NANOSTONE WATER

SINGAPORE INTERNATIONAL WATER WEEK 2021 ONLINE

Nanostone Water Innovative Ceramic Membrane technology in Water Treatment Applications

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Improved economics and reliability for SWRO pretreatment operations using novel ceramic filtration technology

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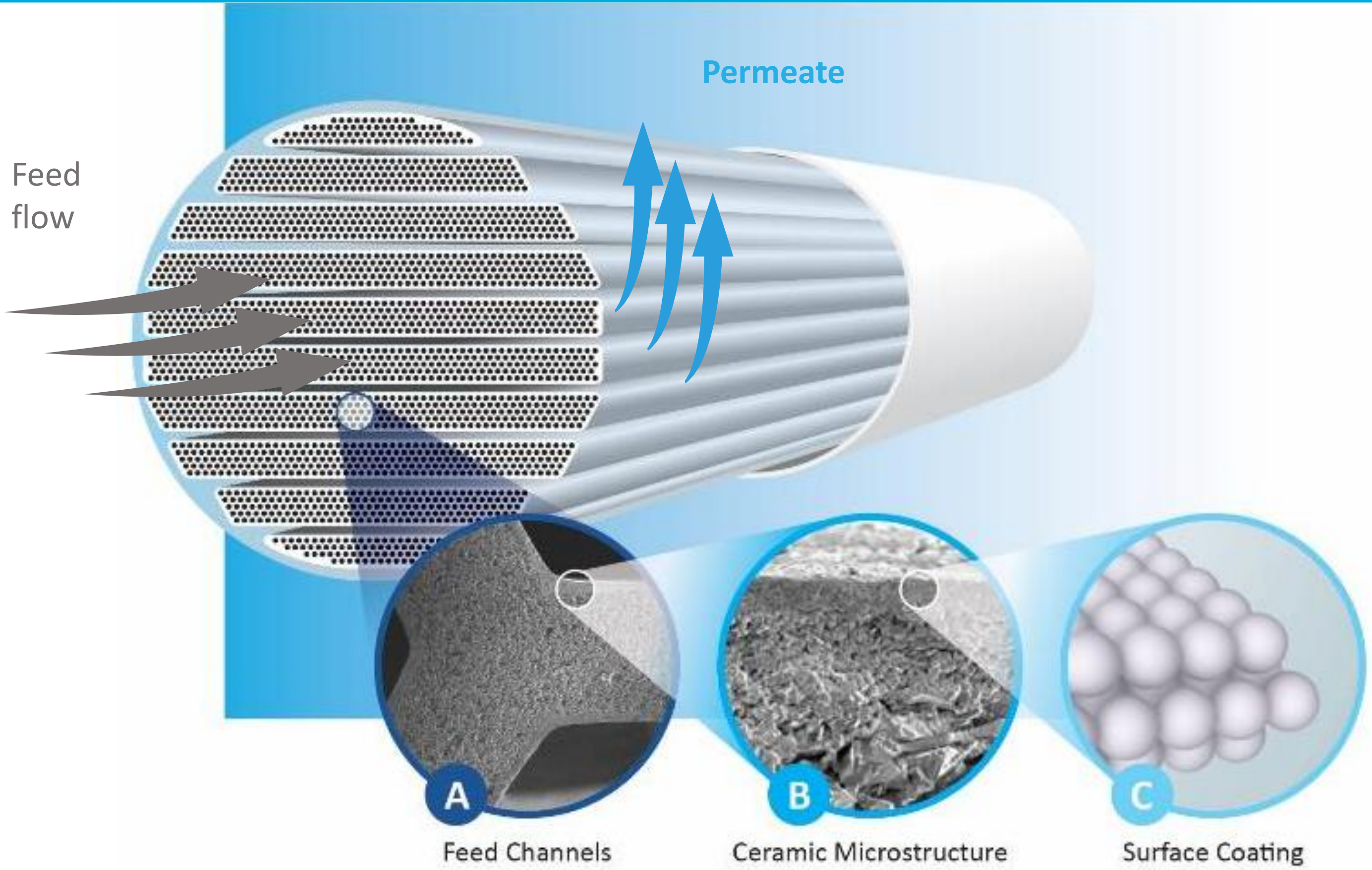
Biggest Desalination Pretreatment Issues Today

- Pre-treatment for desalination is a serious global problem
- Many membrane pre-treatment systems are under performing or failing
    - Some recoveries are down to 40%
    - Lack of DOC removal leads to RO fouling
- Sea water presents treatment issues – very different than fresh surface water
    - high algae concentrations
    - high solids
    - corrosive nature of sea water
- Need a form of pre-treatment that is specifically suitable and robust for these issues

Nanostone Module (Universal Design)

- α- Al_2O_3 ceramic membrane
- 262 ft^2/24.3 m^2 area
- Inside to out filtration, dead end
- 0.03 microns pore size, 2.4 mm feed channels
- 7 bar rated pressure
- Overall height 1.9 m, Dia 9.8 in, shipping weight 95 kg
- Duplex SS Permeate Port
- Allows one for one swap of PUF
- Technology advanced on the inside, but highly integrable on the outside
- Conscious decision round housing for easy PUF retrofit

Nanostone Module



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Ideally Suited for Desalination Pre-treatment

- Membrane and module are sea water resistant
- Large channels (2.4 mm) can hold a large amount of solids and algae
- Minimal pre-treatment (coagulation only) is necessary to function optimally
  - no need for Dissolved Air Floatation (DAF) or other forms of clarification,
  - saving space and complexity while improving reliability
- Can operate optimally with coagulation removing organics significantly improving downstream RO operations
  - many membrane systems avoid coagulation placing burden on downstream processes
- High fluxes (> 200 lmh) can be achieved reducing footprint
  - many desalination plants are located in urban areas land is a premium
- Rigorous cleaning can be achieved with high flow backwashing and chemicals

Overview of Pilot at Tuas

Objectives

- Stable UF-performance at economical feasible flux
- Highest possible NOM/DOC removal for downstream RO
- Absolute filtration for SS (low Turbidity, SDI)

Pre-treatment

- Continuous 5 days 2 ppm NaOCl dose, +6 ppm shock dose for 2 days (8ppm)
- Sieve 20 mm
- Rough screen 2mm (other MF/UF pilots on site have a 400µm or finer screen)
- In-line coagulation with $FeCl_3$, pH-control and 1-3 minute contact time

Logistics

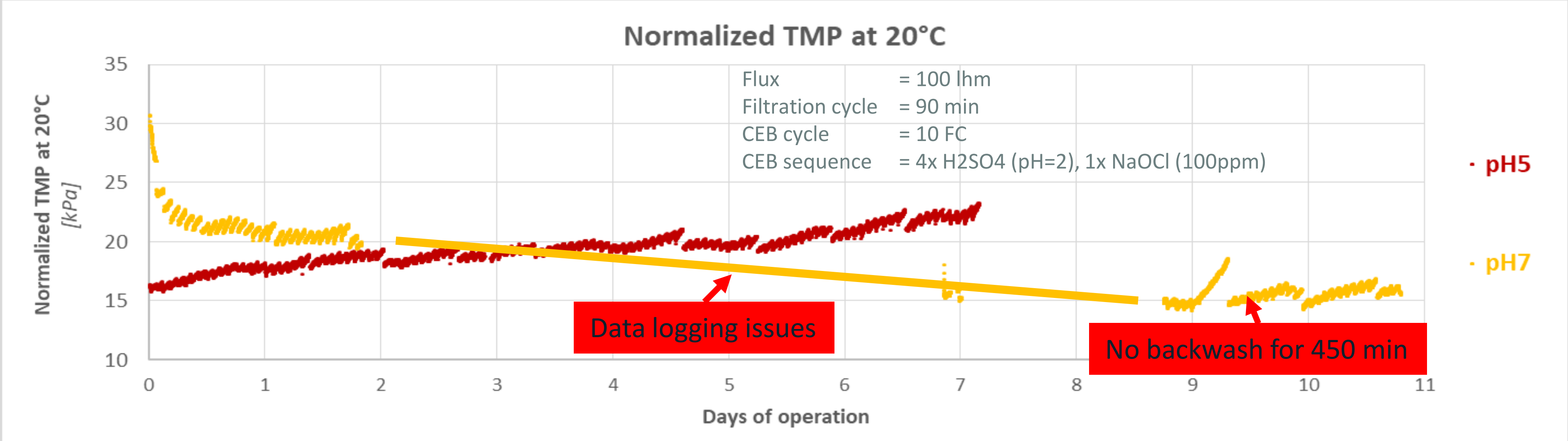
- Trial of 6 months
  - 3 months optimization
  - 3 months longer-term monitoring

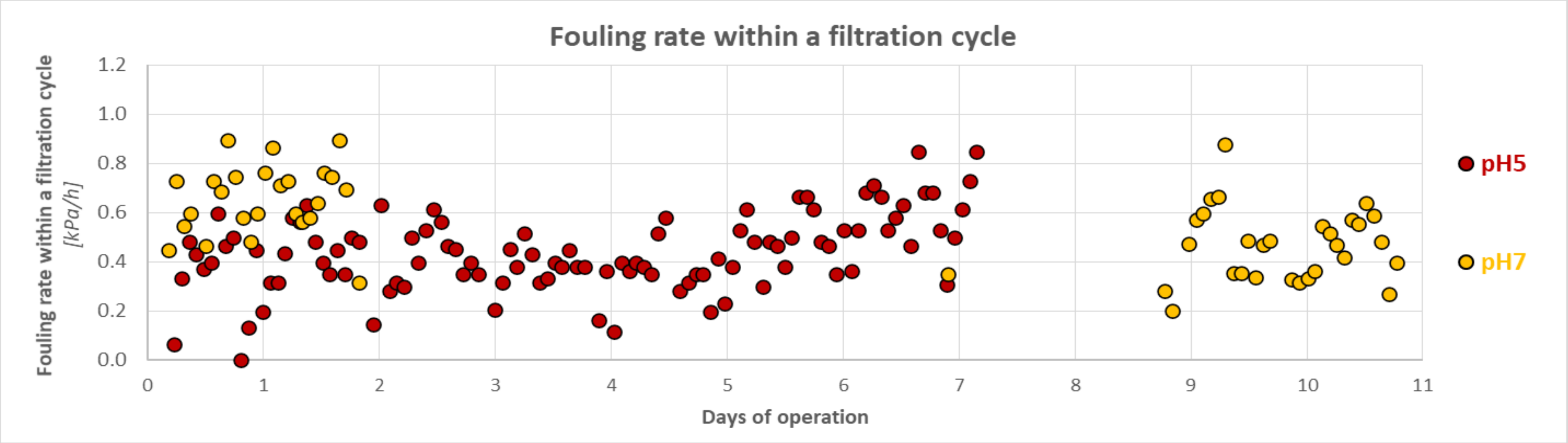
Overview of Pilot at Tuas

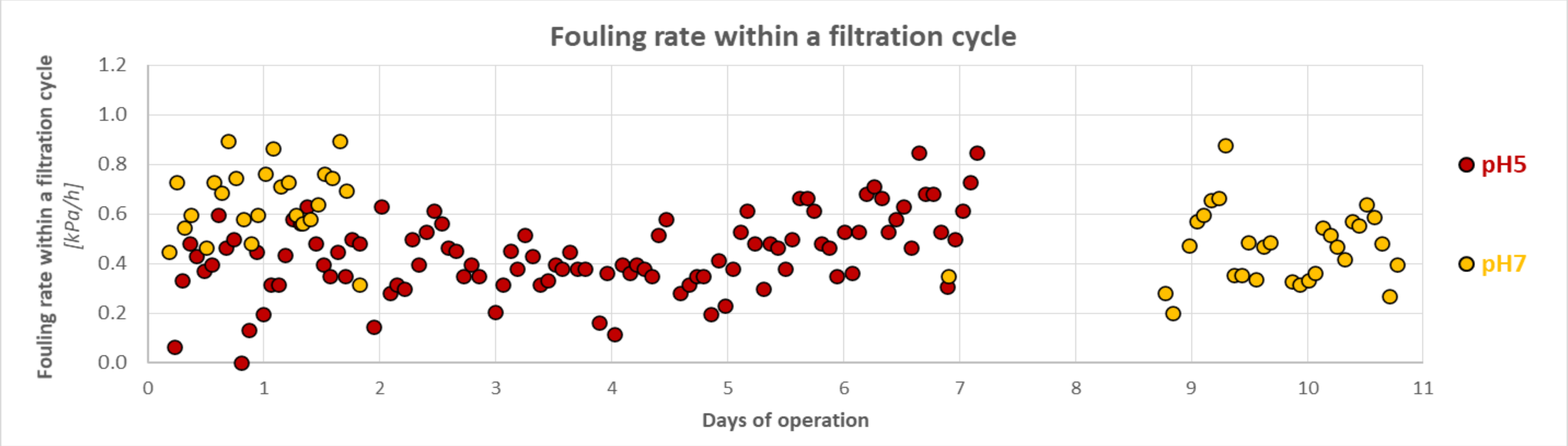
Jar Testing	• Find initial coagulant dose and pH-range (done)
Commissioning	• Delayed by Covid-19 circuit breaker events
In-line coagulation	• Initial optimization, 4 weeks (done) • Confirm jar tests in a continuous process • Find optimum pH (done)
Optimization	• Establish critical flux, 4 weeks (done) • Establish filtration time or optimum load L/m2, 2 weeks (done) • Establish CEB frequency, 3 weeks (done)
Long-Term Operation	• Confirm/validate optimum operation, 12 weeks

Technical background/research at TUAS (PUB) – Optimizing ILC

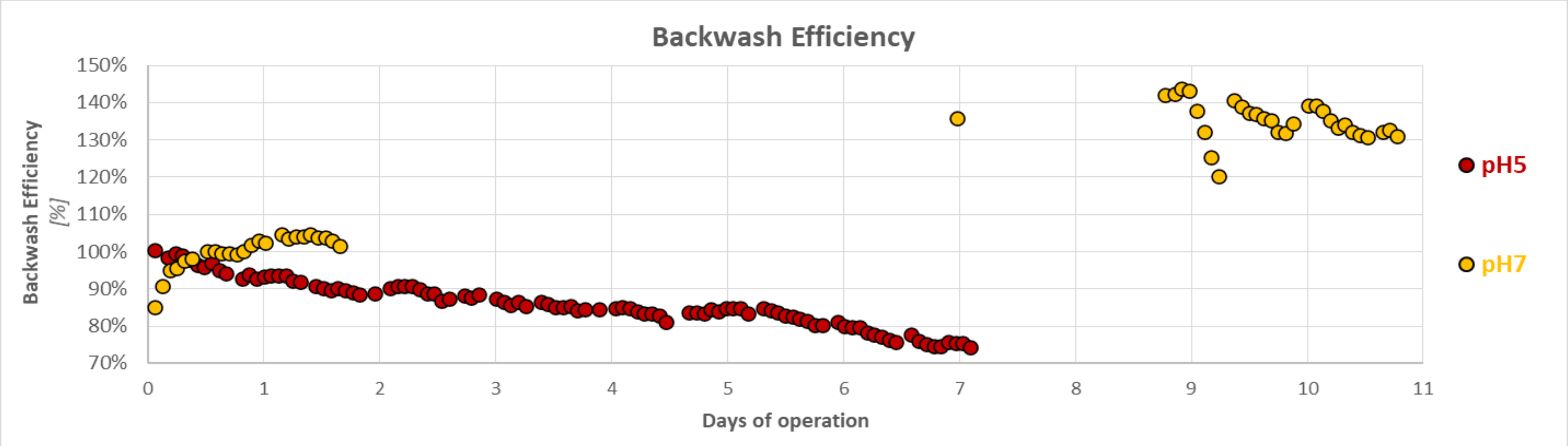
- Based on theory expectations for pH 5 are:
  - Closer to “Enhanced” coagulation
  - Higher removal percentage DOC (humic fraction)
  - Some irreversible fouling caused by charged matter
  - Charged metal organic complexes formed
- Based on theory expectations for pH 7 are:
  - Closer to “Sweep” flocculation
  - Lower removal rate DOC (mainly HMW fraction)
  - Less irreversible fouling caused by formation of uncharged $Fe(OH)_3$


Normalized TMP at 20°C
Normalized TMP at 20°C [kPa]
Days of operation
Flux = 100 lhm
Filtration cycle = 90 min
CEB cycle = 10 FC
CEB sequence = 4x H2SO4 (pH=2), 1x NaOCl (100ppm)
Data logging issues
No backwash for 450 min
pH5
pH7


Fouling rate within a filtration cycle
Fouling rate within a filtration cycle [kPa/h]
Days of operation
pH5
pH7

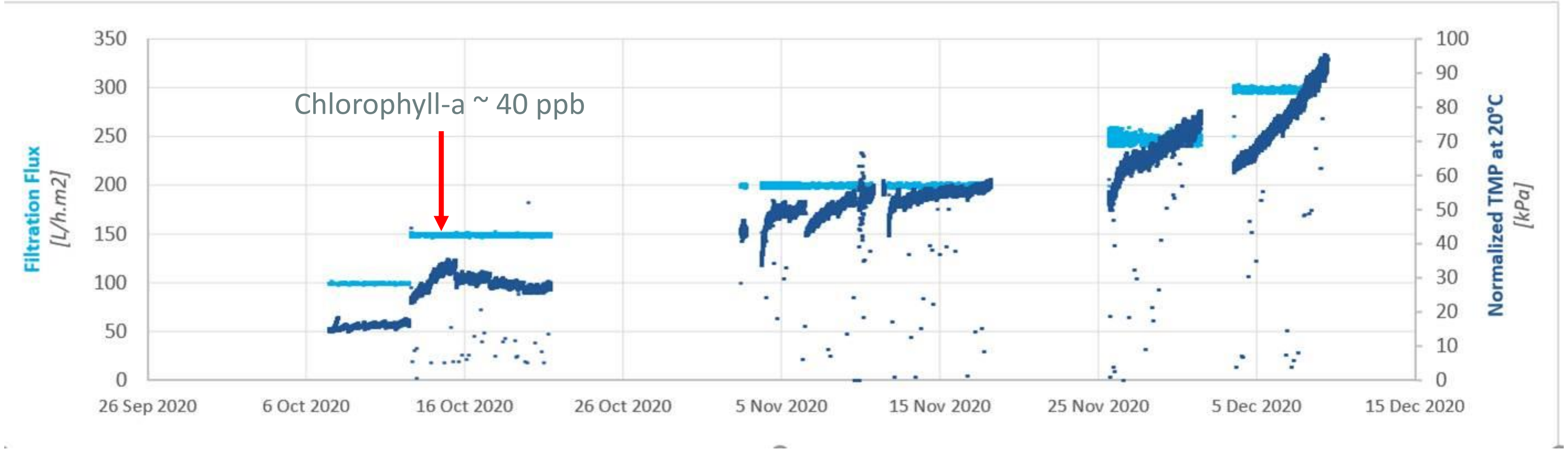


Fouling rate within a filtration cycle
Fouling rate within a filtration cycle
[kPa/h]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
Days of operation
pH5
pH7



Backwash Efficiency
Backwash Efficiency
[%]
150%
140%
130%
120%
110%
100%
90%
80%
70%
0
1
2
3
4
5
6
7
8
9
10
11
Days of operation
pH5
pH7

Critical Flux Determination



CIP Frequency:

Fouling rate for 100 lmh run = 0.2761 kPa/day (~360 days CIP frequency)

Fouling rate for 150 lmh run = 0.2951 kPa/day (~340 days CIP frequency)

Fouling rate for 200 lmh run = 2.4313 kPa/day (~45 days CIP frequency)

Fouling rate for 250 lmh run = 3.2266 kPa/day (~31 days CIP frequency)

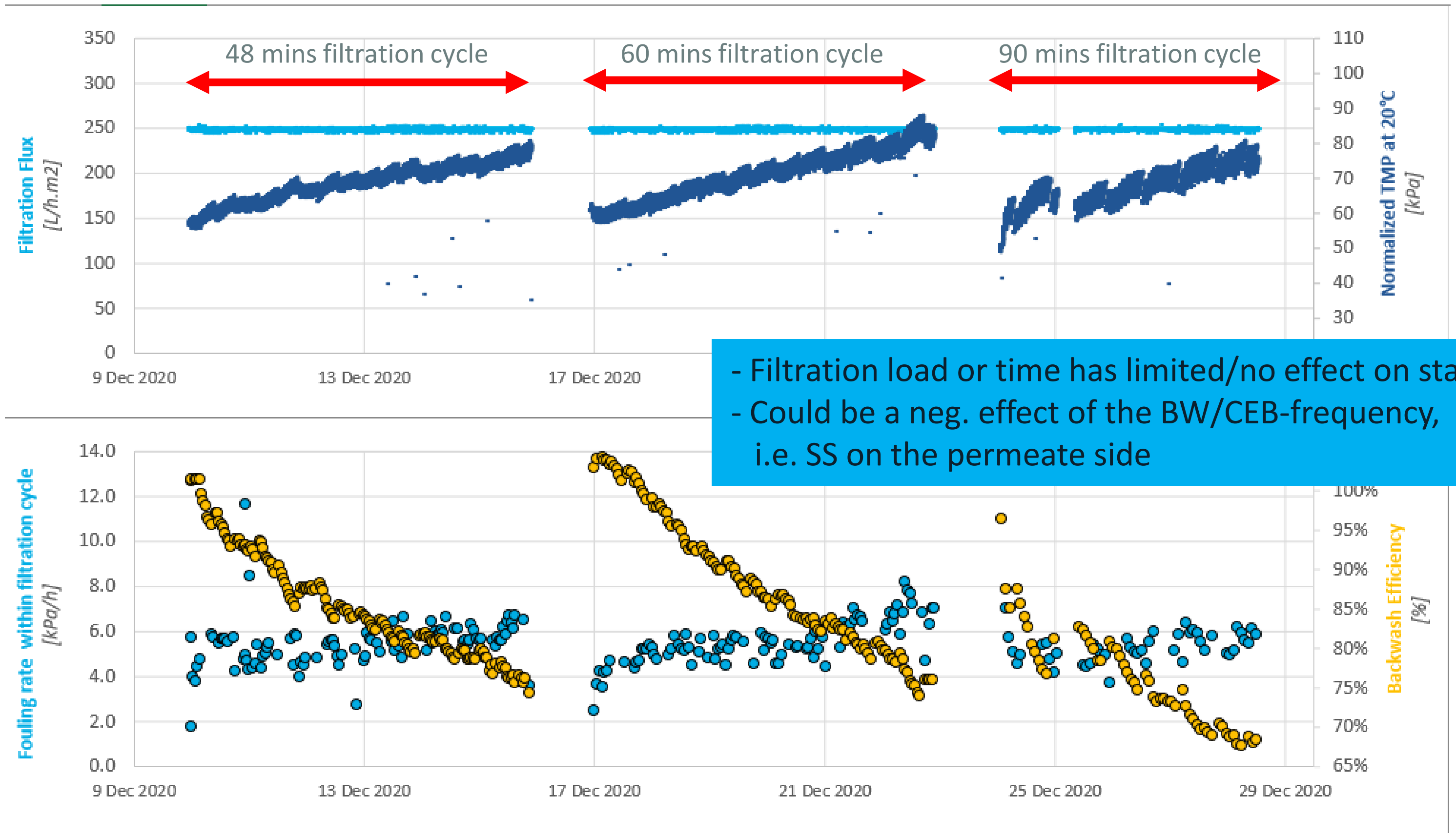
Fouling rate for 300 lmh run = 4.6611 kPa/day (~22 days CIP frequency)

At all fluxes (even 300 lhm) critical flux is not reached

- Fouling at higher flux mainly caused by BW efficiency loss
- 300lhm not feasible in feed/discharge capacity on site
- 250 lhm chosen to further optimize (stabilization)

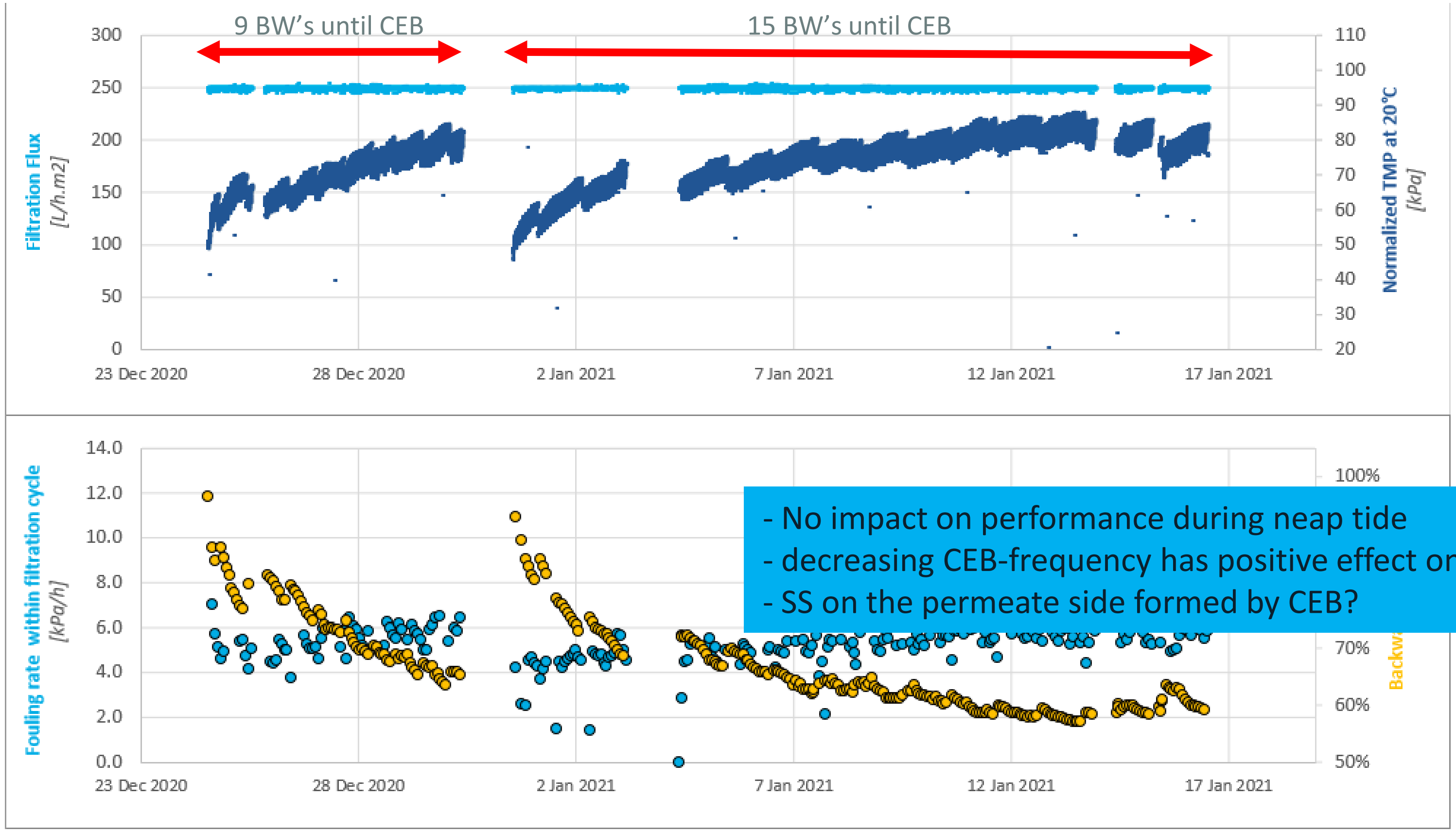
Note: based on initial TMP = 50 kPa and TMP before CIP = 150 kPa

Backwash Frequency Optimization



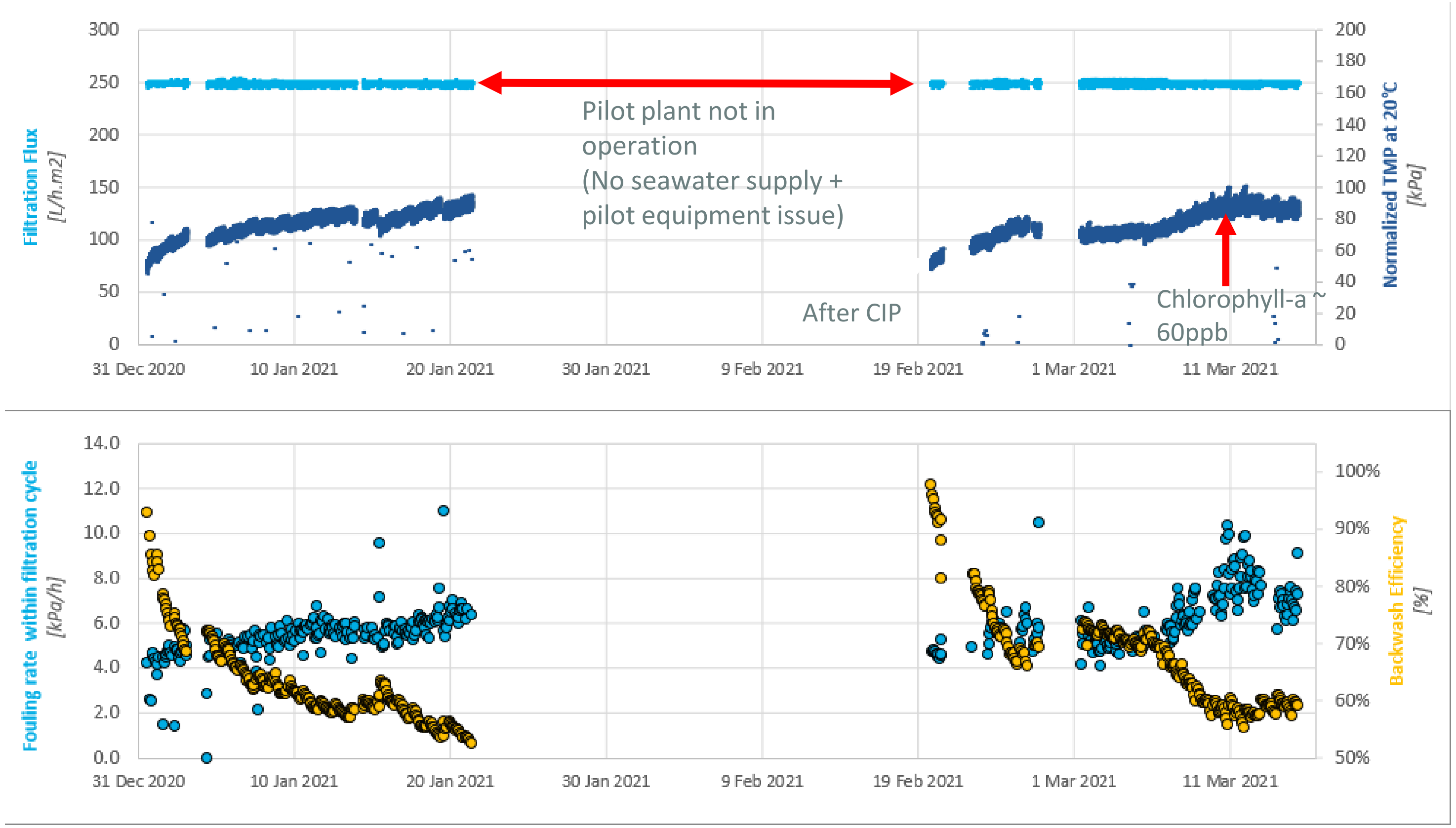
- Filtration load or time has limited/no effect on stability
- Could be a neg. effect of the BW/CEB-frequency, i.e. SS on the permeate side

CEB Frequency Optimization



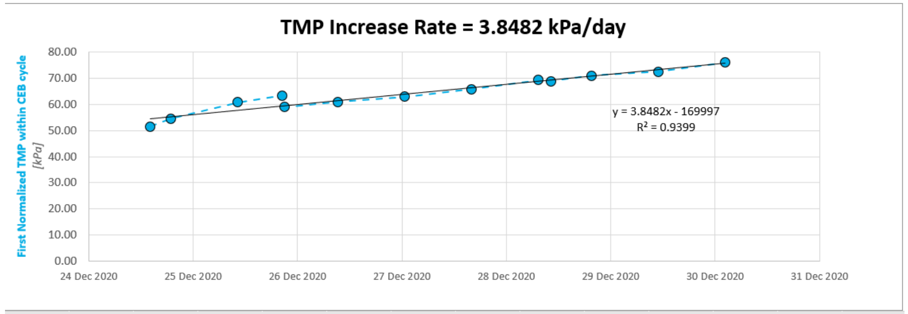
- No impact on performance during neap tide
- decreasing CEB-frequency has positive effect on stability!
- SS on the permeate side formed by CEB?

Long Term Operation



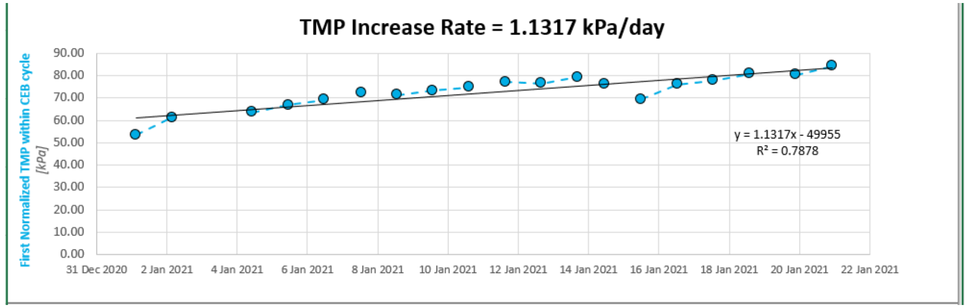
Estimated CIP Frequency

- Flux – 250 lmh with 90 mins filtration cycle
- CEB frequency – after every 9 BW's



- CIP frequency = 26 days
- Based on initial TMP = 50 kPa and TMP before CIP = 150 kPa

- Flux – 250 lmh with 90 mins filtration cycle
- CEB frequency – after every 15 BW's

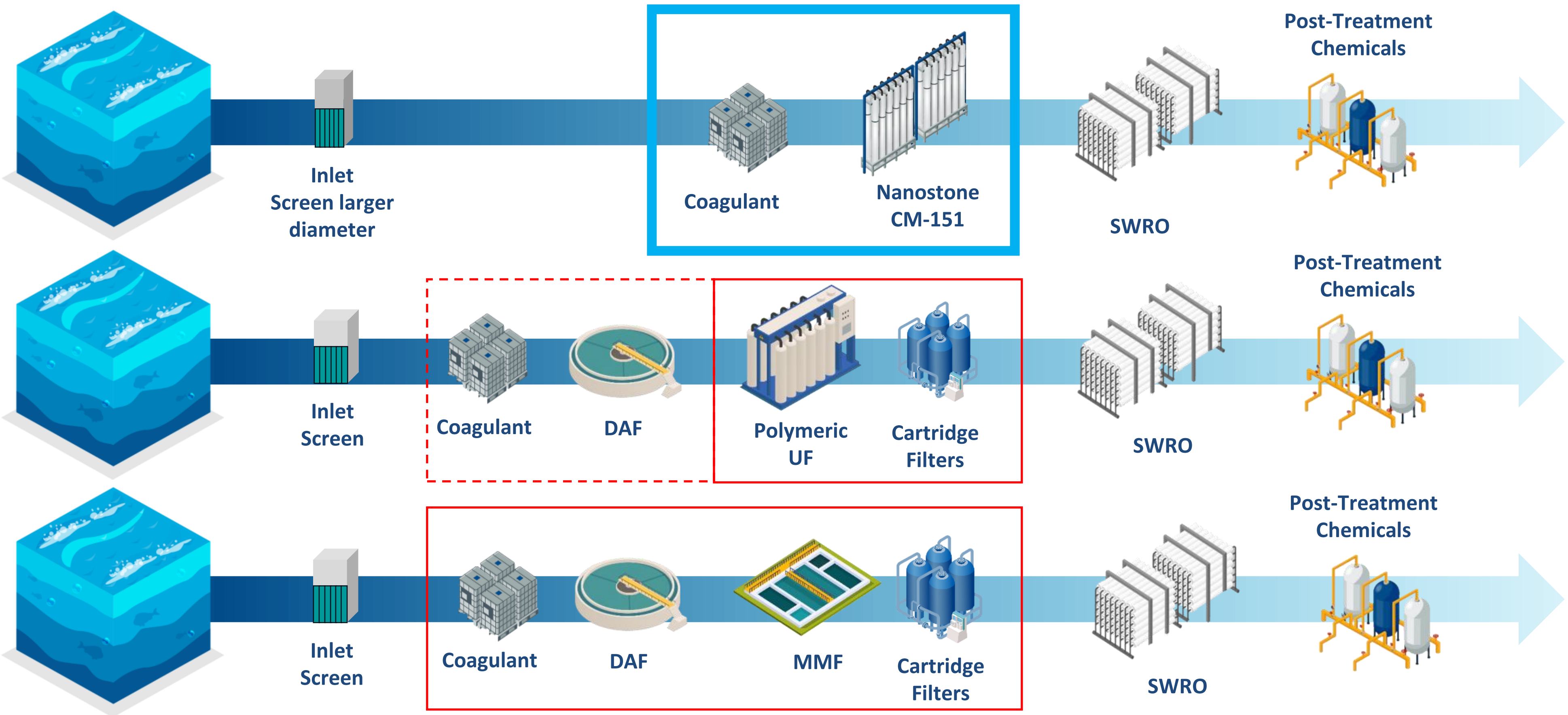


- CIP frequency = 89 days
- Based on initial TMP = 50 kPa and TMP before CIP = 150 kPa

Summary of results

- Membrane operates very well (during algae blooms and neap tide events) with minimal pretreatment - coagulation only – NO DAF
- Very favorable operating conditions
  - Flux 250 lhm at 90 min filtration cycles
  - CEB after 15 FC cycles (approx. 1/day)
  - low pH (2) with 100 ppm H2O2 and then 15 FC later NaOCl (100ppm)
  - <u>High flux means lower footprint</u>
- However further optimization is possible since most likely SS is formed during CEB with NaOCl at 100 ppm
  - We can not lower pH of NaOCl CEB (pilot is limited)
  - No NaOCl CEB has negative effect on overall performance

Nanostone Optimized for **Lowest Pretreatment Costs**



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Insert video 2-CRWA testimonial

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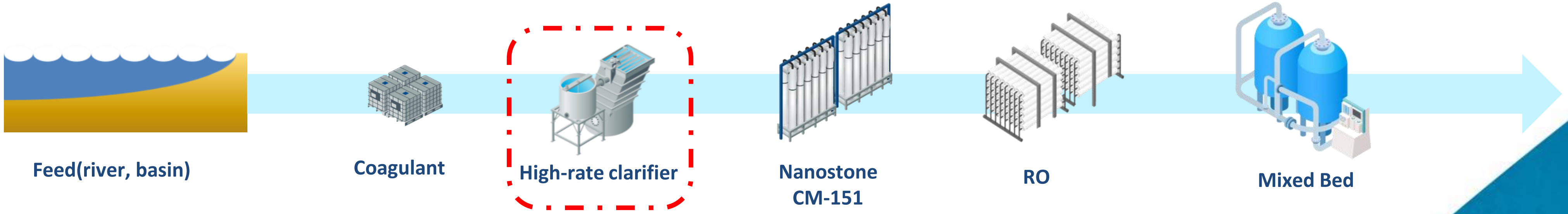
Industrial Raw Water Treatment

Large industrial process water users build surface water treatment plants with:

- RO Pre-treatment composed of
  - Clarifier to reduce incoming TSS and handle solids variability from surface water source
  - Multimedia Filter to bring down TSS and filter out organics by adding coagulant
  - Polymeric UF to reach SDI and allow for stable operation of the RO

➢ **Nanostone Ceramic UF Solution**

- Direct feed from the surface water providing UF quality permeate to the RO
- Or a quick clarifier upstream depending on client's requirement and incoming TSS variability
- Lower CapEx (1 system instead of 2 or 3), lower OpEx (chemicals, electricity), lower footprint
- Robust and stable operation with CUF warranty 10 to 15 years



Hengyang Power Plant BFW – Shanghai, China

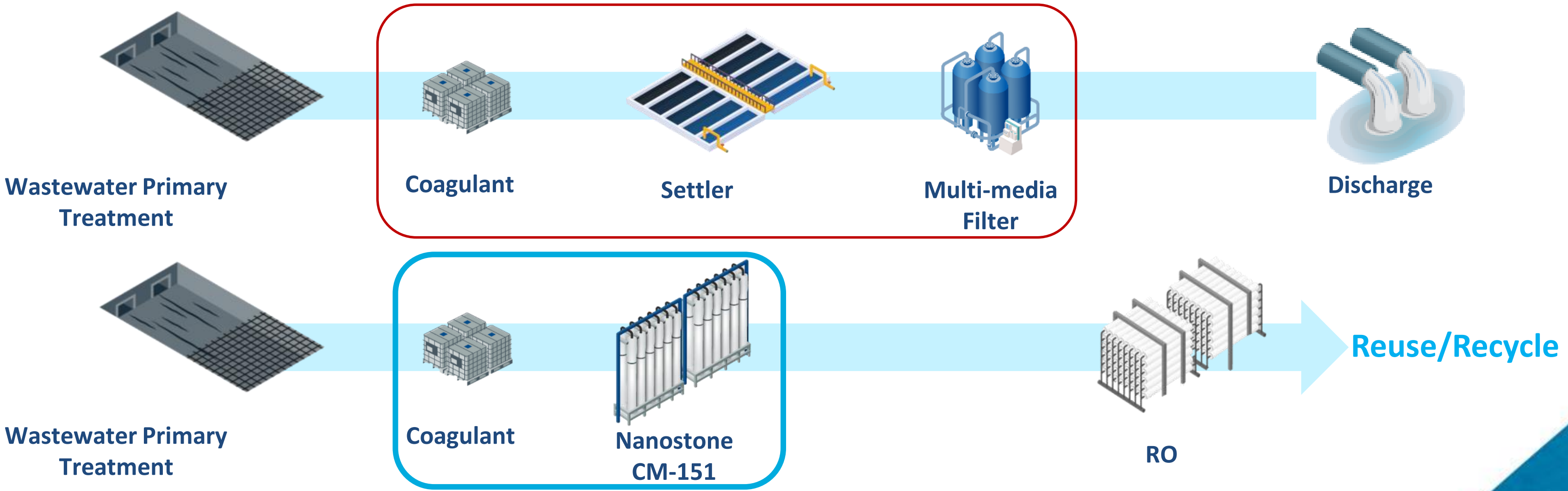
End-User Name	Hengyang Pyroelectricity
Application:	Clarified Surface Water to Boiler Feed
Start Up Date:	October 2017
Overall Plant Flow:	2.28 MGD (360 m^3/hr)
Incumbent System:	Hyflux – 4 x 28 membranes per skid
NSW Design:	14 x 4 = 56 modules total
Feed Quality:	< 5 NTU in-line coagulated feed
Design Flux:	Operating at >180 GFD (>300 lmh)
Recovery:	>94%

Side by Side Comparison	Hyflux	Nanostone
Matching system	112 Modules	56 Modules
Operational Flow	1,140,000 GPD	2,240,000 GPD
Silt Density Index (SDI)	4-5	< 2

Industrial Wastewater Reuse/Recycling

Industrial Wastewater Reuse/Recycling

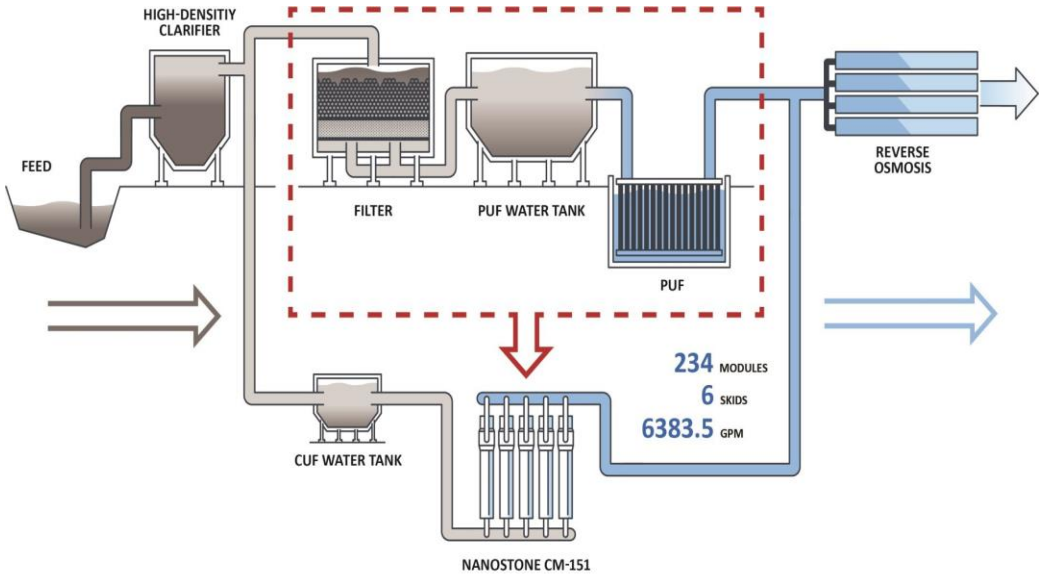
- Suitable for Power, Mining & Metal processing, Semiconductors, Chemicals, Refinery & Petrochemicals
- Direct feed from non-biodegradable wastewater into Nanostone CUF to produce safe and reliable feed for the RO
- Downstream biological WWTP, feed from the secondary clarifier into Nanostone CUF to produce safe and reliable feed for the RO
- Compact and robust solution with competitive lifecycle cost



Xiaojihan Coal Mine Wastewater Reuse – Shanxi, China

End-User Name	Xiaojihan Coal Mine
Application:	Coal Mine Wastewater Reuse
Start Up Date:	May 2019
Overall Plant Flow:	9.2 MGD (**1452 m^3/hr**)
Incumbent System:	Submerged Polymeric UF Membrane
NSW Design:	6 x 39 modules
Design Temperature:	68 ° F (20 ° C)
Feed Quality:	<5 NTU Clarifier effluent (Soft/Coag)
Design Flux:	150 GFD (**254 lmh**)
Recovery:	98.9%
Permeate Quality:	<0.2 NTU

Side by Side Comparison	Submerged PUF	Nanostone
Fiber breakage	Yes	No
Operational Flow	6.4MGD	9.2 MGD
Silt Density Index (SDI)	Instable	< 2



Semiconductor Manufacturer – Shanghai, China

End-User Name	Semiconductor Manufacturer
Application:	Semiconductor Wastewater Reuse
Start Up Date:	October 2017
Overall Plant Flow:	0.32 MGD (50 m^3/hr) Mixed waste; 0.16 MGD (25m^3/hr)/each, Phase II-IV Grinding waste
Incumbent System:	Mixed WW: clarifier + filter, discharged; no reuse possible Grinding WW: 3 x 10 Norit X-flow
NSW Design:	Mixed waste: 1 skid - 18 CM-151 modules Grinding waste: 3 x 6 CM-151 modules
Design Temperature:	68 – 77° F (20 – 25° C)
Feed Quality:	Mixed waste: 8,000-10,000NTU Grinding waste: 2,000-3,000NTU
Design Flux:	Mixed waste: 67 GFD (114 lmh) Grinding waste:100GFD(170 lmh)
Recovery:	Mixed waste >85%; Grinding waste: >90%; all reused
Permeate Quality:	<0.15 NTU

Mixed WW (new)

Grind WW (retrofit)

We want to hear from you…

- General feedback on pretreatment?
- Piloting for ongoing or under planning or construction projects?
- Performance improvement for pre-treatment?

Let’s chat further…

Q/A

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THANK YOU

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