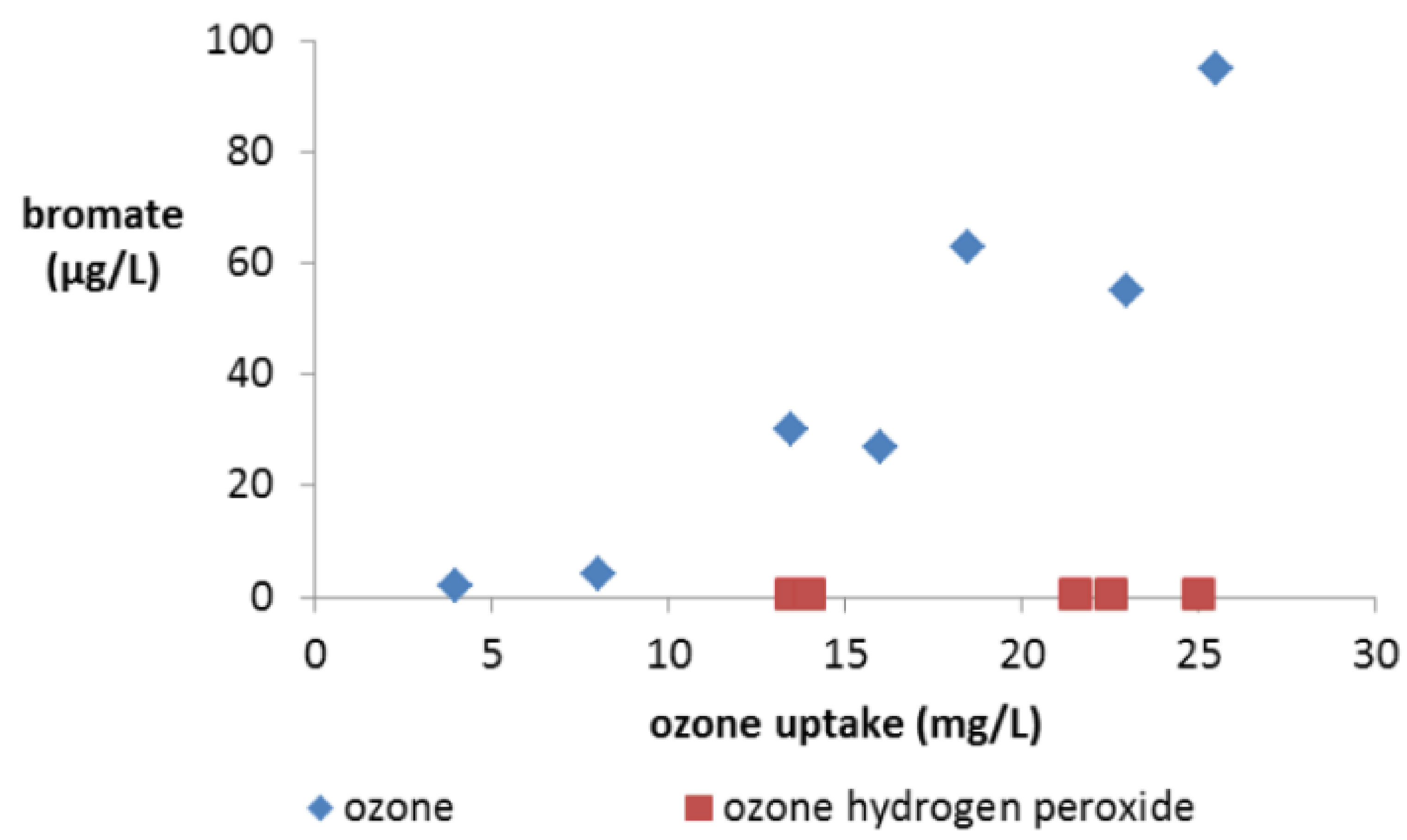
Pharmaceutical degradation – 0.9 O_3/DOC



Bromate: 2.97 µg/L

Ozonation, AOP & Bromate formation

- Maximizing pharmaceutical degradation, minimizing bromate formation



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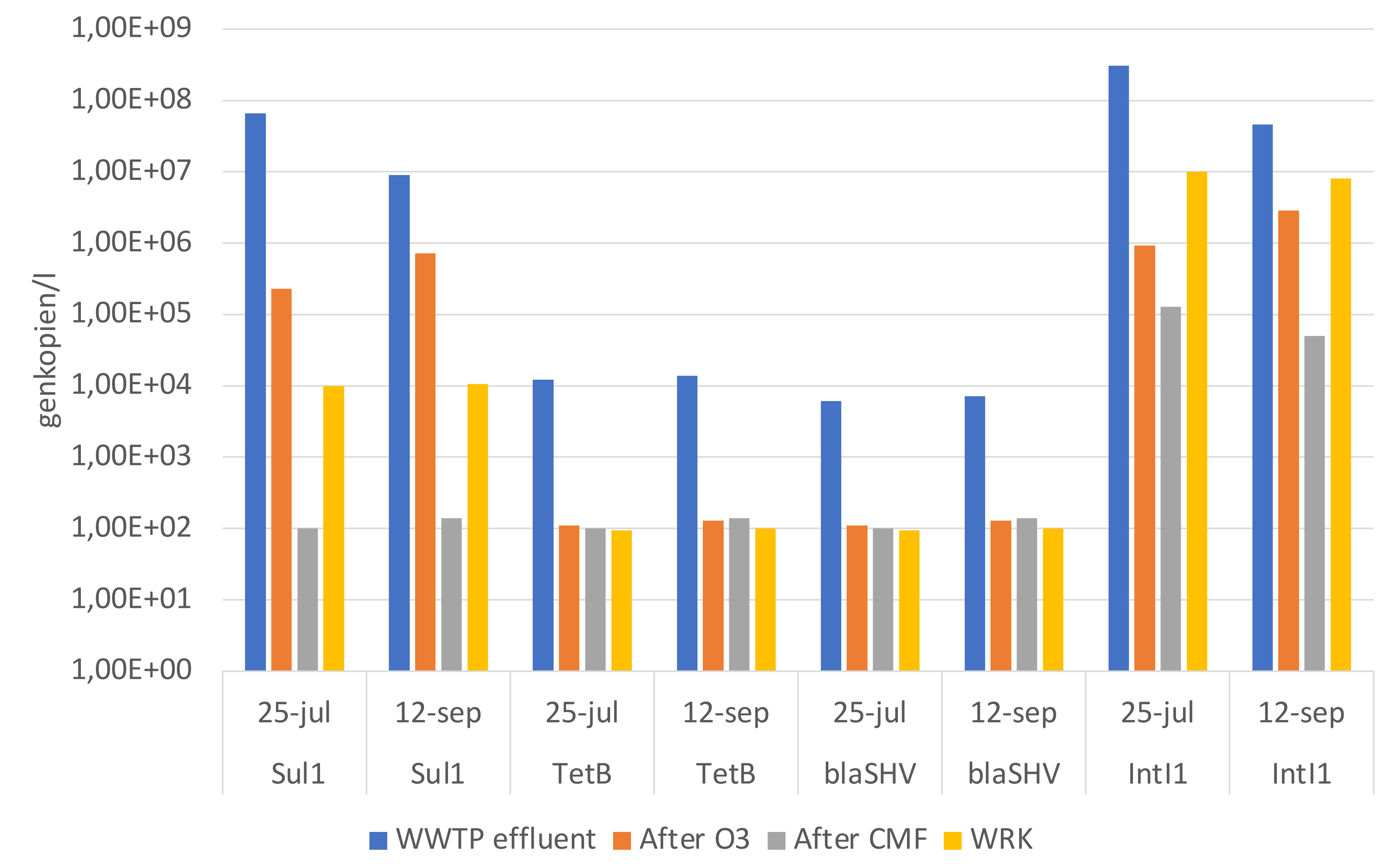
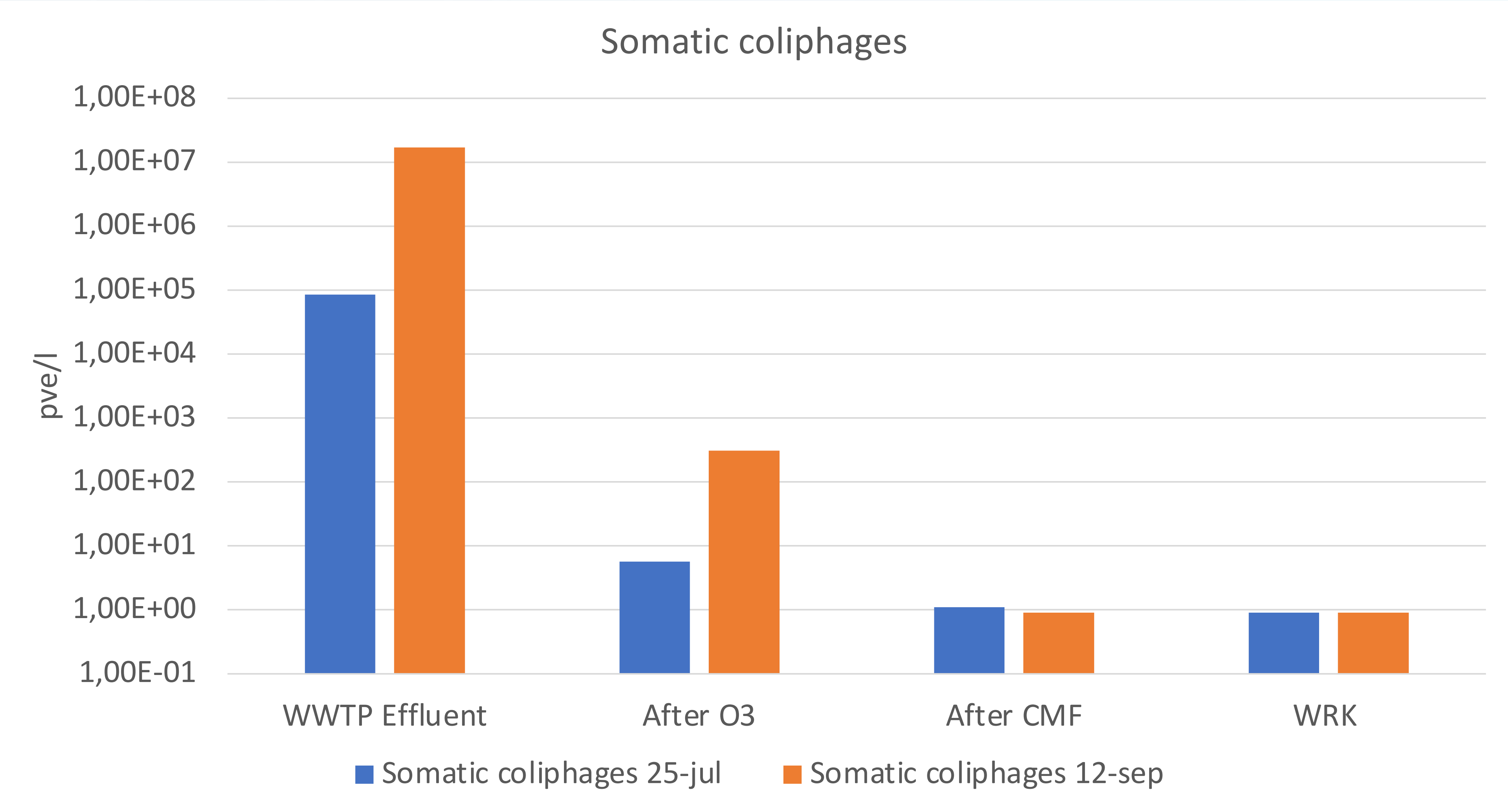
Antibiotic-resistant gene removal by O_3 - CMF



Bertelkamp, C. et al. (2020) TKI Sluiten watercyclus Noord-Holland

Virus removal by O_3 – CMF



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High-end reuse

- GAC/UV posttreatment possibly relevant for disinfection and removal organic micropollutants still present in O_3-coagulation-CMF effluent
- RO post-treatment known treatment step for high-end reuse scenarios (industry (demi)water)
- This study: explorative O_3-coagulation-CMF RO post-treatment experiments

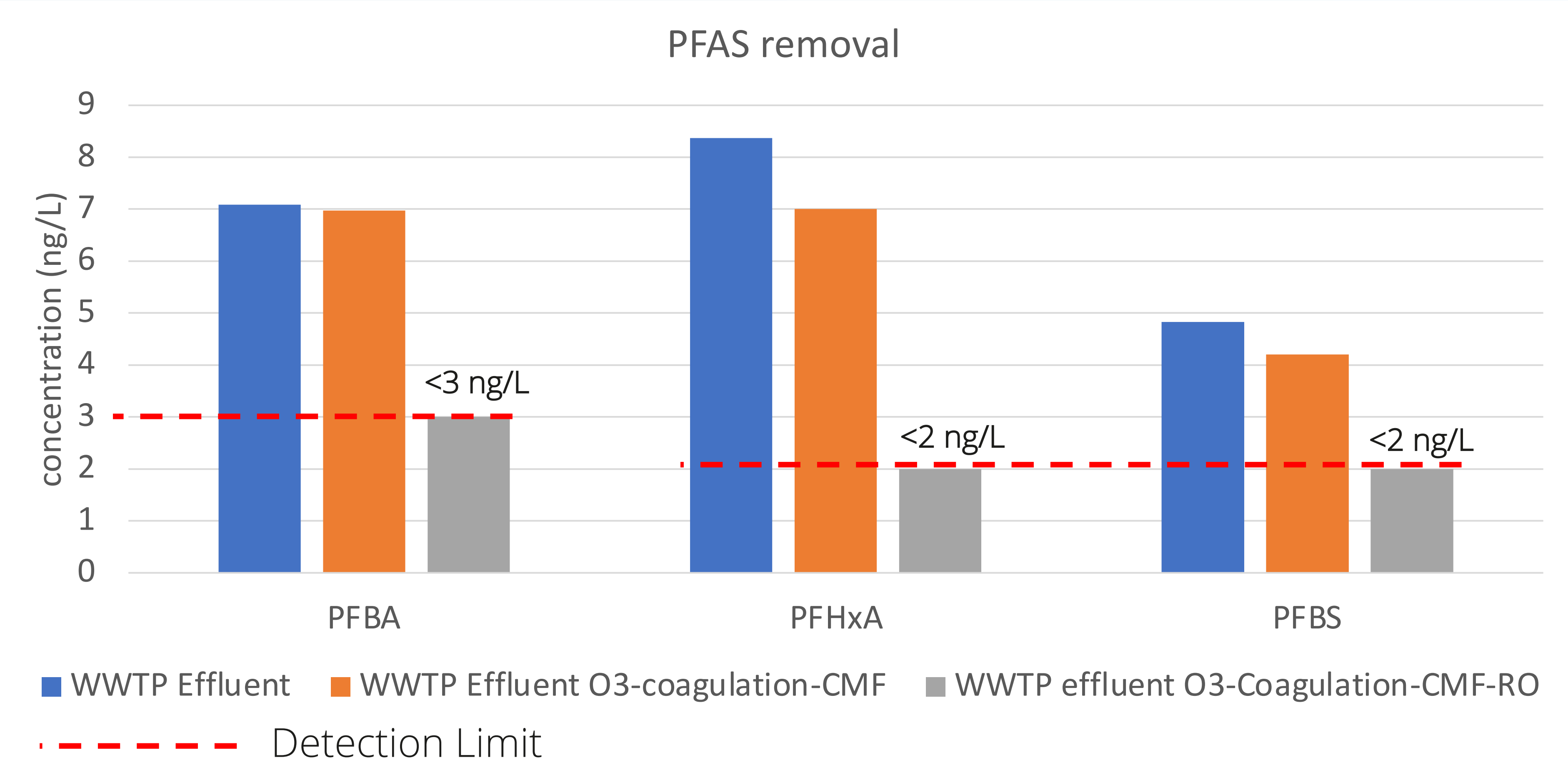
Process selection

Effluent WWTP Wervershoof	Source for re-use
O_3 Treatment	Degradation organic micropollutants and flux enhancement CMF
Ceramic Microfiltration	Removal suspended matter, microplastics and bacteria
RO	Demineralization, barrier broad range pollutants

Goal RO Posttreatment: water quality improvement

	WWTP Effluent	Pilot effluent	RO permeate
NH_4^+	19 mg/L	-	0.28 mg/L
Cl^-	183 mg/L	-	3 mg/L
NO_3^-	2.1 mg/L	-	0.49 mg/L
NO_2^-	0.51 mg/L	-	<0.007 mg/L
DOC	10.13 mg/L	7.14 mg/L	<0.20 mg/L
SO_4^{2-}	93 mg/L	-	<2 mg/L

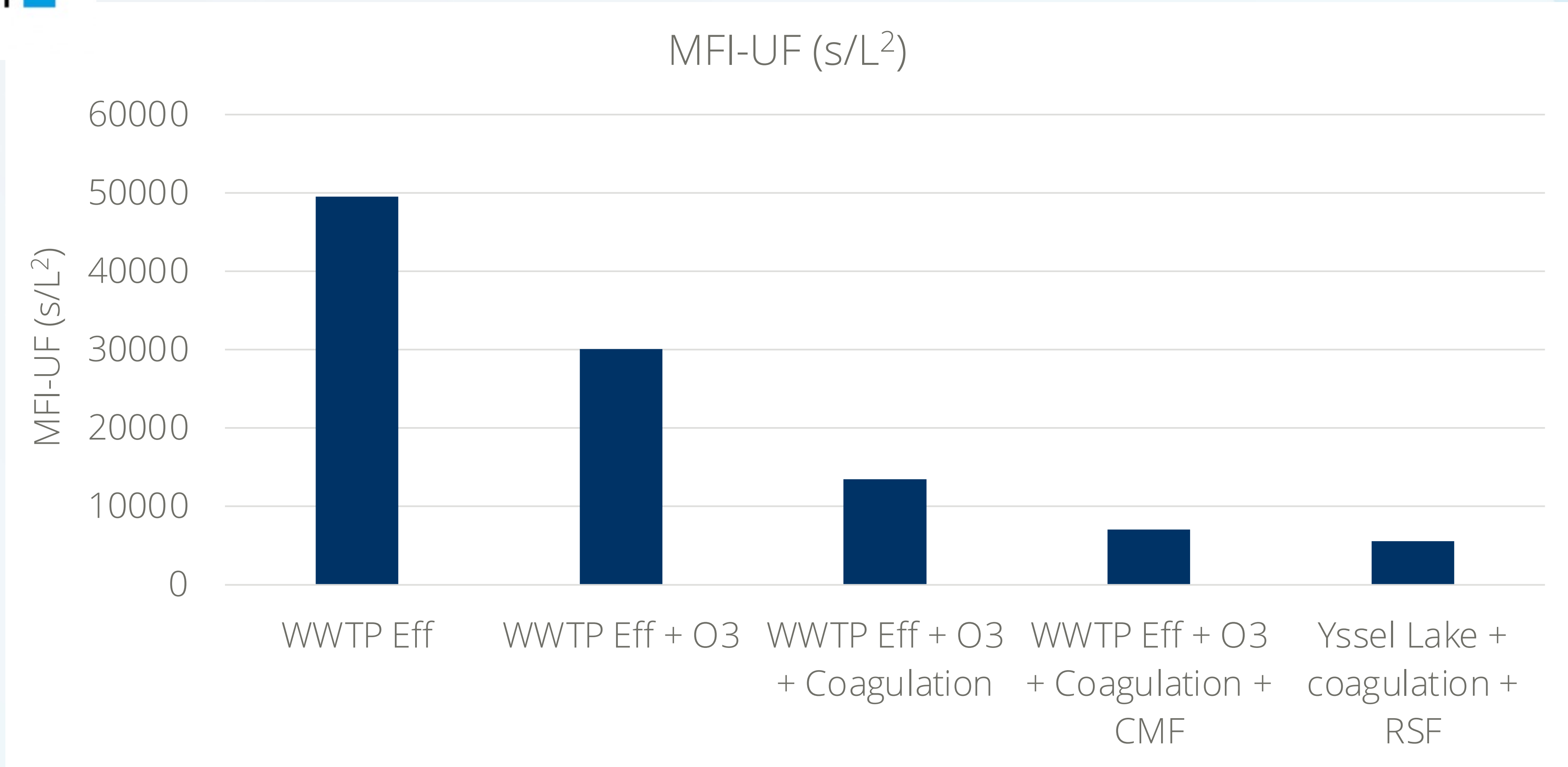
RO treatment: barrier against PFAS



RO: water quality & performance

- Explorative study: How does pilot effluent compare to WRK water in terms of water quality for RO applications?
- Focus on pretreatment for RO
- Membrane Fouling Index (MFI-UF) can be used as tool for predicting particulate fouling rate in RO systems
- Particulate fouling potential is based on constant flux testing in a conditioned bench scale UF setup
- Disclaimer: monitoring biofouling and long-term testing is needed for full picture

MFI-UF pilot effluent & WRK water



RO: pretreatment is key!

Future research

- New pilot: 5 m^3/h
- Continuous mode
- Water quality assessment
- Ozonation
- In-line coagulation
- CMF (C1 full scale membrane)

Closing the watercycle

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HHNK water authority

Thank you for your attention!

Martin Spruijt, PWN Technologies
Martin.Spruijt@pwnt.com

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Tackling Micropollutants in Wastewater

Approaches on Implementation and Innovation in Europe and The Netherlands

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Rijkswaterstaat
Ministry of Infrastructure and Water Management