CERAMAC®-19 DEMONSTRATION PLANT CERAMIC MICROFILTRATION AT CHOA CHU KANG WATERWORKS

Gilbert Galjaard
PWN Technologies

America's Authority in Membrane Treatment
AMTA
American Membrane Technology Association
Improving America's Waters Through Membrane Treatment and Desalting

American Water Works Association
The Authoritative Resource on Safe Water®

acknowledgement

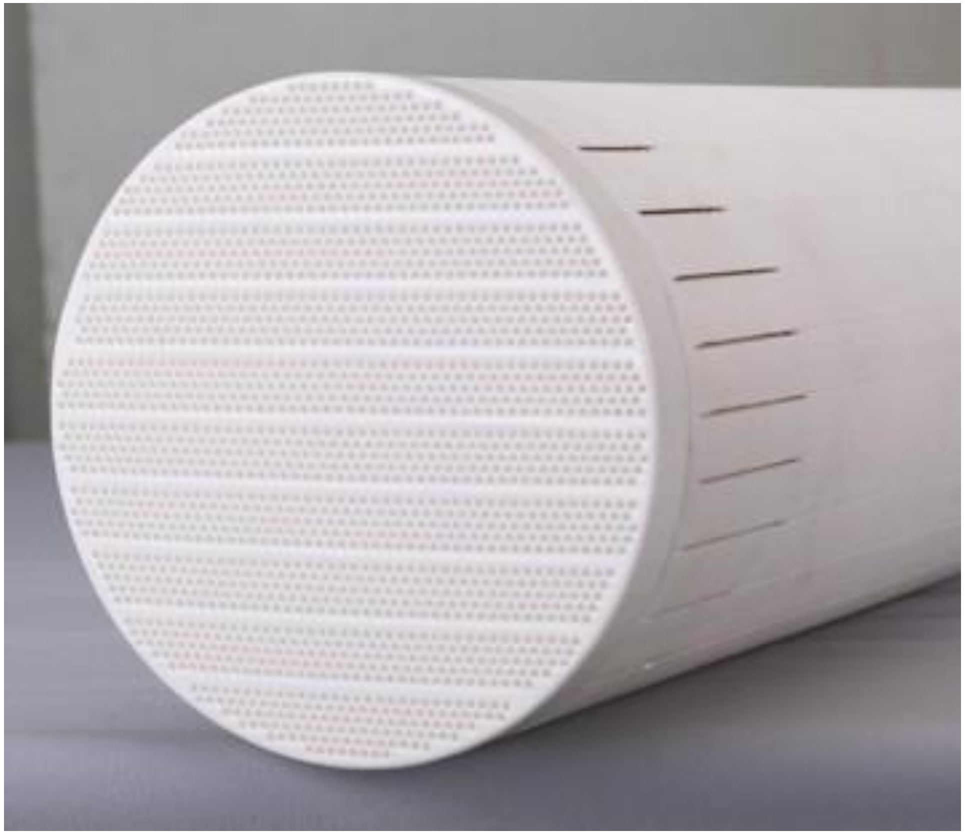
- Environment Water Institute (EWI) Singapore
- Black&Veatch
- United Engineering Singapore (UES)
- Metawater
- RWB water services
- University of Arizona (Snyder Group)
- Xylem, WEDECO, ITT

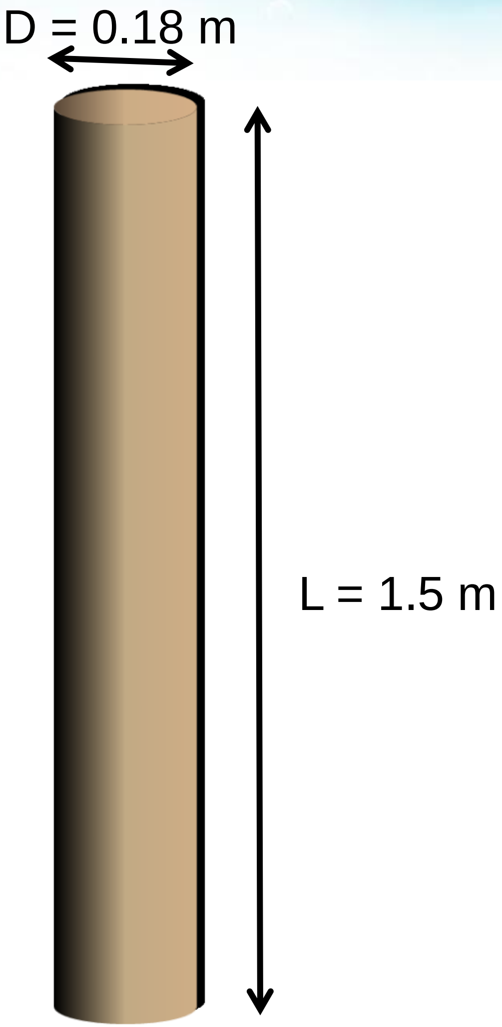
background

ceramic membrane advantages

- long life expectancy > 15 years?
- capability to use strong cleaning chemicals and oxidants
- no risk of fiber breakage
- very narrow pore size distribution
- can be operated with very high backwash rates and BW pressure

Metawater ceramic MF membrane





Water for All: Conserve, Value, Enjoy

TECHNOLOGIES

courtesy of Metawater

courtesy of Metawater

ceramic membrane disadvantages

- economical feasibility
- low productivity at high backwash intervals

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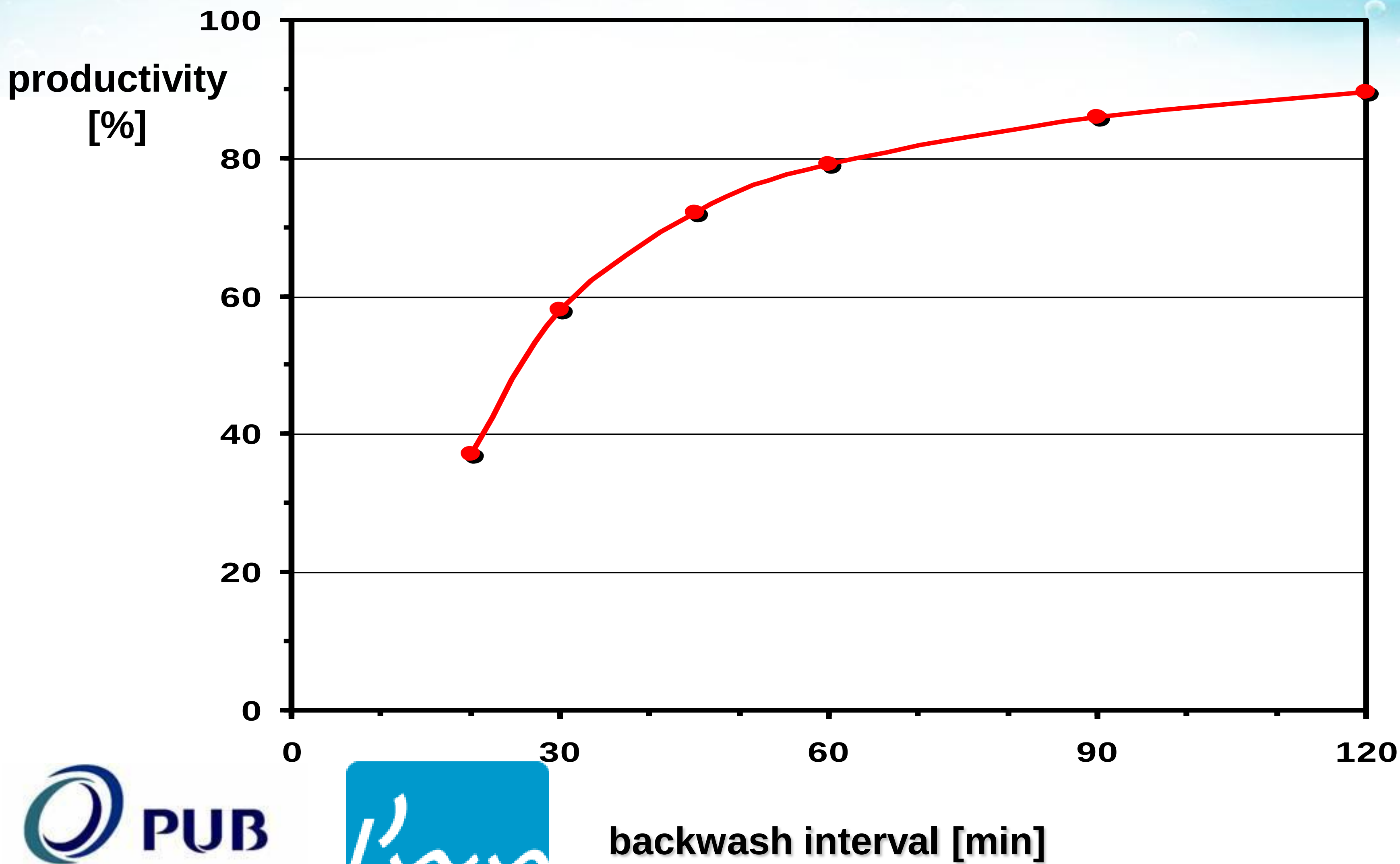
TECHNOLOGIES

productivity as function of backwash interval



PWN Technologies CeraMac®

- on the market since 2011
- 200 elements in 1 pressure vessel
- improved economical feasibility
  - higher productivity
  - very compact, low footprint
  - less stainless steel
  - lower energy consumption
- alternative for polymeric membrane processes

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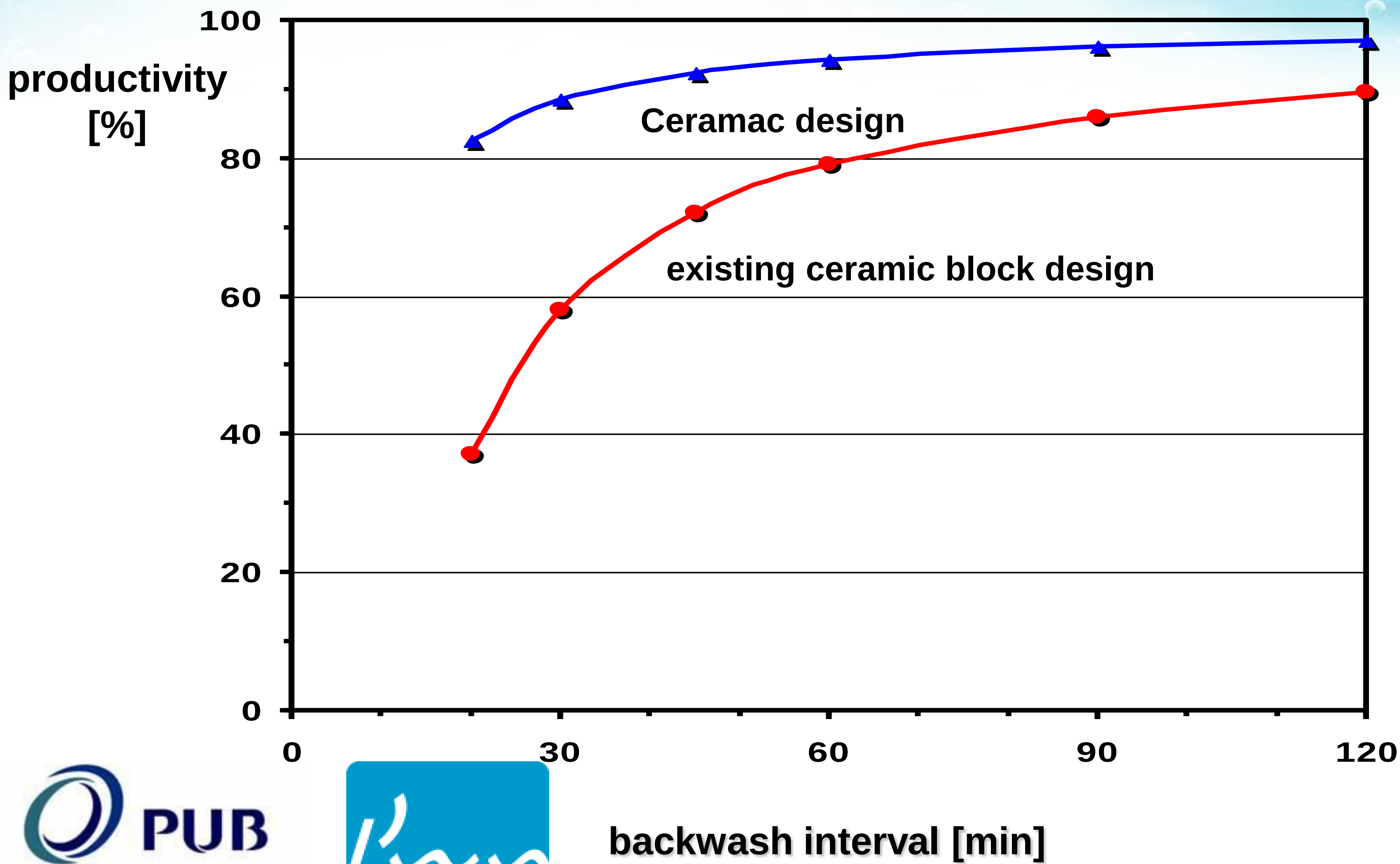
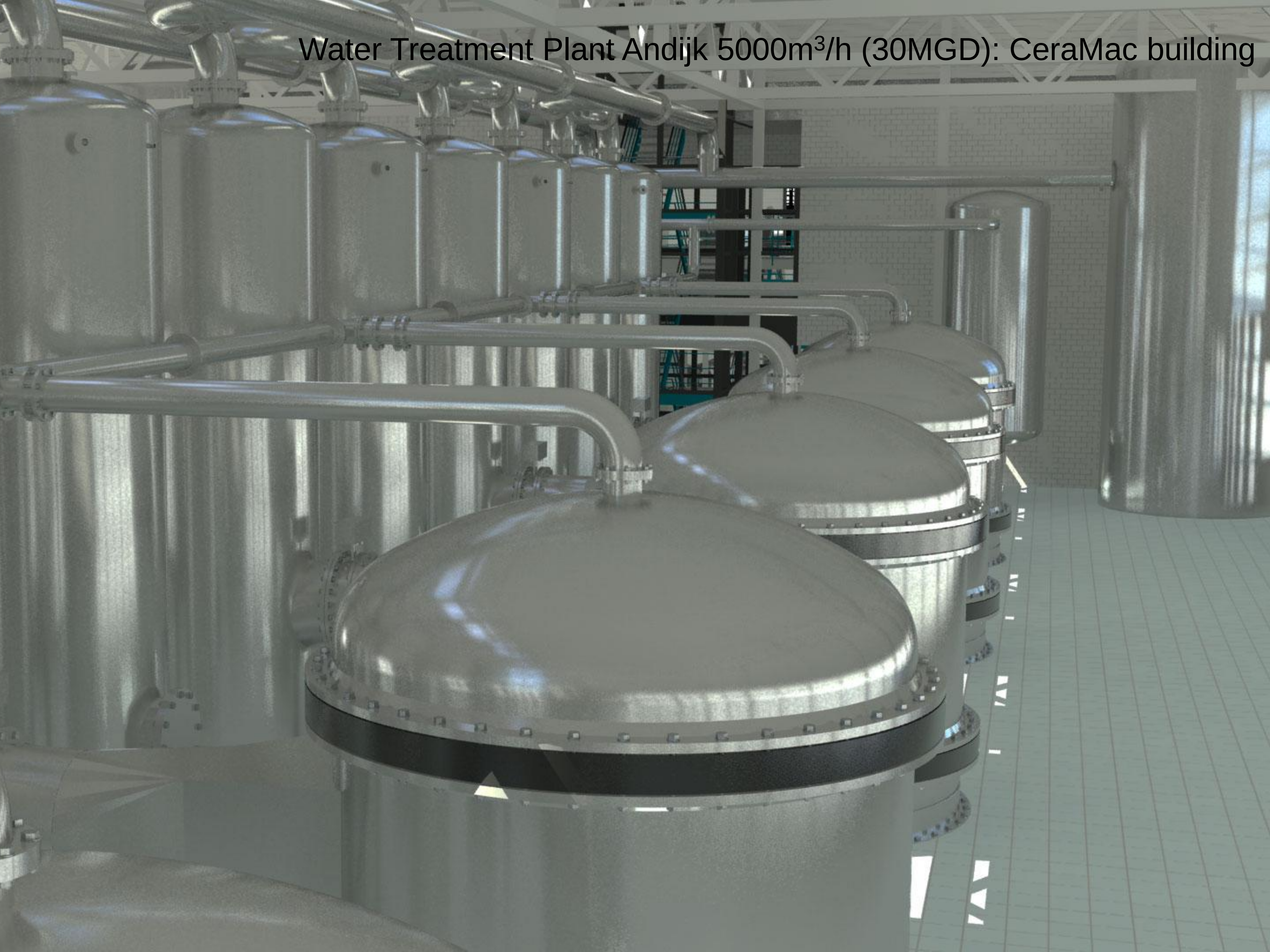
TECHNOLOGIES

productivity as function of backwash interval



Water Treatment Plant Andijk 5000m^3/h (30MGD): CeraMac building



interest PUB in CeraMac®

- Public Utility Board, Singapore's National Water Agency
- prove of technology
  - advantages ceramic membranes
  - CeraMac® process
- determine realistic capital and operational costs
- determine and optimise pre-treatment conditions
- determine water recovery
- experience in operation
- develop important data and knowledge for a full-scale design

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demonstration testing program

- design and construction of 3 MLD (1MGD) CeraMac® demonstration plant
- site location Choa Chu Kang Water Works
  - very challenging water
  - side by side comparison can be made with existing polymeric system
- 18 months of operation
- funding of Environment Water Institute (EWI) , PUB, and PWNT

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Choa Chu Kang Waterworks

- phase 1 commissioned in 1975 (182.000m^3/d, 48MGD)
- source is blended surface water from 3 reservoirs
  - Tengeh
  - Kranji
  - Pandan
- phase 2 commissioned in 1981 (also 182.000 m^3/d)
- phase 1 upgraded in 2008 sand filters replaced by polymeric UF to control suspended (biological) matter

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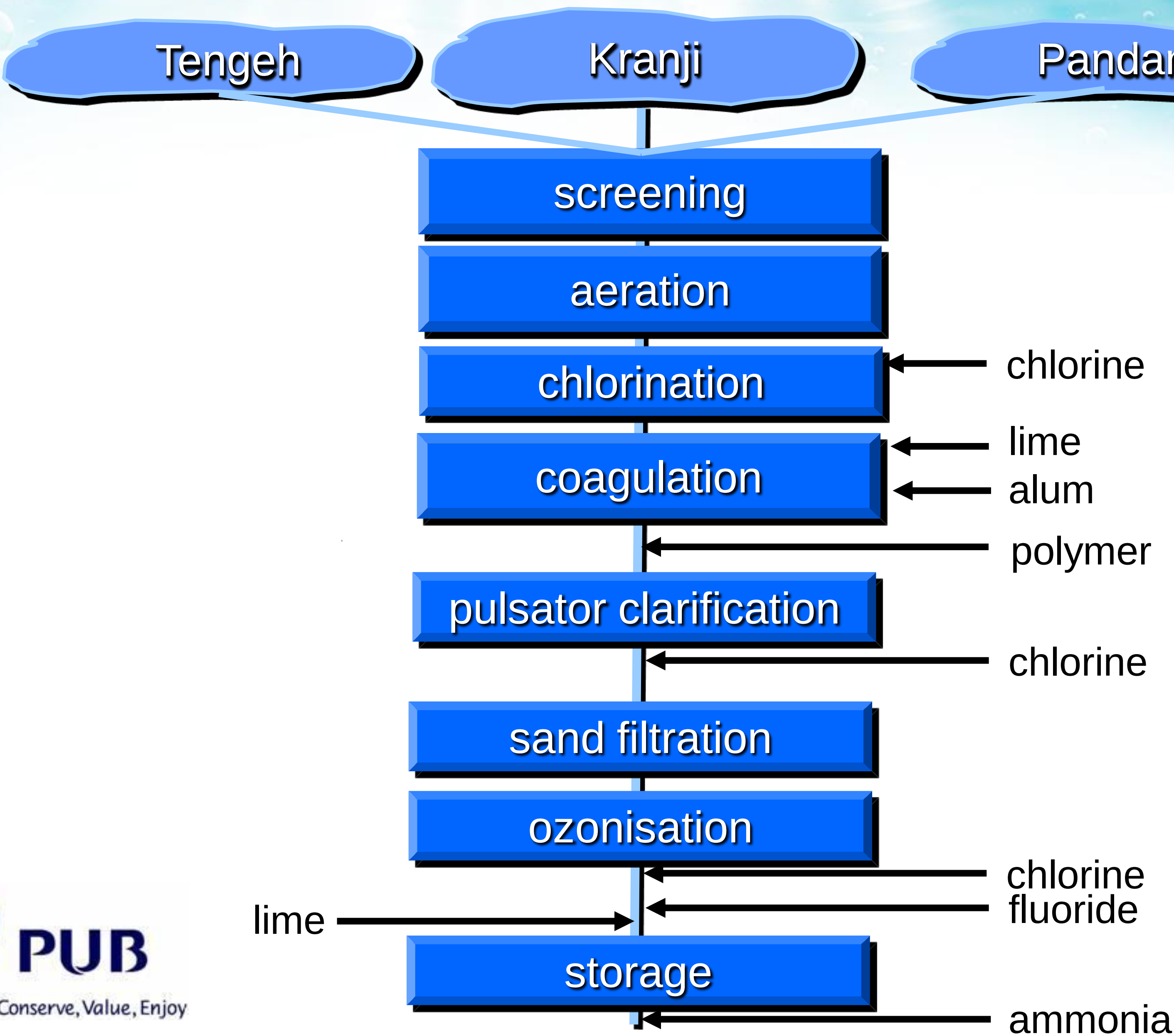
CCKWW 1975-2007



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specific tests and evaluation

- alternative for sand filters
- find optimal operation
  - flux (maximize to reduce capital costs)
  - backwash frequency
  - enhanced backwash frequency
  - chemical cleaning frequency
- influence ozone on membrane performance
- long term stability
- operational costs
- sustainability

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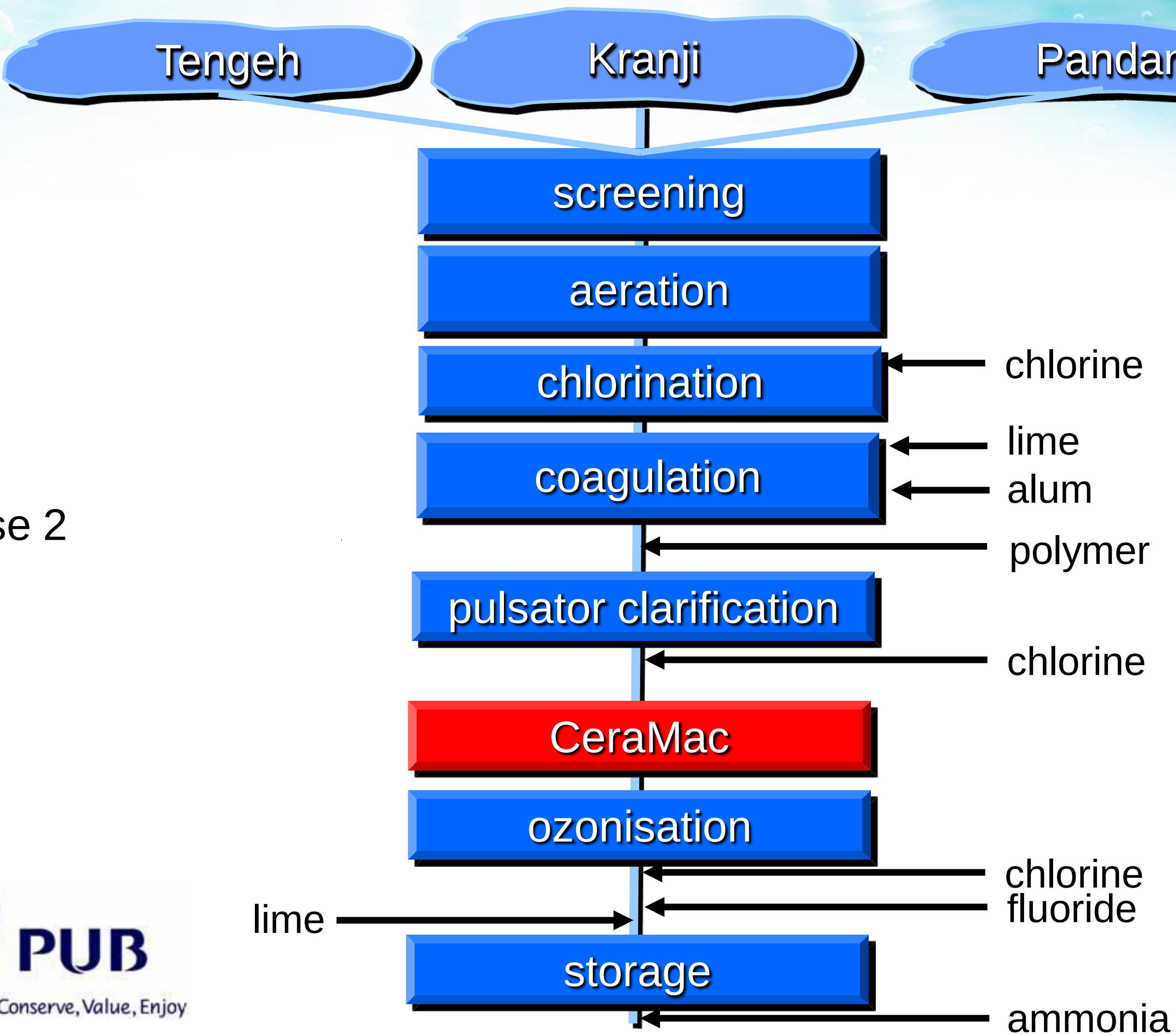
experimental set-up

possible scenario's for CCKWW

phase 2



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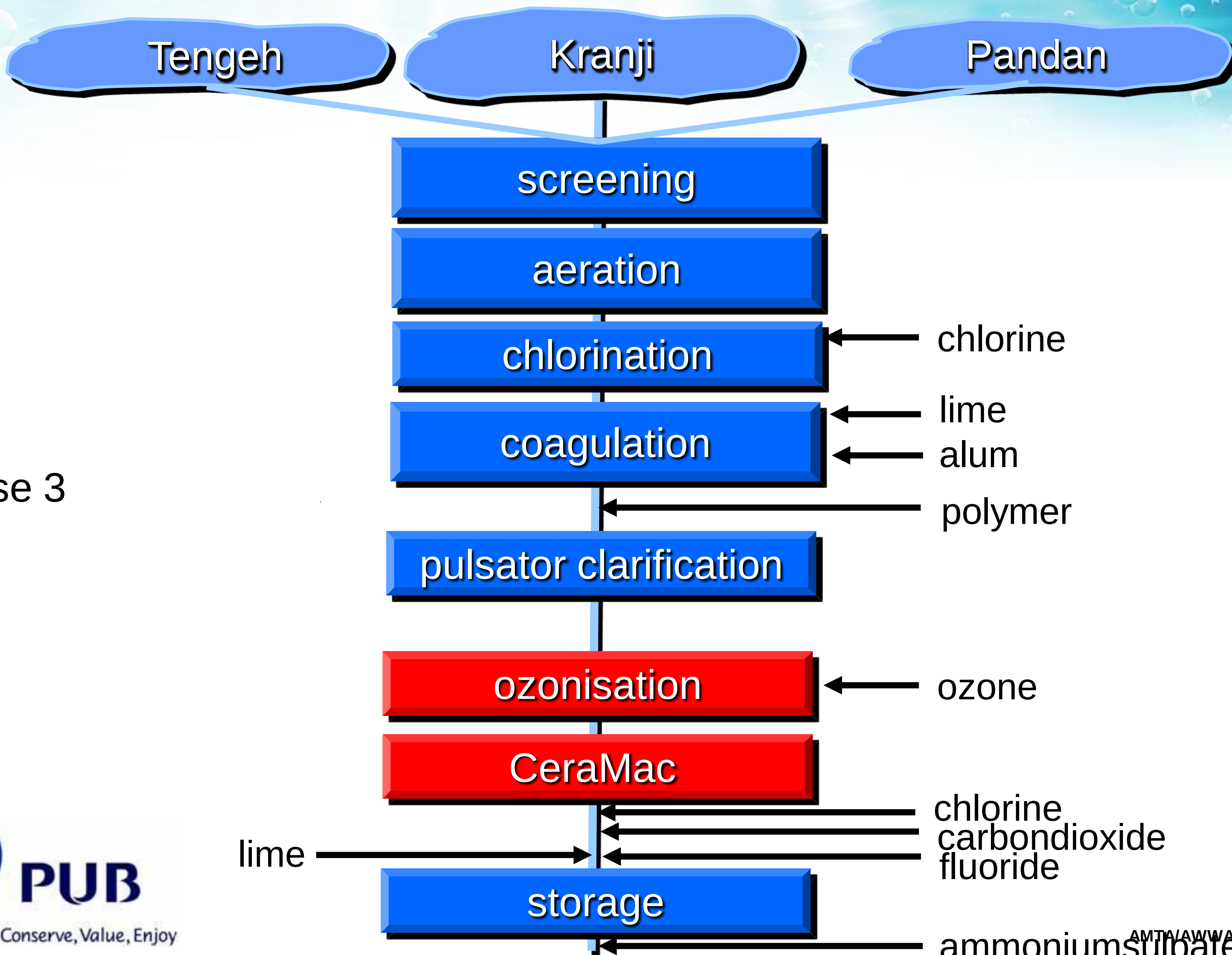
possible scenario’s for CCKWW

phase 3



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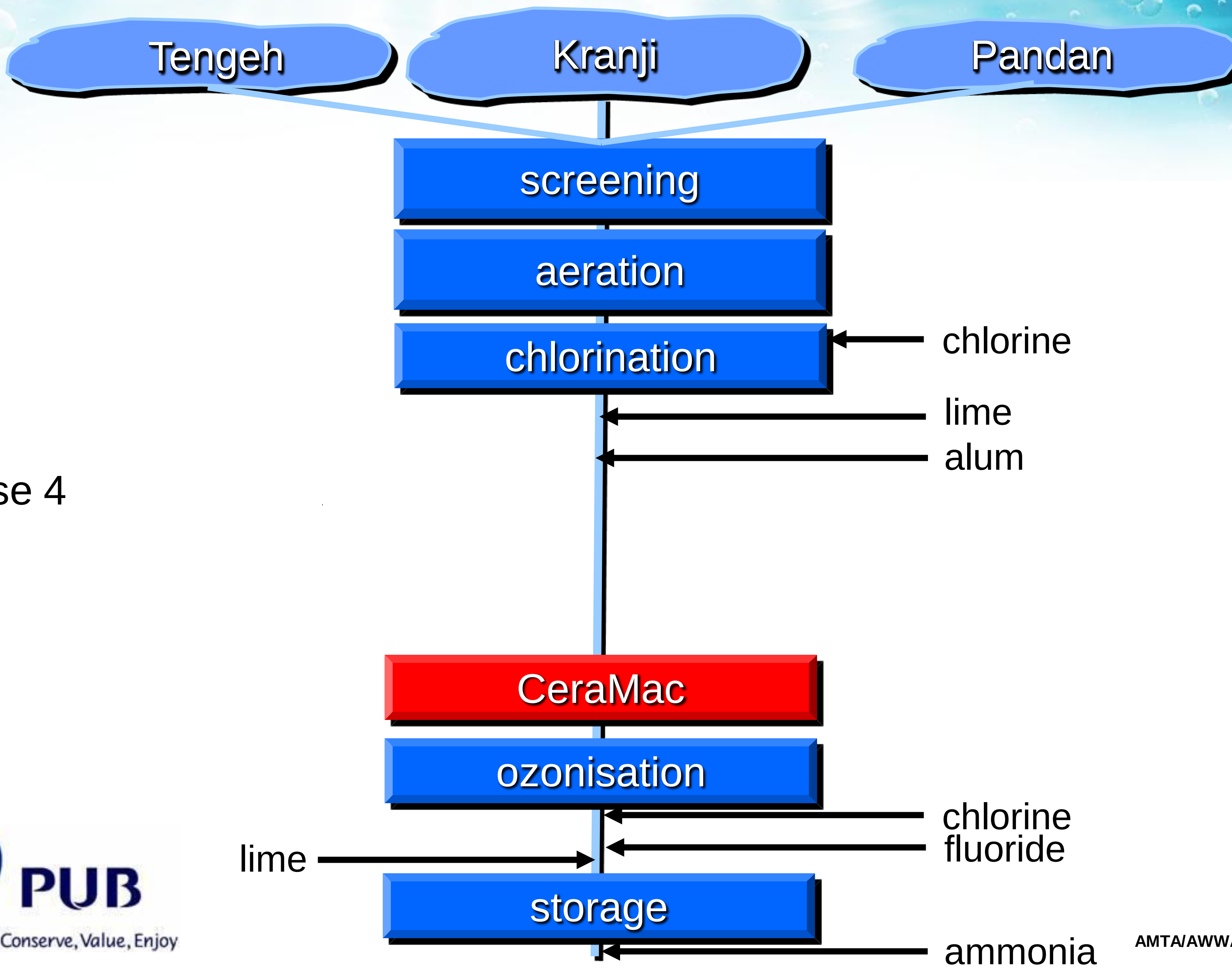
possible scenario’s for CCKWW



phase 4

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experimental set-up

- phase 1: design, construction & SAT
- phase 2: clarified water
- phase 3: ozonated clarified water
- phase 4: in-line coagulation
- phase 5: longterm testing

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experimental set-up phase 2

- critical flux determination
- optimize back wash frequency
- optimize enhanced backwash frequency

- test runs are carried out at the same surface load
  - fixed totall produced volume (m3/m2)
  - fixed volume per filtration cycle (L/m2)
  - fixed volume per EBW-cycle (L/m2)

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operational parameters phase 2

Parameter	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Flux (lmh)	50	100	150	200	200	200	200	200	200
BW Interval (min)	60	30	20	15	15	30	15	15	30
EBW Interval (A)	11th BW	11th BW	11th BW	11th BW	11th BW	6th BW	16th BW	31th BW	31st BW
EBW Interval (B)	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A
Recovery (V%)	93.4	93.4	93.4	93.4	93.4	96.4	93.6	93.8	96.8
Total Filtration runtime (h)	600	300	200	150	300	300	300	300	300
Total Volume produced (m^3)	14250	14250	14250	14250	28500	28500	28500	28500	28500

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experimental set-up phase 3

- determine ozone decay with bench-scale test
- design ozone installation
  - target 0,5 mg O_3/L on membrane surface
  - max capacity at found optimum phase 2
- determine impact ozonated feed on operation at found optimum phase 2
- find new optimum

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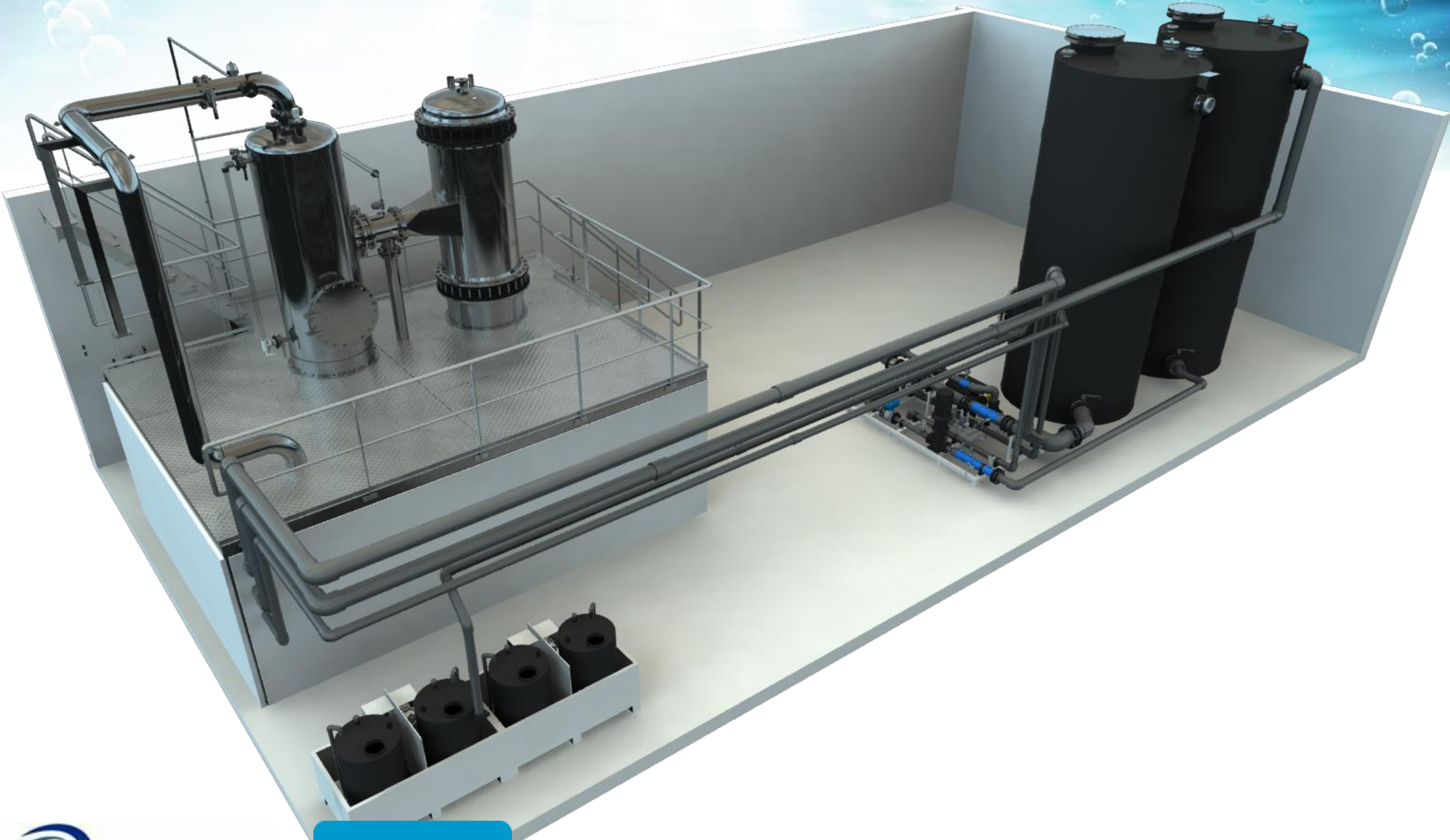

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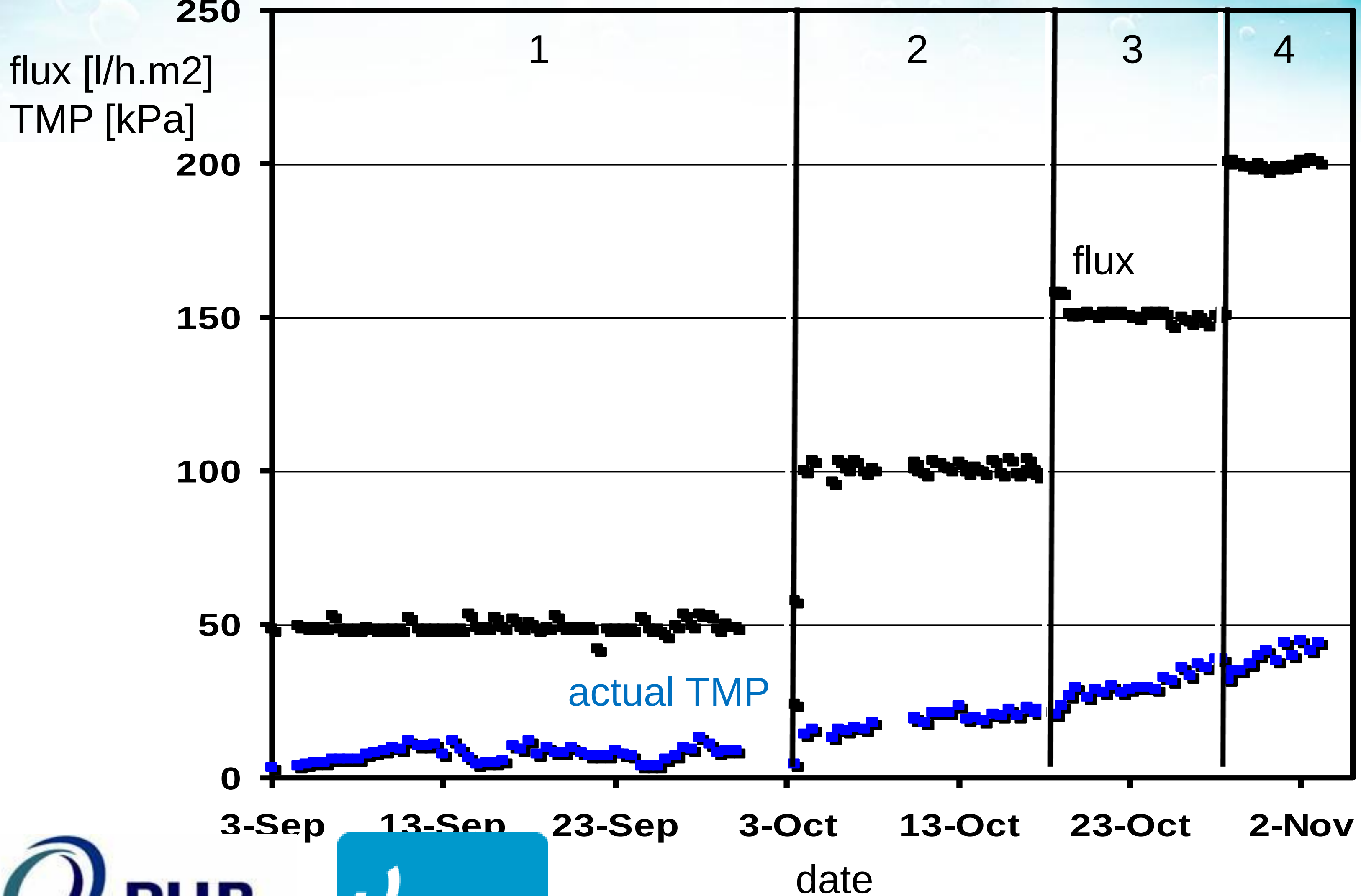
SWL 5 TONNE
KEEP CLEAR
KEEP CLEAR

summary results phase 2

TMP run 1 – 4 (phase 2)



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operational parameters phase 2

Parameter	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Flux (lmh)	50	100	150	200	200	200	200	200	200
BW Interval (min)	60	30	20	15	15	30	15	15	30
EBW Interval (A)	11th BW	11th BW	11th BW	11th BW	11th BW	6th BW	16th BW	31th BW	31st BW
EBW Interval (B)	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A
Recovery (V%)	93.4	93.4	93.4	93.4	93.4	96.4	93.6	93.8	96.8
Total Filtration runtime (h)	600	300	200	150	300	300	300	300	300
Total Volume produced (m^3)	14250	14250	14250	14250	28500	28500	28500	28500	28500

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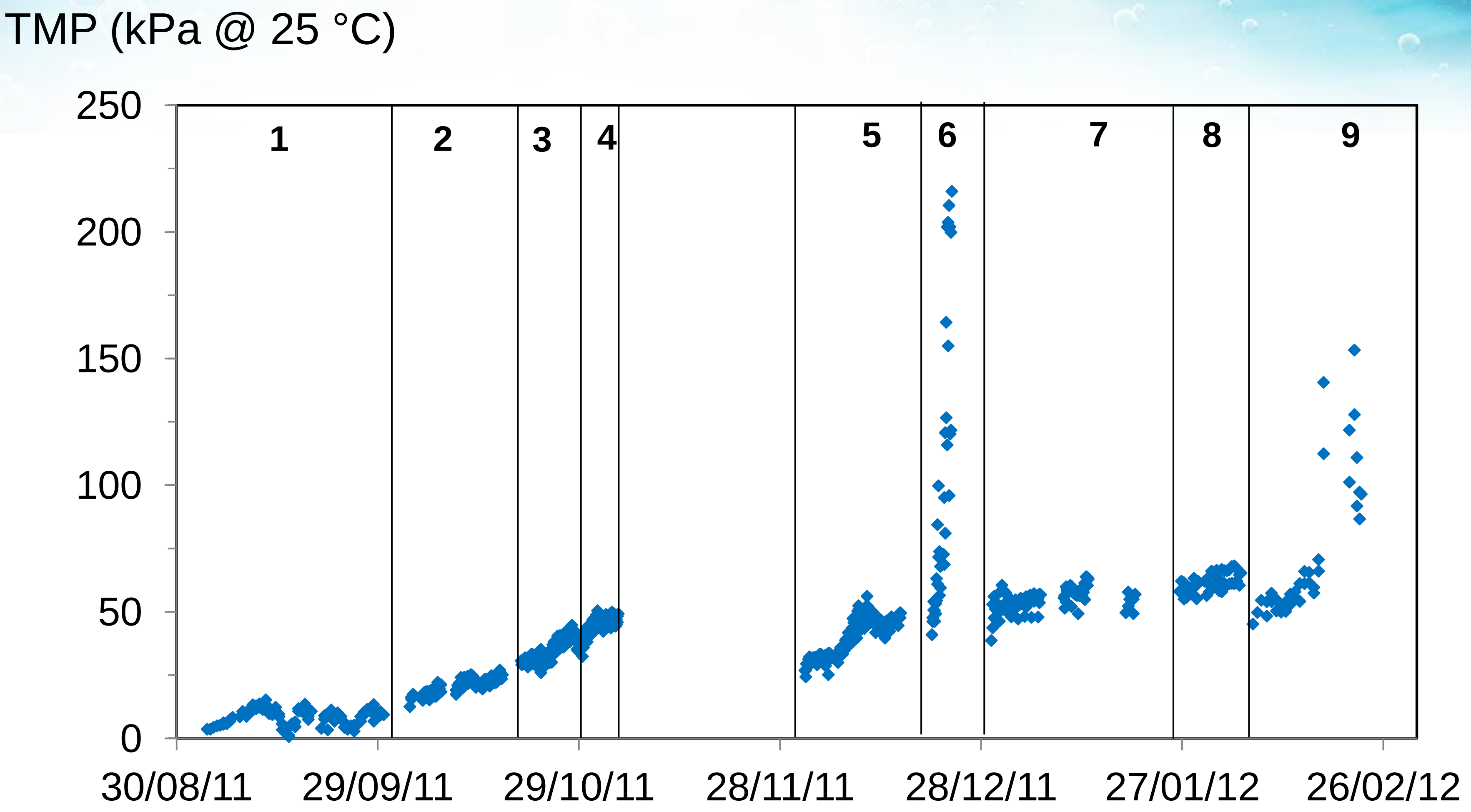
TMP during phase 2



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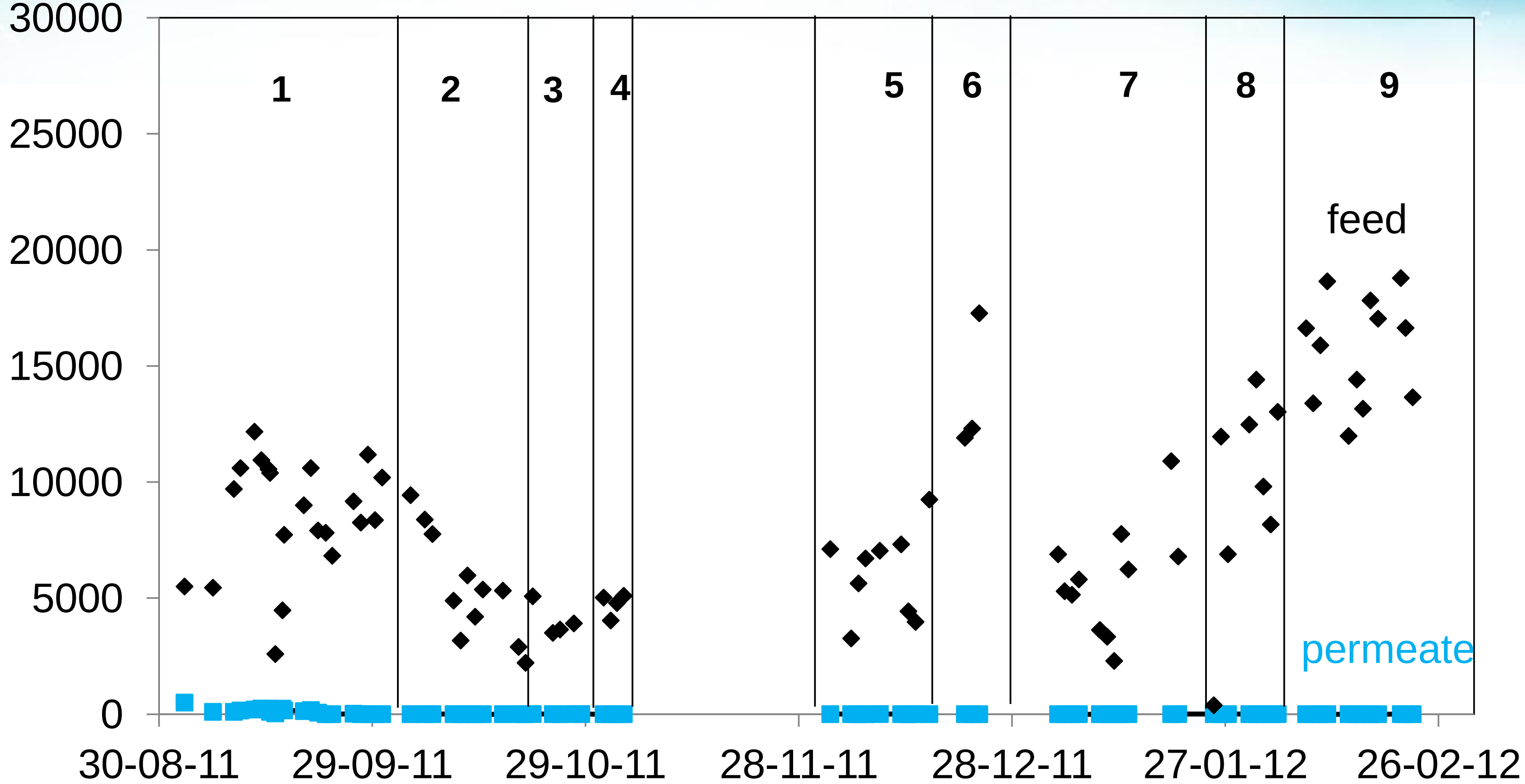
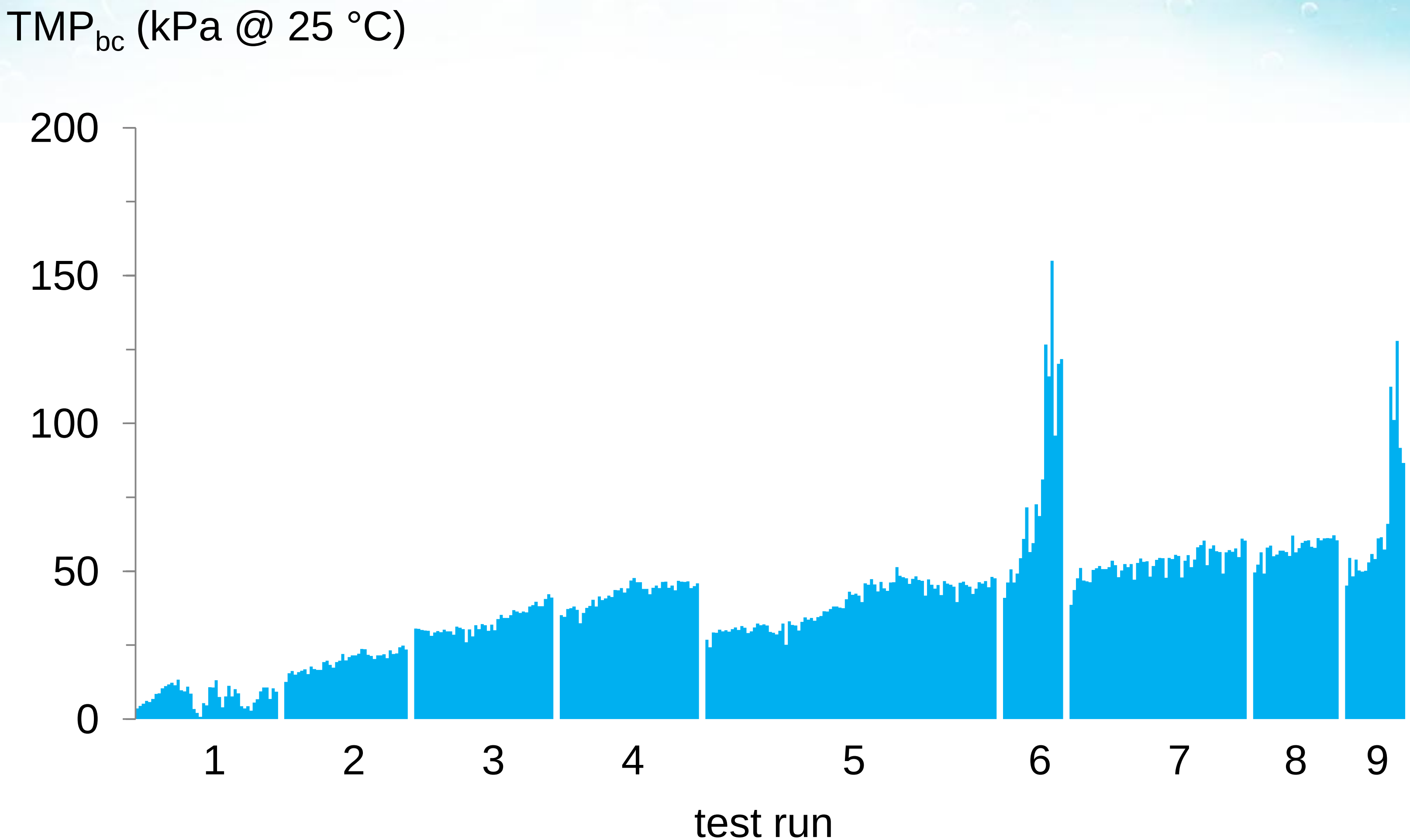
particle counts

Number of particles > 1 µm



Water for All: Conserve, Value, Enjoy

TMP after backwash



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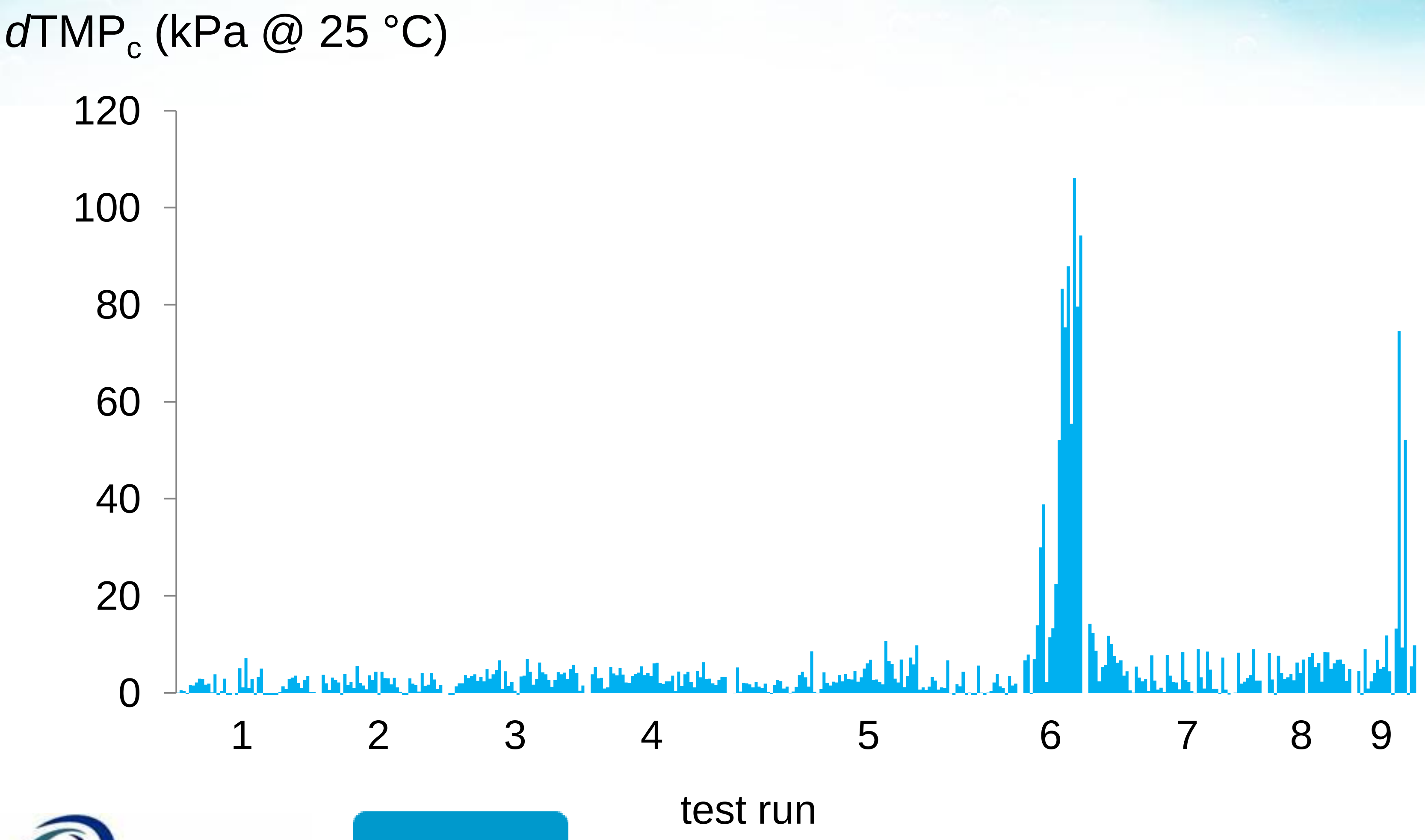
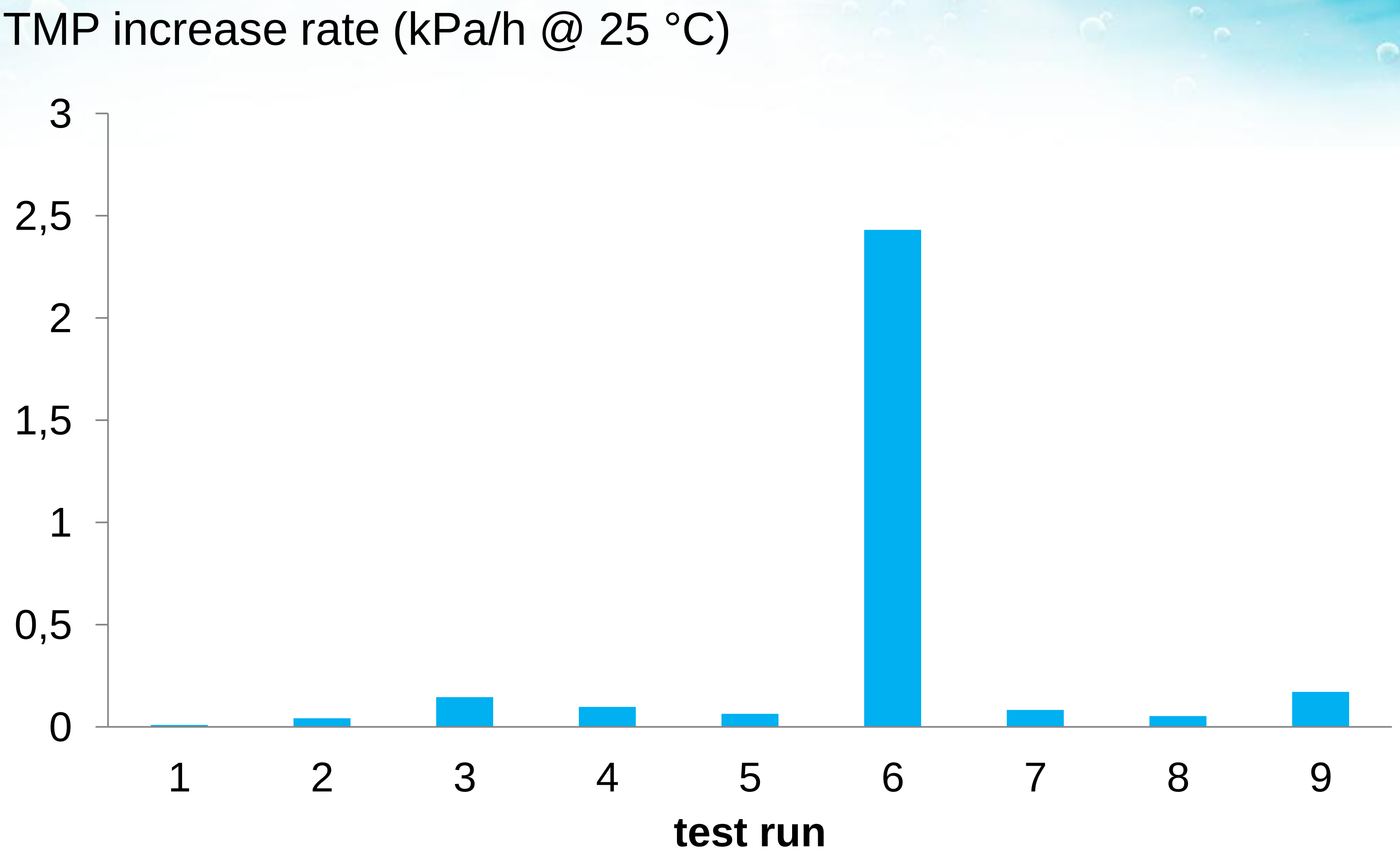
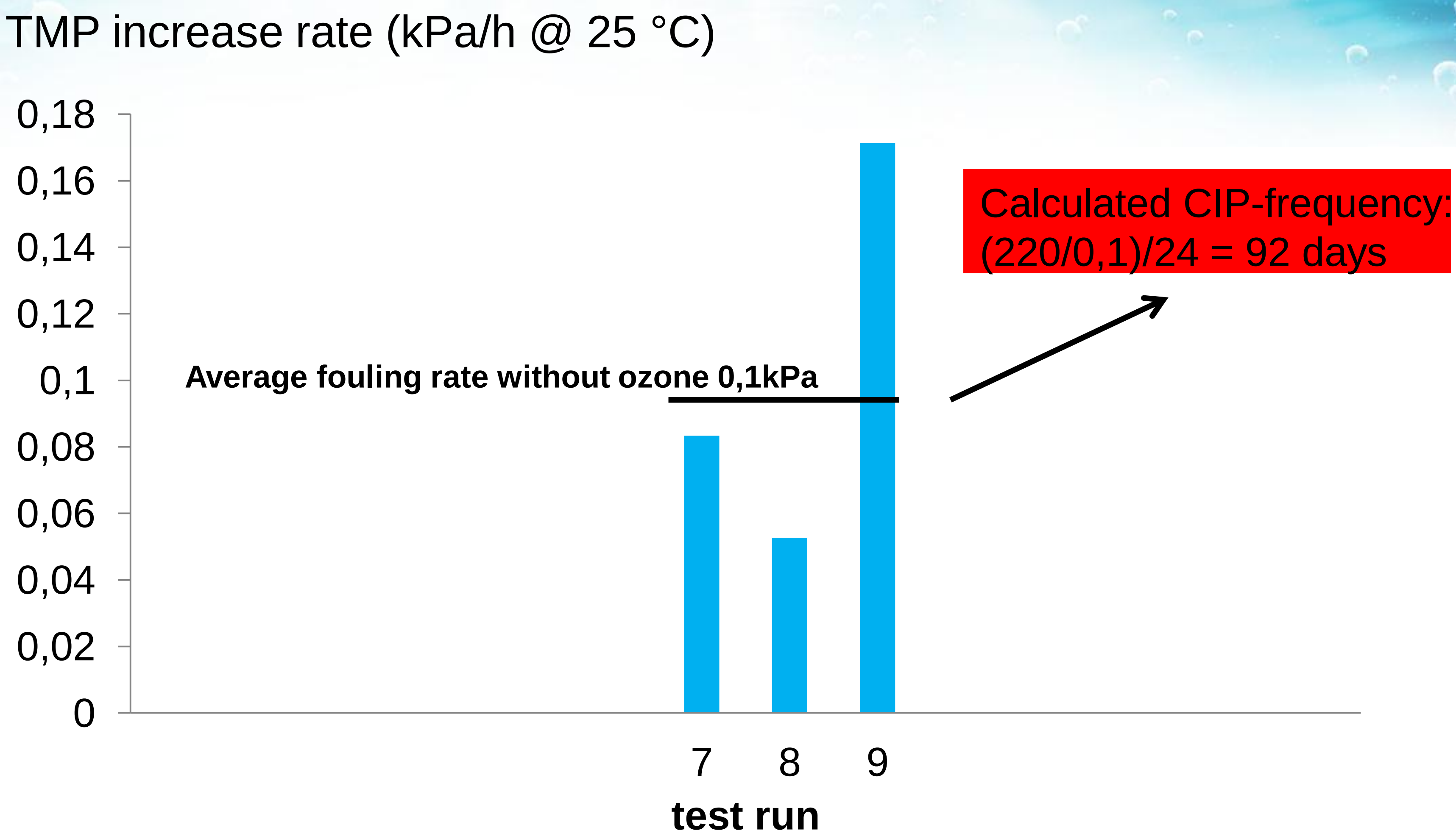
TMP increase over EBW cycle



fouling rate



performance evaluation



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phase 2: clarified water

- start 1st of September 2011
- ended 23th of February 2012
- found optimal operation
  - flux : 200 lmh
  - BW-frequency : 2/h
  - EBW-frequency : 2-3/d (NaOCl 100ppm)
  - : 0-1/d (HCl pH=2 with 100ppm H2O2)
  - CIP frequency : >90 days
  - water recovery : >95%

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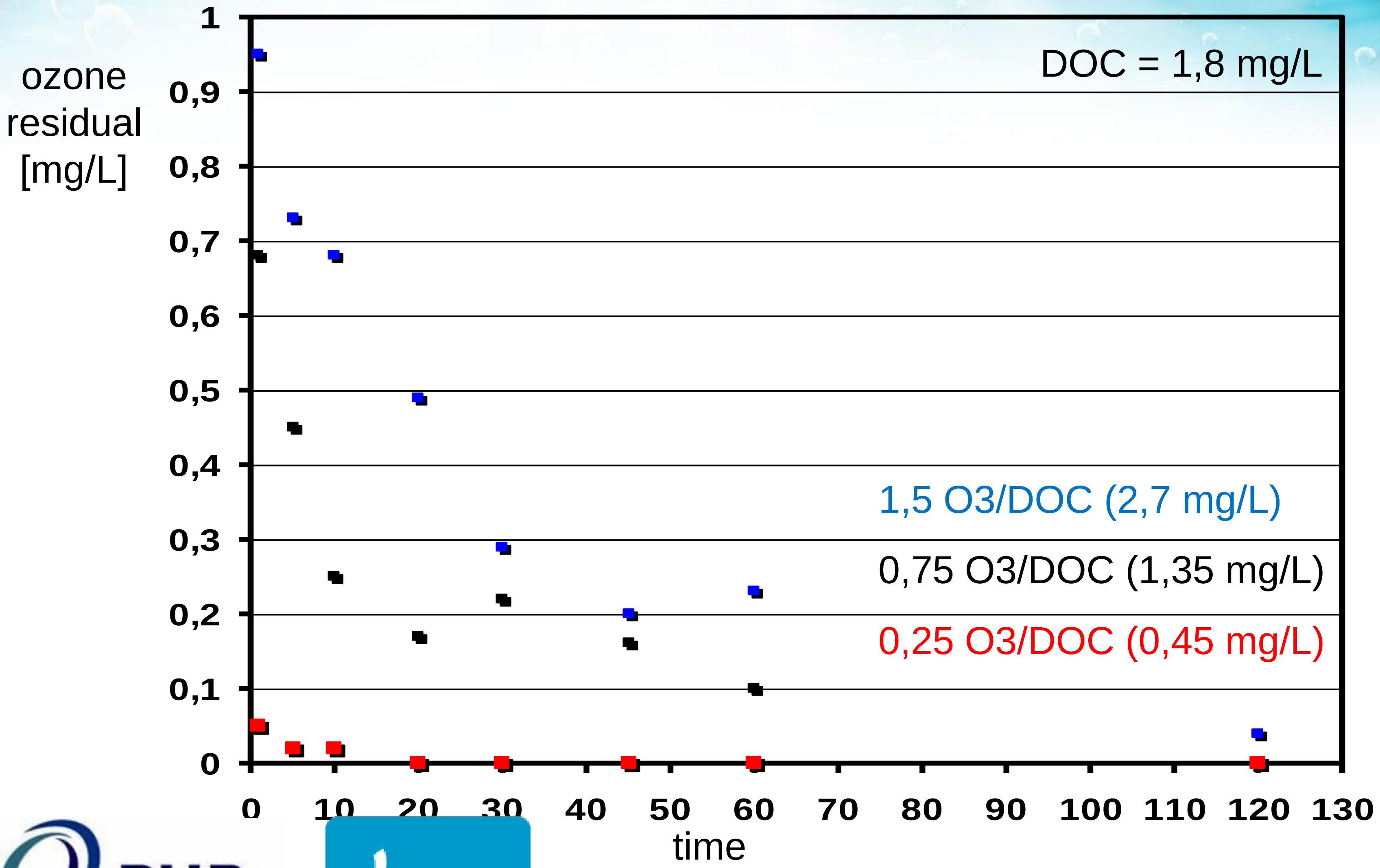
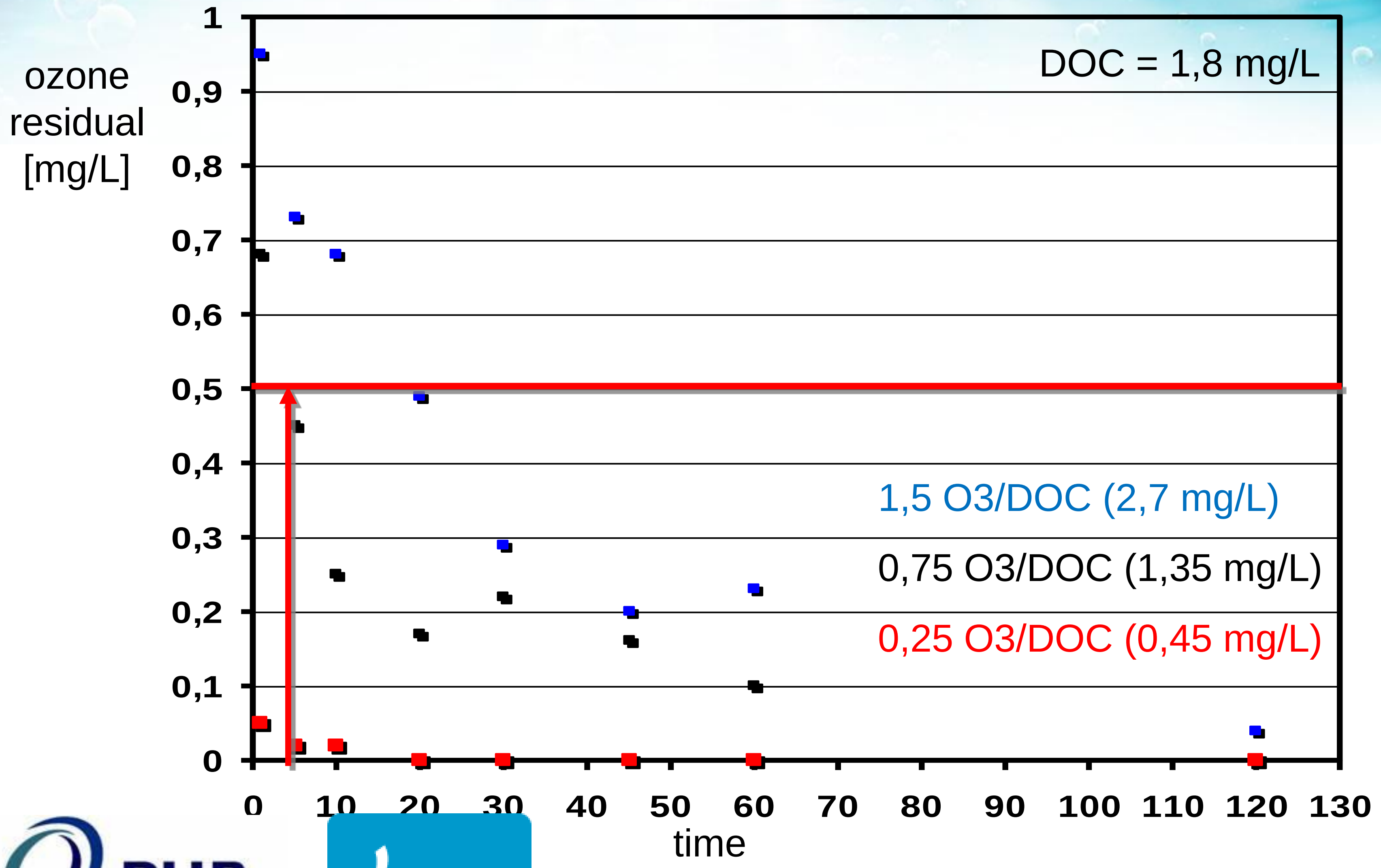
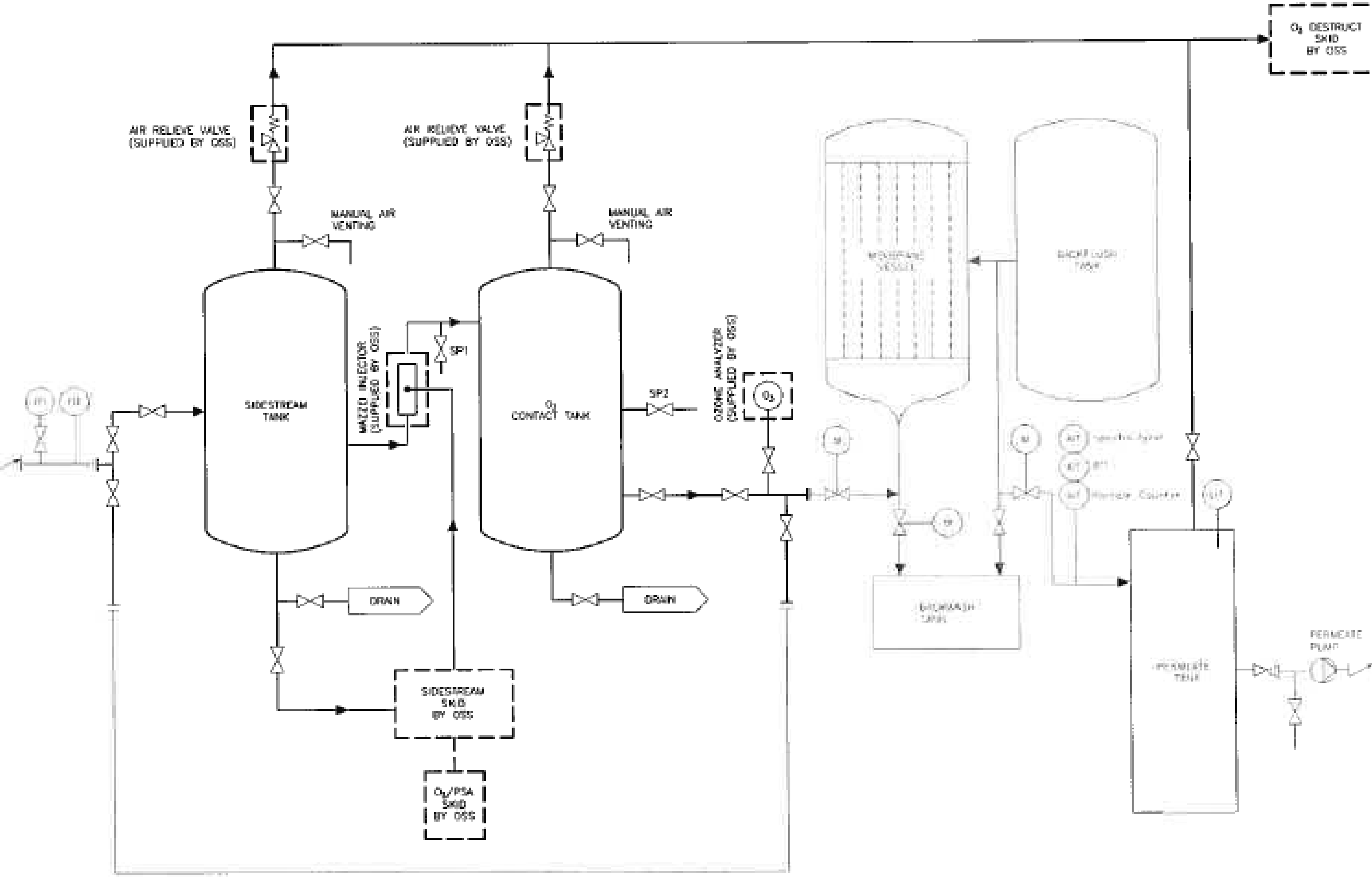
summary results phase 3 until now

ozone decay tests



ozone decay tests





O_3 DESTRUCT SKID BY OSS
AIR RELIEVE VALVE (SUPPLIED BY OSS)
AIR RELIEVE VALVE (SUPPLIED BY OSS)
MANUAL AIR VENTING
MANUAL AIR VENTING
SIDESTREAM TANK
MAZZEI INJECTOR (SUPPLIED BY OSS)
SP1
O_3 CONTACT TANK
SP2
OZONE ANALYZER (SUPPLIED BY OSS)
O_3
DRAIN
DRAIN
SIDESTREAM SKID BY OSS
O_3/PSA SKID BY OSS
AIT
AIT
AIT
Particle Counter
PERMEATE PUMP

operational parameters phase 3

Parameter	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14
Flux (lmh)	200	200	200	200	240	240	240
BW Interval (min)	15	30	30	30	30	60	180
EBW Interval (A)	31th BW	31th BW	15th BW	15th BW	15th BW	8th BW	4th BW
EBW Interval (B)	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A	5th EBW-A
Recovery (V%)	93.8	96.8	96.6	96.6	97.2	98.4	99.6
Total Filtration runtime (h)	300	300	300	300	250	250	250
Total Volume produced (m^3)	28500	28500	28500	28500	28500	28500	28500

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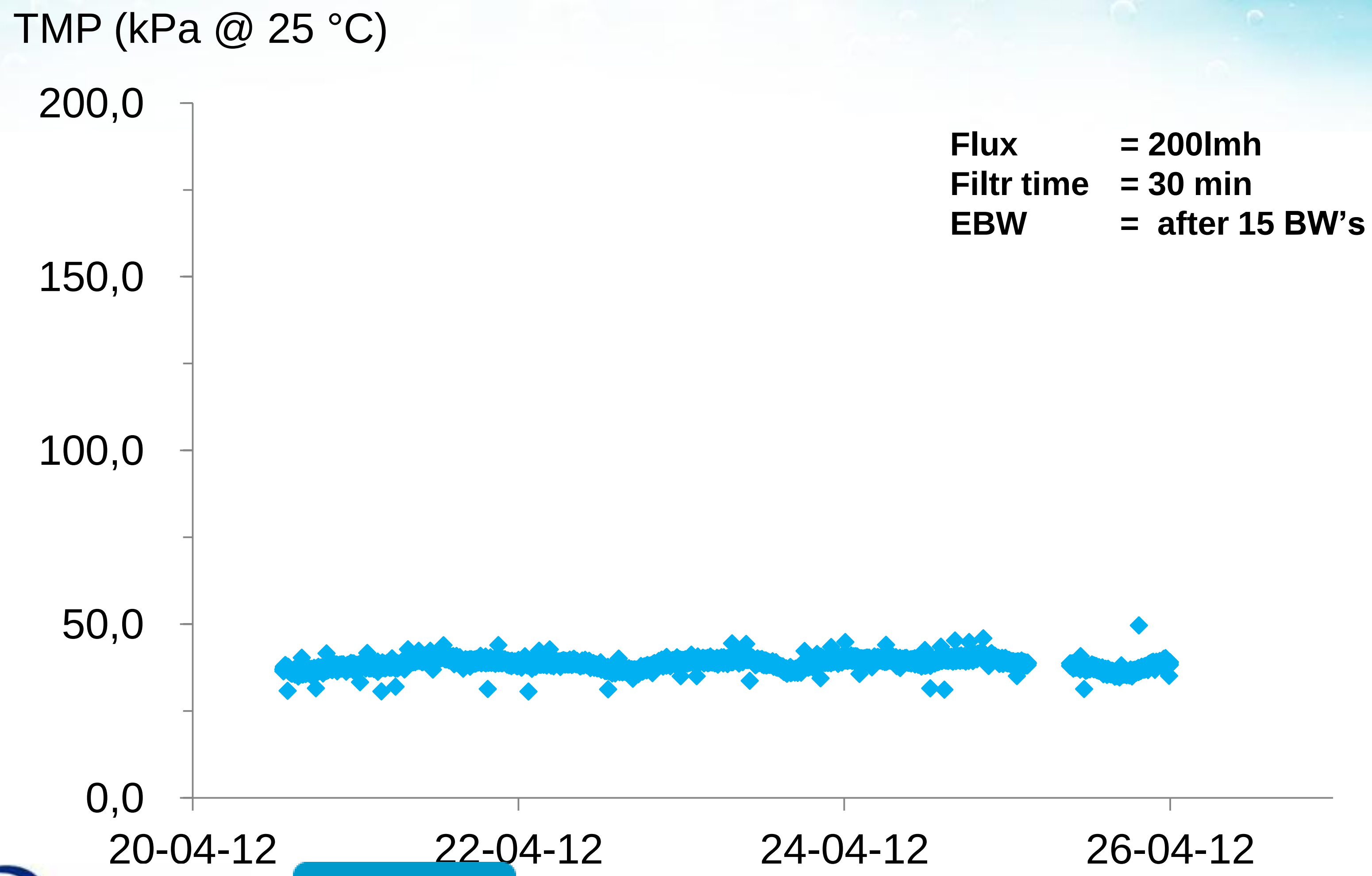
TMP curve run 10 – ozonated feed



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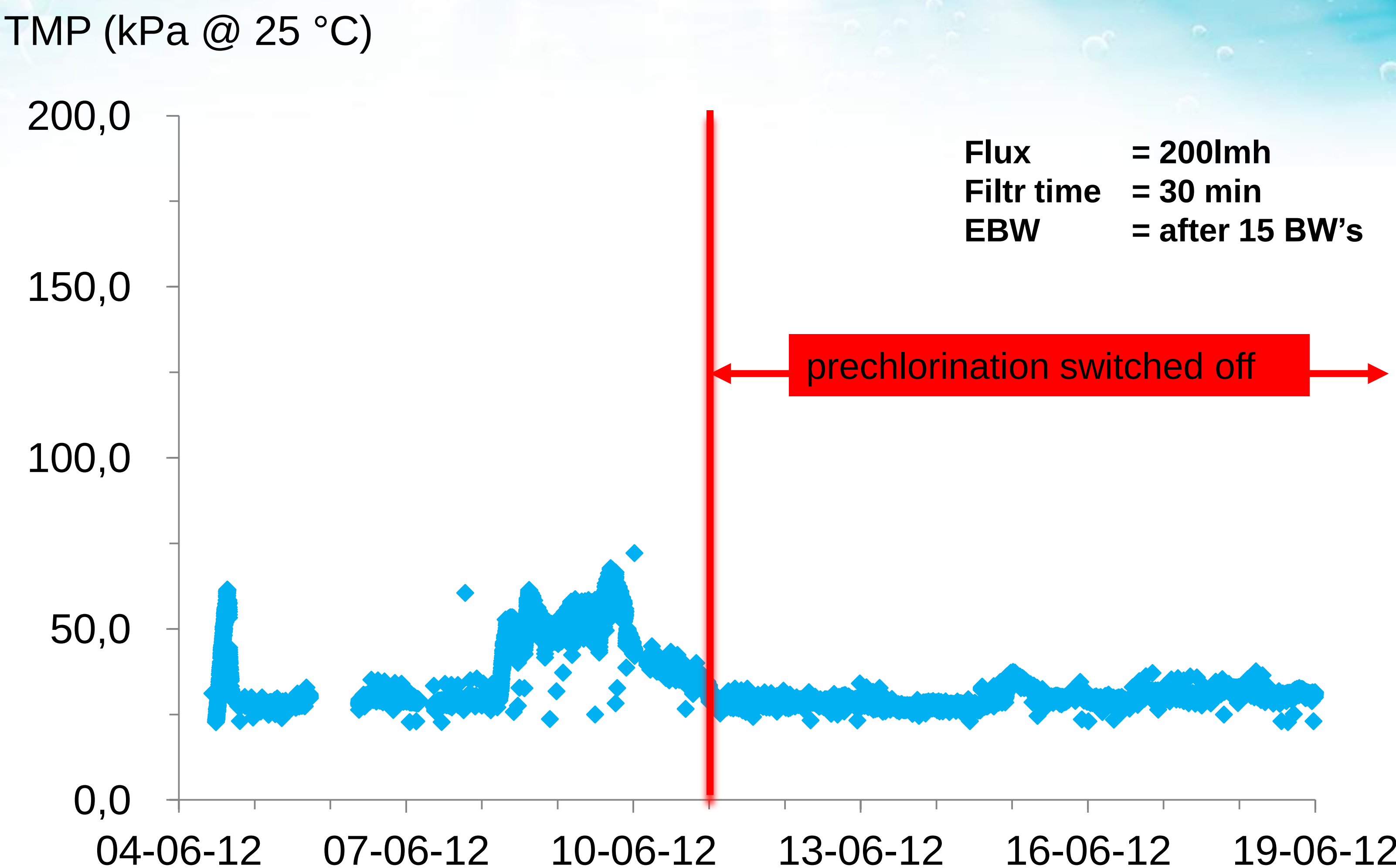
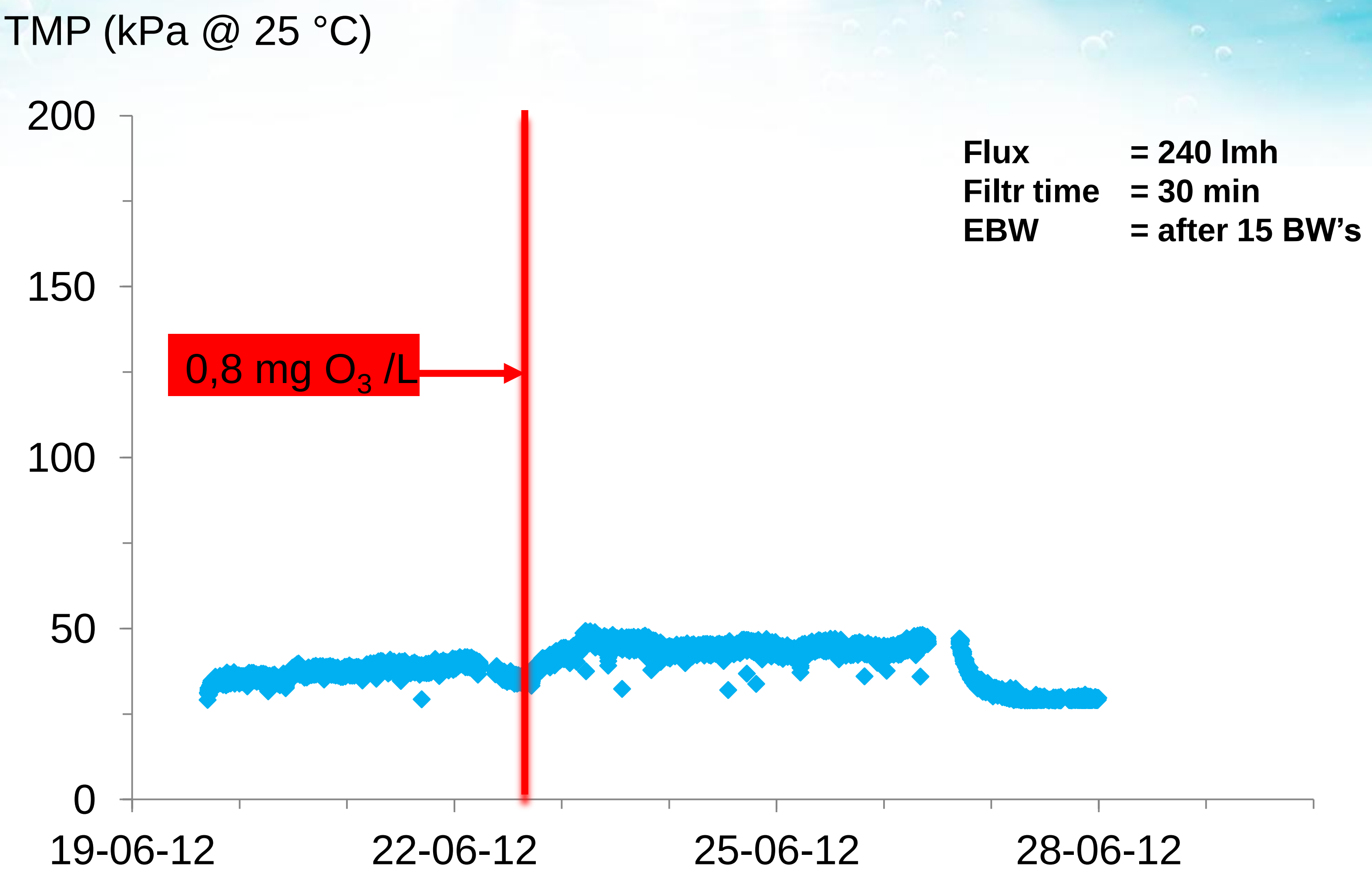
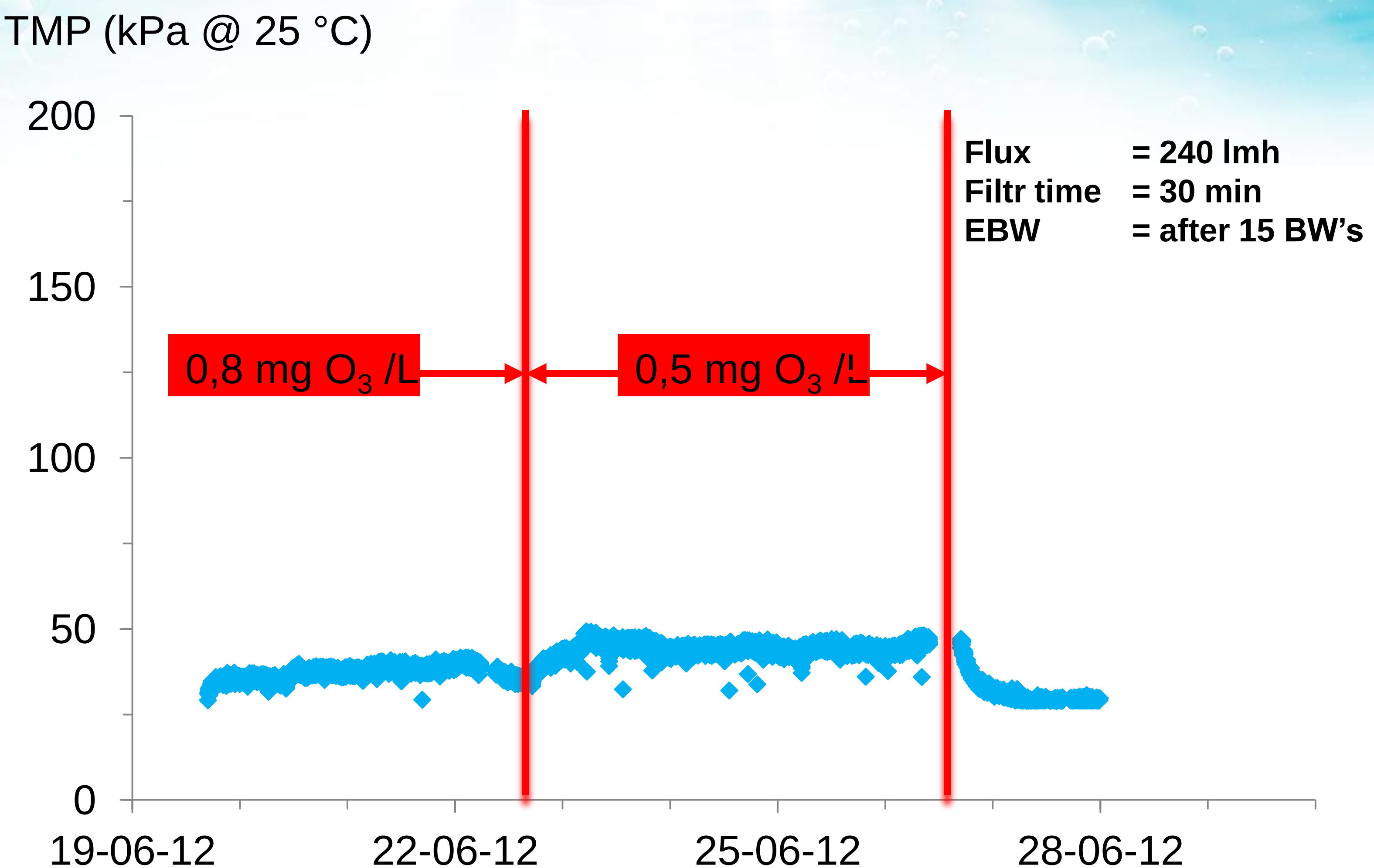
TMP curve run 11 – ozonated feed



TMP curve run 12 – ozonated feed



TMP curve run 12 – ozonated feed



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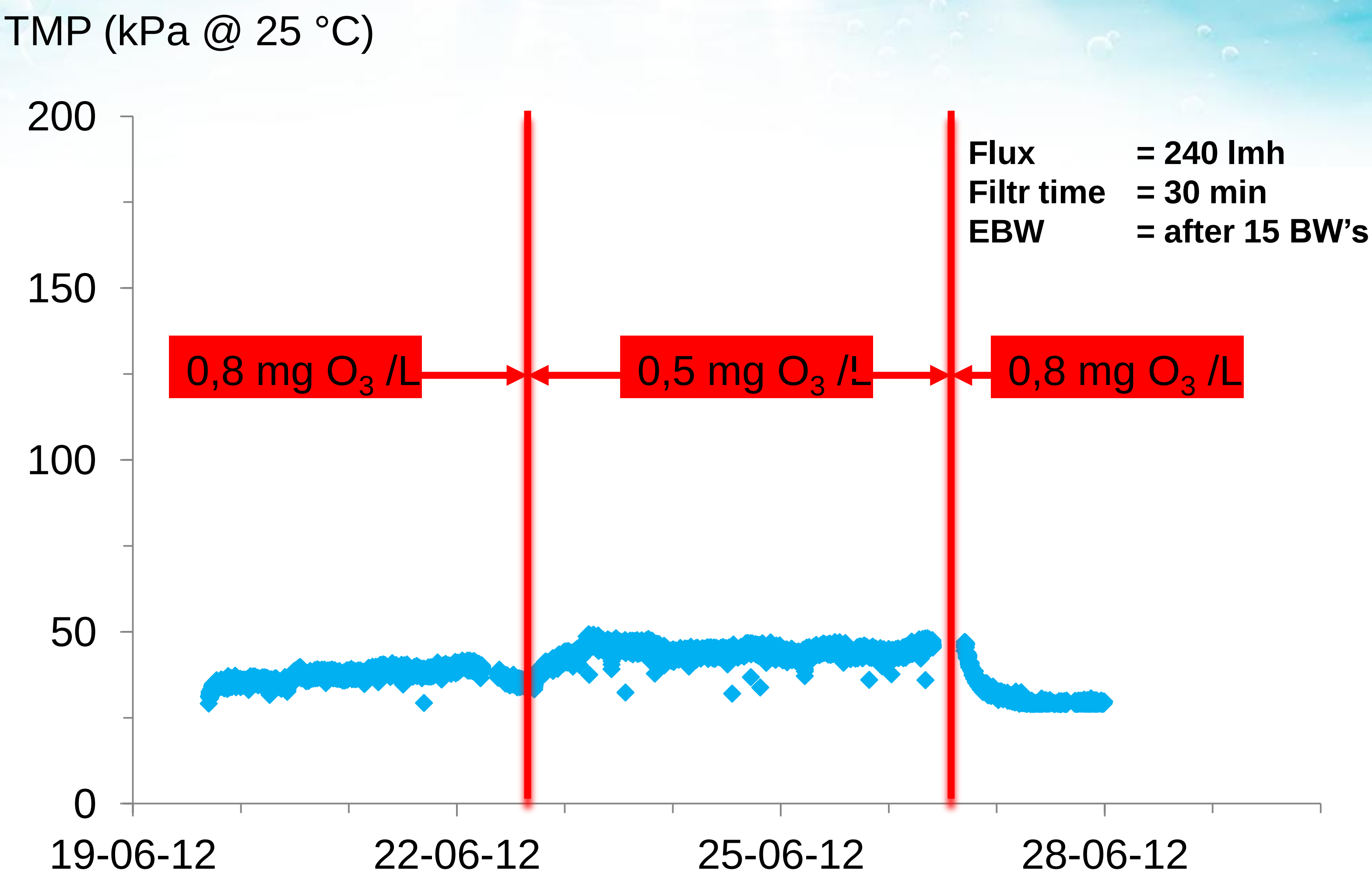
TMP curve run 12 – ozonated feed



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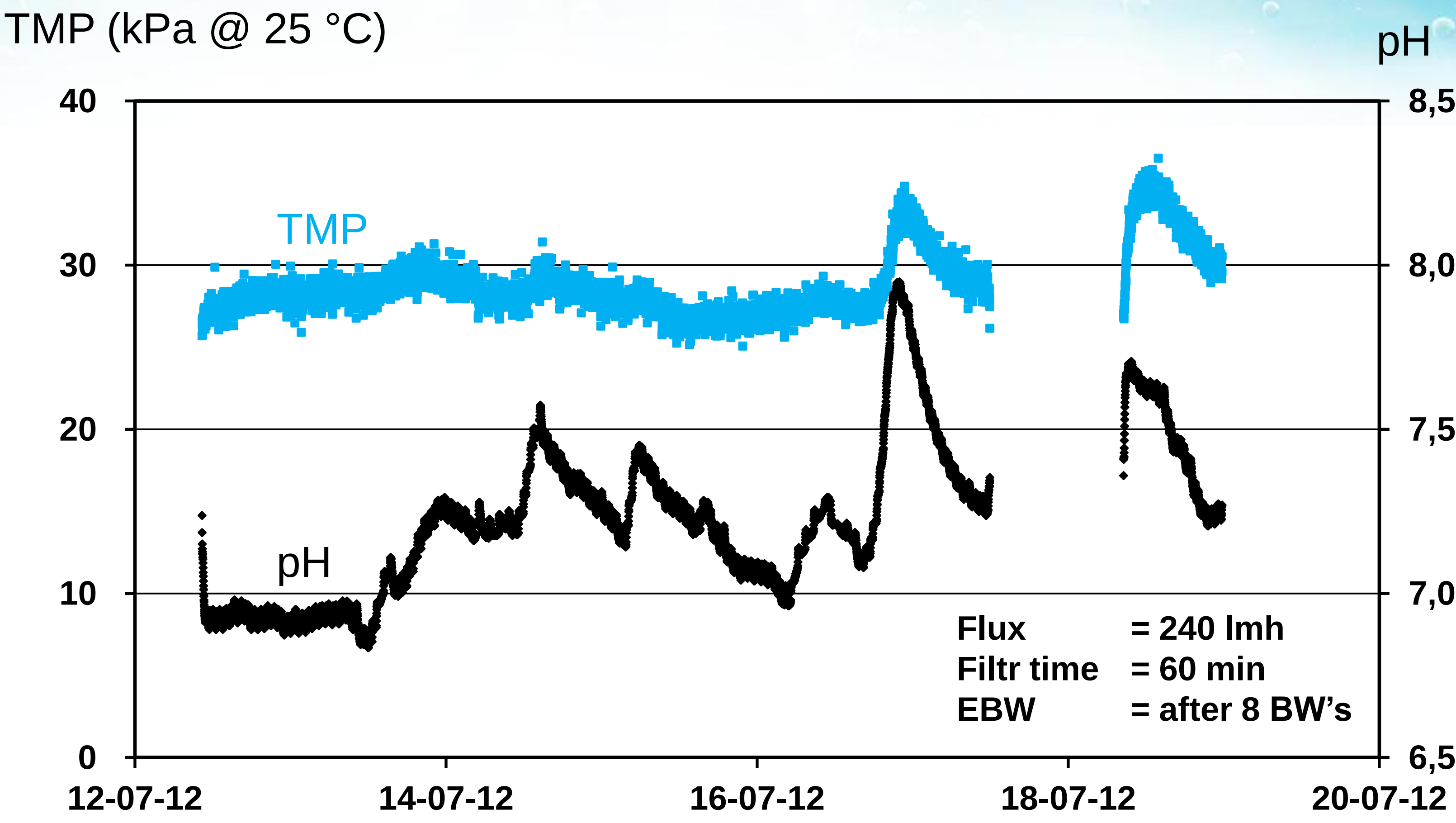
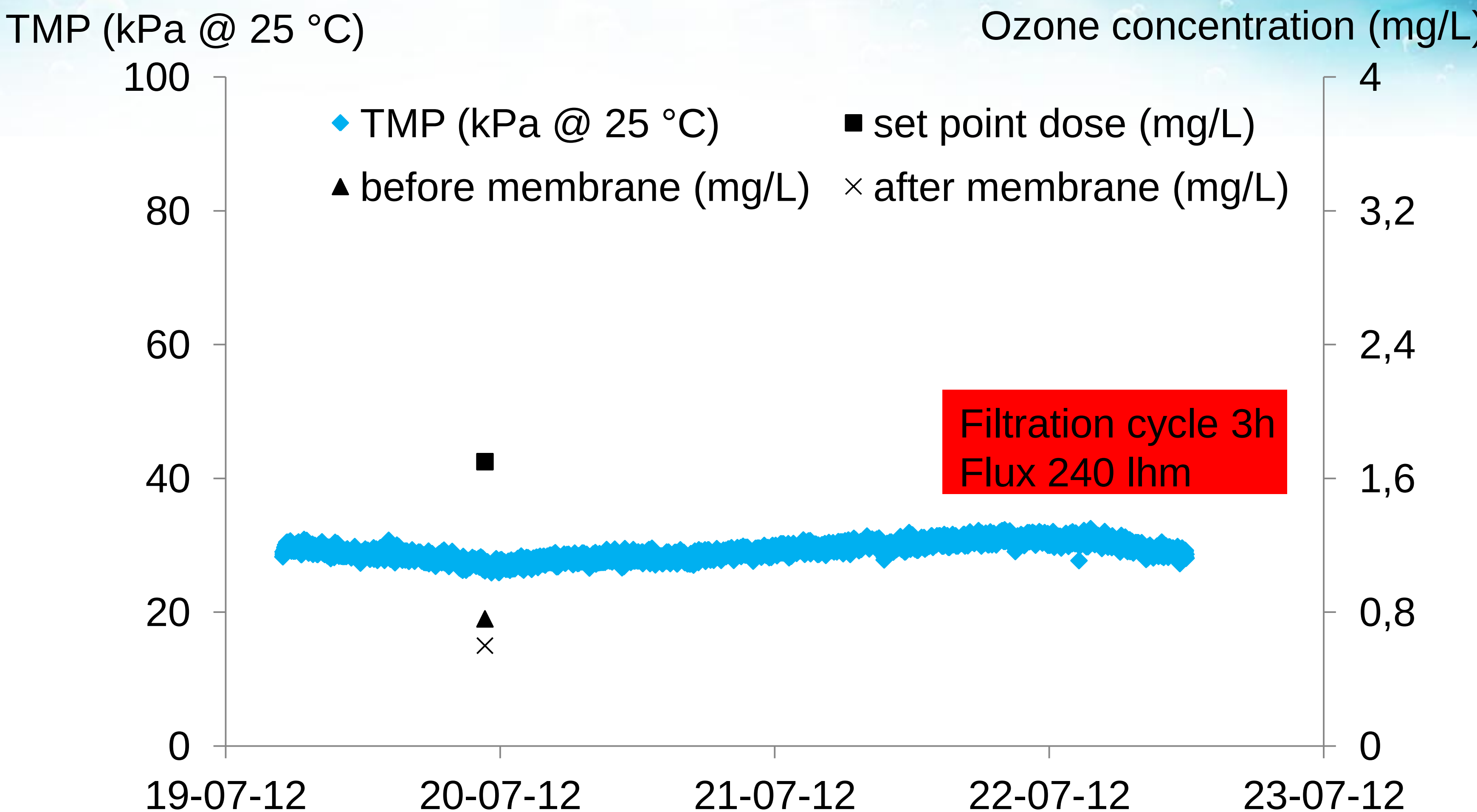
Run 13 TMP and feed water pH



Run 14: TMP and ozone dosing



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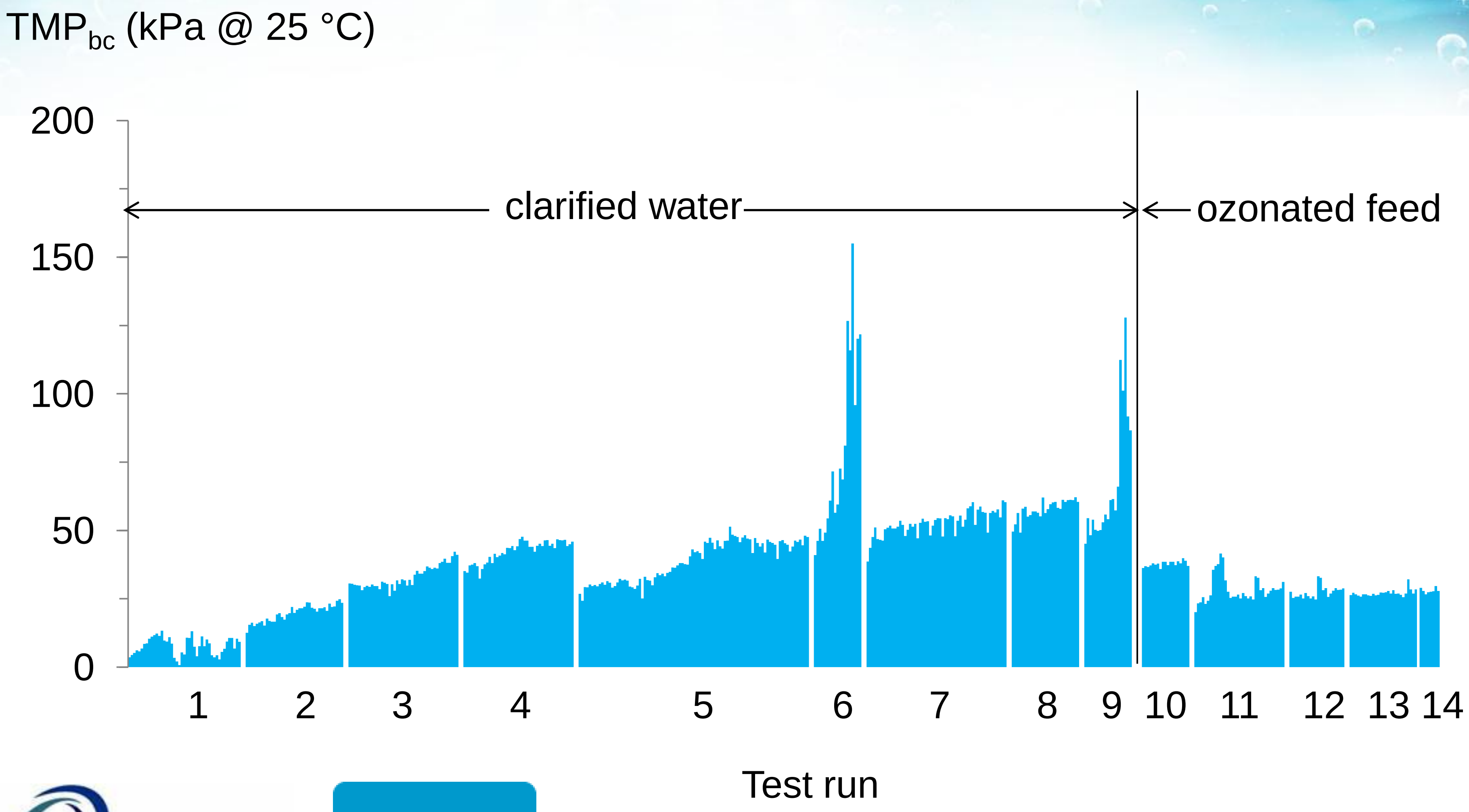
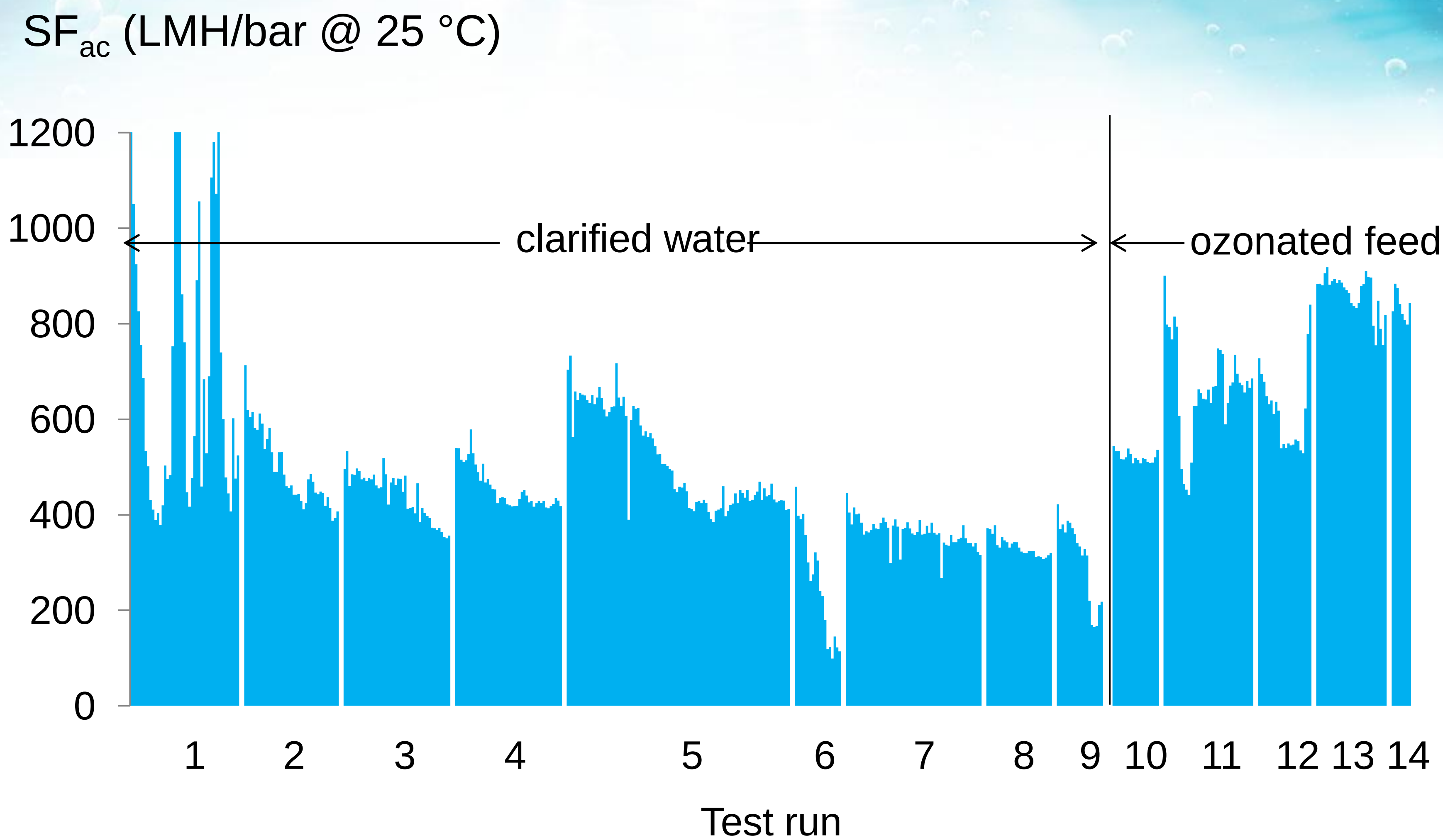
phase 3: ozonated clarified water

- start 20st of April 2012 – still under investigation
- pre-chlorination makes ozone dosage difficult to control
- residual ozone concentration influences permeability
- pH influences permeability and process stability (pH<7,7)
- ozone influences operation dramatically
- installation runs stable at max capacity feedpump

TMP after backwash



specific flux during filtration cycle



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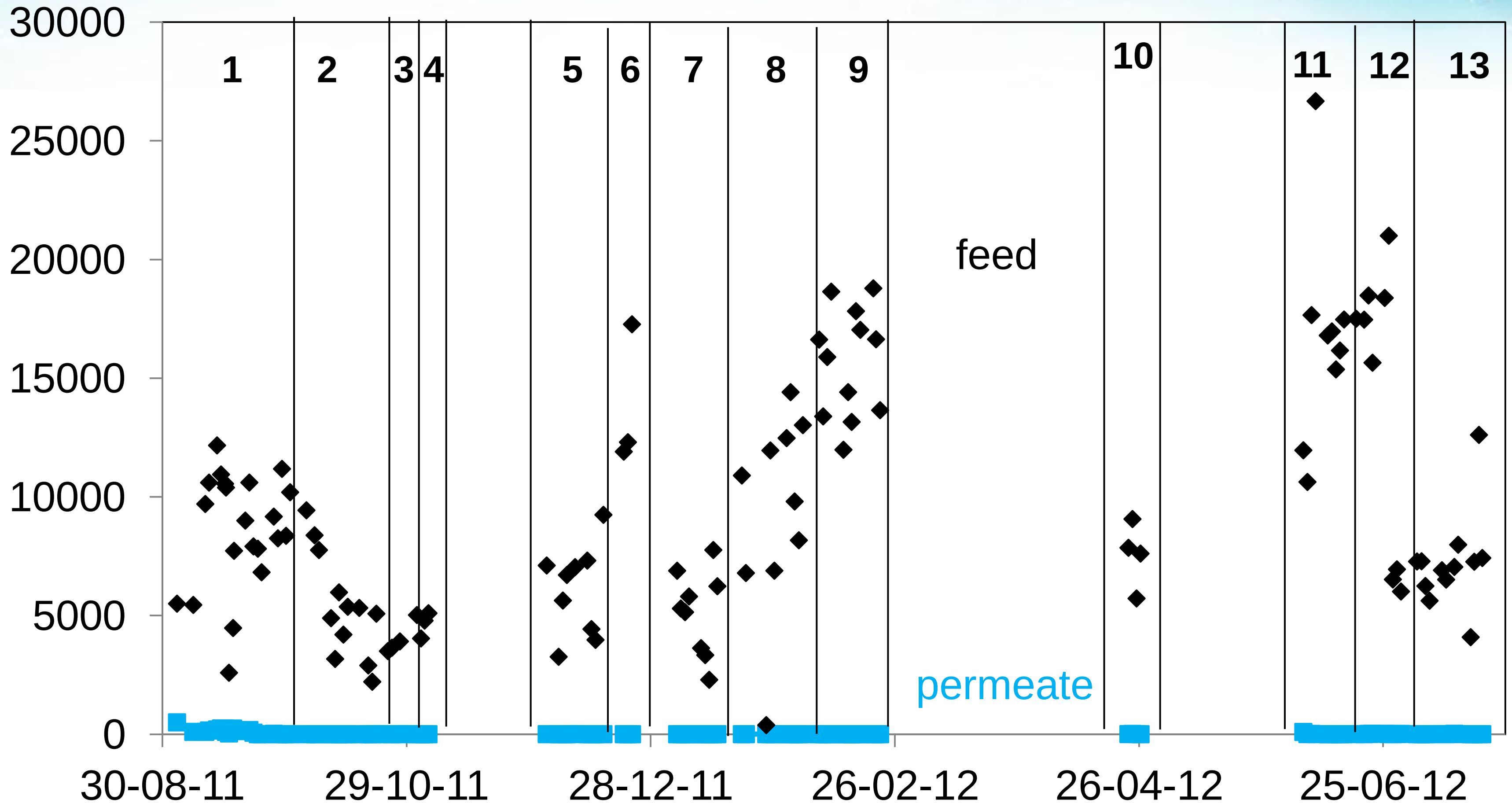
particle counts

Number of particles > 1 µm



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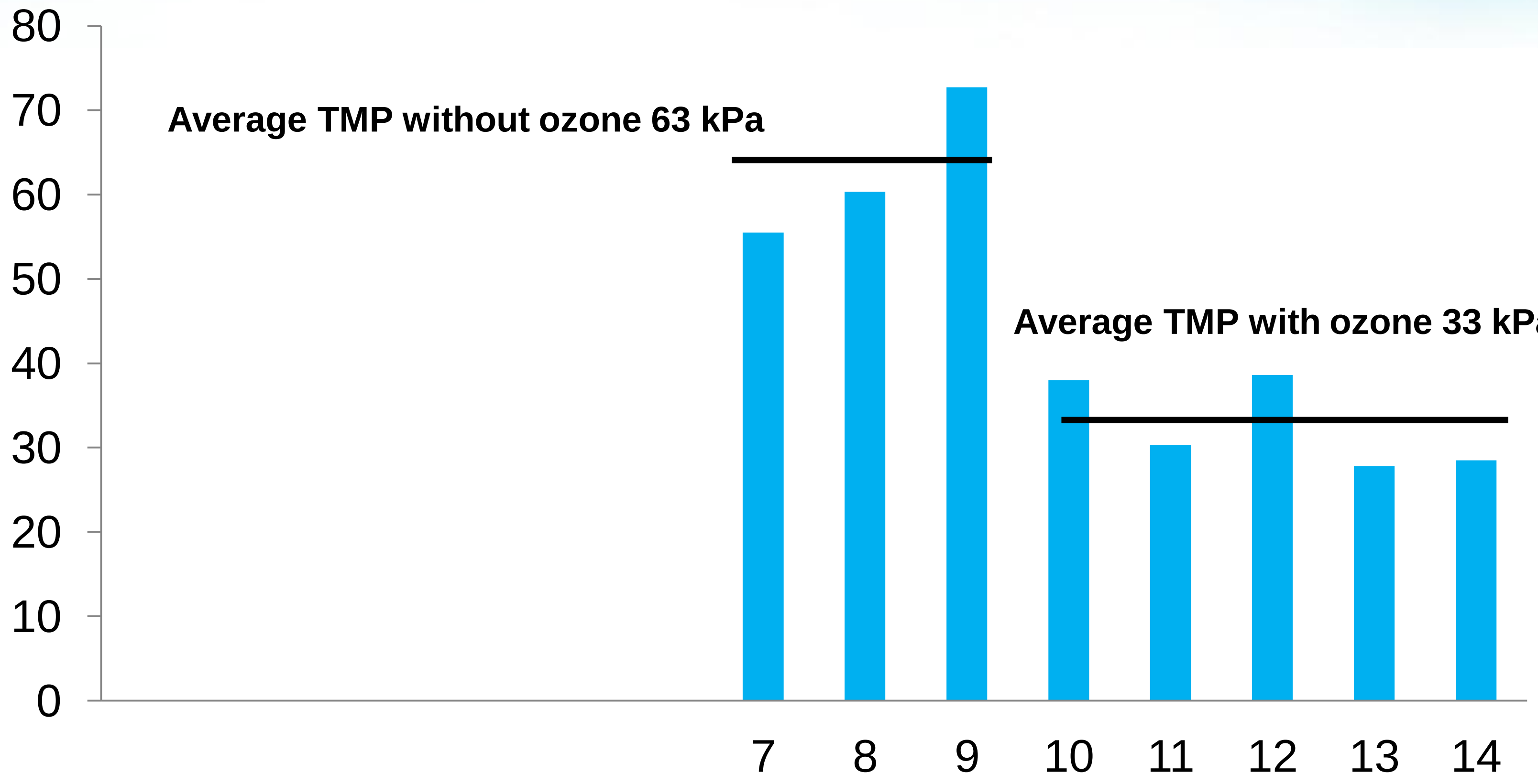
performance evaluation

Average TMP for each run (kPa @ 25 °C)



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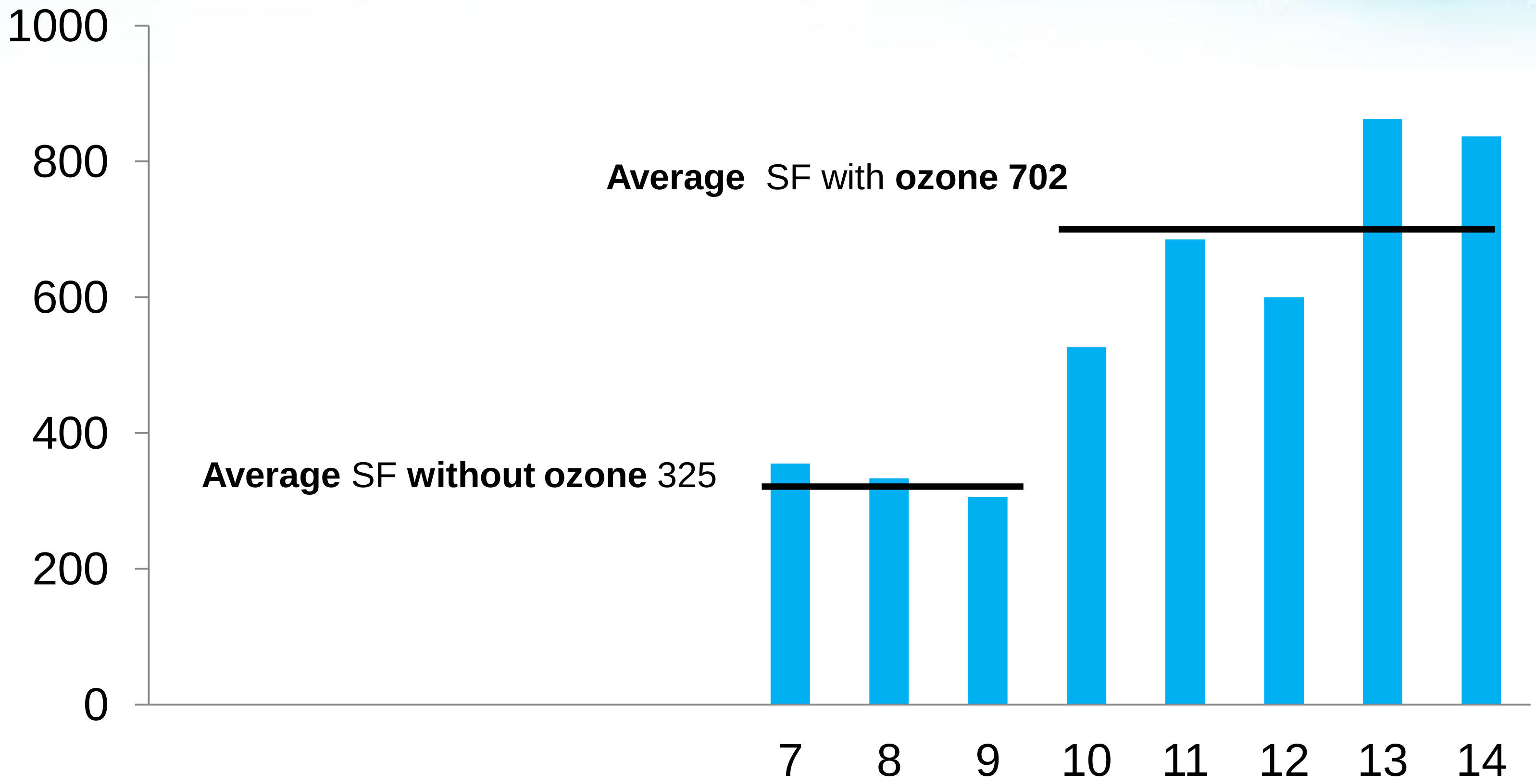
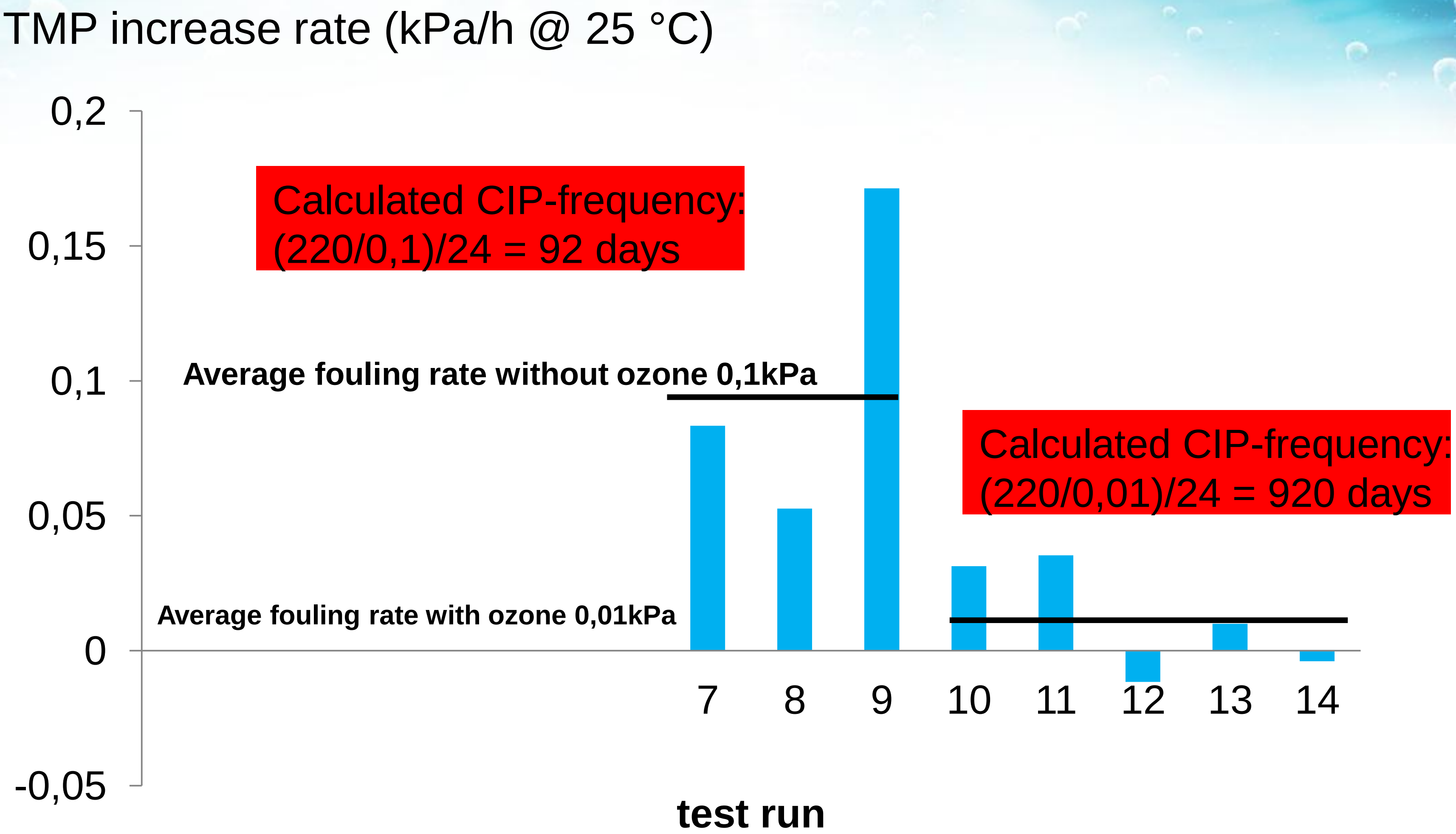
performance evaluation

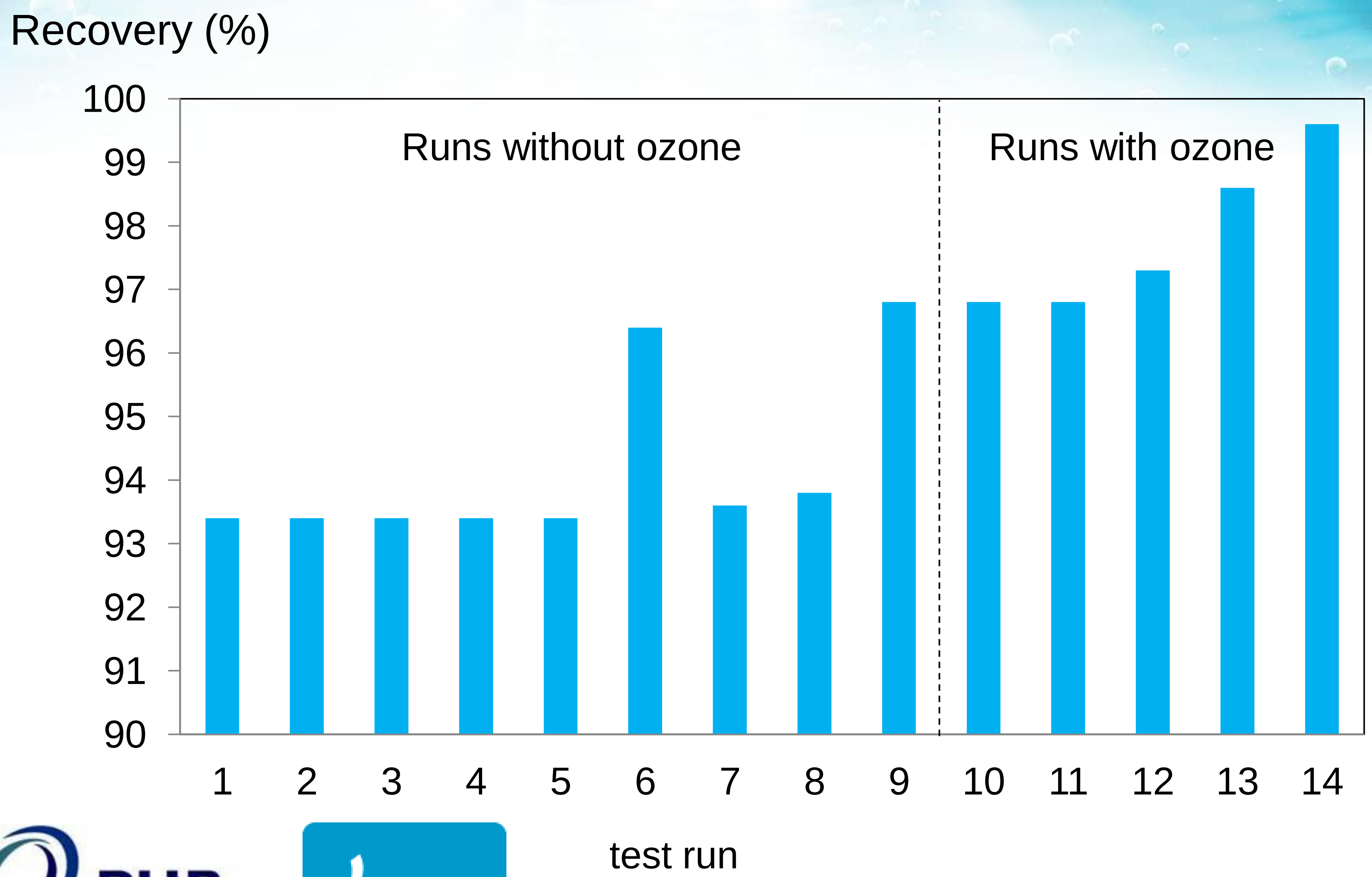
Average specific flux for each run (LMH/bar @ 25 °C)



performance evaluation



recovery at different runs



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found optimum operation

	Run 8	Run 13&14
Parameter	**without O_3**	**with O_3**
Flux (lmh)	200	>240
BW Interval (min)	30	>180
EBW Interval (A)	31th BW	>4th BW
EBW Interval (B)	5th EBW-A	5th EBW-A
Recovery (V%)	96.8	>99,6
Fouling rate (kPa/h)	0,1	0,01
CIP frequency (days)	80-100	>360

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conclusions so far

- CeraMac® is technically feasible as alternative for sand filtration with an without ozone
- ozone dosage upfront of the membrane enhances the filtration process significantly
  - increase of permeability
  - lower fouling rate
  - higher recovery
- found temporary optimum is unsurpassed on this water type and scale
- pH influences permeability and the stability of the process when ozone is applied and should be kept below a pH of 7,7

recommendations

- continue ozone test on clarified water
- optimize flux, residual ozone concentration, BW and EBW-frequency further after increasing capacity feed pump to max piping can hold
- determine economical feasibility:
  - make preliminary design based on found optimum
  - perform long term test to fine tune operational costs
- investigate synergy between ozone and ceramics
  - formation of OH-radicals, singlet oxygen?
  - necessary residual ozone concentration on membrane surface
  - water quality changes (i.e. taste, odor, virus removal, biostability)
  - influence pH (i.e. surface charge, zeta potential particles)

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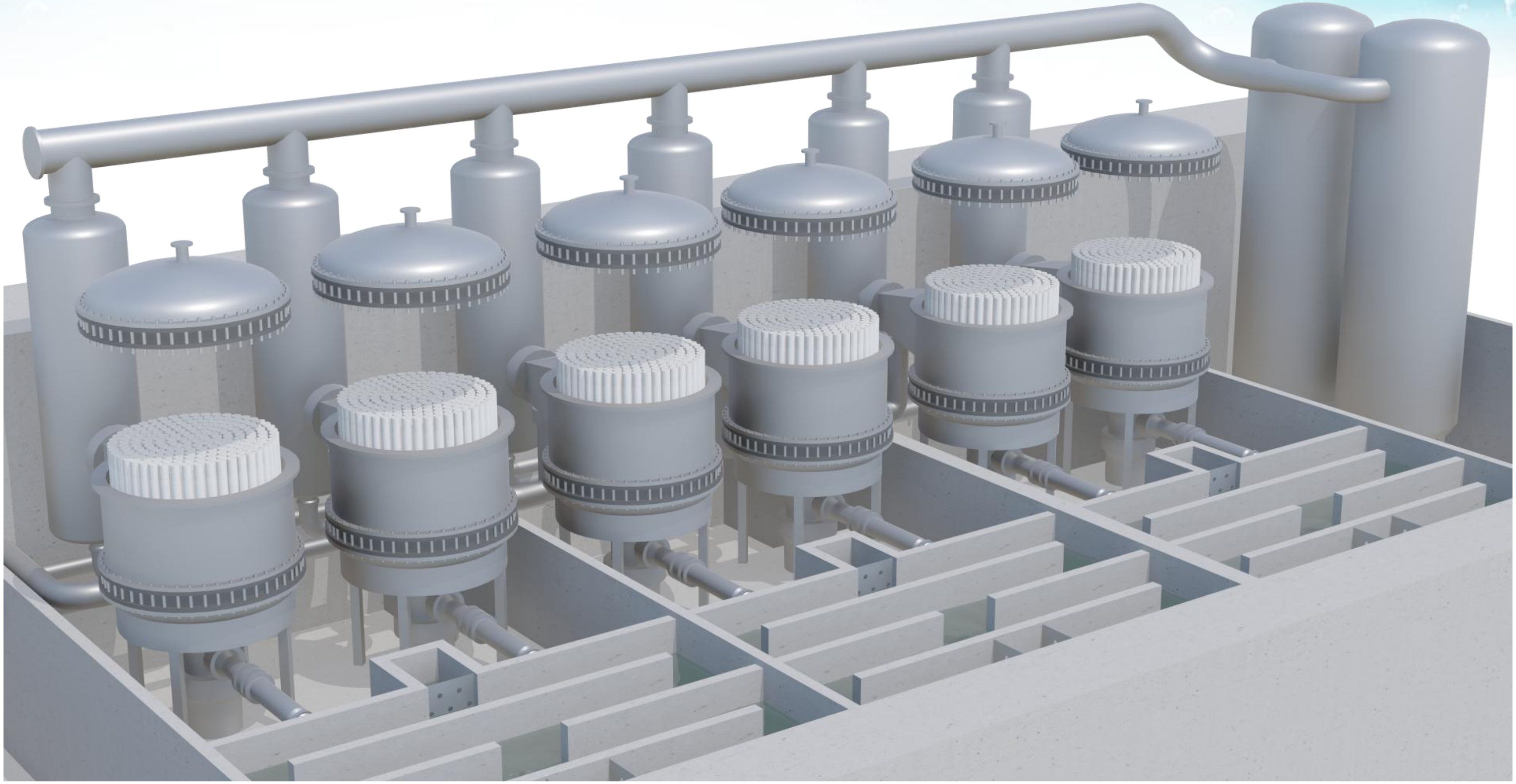
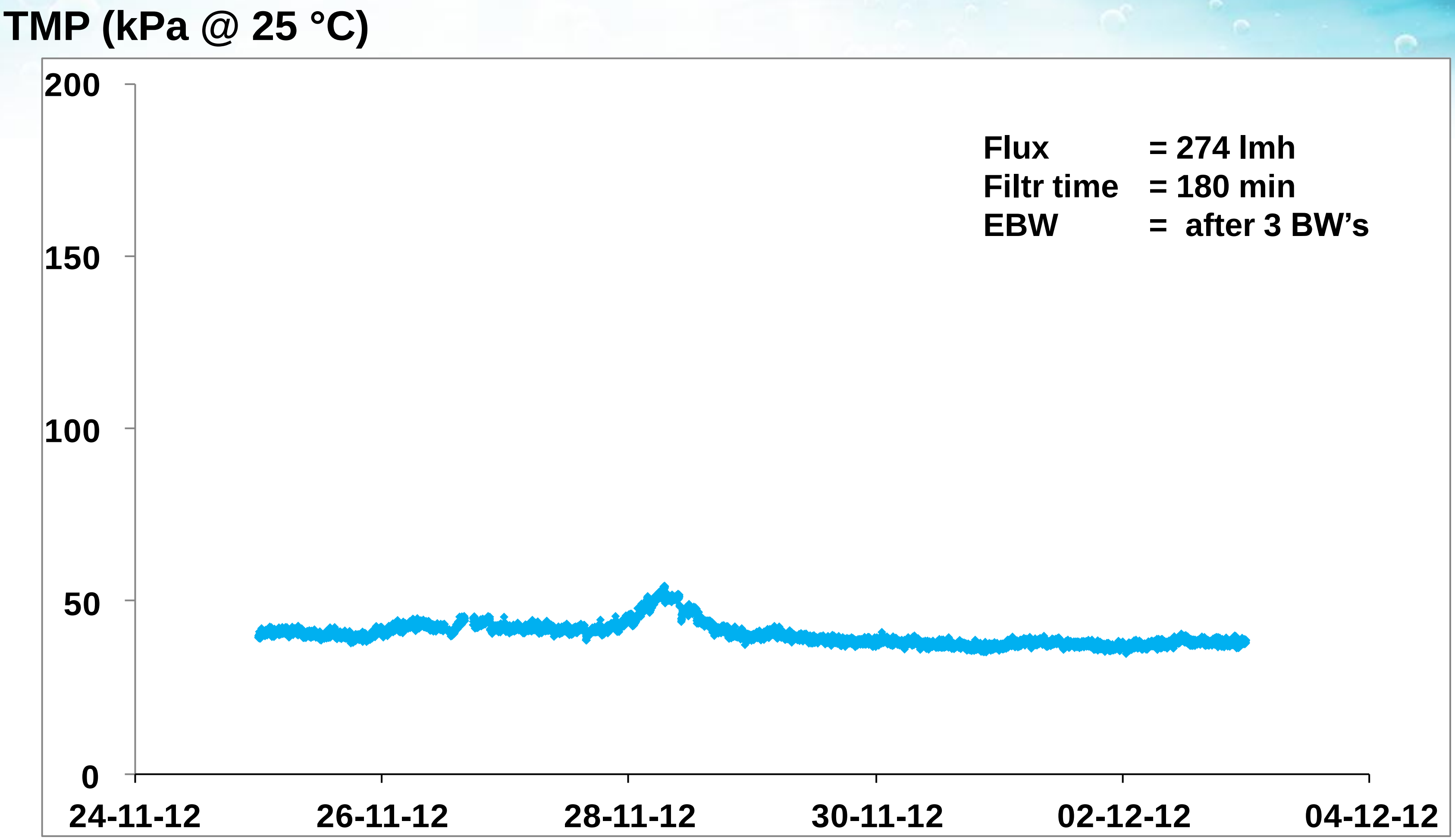
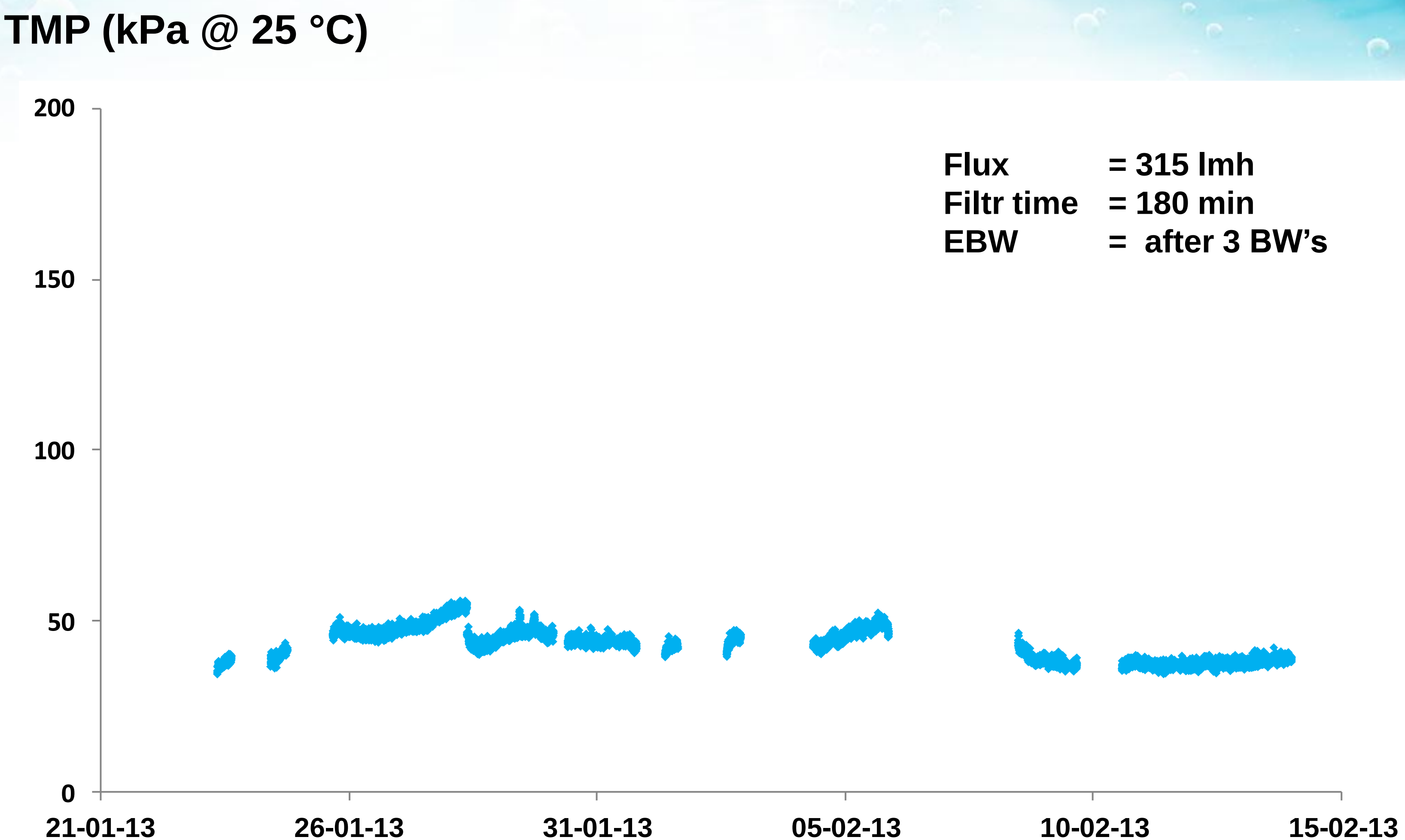


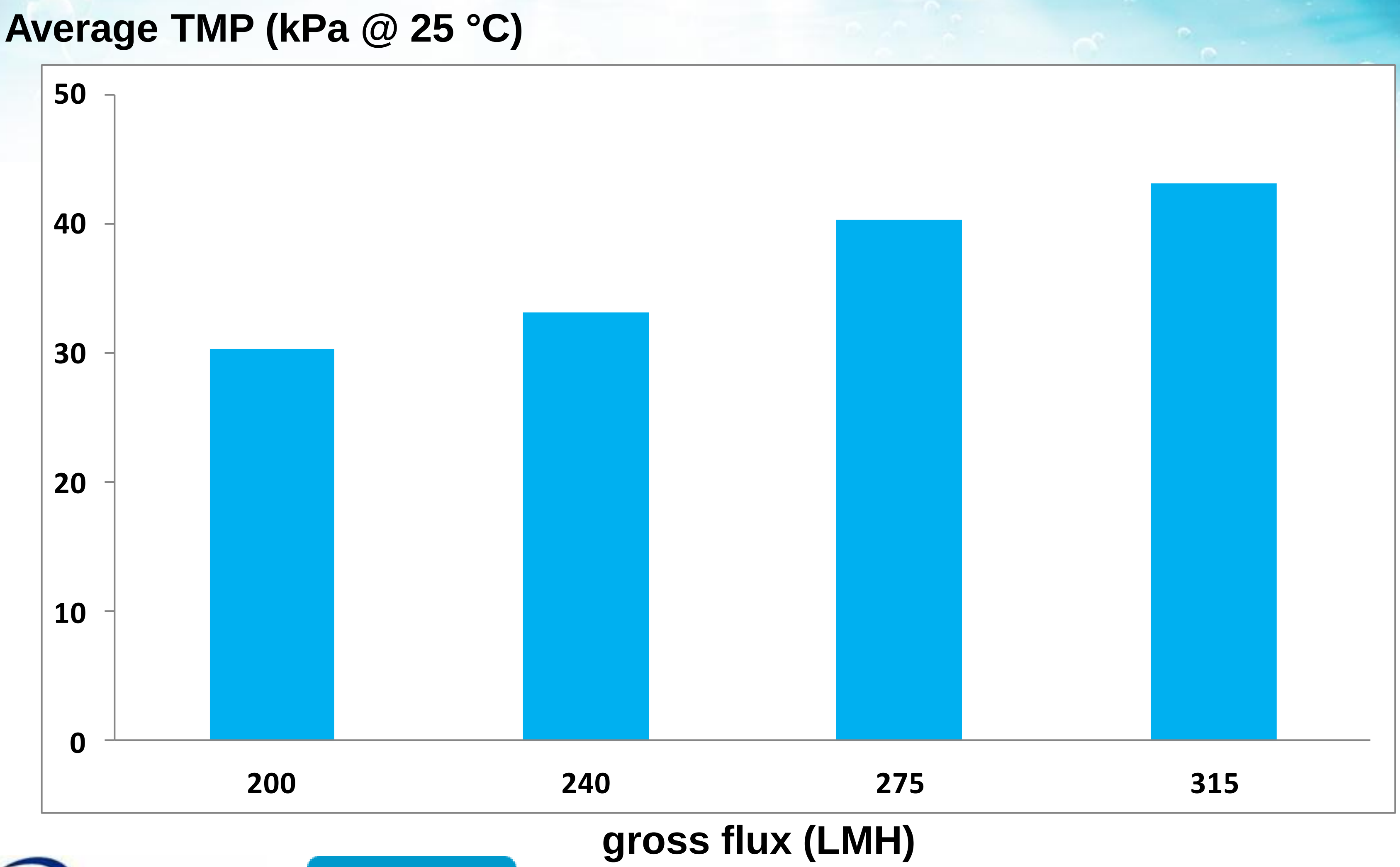
TMP curve run 15 – ozonated feed



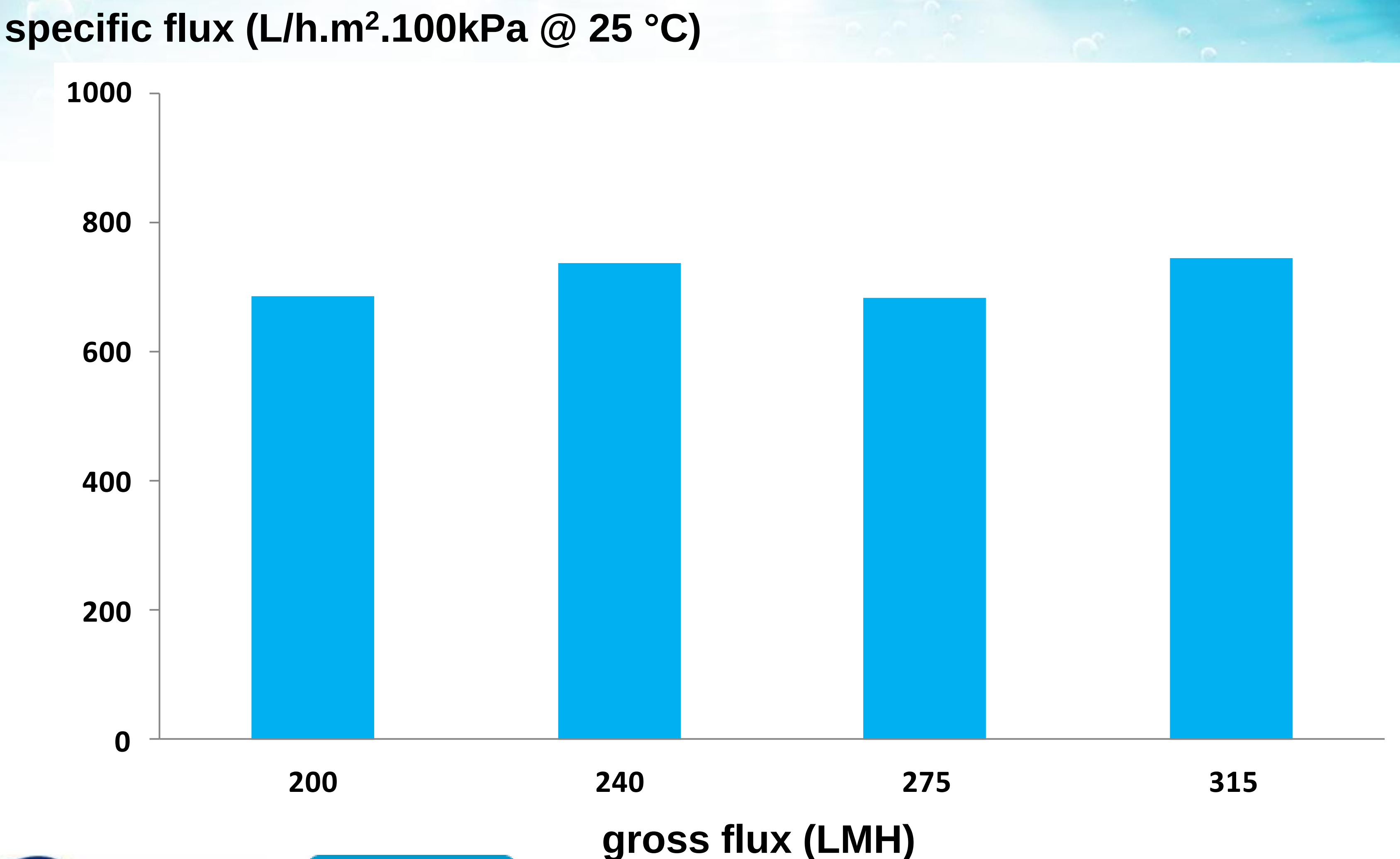
TMP curve run 16 – ozonated feed

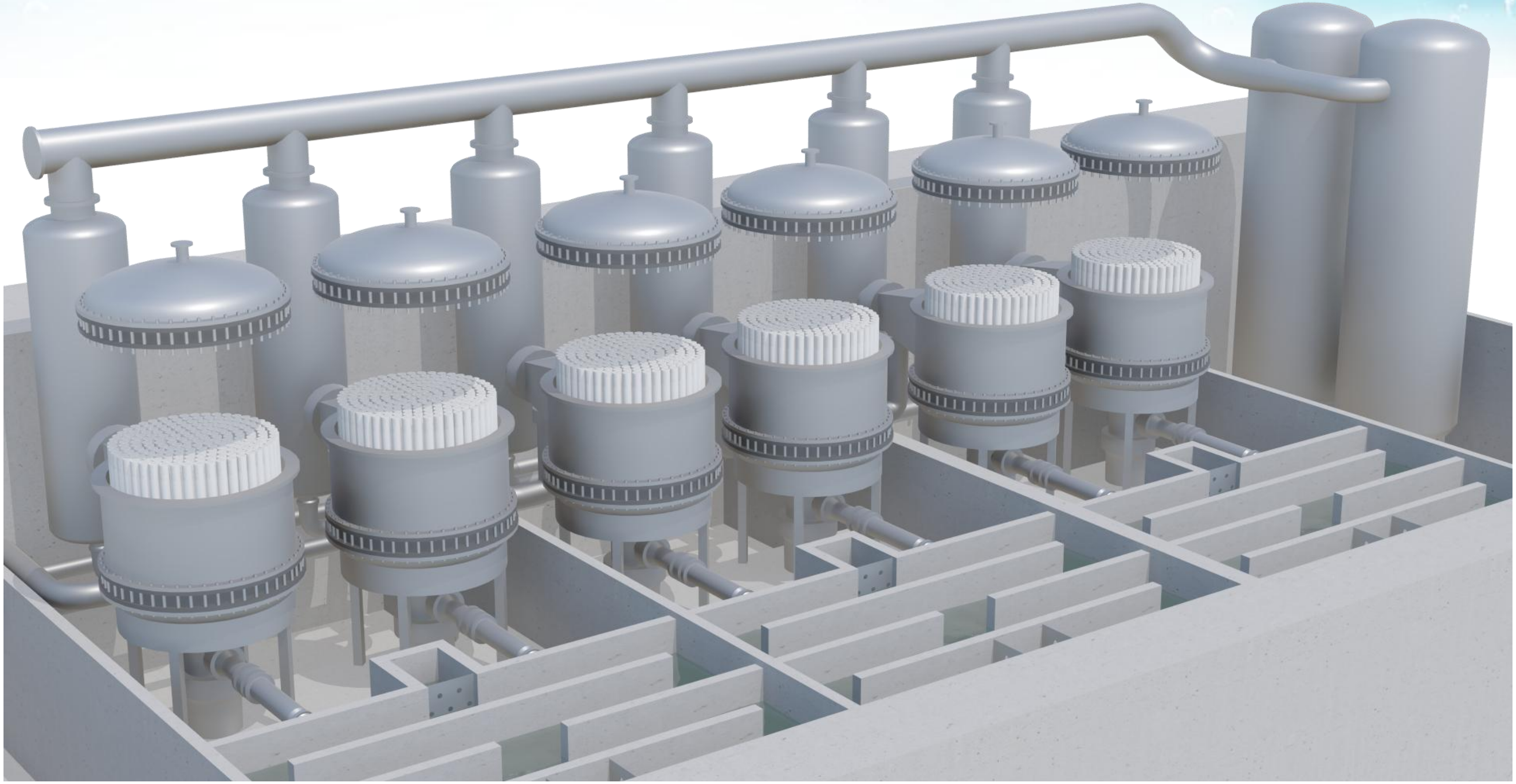


TMP at different fluxes – ozonated runs



specific flux at different fluxs – ozonated runs





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