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CONFERENCE & EXPOSITION

Ceramic Membranes for Reuse

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acknowledgements

- Clement, Tian, and Tan (2009)
- Dow, Murphy, Clement, and Duke; Water, (2013)
- Zheng, Shorney-Darby, and Galjaard (2015)
- Metawater

objectives

- evaluate pre-treatment to optimize the performance of ceramic membranes for reuse applications
  - coagulation
  - oxidation
  - performance parameters:
    - flux
    - cleaning protocols
    - treated water quality
    - suitability for downstream RO
- identify benefits of ceramic membranes in reuse applications

background

Location	Membrane	Pre-treatment
Bedok, Singapore	intermediate	Pre-coag, pre-ozone
Asian client	4.3 sqft (0.4 m2)	Pre-coag, pre-chlorination and pre-ozone
Australia	269 sqft (25 m2)	Pre-coag, pre-ozone
Current Australia pilot	269 sqft (25 m2)	Pre-coag, pre-ozone
Medemblik, NL	4.3 sqft (0.4 m2)	Pre-coag, pre-ozone
Metawater Reuse Plant	269 sqft (25 m2)	Pre-coag, pre-ozone

ceramic microfiltration

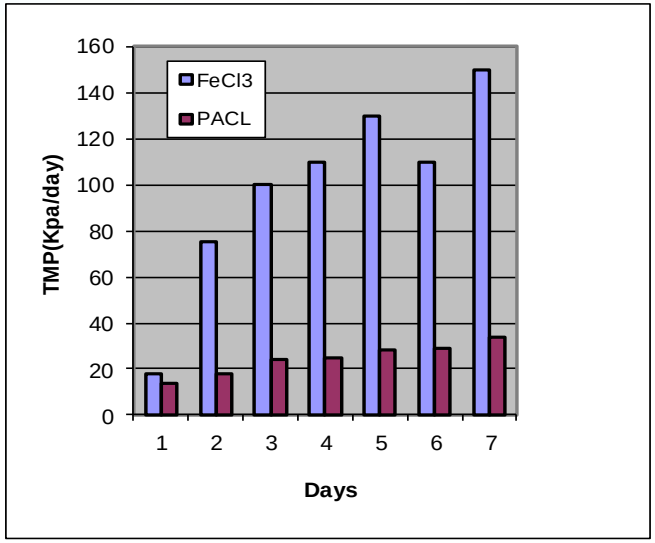
- Metawater ceramic microfiltration module
- total membrane filtration area 25 m^2 (~269 ft^2)
- pore size of 0.1 µm
- 2000 filtration channels

coagulation and ozone pre-treatment (Bedok, Singapore)

- 12 month pilot
- two intermediate sized membranes in parallel
- TOC = 6 to 7 mg/L
- turbidity = 5 to 6 NTU
- temperature = 29 oC
- initial testing showed PACl better than ferric coagulant
- ozone dosed directly upstream of membrane
  contact time unknown

Clement, Tian, and Tan (2009)

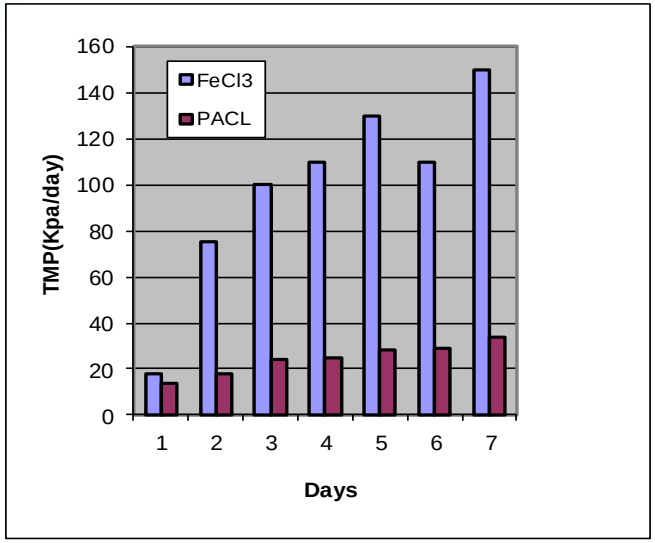
coagulation and ozone pre-treatment (Bedok, Singapore)

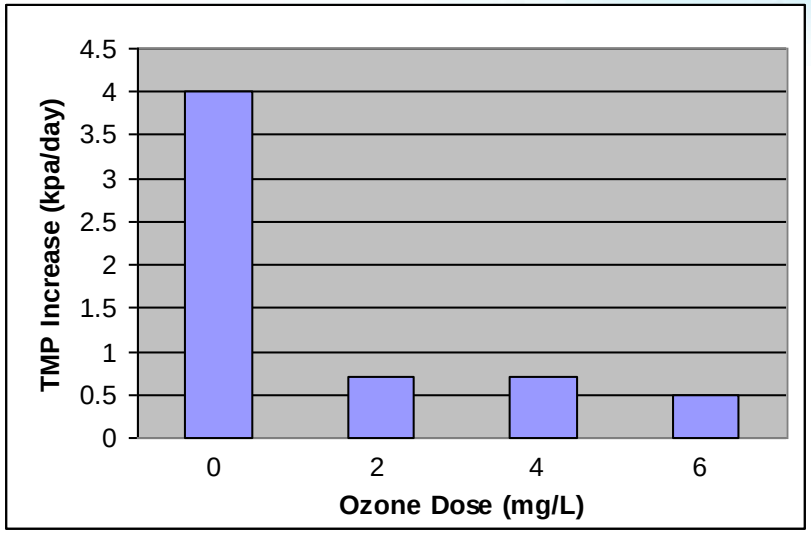


PACl	Flux		Ozone	Fouling Rate	
(mg/L)	(gfd)	(lmh)	(mg/L)	(psi/day)	(kPa/day)
2	119	200	0	2.5 – 5.1	17 - 35

Clement, Tian, and Tan (2009)

coagulation and ozone pre-treatment (Bedok, Singapore)





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2 - 6	119	200	2 - 6	0.07 - 0.1	0.5 - 0.7

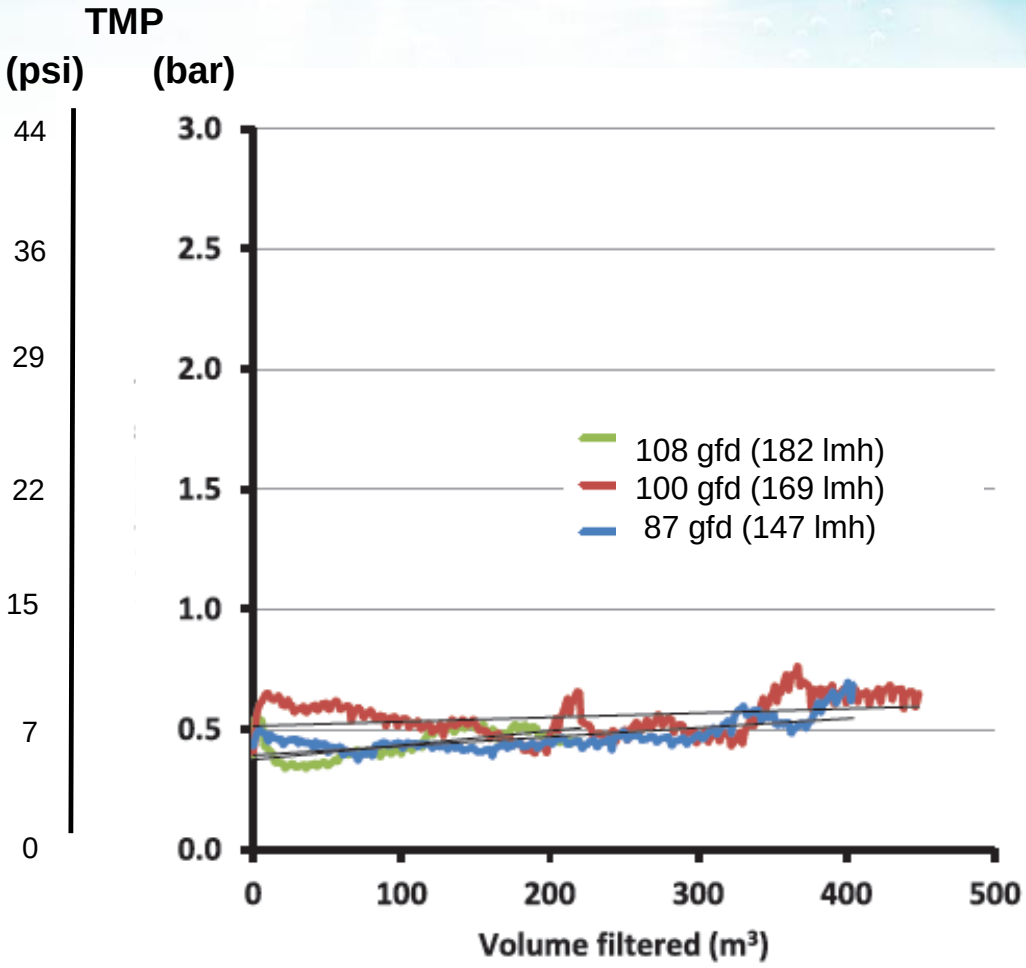
Clement, Tian, and Tan (2009)

Australian pilot - Melbourne

- secondary effluent
- target ozone residual > 0.8 mg/L
- contact time not stated, few seconds
- DOC = 10 to 15 mg/L
- 90 day CIP target
- PACl coagulant (3 mg as Al^{3+}/L)

Dow, Murphy, Clement, and Duke; Water, (2013)

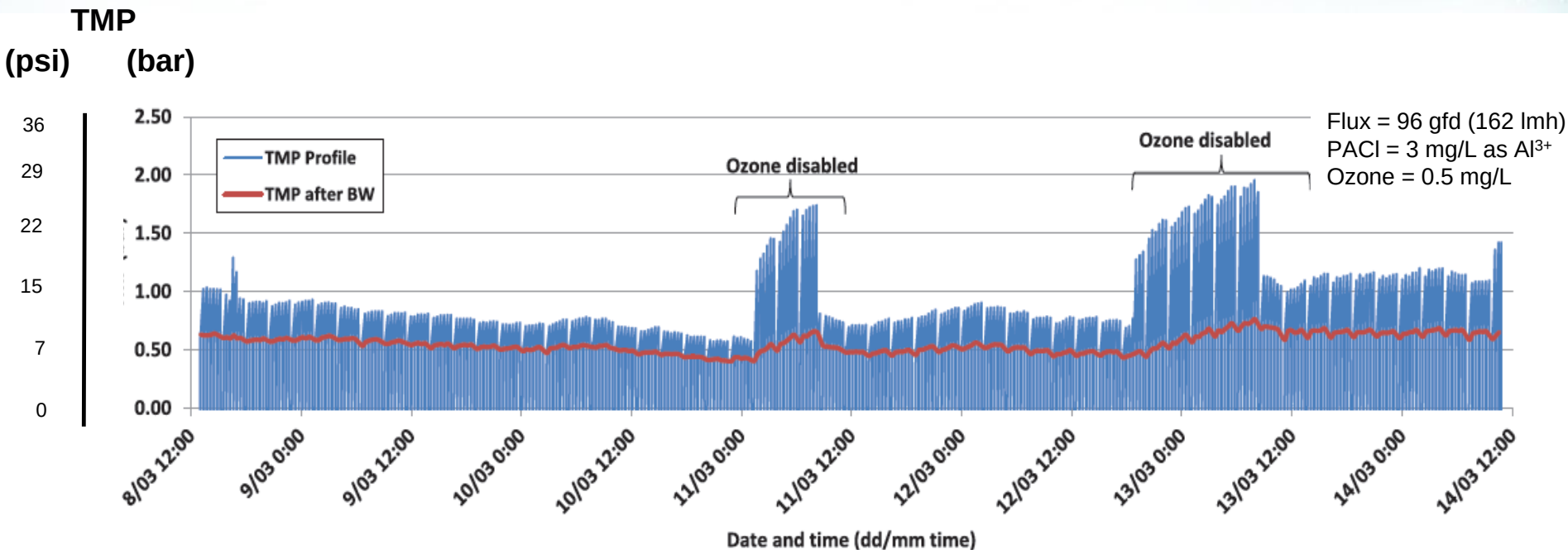
TMP curves at different flux for coagulation with ozone pretreatment at Australian pilot



higher flux not possible due to equipment size limitations

Dow, Murphy, Clement, and Duke; Water, (2013)

Ozone and coagulation pre-treatment at Australian pilot

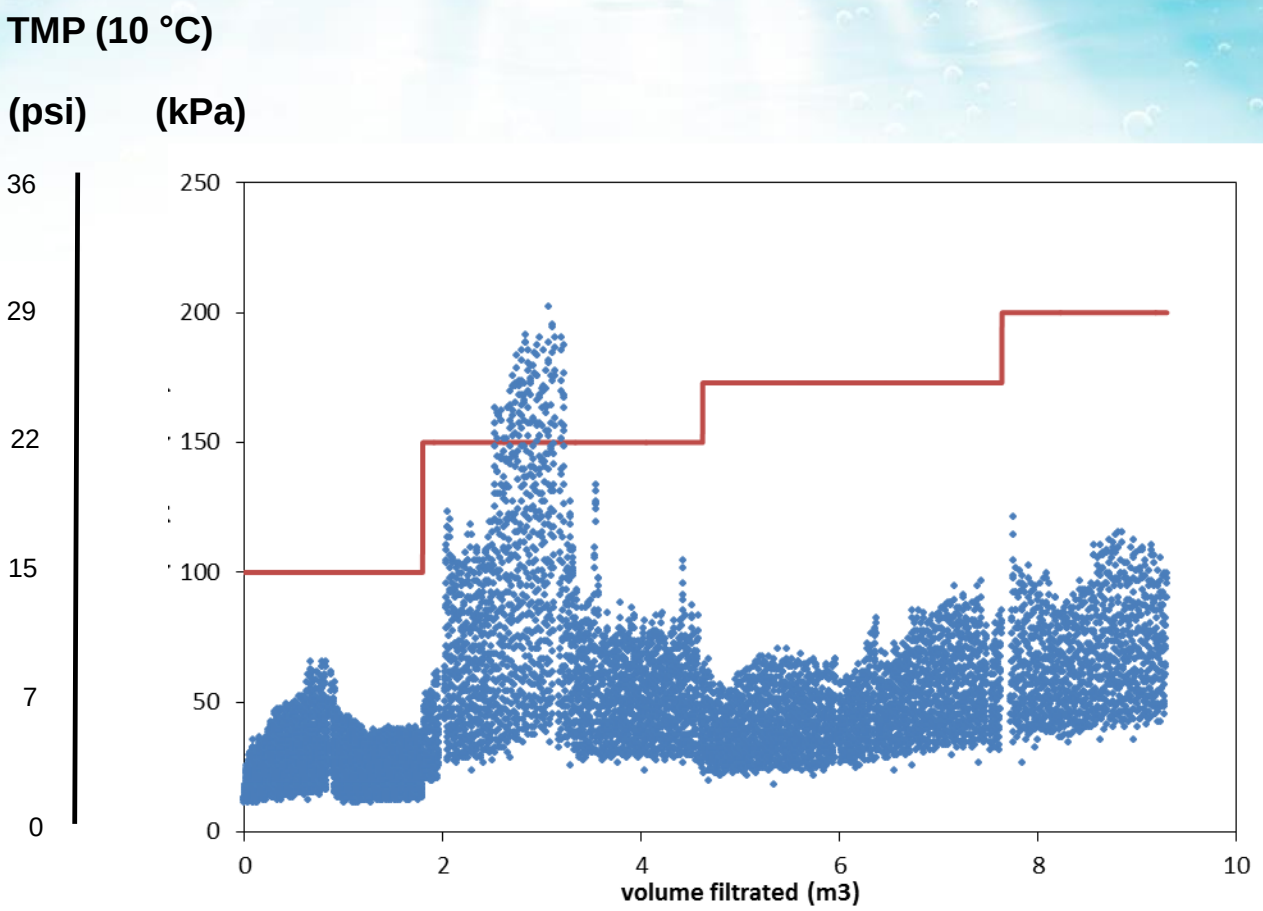


Dow, Murphy, Clement, and Duke; Water, (2013)

Asian client

- pilot with small membrane – 4.3 sqft (0.4 m2)
- approx 8 weeks testing
- TOC = 14 mg/L
- turbidity = 3 NTU
- ozone contactor = 1 minute
- coagulation = 2 minutes
- total ozone contact time = 3 minutes

in-line coagulation pretreatment



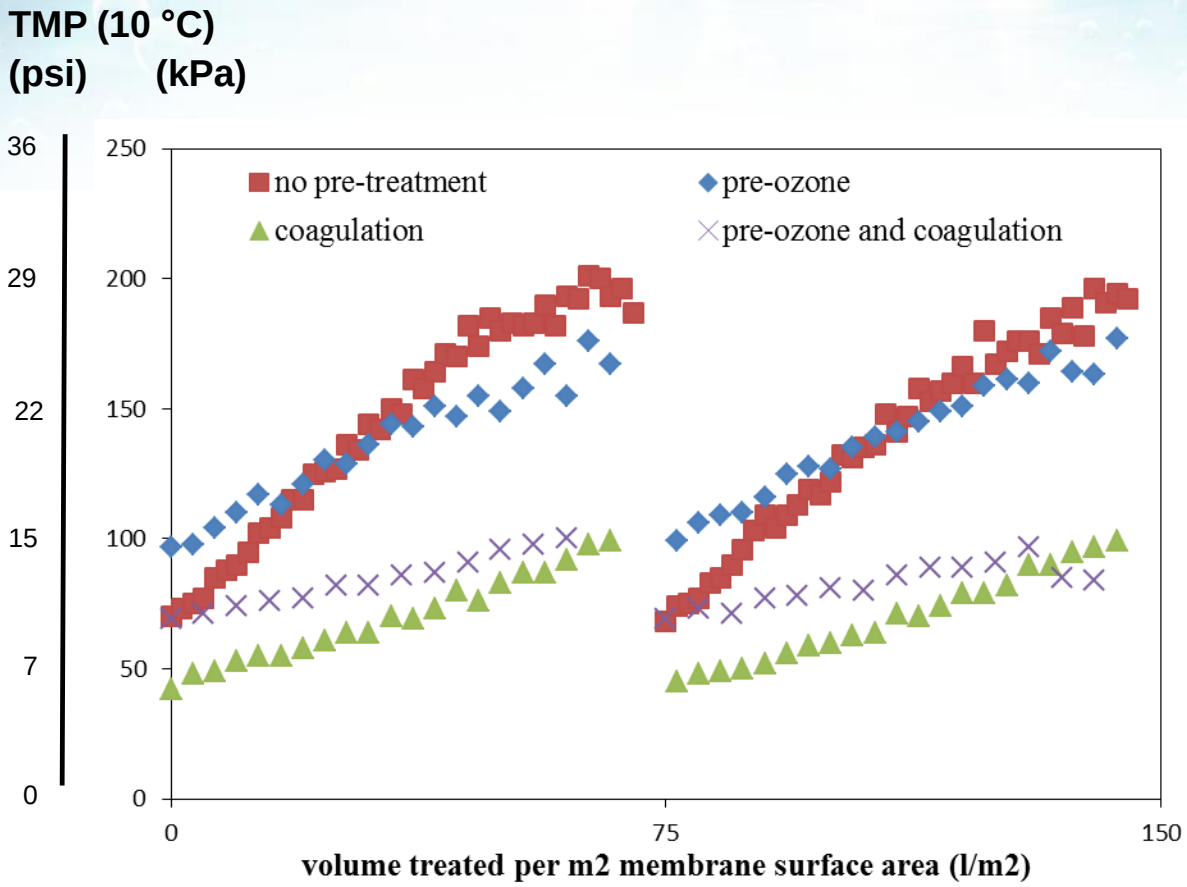
Coagulant	Flux		Ozone	Fouling Rate	
(mg/L as Al^{3+})	(gfd)	(lmh)	(mg/L)	(psi/day)	(kPa/day)
Up to 7	59	100	0	0.07	0.5
Up to 7	119	200	0	1.3	9.3

Asian client (from Zheng, Shorney-Darby, and Galjaard, 2015)

Asian client (pilot results for pre-coagulation)

Parameter	Units	Value
Flux (maximum instantaneous)	lmh	189
BW interval	min	32
EBW frequency	days	1 per day
Coagulant dose	mg/L	6 mg/L Al^{3+}
Coagulant mixing	min	2.9
CIP target invertavl	days	>30

TMP under different pre-treatment conditions

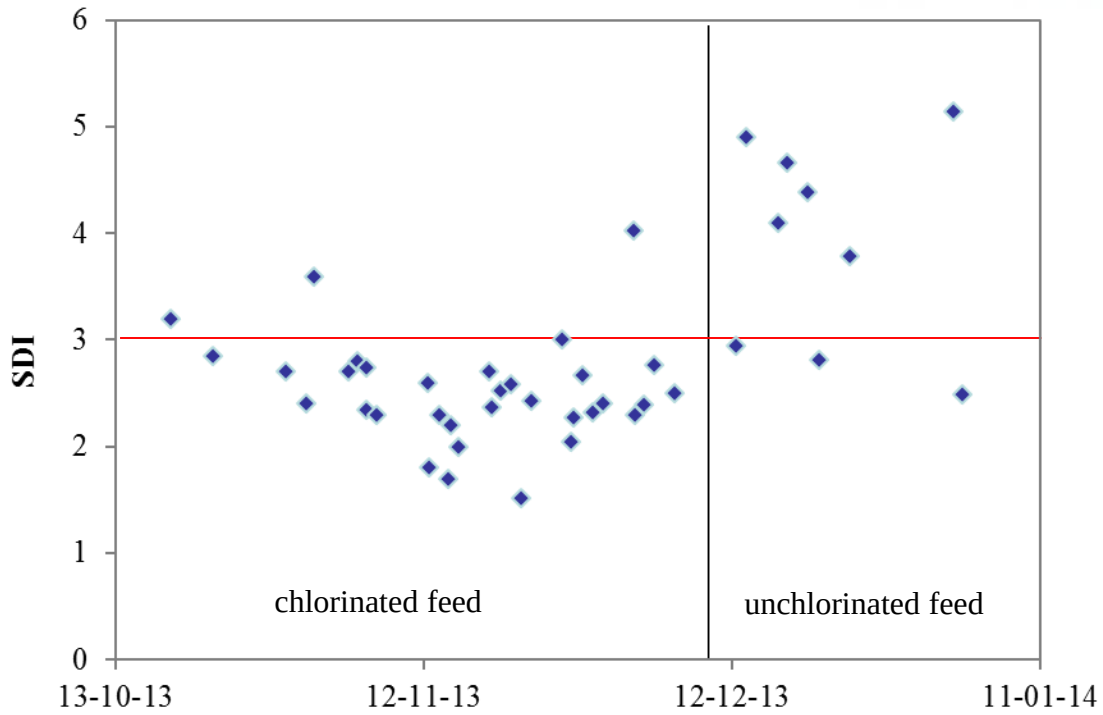


- 59 gfd (100 lmh) for direct filtration
- 119 gfd (200 lmh) for In-line coagulation and pre-ozone alone
- 178 gfd (300 lmh) for combined pre-ozone and coagulation pretreatment

>10mg/L applied ozone dose

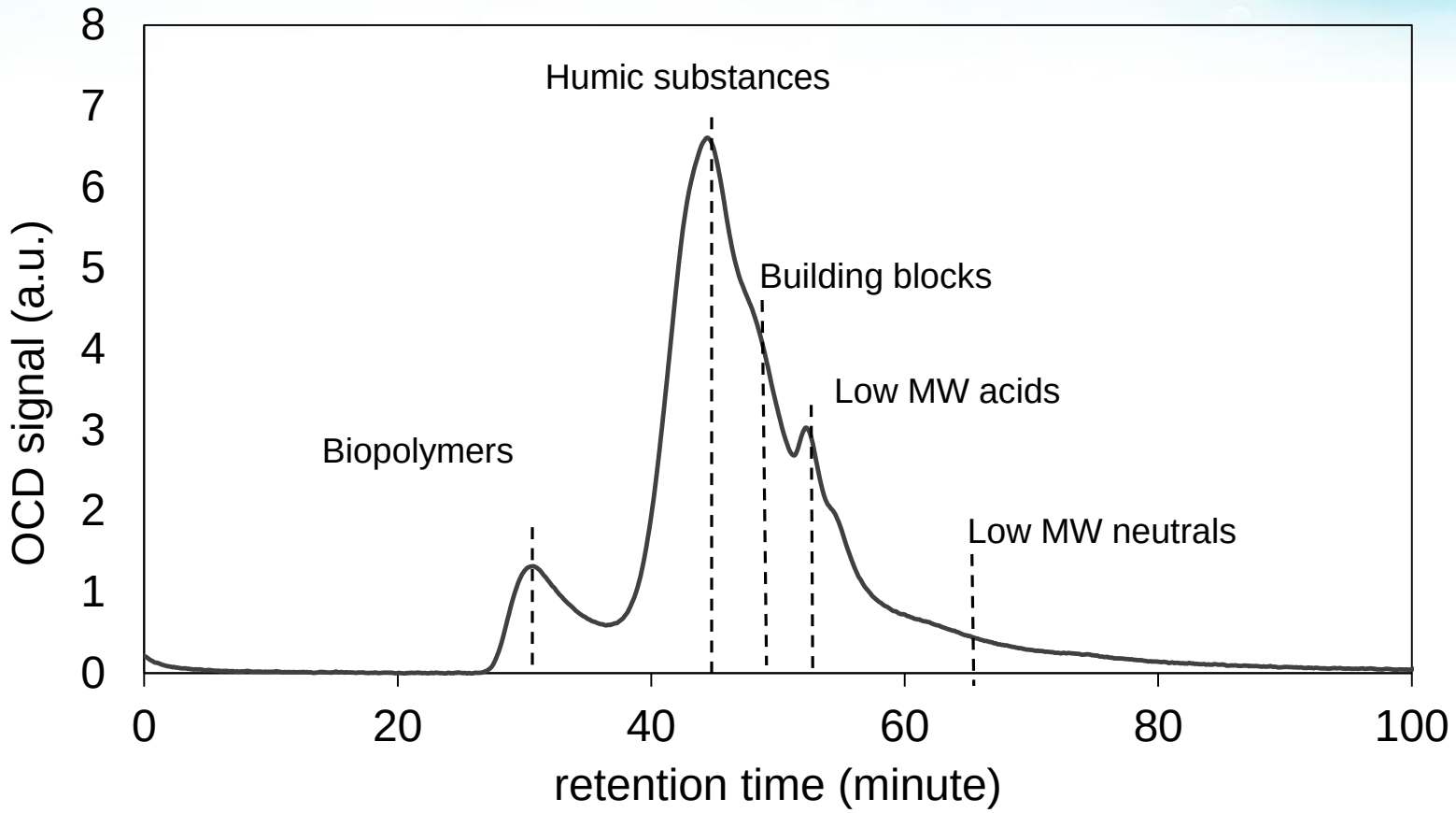
Asian client (from internal PWNT report)

SDI of membrane permeate

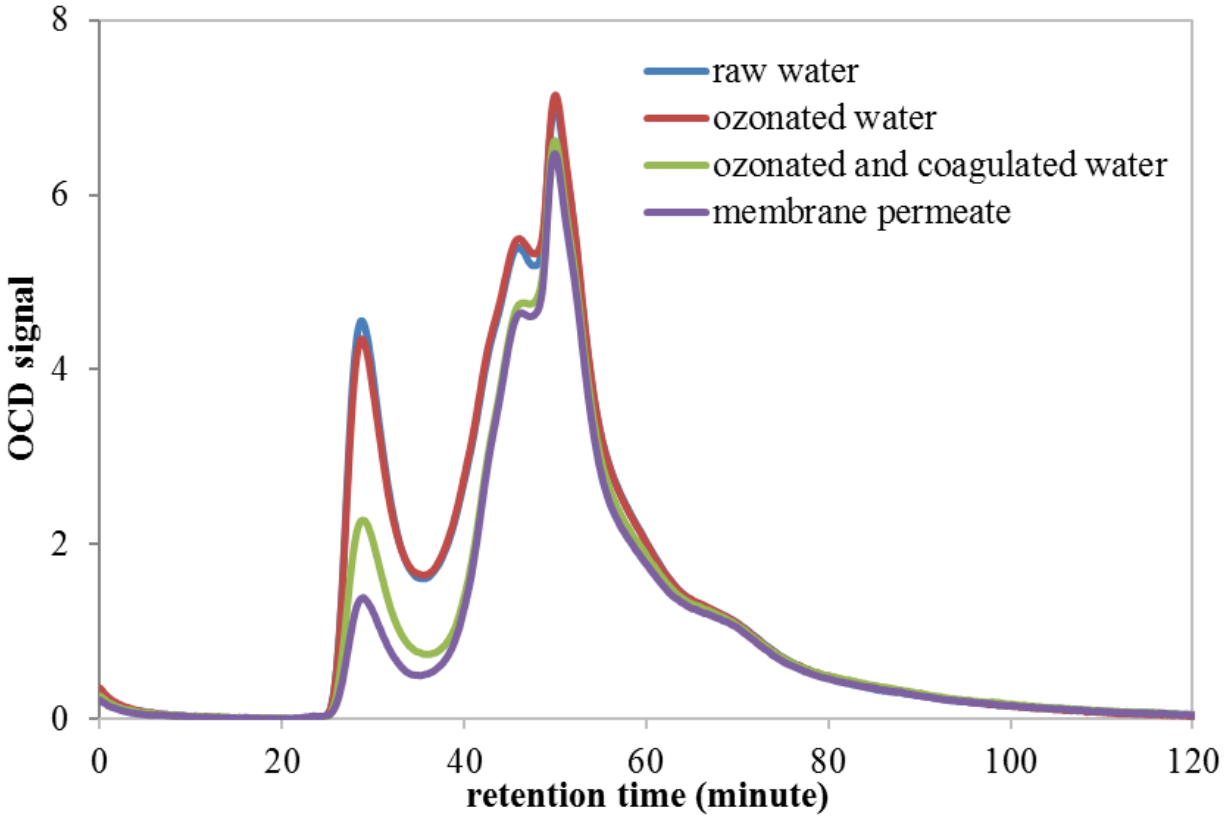


Asian client (Zheng, Shorney-Darby, and Galjaard (2015))

DOC fractions

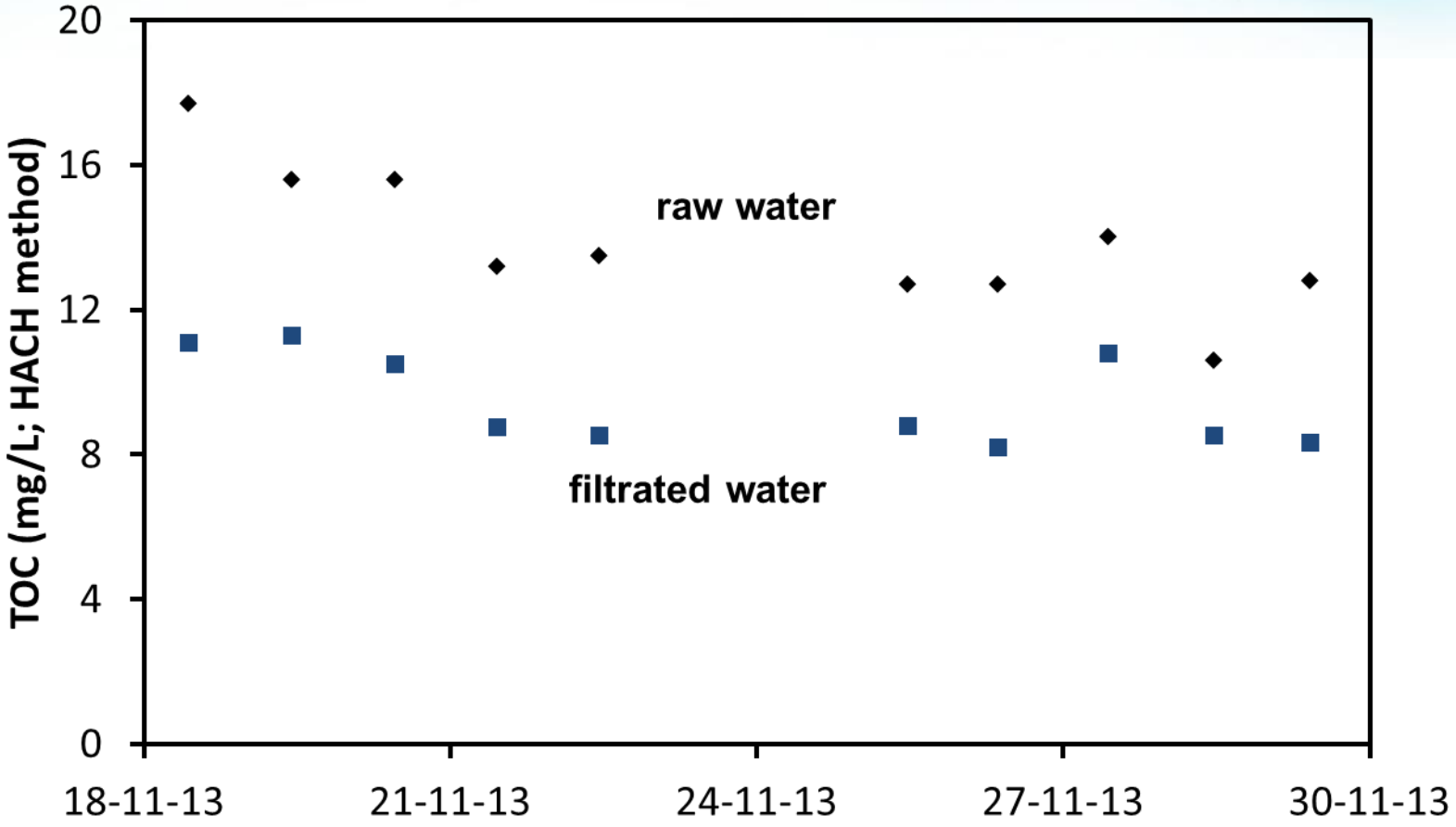


NOM change and removal with pre-ozone and coagulation



Asian client (Zheng, Shorney-Darby, and Galjaard (2015))

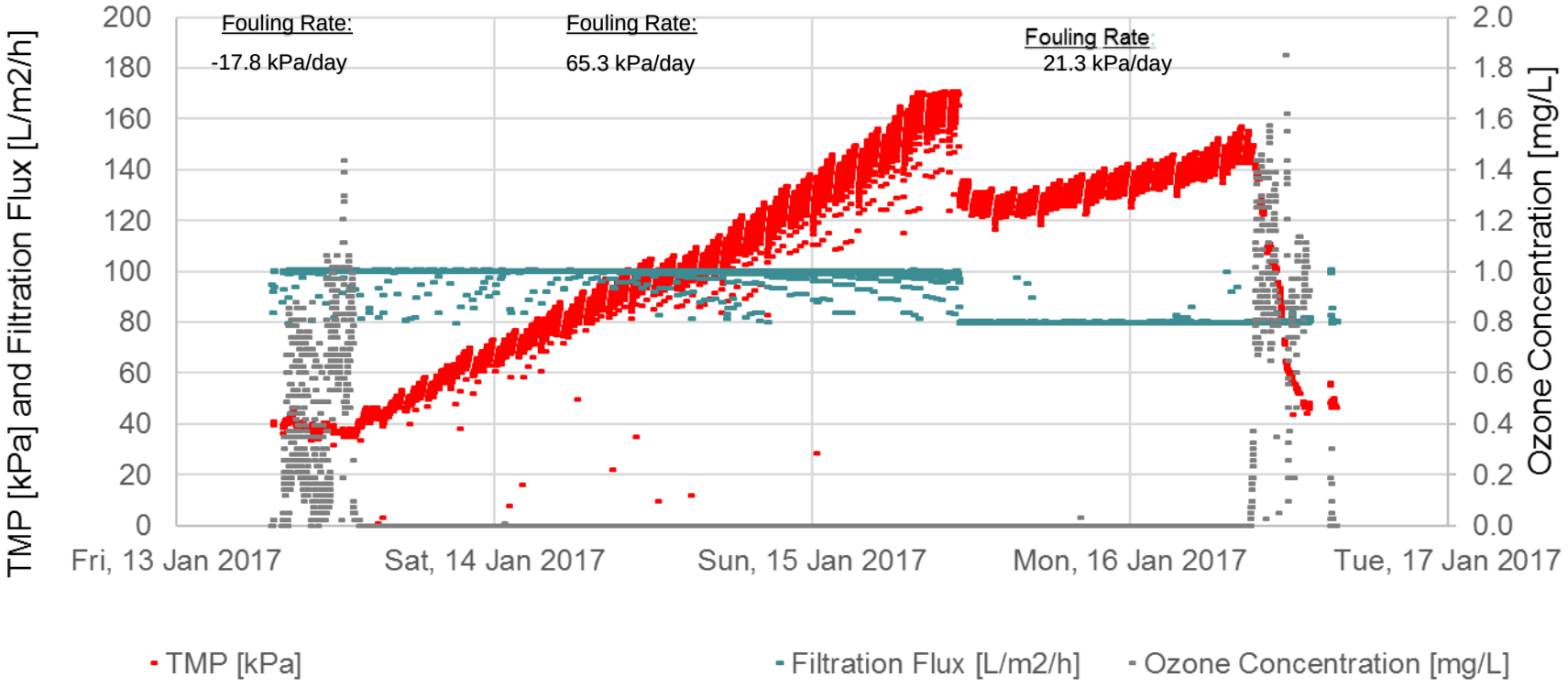
TOC concentration Sachtocklar PACl (6 mg/L Al^{3+}) flux of 112 gfd (189 lmh) with chlorinated feed water



Asian client (PWNT, internal report, 2014)

Ozone Influence on Membrane Performance

Current Pilot, Australia



Medemblik, NL Pilot

- starting up now
- coagulation and ozone pre-treatment
  - measure ozone demand and decay
- systematic water quality evaluation
  - organic characterization LC-OCD
  - metals
  - general water quality
  - biological quality
- bench-scale ion exchange pre-treatment

full-scale treatment

- Metawater research – similar findings
  - residual ozone control
  - coagulant dose optimization
  - residual ozone concentration
- full-scale system in Japan
  - comparable flux
  - CIP interval > year
  - optimized coagulant dose and BW interval

conclusions

Site	Achieved flux	Pre-treatment	Other highlights
Bedok, Singapore	119 gfd (200 lmh)	PACl + ozone	Ozone greatly reduced fouling rate
Australian Pilot	108 gfd (182 lmh) [higher flux possible]	PACl + ozone	Ozone > 0.8 mg/L residual on membrane (>>90 day CIP interval); PACl dose at 3 mg/L Al^{3+}
ACC	178 gfd (300 lmh)	PACl + ozone	Low SDI, but high ozone dose needed (e.g., ~ 10 mg/L)
ACC	112 gfd (189 lmh)	PACl	Optimized dose at approx. 2 to 6 mg/L as Al^{3+}
Medemblik, NL	To be determined	Coagulant, ion exchange, ozone	Broader water quality evaluation

- Optimized pre-treatment, with coagulation and sometimes oxidation, can yield sustainable and high flux with ceramic membranes
- More research needed on treated water quality

conclusions

- ceramic membranes can perform well for secondary effluent reuse applications
- coagulation necessary for fouling control
- PACl often used
- ozone can:
  - increase sustainable flux
  - reduce CIP frequency
  - lower operating TMP
  - provide disinfection and oxidation
  - (but ozone demand is often high)

questions