Results from SIXTEN the pilot plant

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Outline

- Background: Norrvatten and Stockholm Vatten och Avfall
  - Raw water - Lake Mälaren
  - Water treatment processes
- Challenges & Aims
- SIX/CeraMac pilot
- Results
  - Overview water quality
  - SIX water quality
  - CeraMac operational data
  - DOC characterization
- Conclusions and future perspectives

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BACKGROUND

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Norrvatten & Stockholm Vatten och Avfall

- Together providing around 2 million people with drinking water
- Raw water source: lake Mälaren, the third largest lake in Sweden (1140 km^2)
- Eastern part is a protected area

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Raw water - Lake Mälaren

Lake Mälaren
Catchment area: 22 600 km^2
Surface Area: 1 140 km^2
Run-off: 5 billion m^3/year

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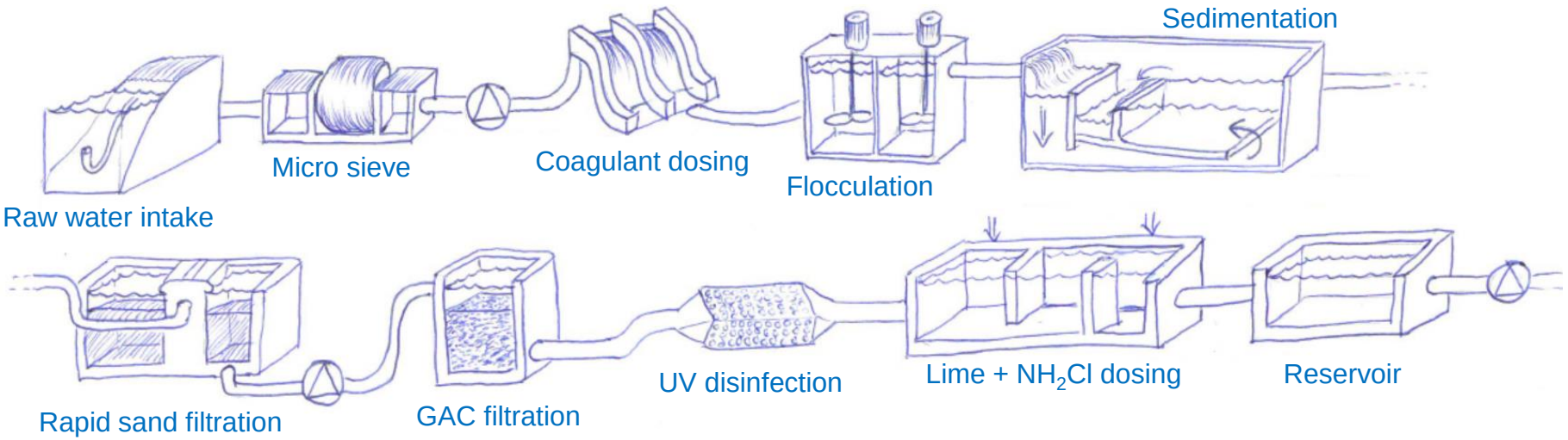
Norrvatten & Görväln WTP

- Norrvatten was established 1926
- One surface water treatment plant - Görvälnverket
- Production of ~140,000 m^3 day^{-1} for 600,000 inhabitants in 14 municipalities

Norrvatten & Görväln WTP

- Conventional treatment with (Al) coagulation/sedimentation/sand filtration, GAC filtration, UV and monochloramine disinfection



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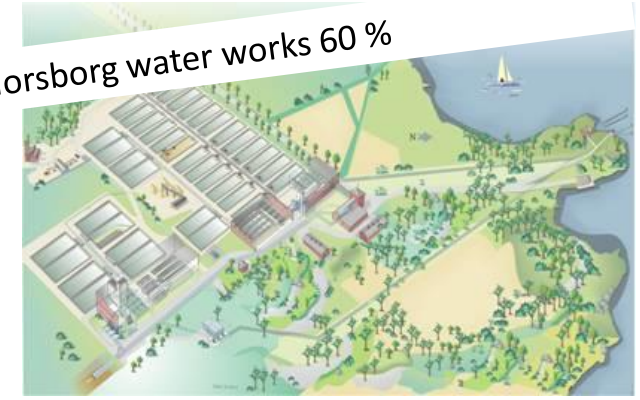
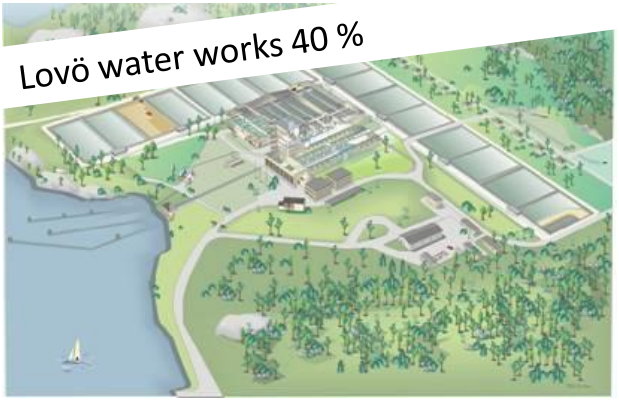
Stockholm Vatten och Avfall





- Stockholm Vatten och Avfall (Stockholm Water and Waste) is a municipal own company.
- Every day SVOA in average produces 410,000 m³ of drinking water in the two water treatment works of Lovö and Norsborg, and distributes it to 1.4 million people in Stockholm area

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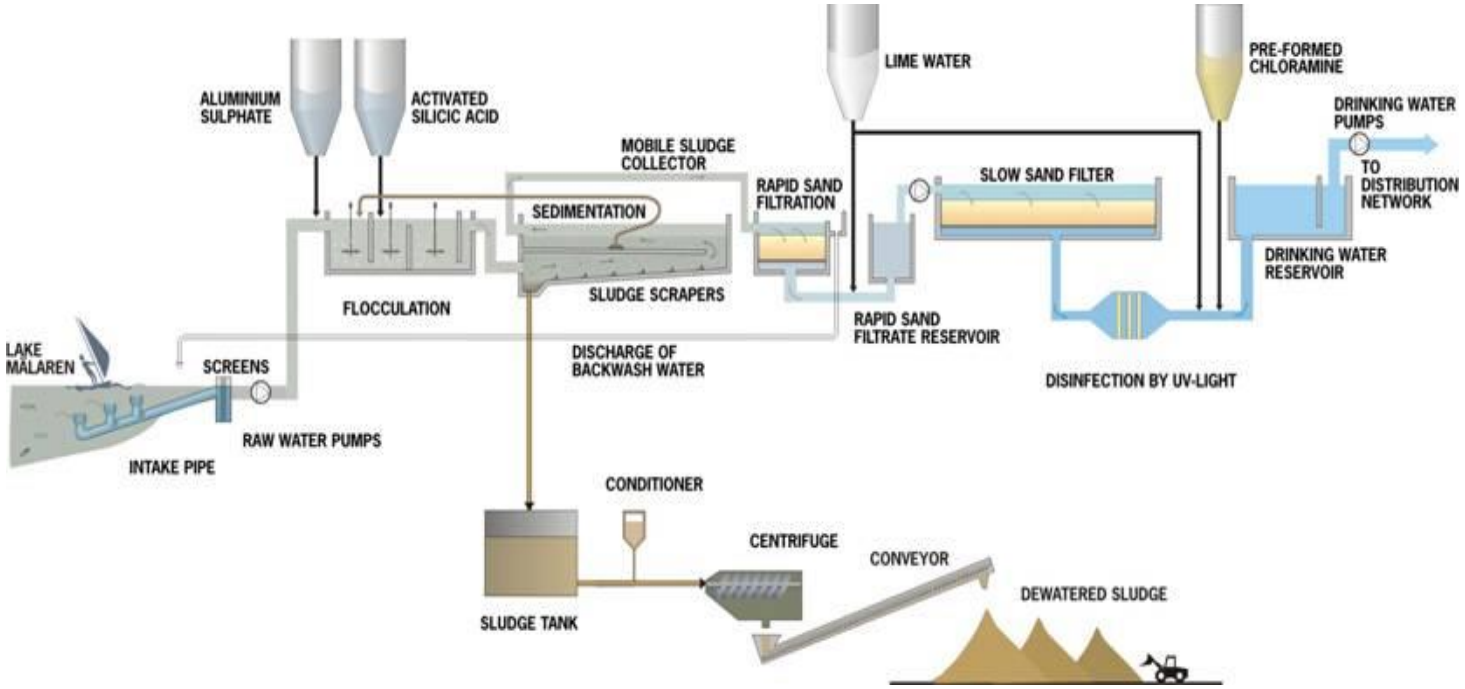
Process at Lovö water works



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Challenges

- Capacity close to maximum
- Climate change
  - Warmer, wetter and more extreme weather conditions
  - Increased occurence of microorganisms, NOM level and fluctuations, heavy algal blooms, transport of compounds from land to water
- Chemical pollutants
  - Boat traffic (oil, diesel), pharmaceuticals, pesticides, PFAS etc.
  - WTP lacks chemical barrier (PAC can be dosed in case of emergency)

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Construction of a new WTP/treatment line/step is an option for increased quantity and quality of drinking water

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Aims with new process

- Meet future capacity needs
- Chemical barrier
- Increase NOM removal
- Maintain or increase the biostability in the distribution system
- Decrease the use of chemicals/production of sludge
- Increase the number of microbiological barriers (Norrvatten)

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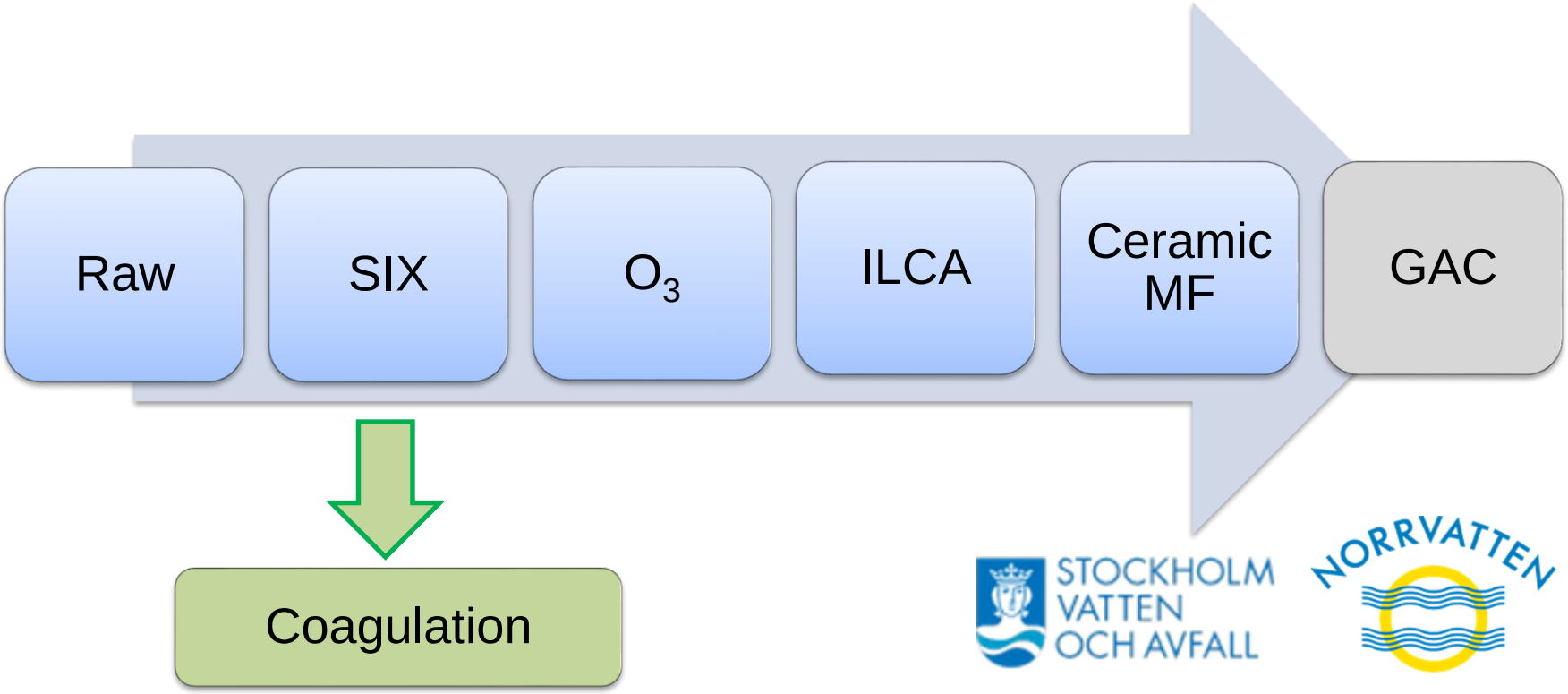
SIX®/CeraMac® pilot

- Process solution provided by PWN Technologies
- One year pilot study (Oct 2016-2017), collaboration between Norrvatten and Stockholm Vatten & Avfall



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SIX®/CeraMac® pilot

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RESULTS

Water quality overview

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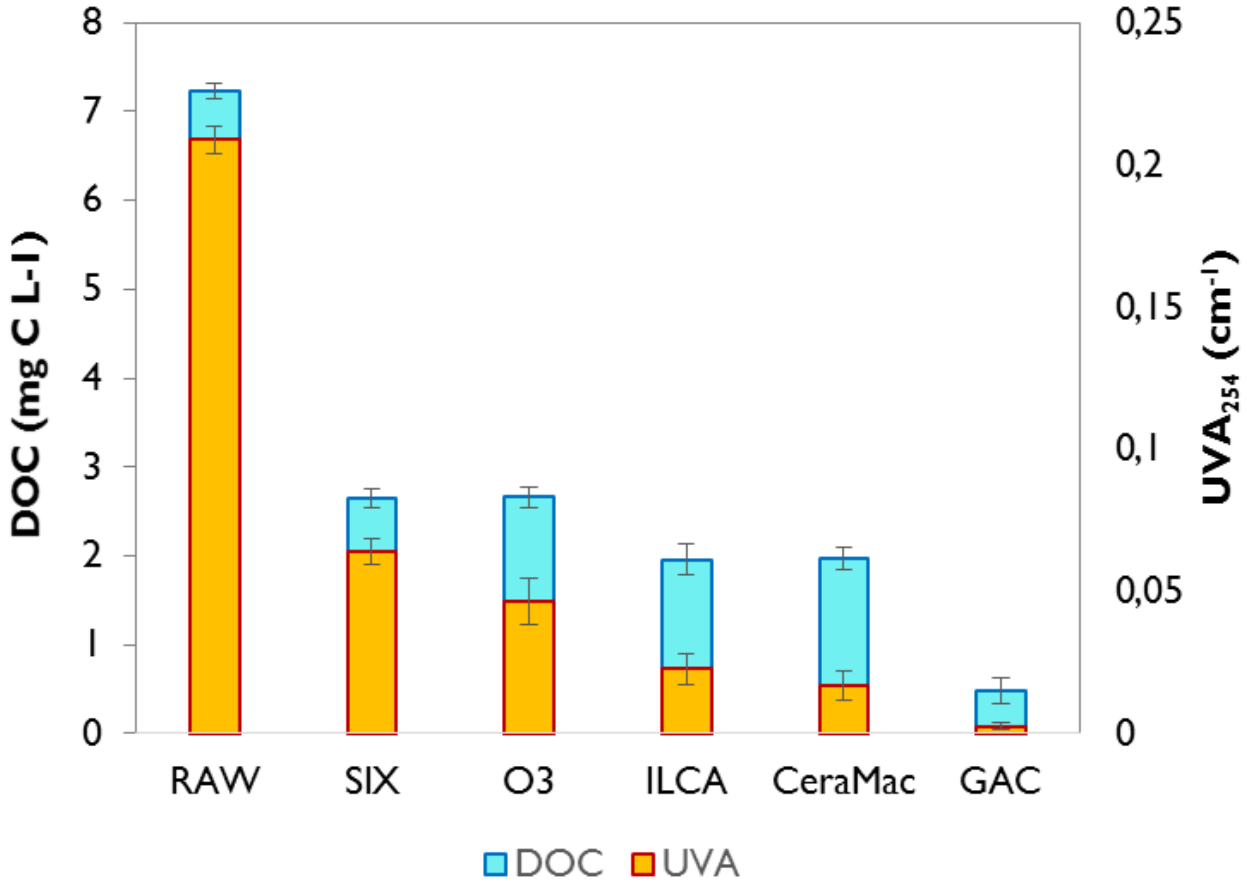
Water quality: SIX/CeraMac



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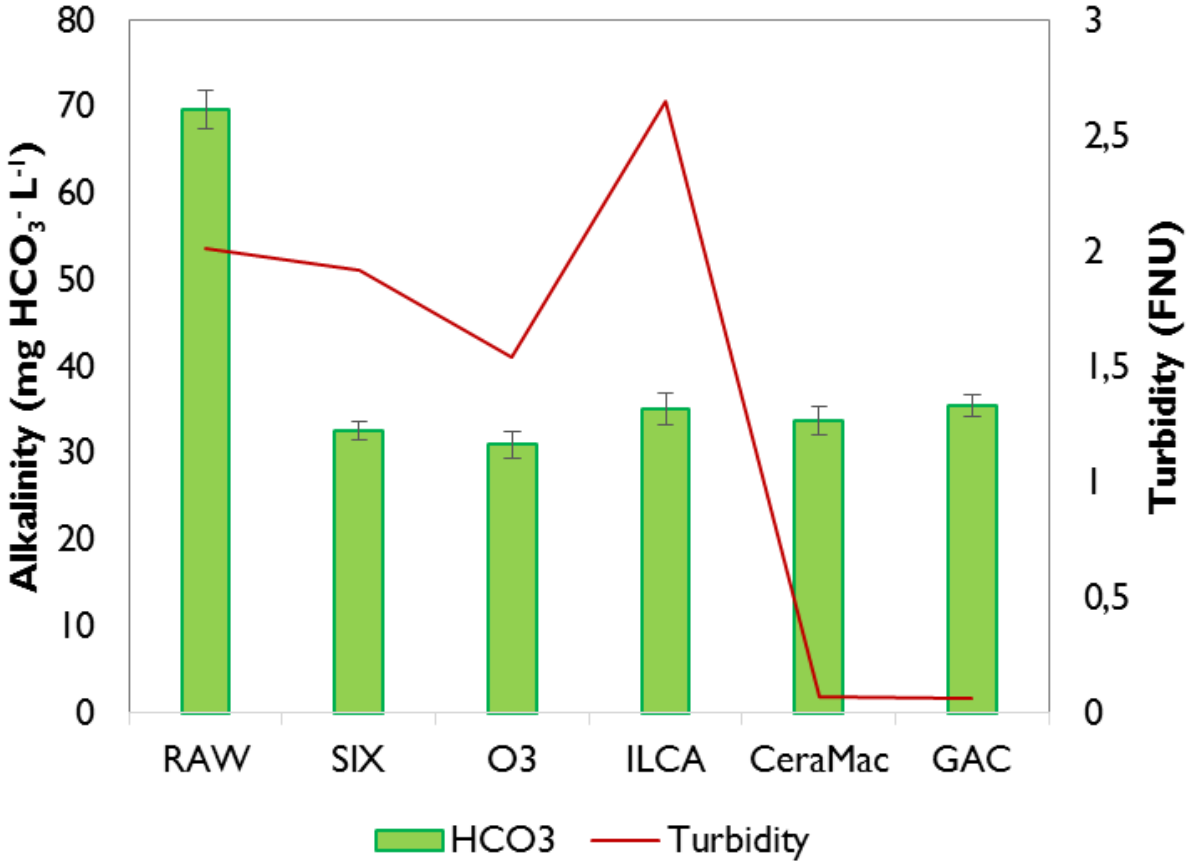
Water quality: SIX/CeraMac



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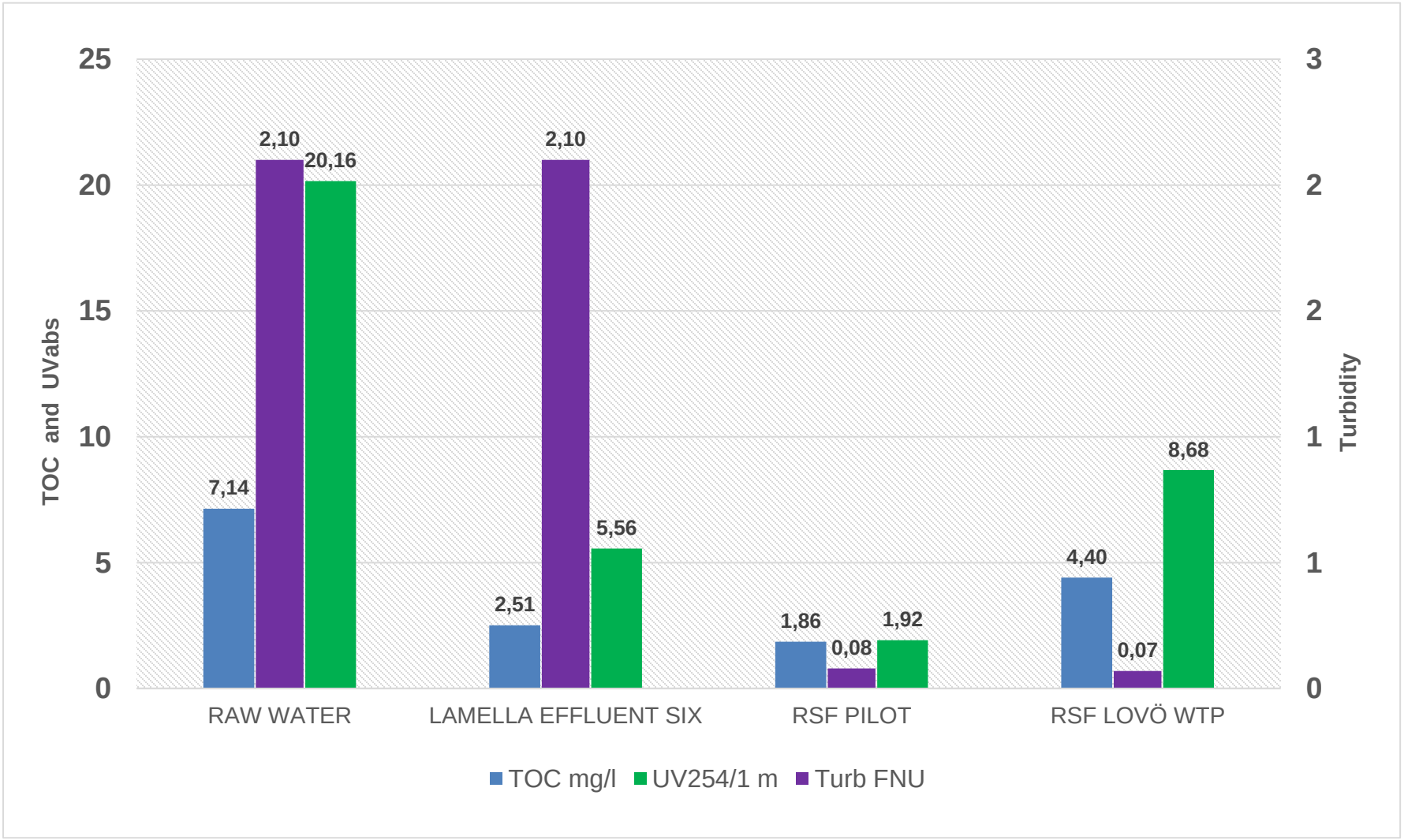
Water quality: SIX → coagulation/sed/RSF

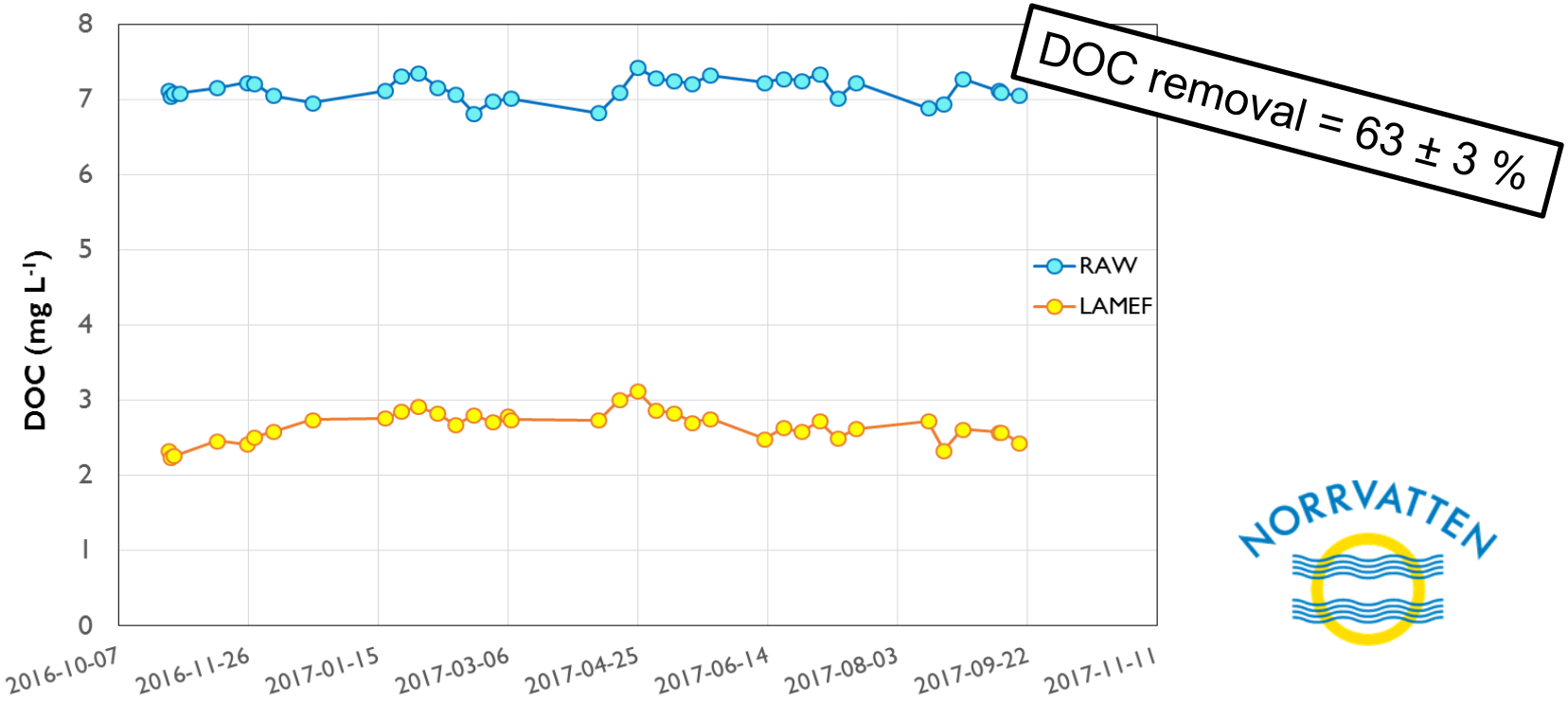


RESULTS – SIX®

Water quality

SIX®

- Resin: Lewatit S 5128
- Operating at a dose of 15 mL/L and 30 min contact time since November 2016
- Aim: balance between high removal of DOC and low removal of alkalinity



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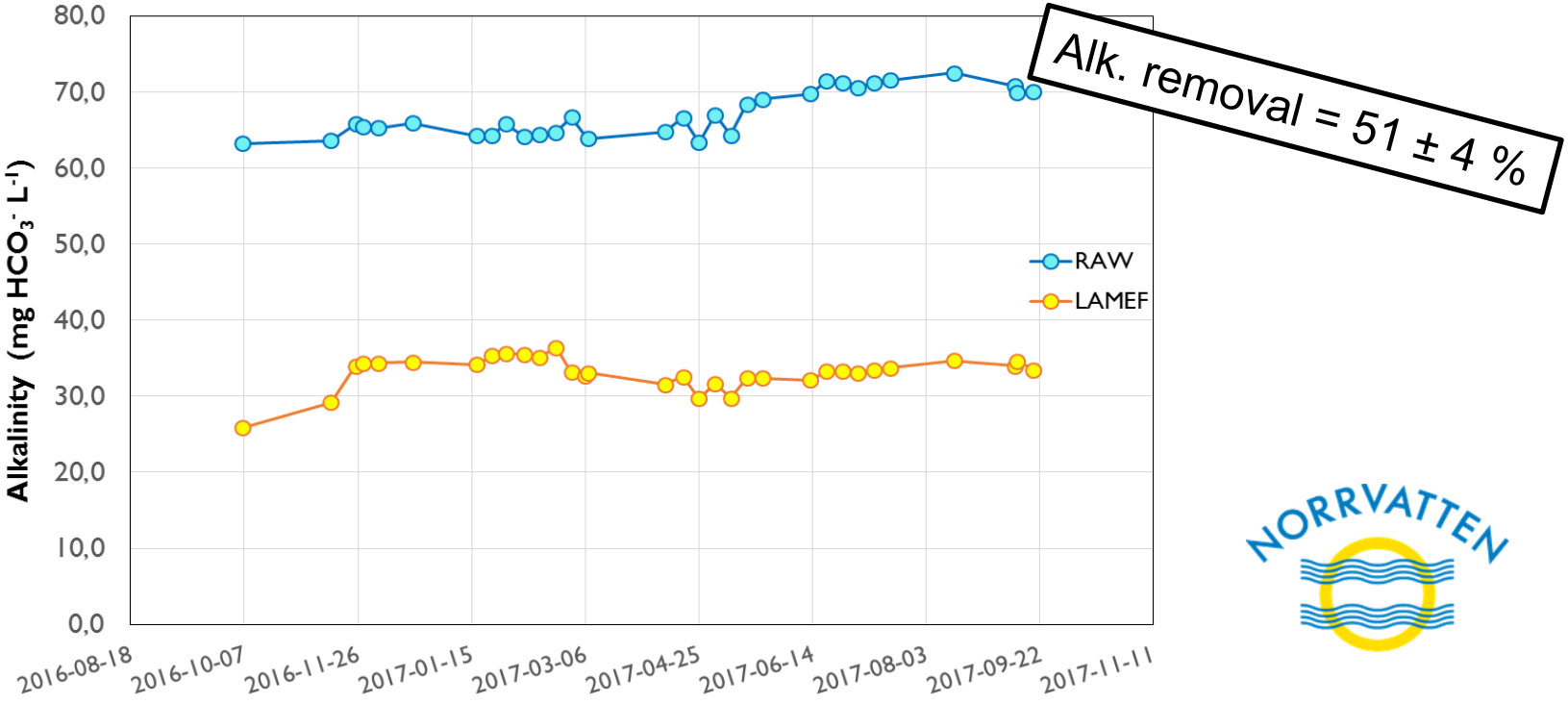


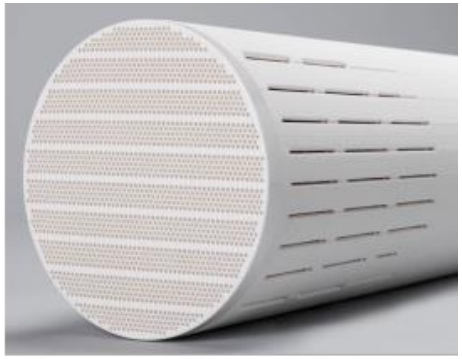
RESULTS – CeraMac®

Operational data

CeraMac®

- Ceramic microfilter (Metawater), 0.1 µm pore size
- Membrane surface: 25 m^2
- Dead-end-filtration, constant flux
- Enhanced backwash with NaOCl or H_2O_2/HCl (pH 2)
- CIP with O_3

CeraMac® installed at the water treatment plant Andijk III in the Netherlands



Ceramic membrane element

Membrane test aims

- ❑ Flux tests 150-400 lmh
- ❑ 5 weeks optimization
- ❑ CIP frequency > 3 months
- ❑ O_3 in feed = no need for hypo EBW

Pretreatment

1. SIX
2. SIX + O_3
3. SIX + O_3 + ILCA

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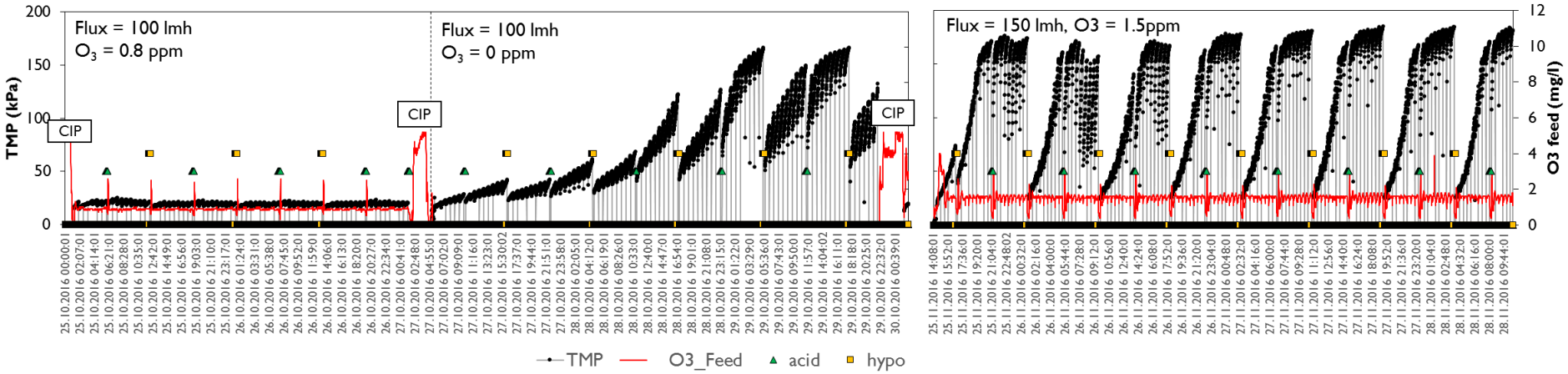
CeraMac operation – SIX (+ O_3)



- Ozone in feed water had a positive impact on the membrane performance
- Unsustainable TMP increase at flux of 150 lmh

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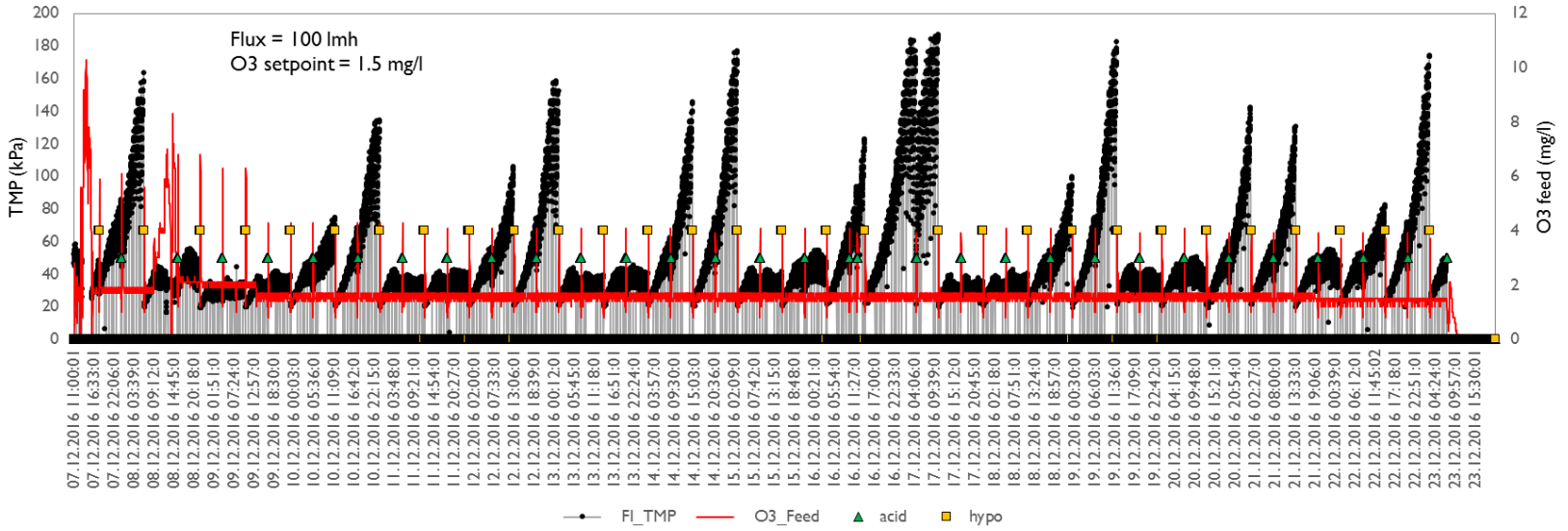
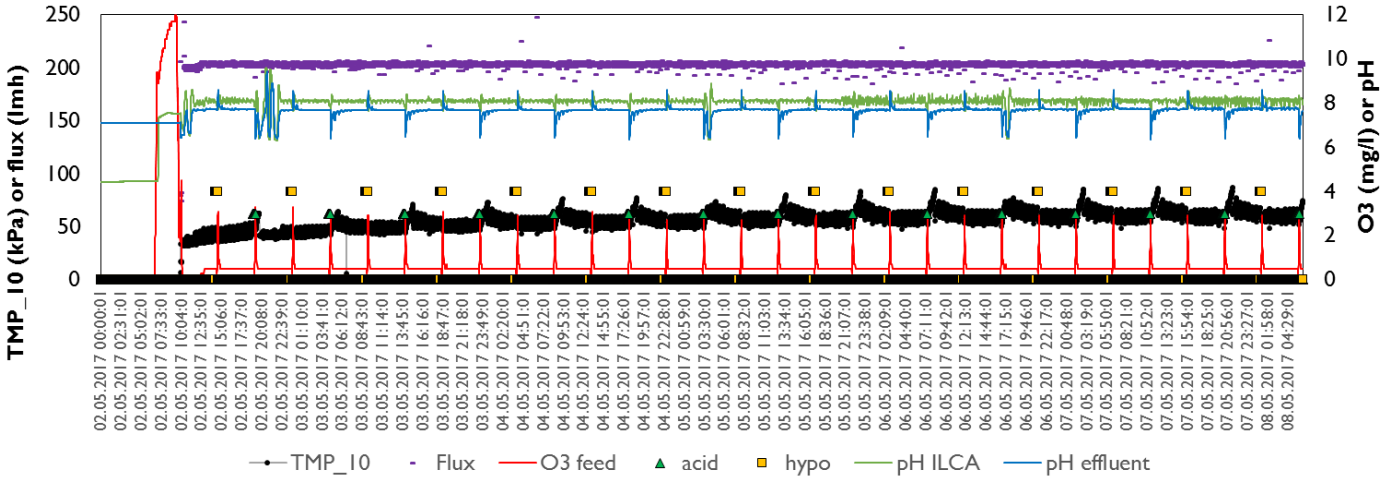
CeraMac – reproducibility issues



- Irregular TMP pattern/significantly lower performance from December 2016
- Occurred abruptely over night after 1 week of stable operation

CeraMac operation – SIX + O_3 + ILCA



- Attempt to solve irregular membrane performance with in-line coagulation (ILCA)
- Ferric (PIX-111) 4.5 mg Fe L^{-1}, pH 7.8
- Flux = 200 lmh
- TMP increase 3.5 kPa day^{-1} → CIP interval 45 days

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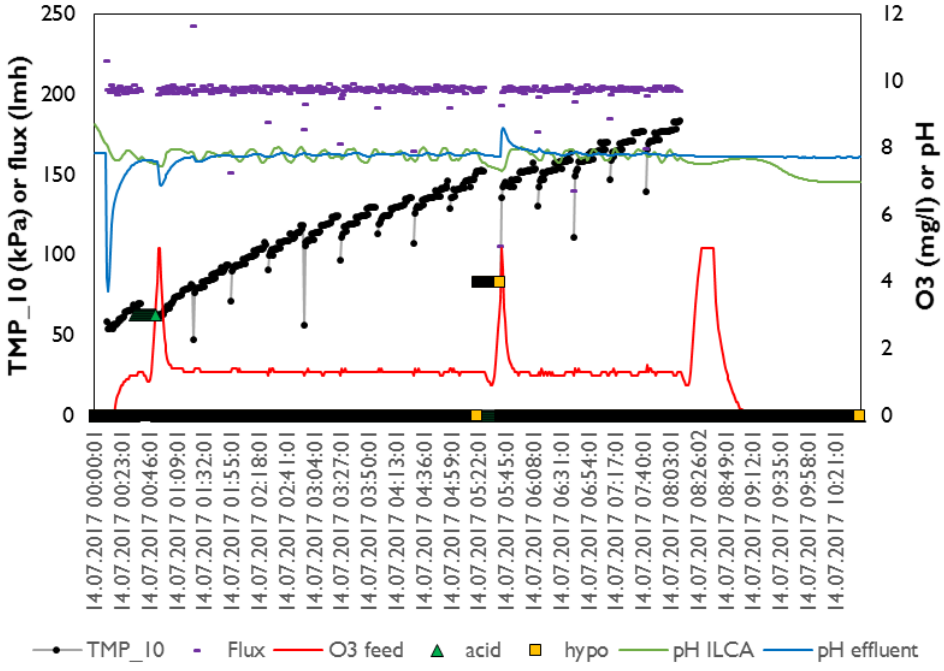
CeraMac – reproducibility issues

- Large deterioration of membrane performance
- TMP increase 351 kPa/day
- CIP interval 0.4 days
- Possible causes:
  - DOC concentration/composition?
  - Algae?
  - Metals?



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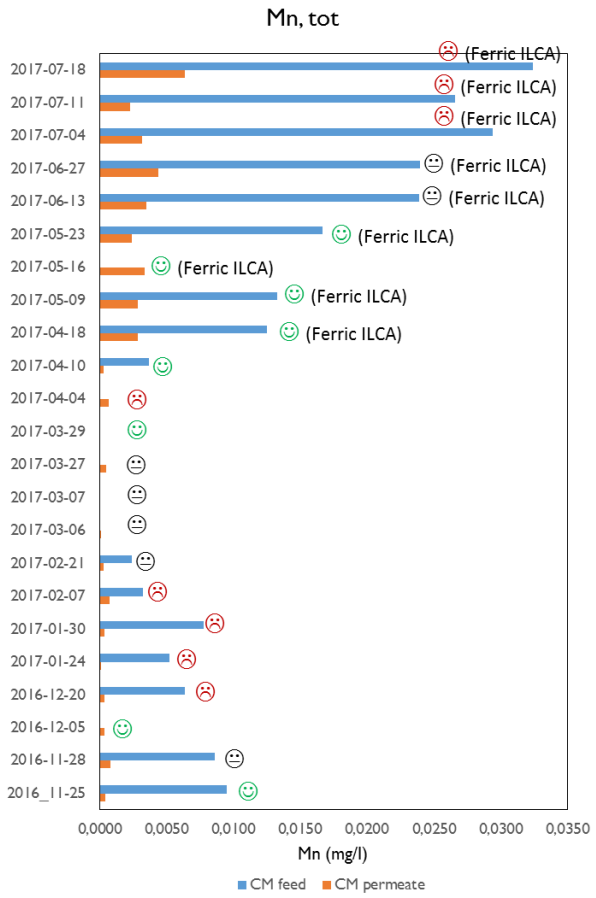
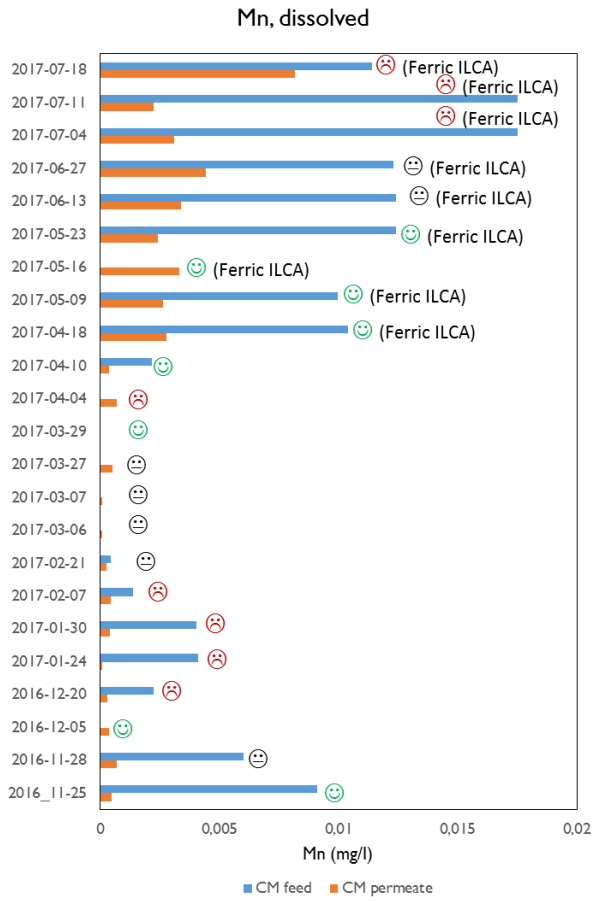
CeraMac – reproducibility issues

- Metals?
  - *Poor performance when using ILCA may be related to manganese fouling*





RESULTS

DOC composition

Effects on DOC composition

- Methods:
  - UV-absorbance (254 nm) and specific UV absorbance (SUVA)
  - LC-OCD
  - Rapid fractionation

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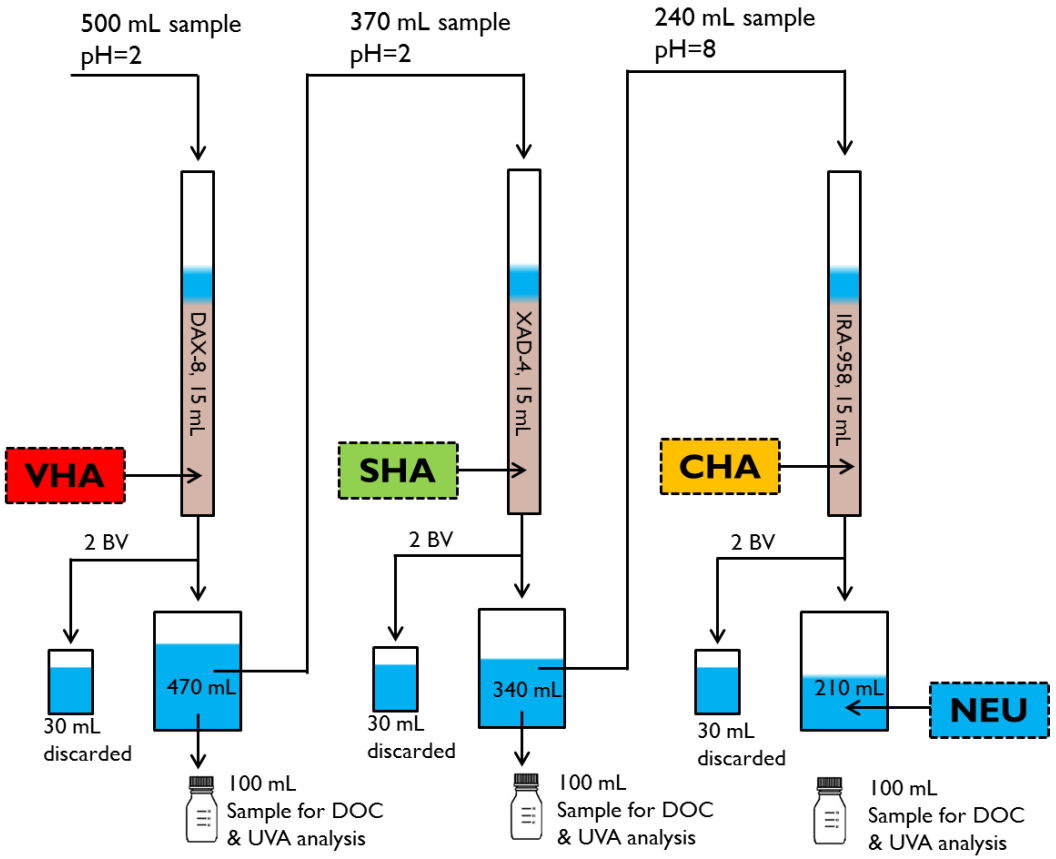
Effects on DOC composition

- Methods:
  - UV-absorbance (254 nm) and specific UV absorbance (SUVA)
  - LC-OCD
  - **Rapid fractionation**

VHA – very hydrophopic acids
SHA – slightly hydrophobic acids
CHA – charged hydrophilics
NEU – neutral hydrophilics



Chow et al 2004, Eikebrokk & Thorvaldsen 2010

Effects on DOC composition

- Methods:
  - UV-absorbance (254 nm) and specific UV absorbance (SUVA)
  - LC-OCD
  - Rapid fractionation
- Changes during treatment with:
  - SIX → O_3 → ILCA/CeraMac → GAC
  - SIX → coagulation/RSF

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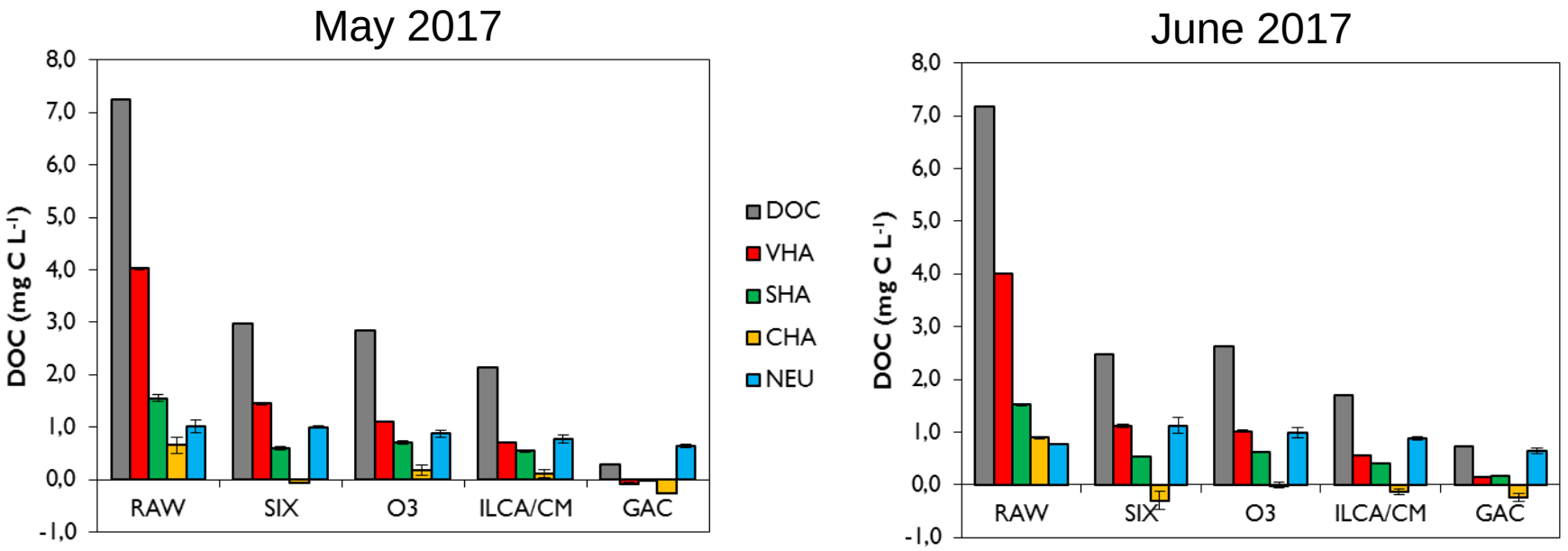
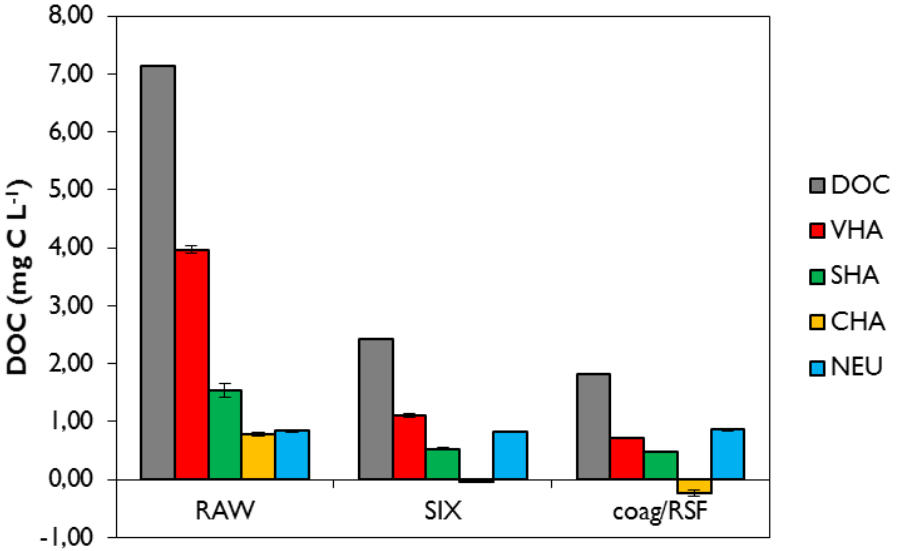
SIX → O_3 → ILCA/CeraMac → GAC

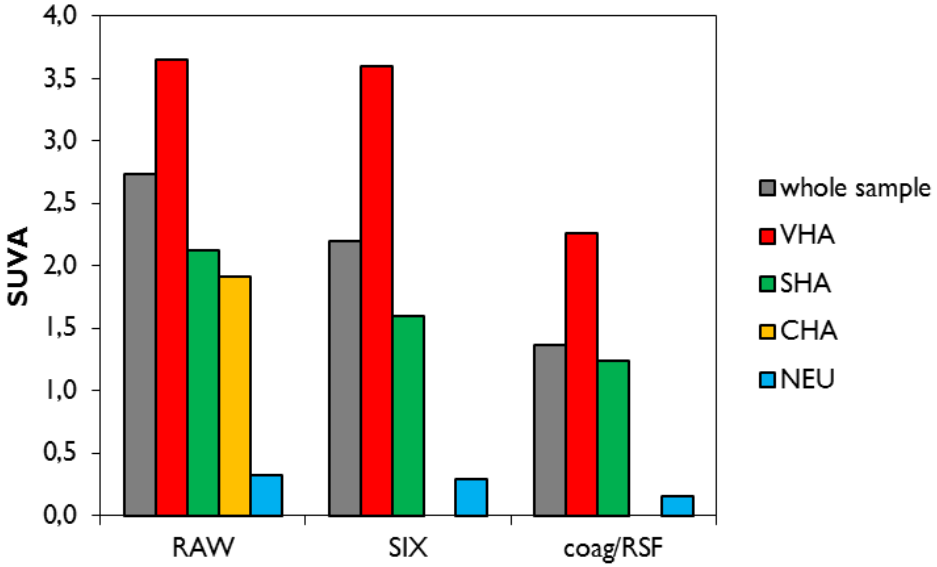


- SIX: complete removal of CHA (ca 60-70% removal of VHA and SHA)
- O_3: transformation of VHA to SHA
- (O_3)/**ILCA**/CeraMac: mainly removal of VHA and SHA
- GAC: new = all but neutrals removed, older = decreased removal of VHA/SHA

VHA – very hydrophobic acids
SHA – slightly hydrophobic acids
CHA – charged hydrophilics
NEU – neutral hydrophilics

SIX → coagulation/sedimentation/RSF





- Coagulation after SIX mainly removes VHA (35 %) and some SHA (11 %)
- Neutral fraction (DOC) remain through all treatment steps, however, some removal occurs of the UV-absorbing part (more sensitive analyis)
- SUVA values show that removal is more or less selective towards UV-absorbing species

Conclusions and future perspectives

- SIX is a highly interesting process for us, continued trials will be done during 2018
- CeraMac has not performed well so far, PWNT will conduct further investigations
- Process alternatives for pilot trials 2018:
  - SIX
  - NF
  - ActiFlo Carb
  - Ozone/GAC
  - UF (/direct filtration)

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Thank you for your attention!

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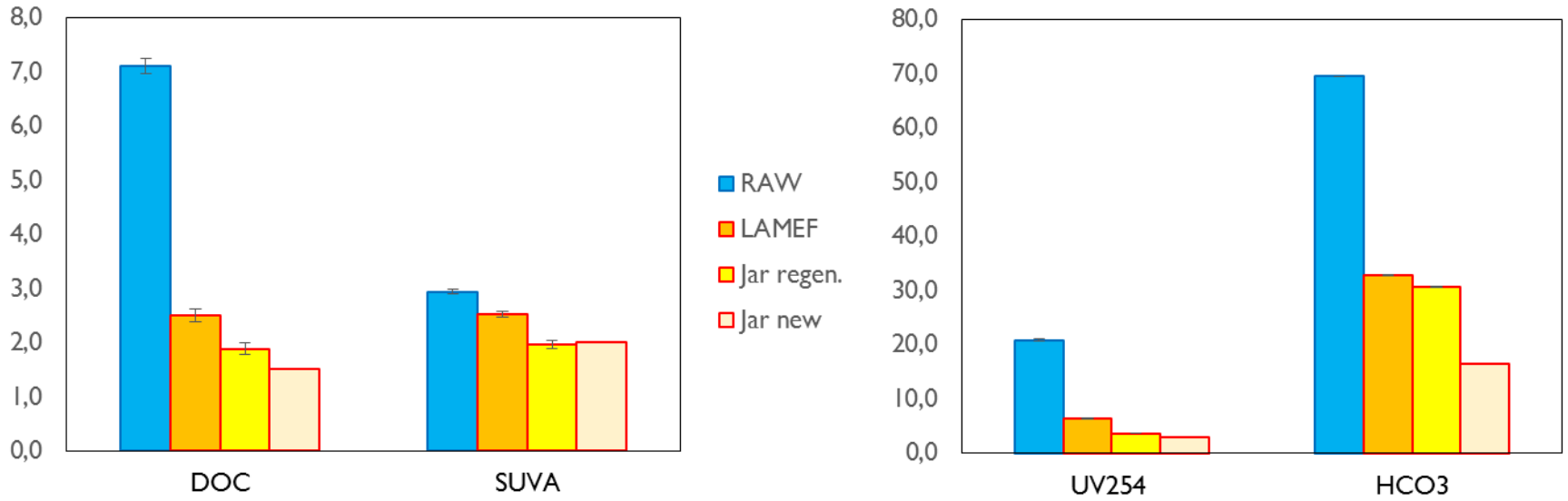
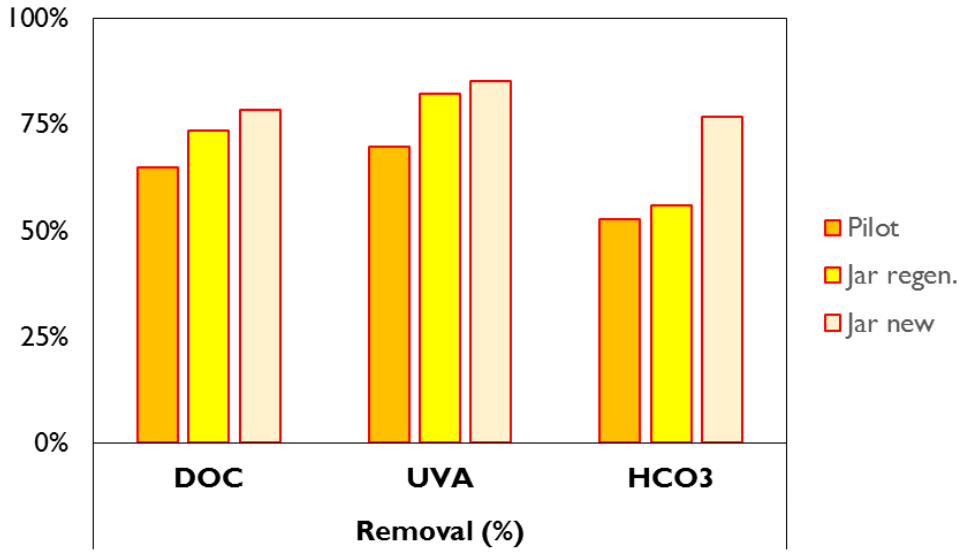
SIX® - pilot vs jar test

- Higher removal efficiency with jar tests (n = 3)
  - possible that contact time in pilot is lower than calculated
- Room for pilot optimization (currently ongoing, air flow)



SIX® - pilot vs jar test

- Higher removal efficiency with jar tests (n = 3)
  - possible that contact time in pilot is lower than calculated
- Room for pilot optimization (currently ongoing, air flow)
- DOC and UVA removal only slightly higher for new resin, significantly lower reduction in alkalinity with regenerated resin



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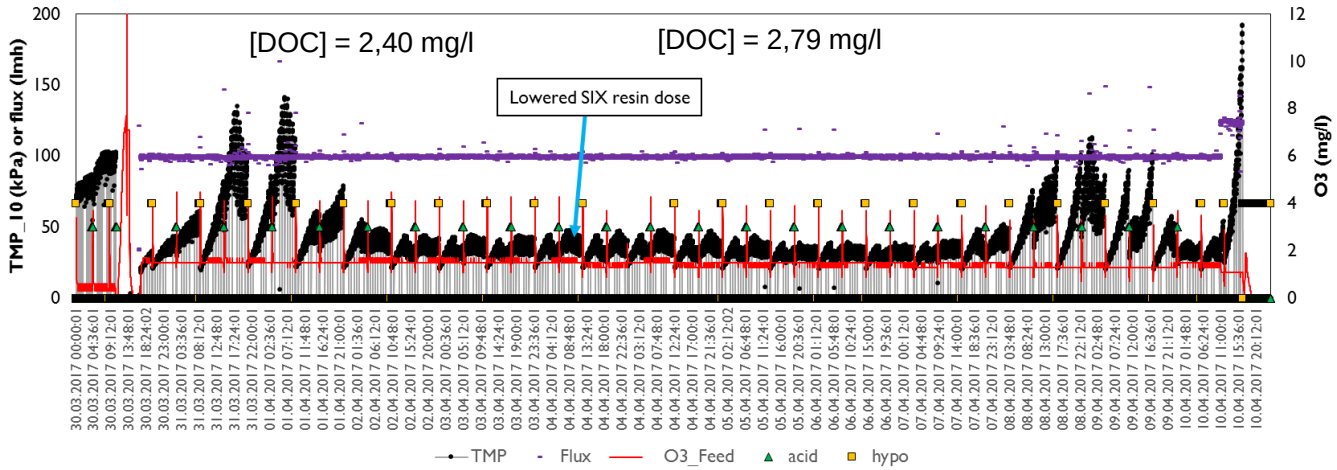
CeraMac – reproducibility issues

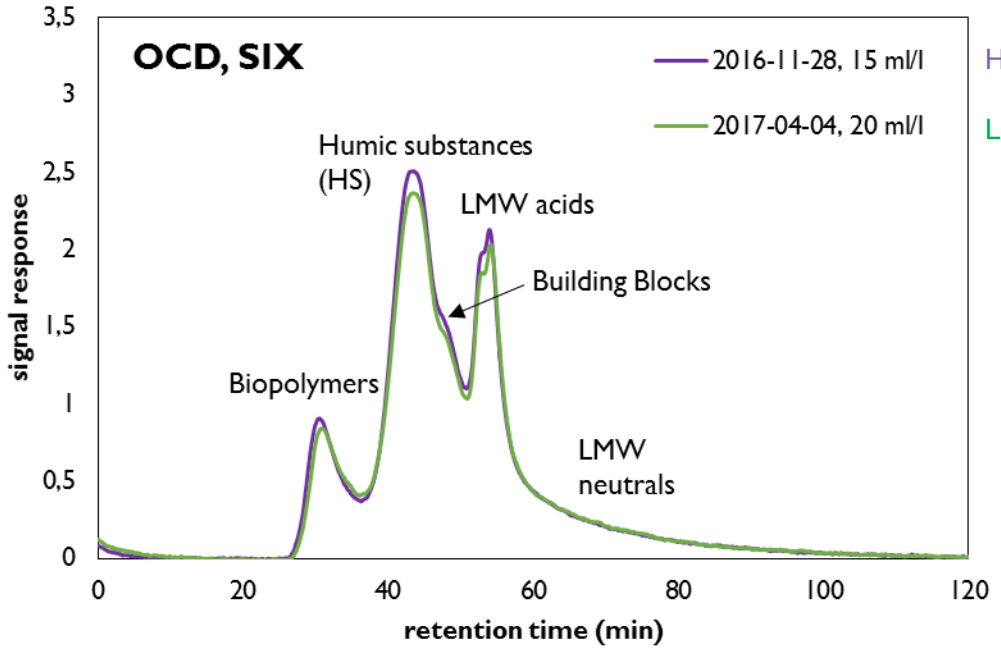
- DOC concentration?
  - *No effect from higher SIX resin dose (= lower feed [DOC])*



DOC mg/L	CM feed	CM perm	SIX dose (ml/l)	Membrane performance
2016-11-14	**2,39**	2,25	15	☺
2017-12-05	**2,56**	2,37	15	☺
2017-04-04	**2,40**	2,29	20	☹
2017-04-10	**2,79**	2,74	15	☹

CeraMac – reproducibility issues

- DOC composition?
  - *No significant change (based on LC-OCD analyzes)*



High membrane performance

Low membrane performance

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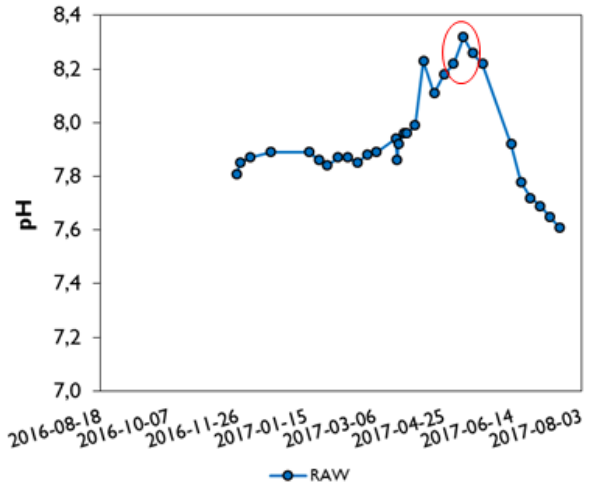
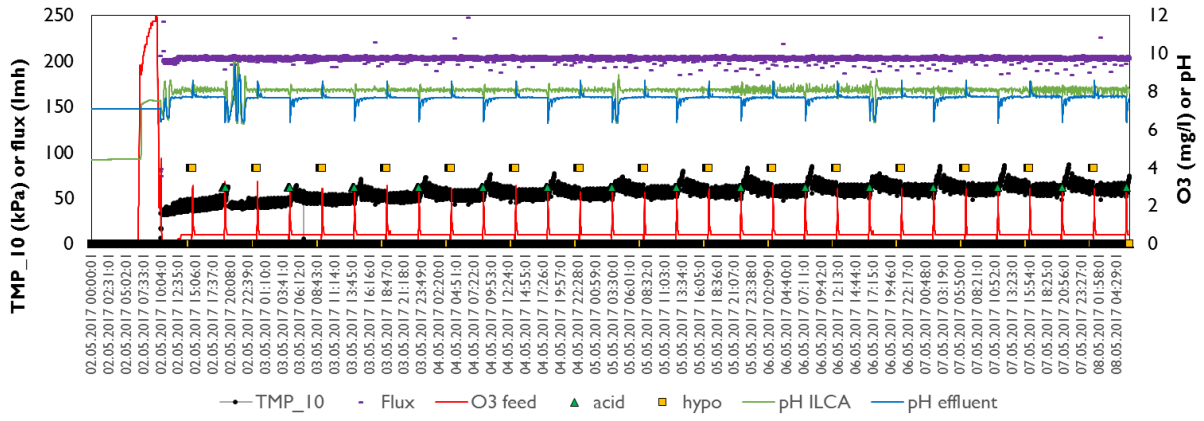
CeraMac – reproducibility issues

- Algae?
  - *Not likely – good performance during spring bloom*





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