Elizabethan source, 21st Century treatment

Innovative Applications of Materials Chemistry in Water Treatment: Part 1 Removal of Contaminants from Drinking Water

Chris Rockey
May 16

Acknowledge and explain...

SOUTH WEST WATER

Contents

SOUTH WEST WATER

- Motive and opportunity
- Suspended ion exchange, in-line coagulation, ceramic microfiltration
- DOC, membrane fouling and DBPs
- Full scale application

Motive...

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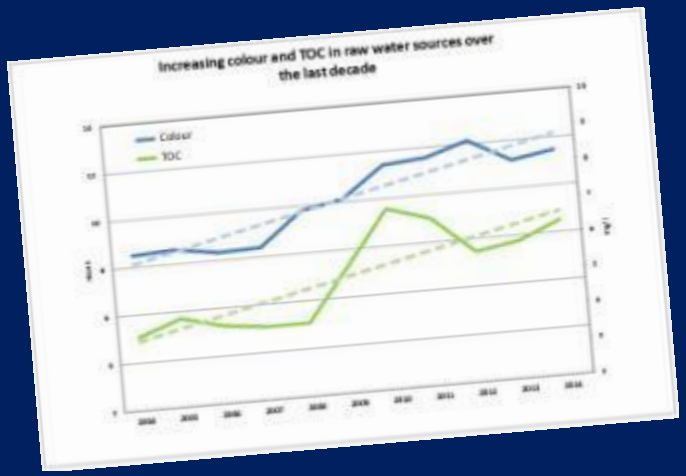
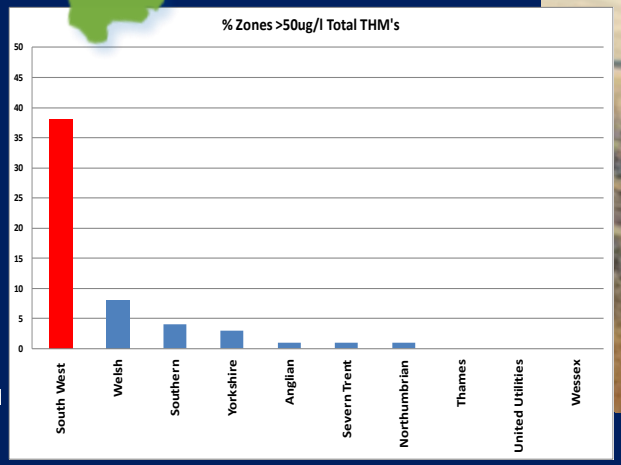




Opportunity

SOUTH WEST WATER

Interreg
2 Seas Mers Zeeën
DOC2C's
European Regional Development Fund

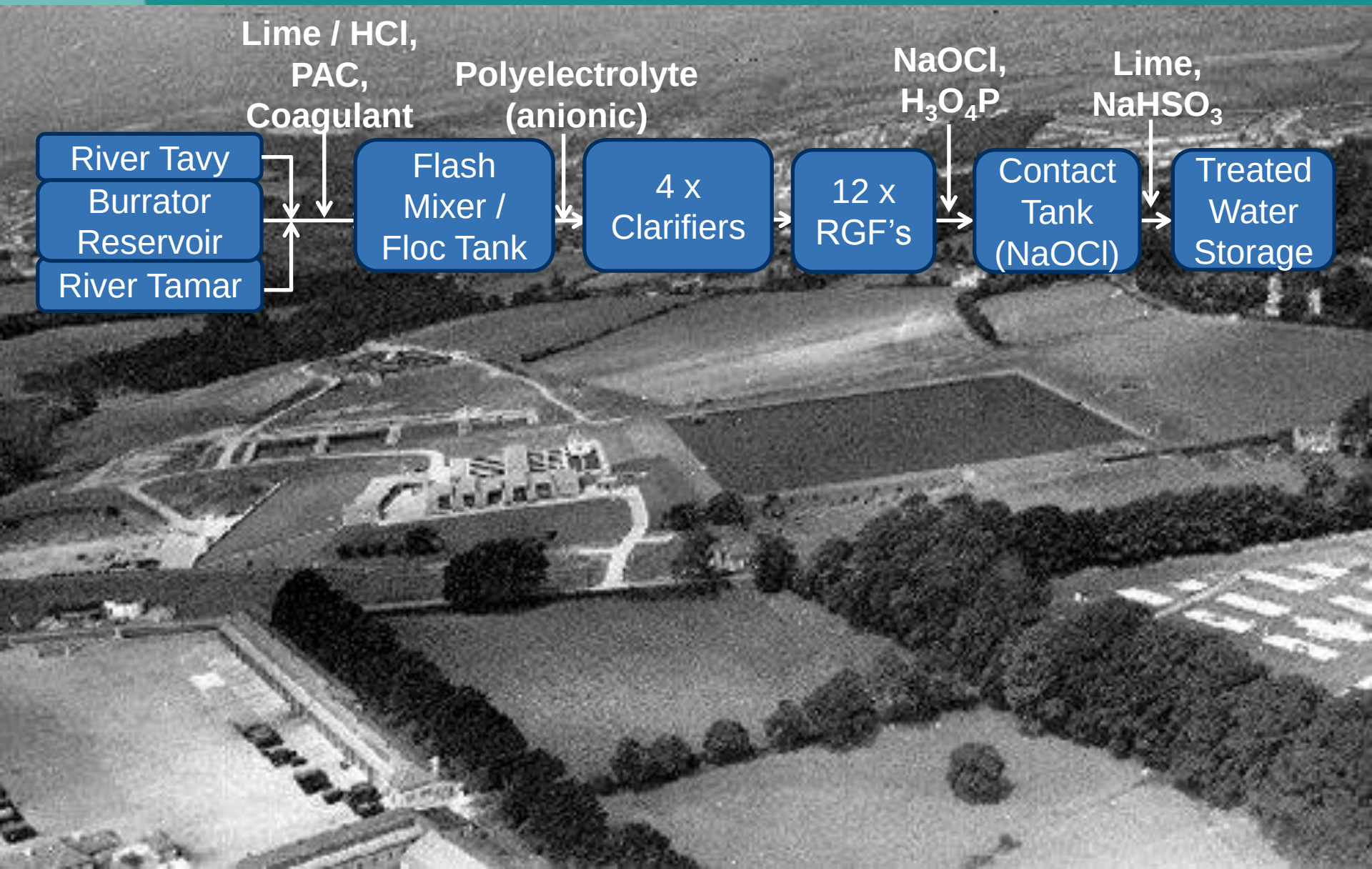
SOUTH WEST WATER

De Watergroep

Université de Lille

TU Delft

Rural Crownhill WTW c1955



Constrained Crownhill c2016

- Access, neighbours and pumping
- Contact tank, GAC and other improvements
- Inappropriate use of space within the city

Reviewed and re-stated treatment goals

- **Absolute Barrier to Cryptosporidium**
- **DOC / disinfection by product reductions**
- **Very compact, forward looking design**
- **Highly automatable, robust and efficient process**
- **Environmental impact/sustainability**
- **Keep consumer bills down in long term**

Pilot testing

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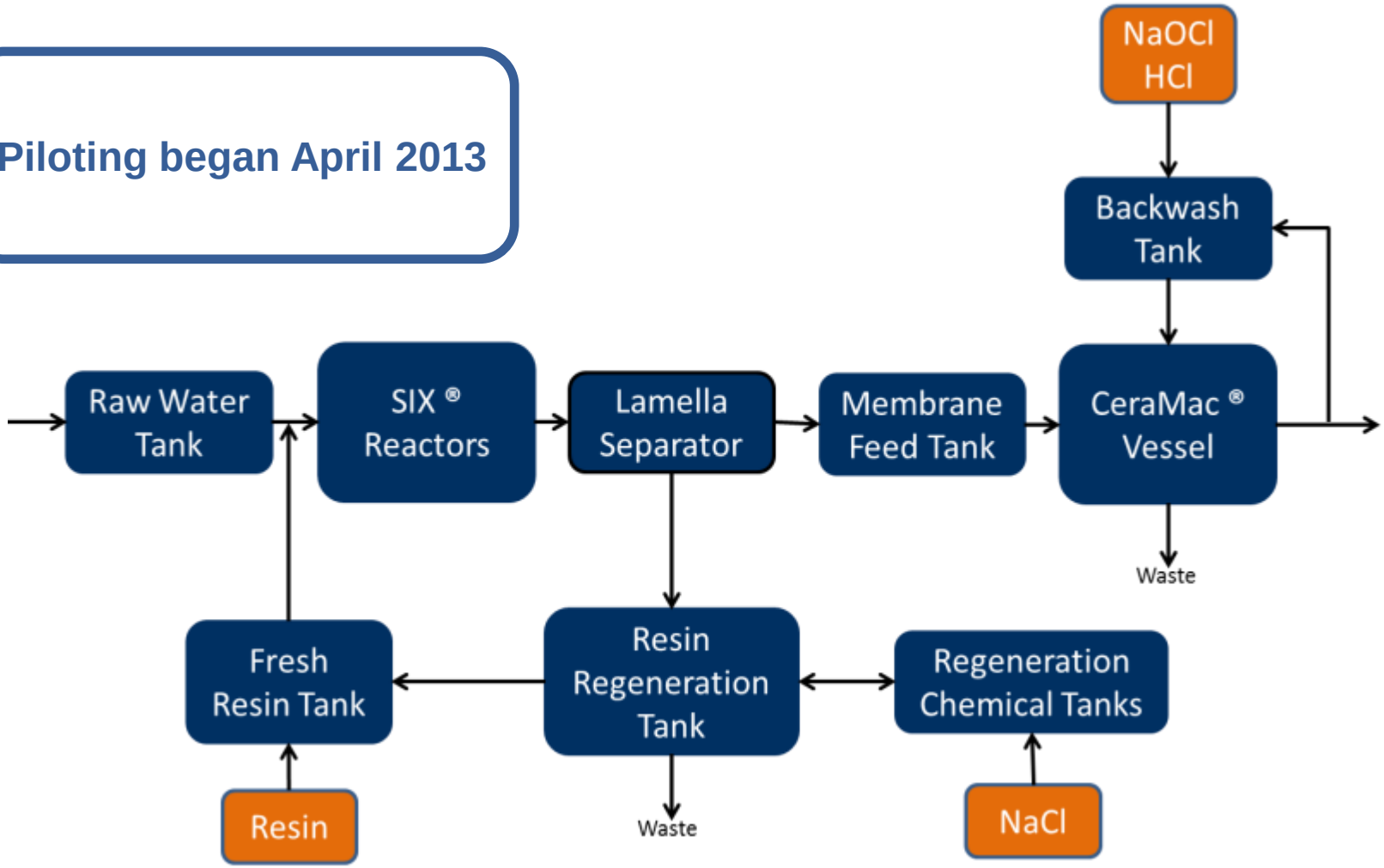
Piloting began April 2013



Process Flow Diagram for the SWW Pilot Study of SIX ® and CeraMac®

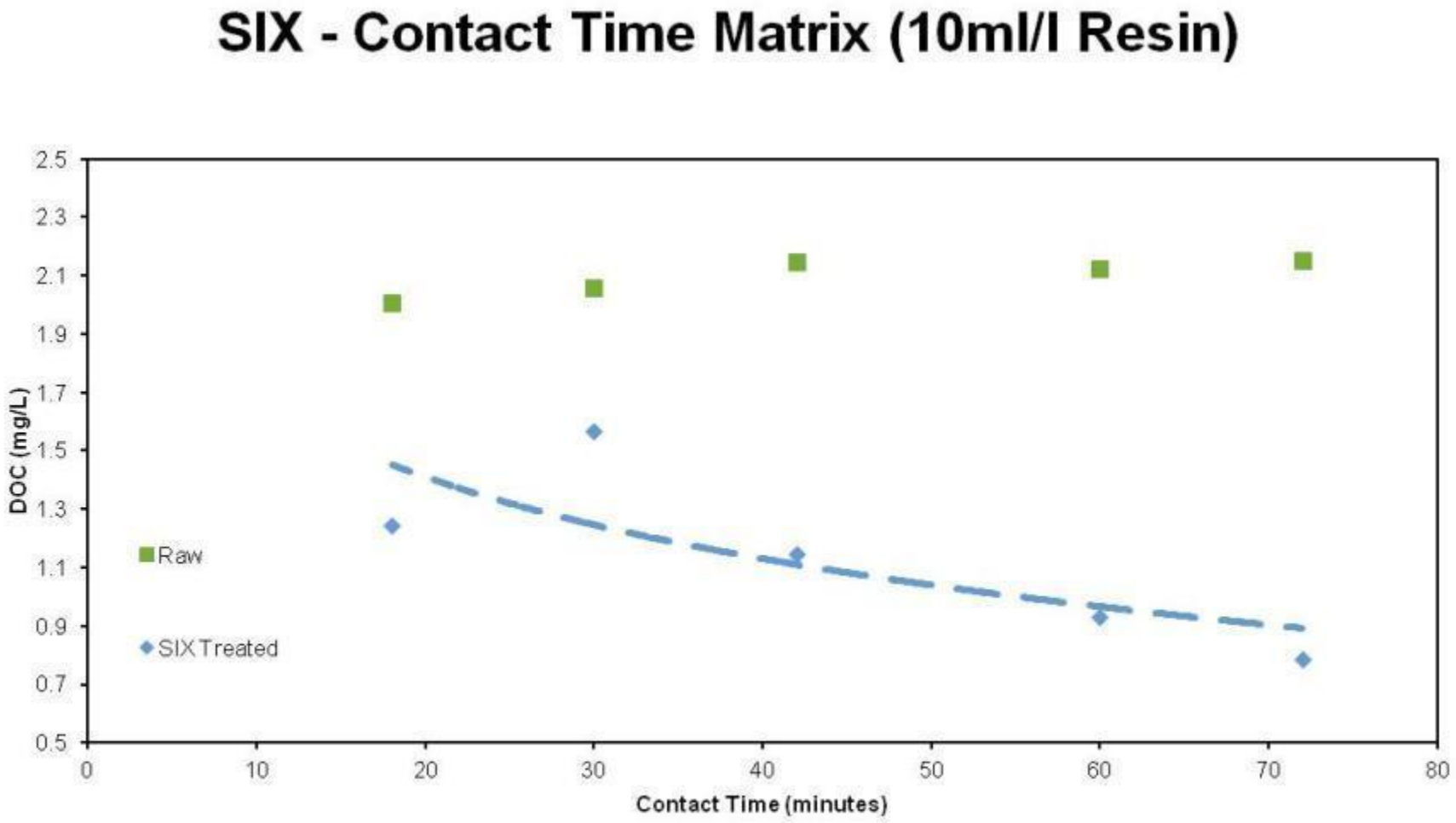
Suspended ion exchange (SIX)

SOUTH WEST WATER

- Raw water flowing through 5 tanks in series
- A small dose of resin suspended in the raw water
- Good mixing (with air) and high turbulence
- Single pass (minimise risk of resin blinding)
- Goal is to minimise footprint/contact time and resin dose by keeping the kinetics fast
- Resin separation (lamella) and regeneration with multiple salt solutions

Contact time

SOUTH WEST WATER



Resin dose

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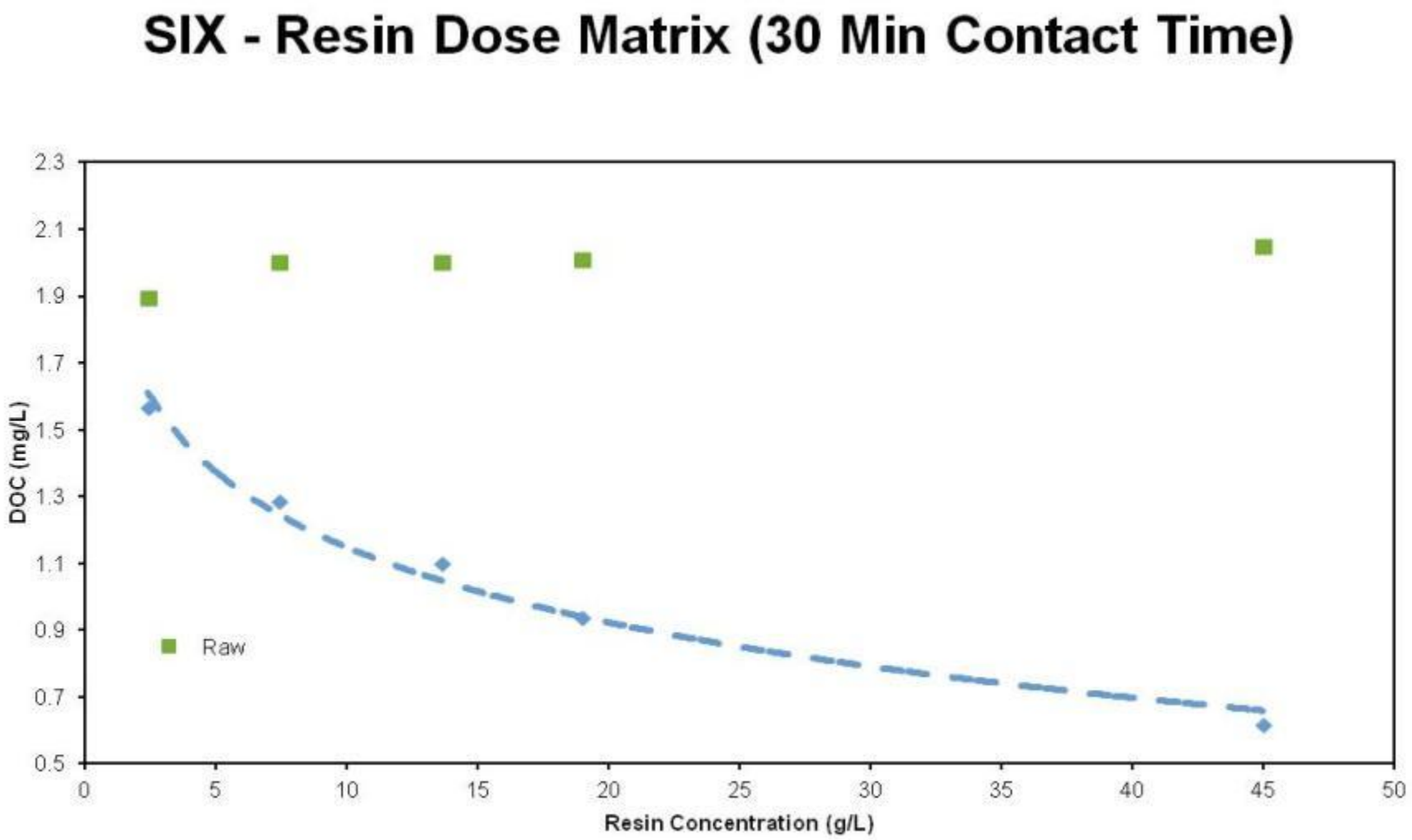
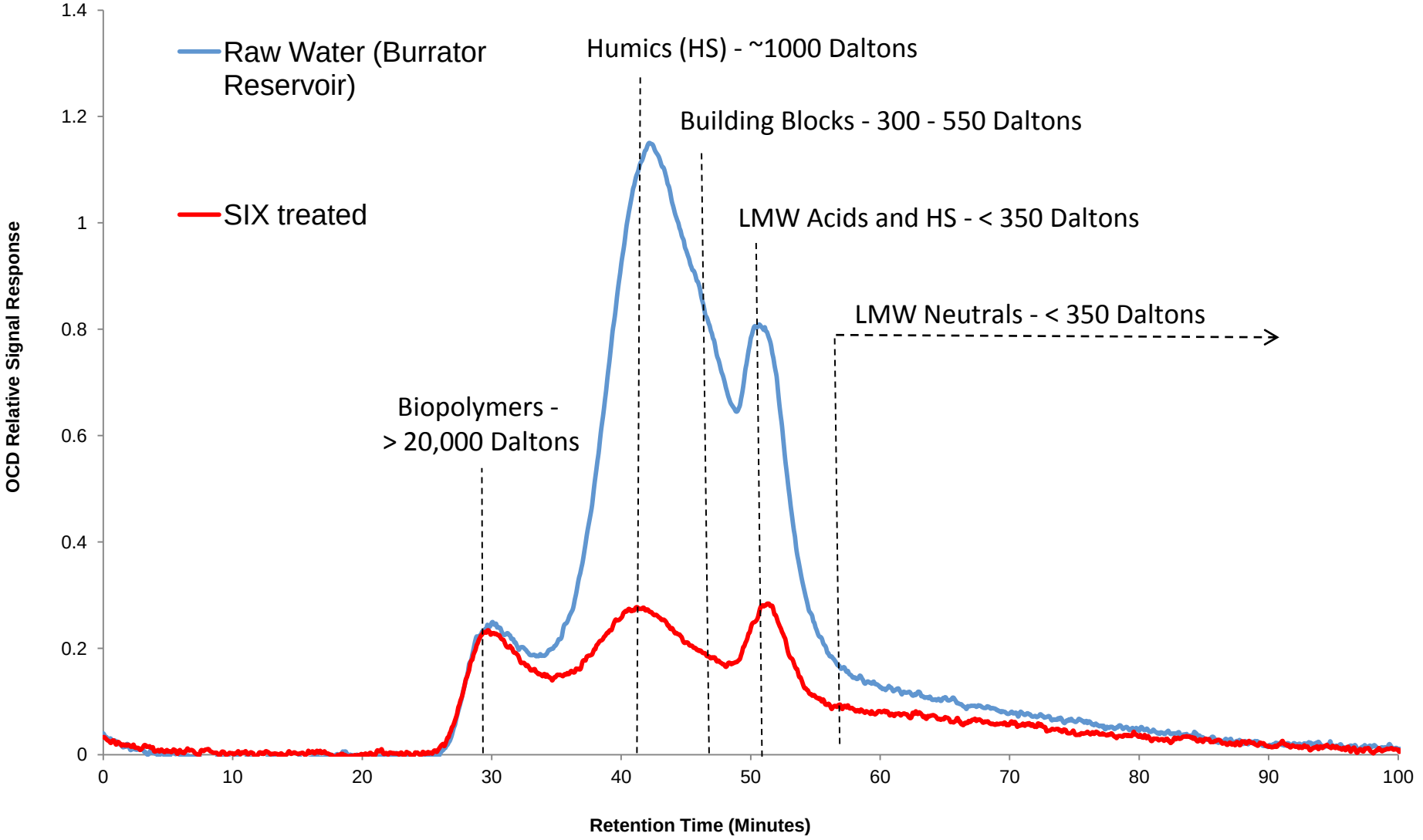


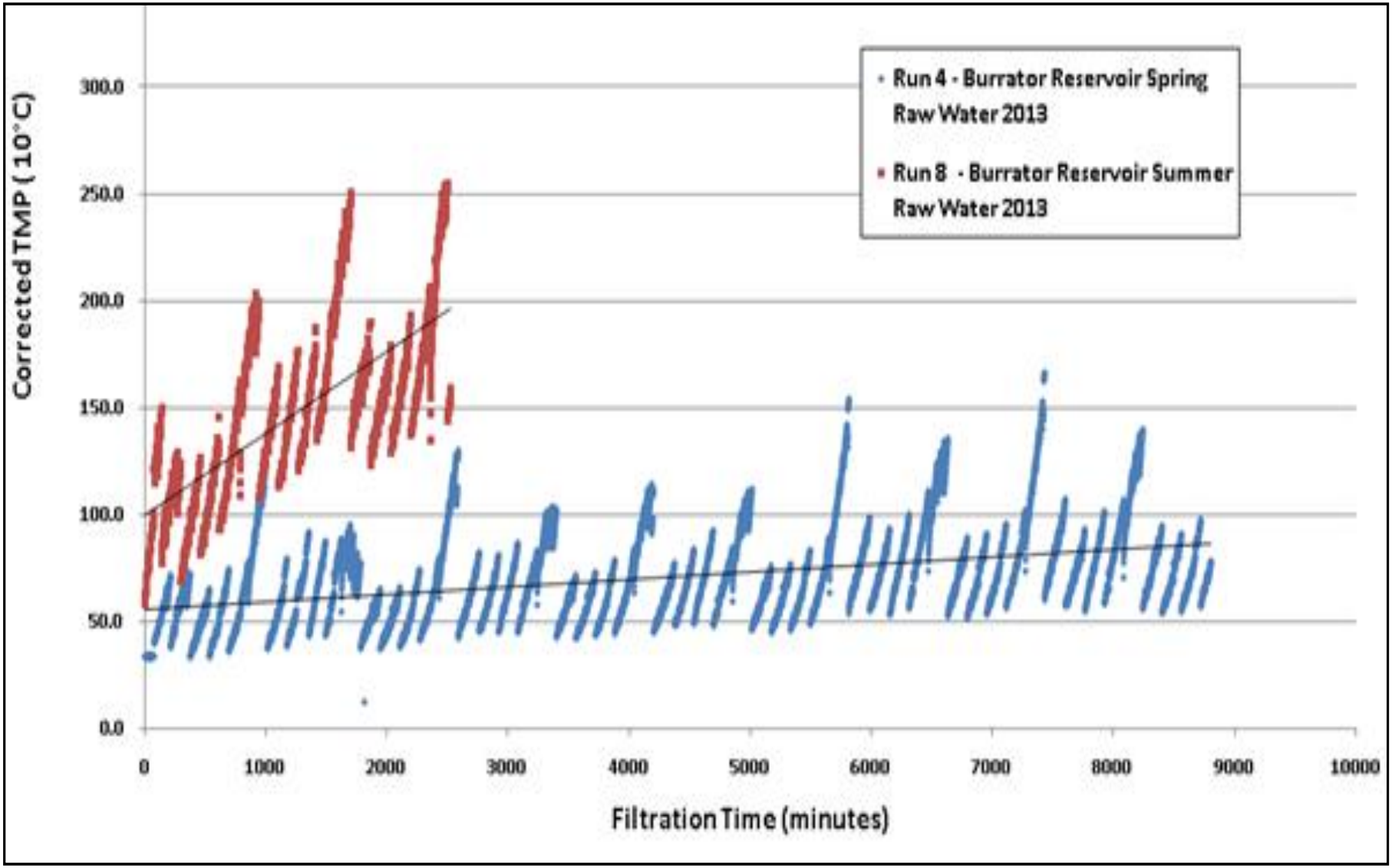
Upland reservoir DOC removal by SIX (LC-OCD)



Ceramic membranes

- Filtration area 25m^2 , 180mm x 1500mm
- Size of monolith cost effective
- Al_2O_3 base layer TiO_2 top layer = 0.1um
- Close to 100 plants, no integrity failures
- High solids loading – direct river???
- Mechanical wash at high pressure
- Chemical cleaning options?
- Cost and recovery issues when applied traditionally

Membrane testing and fouling



Reservoir water quality change

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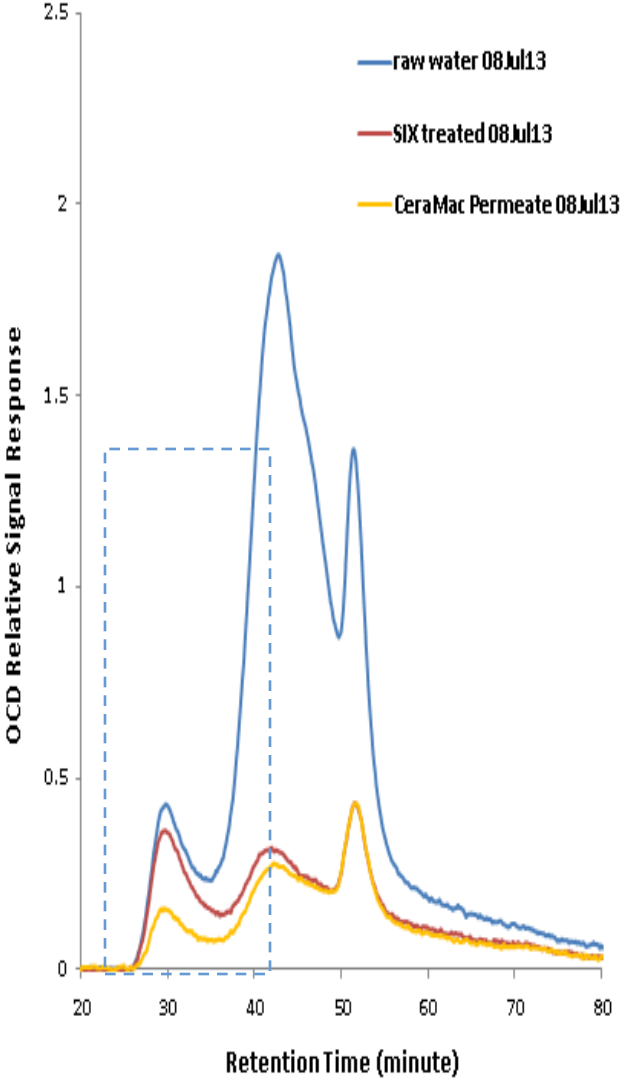
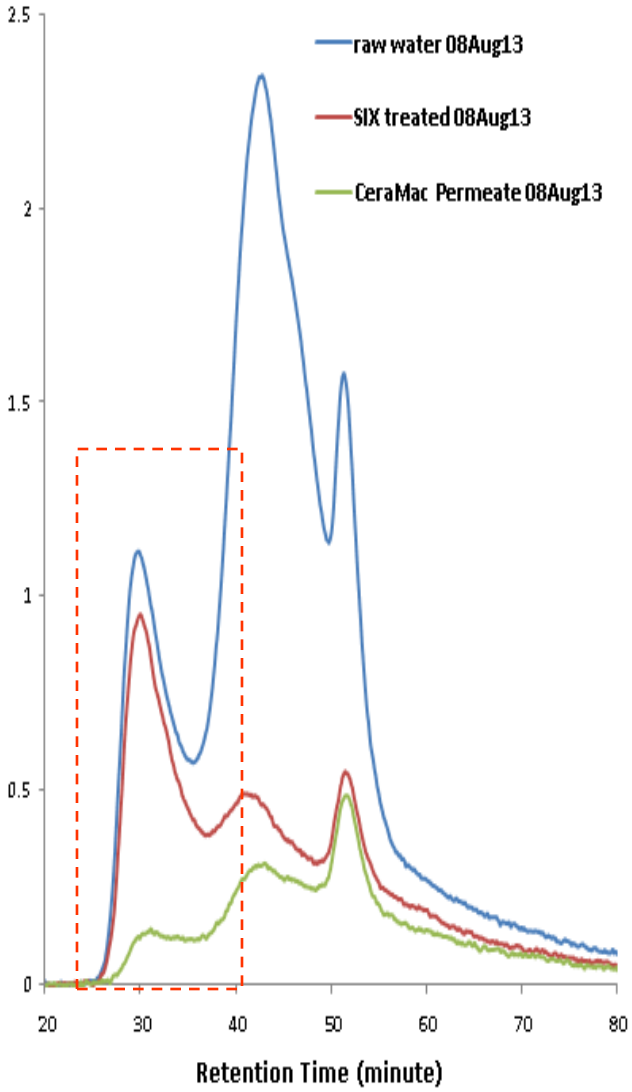
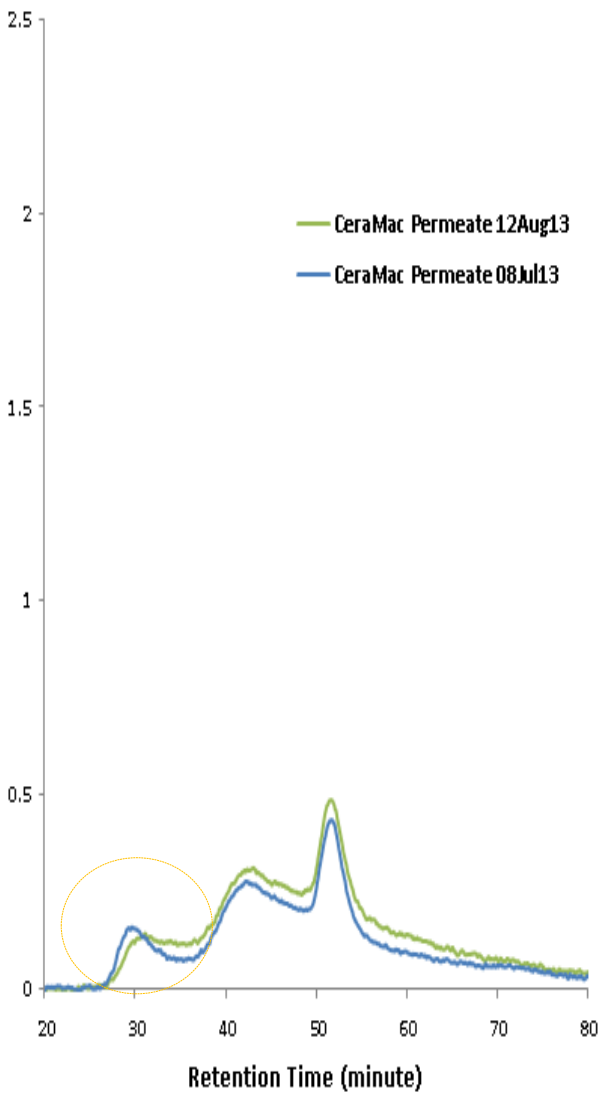
Spring Quality



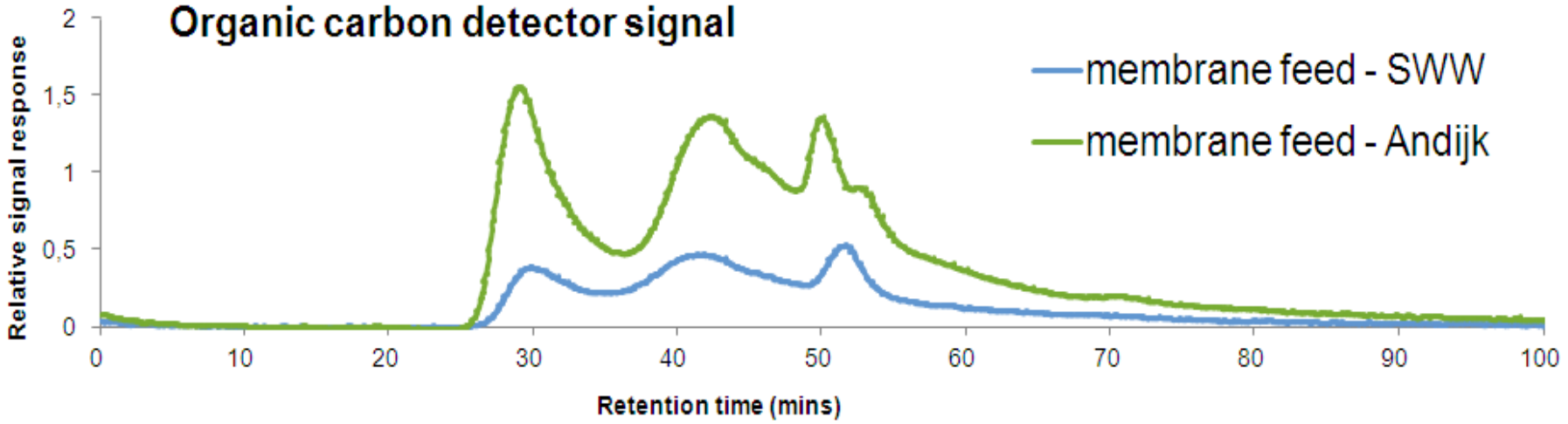
Summer Quality

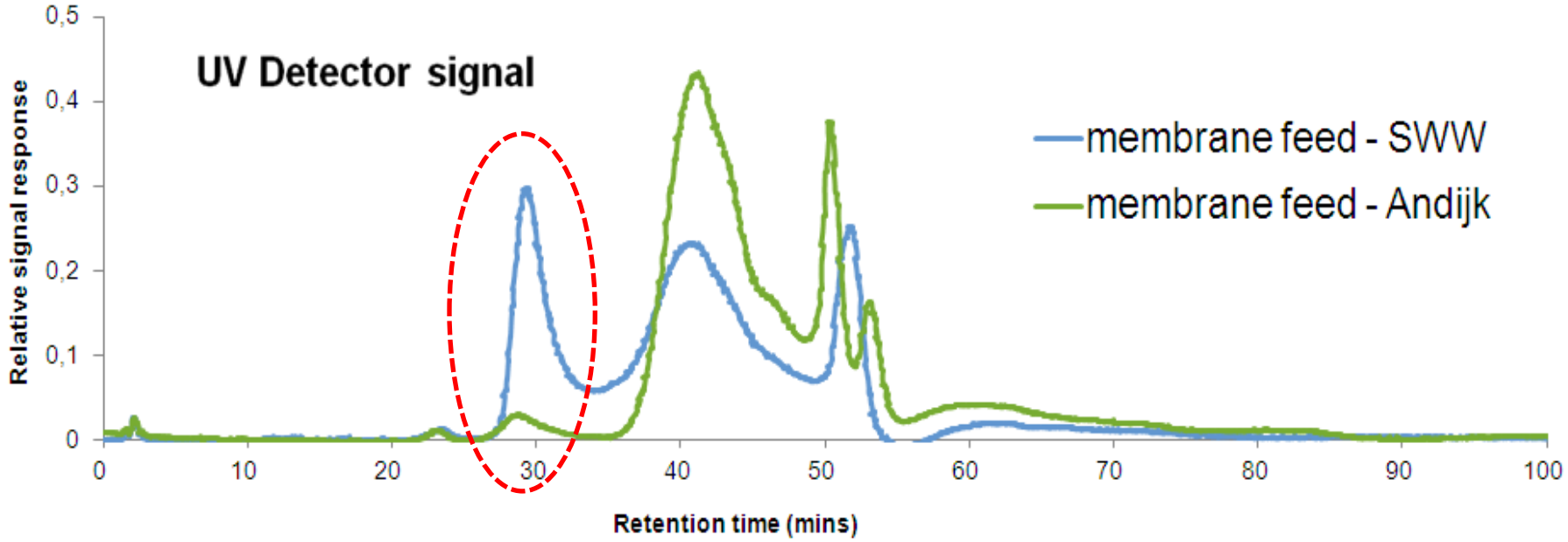


Permeate Comparison

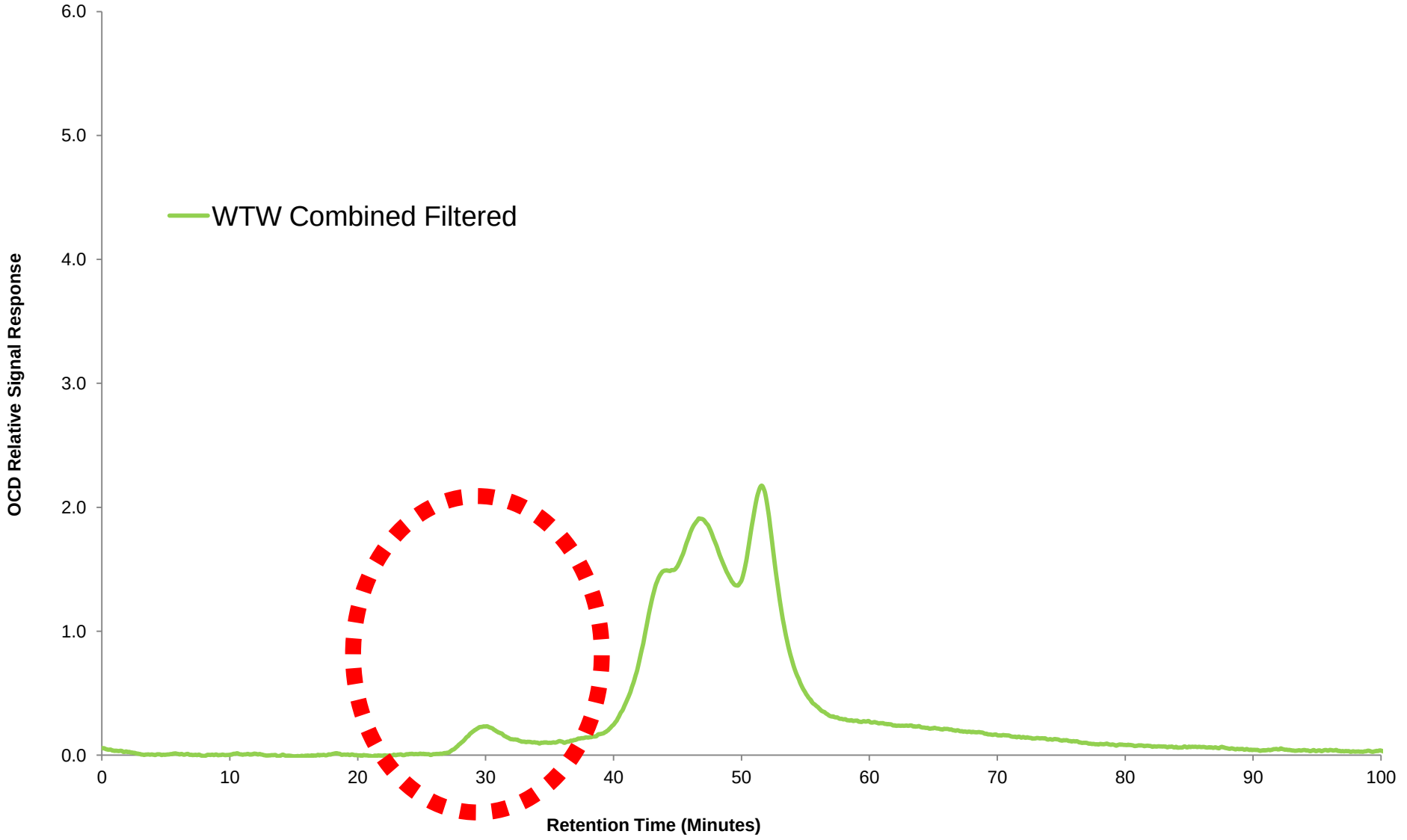


DOC characteristics comparison

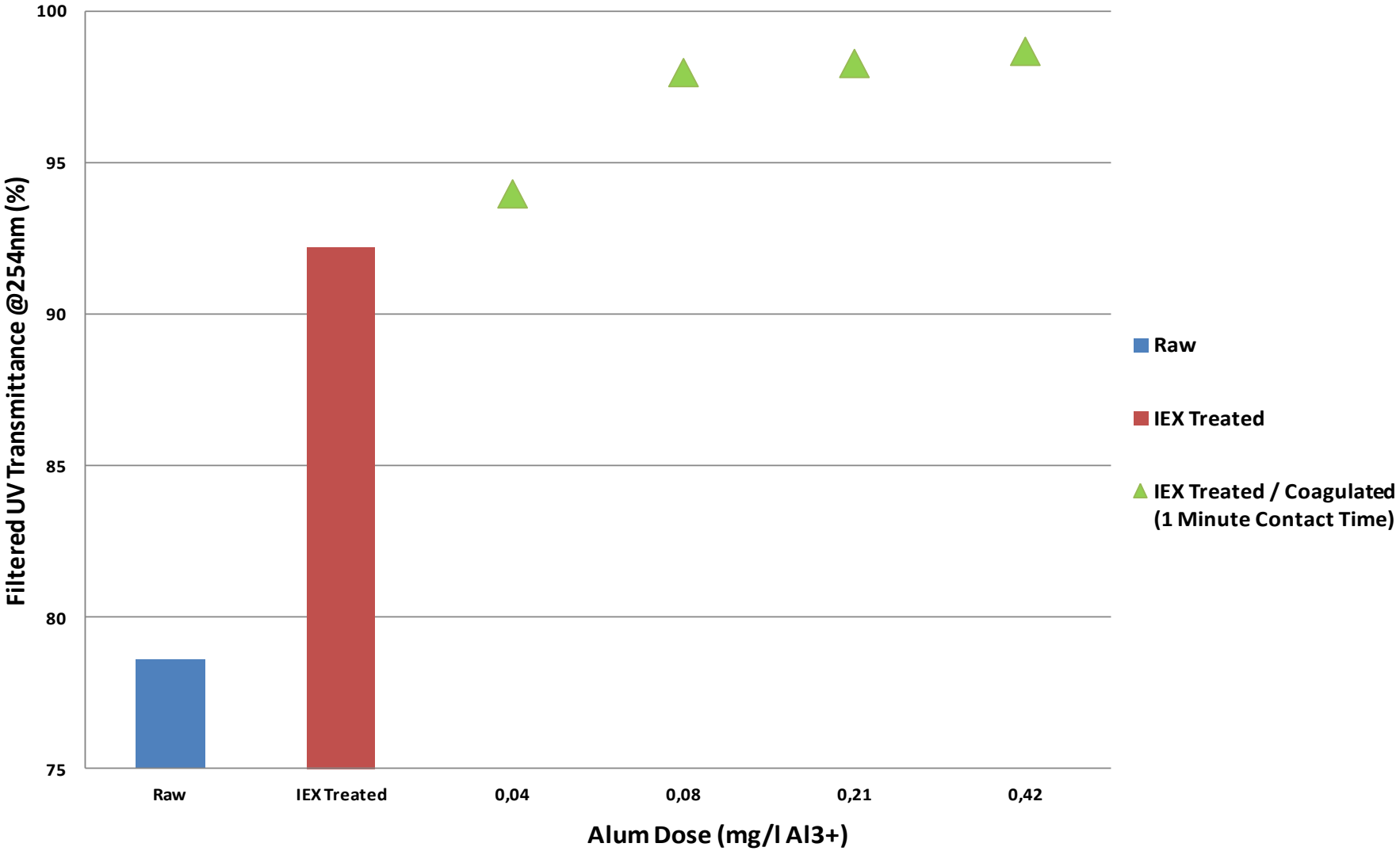




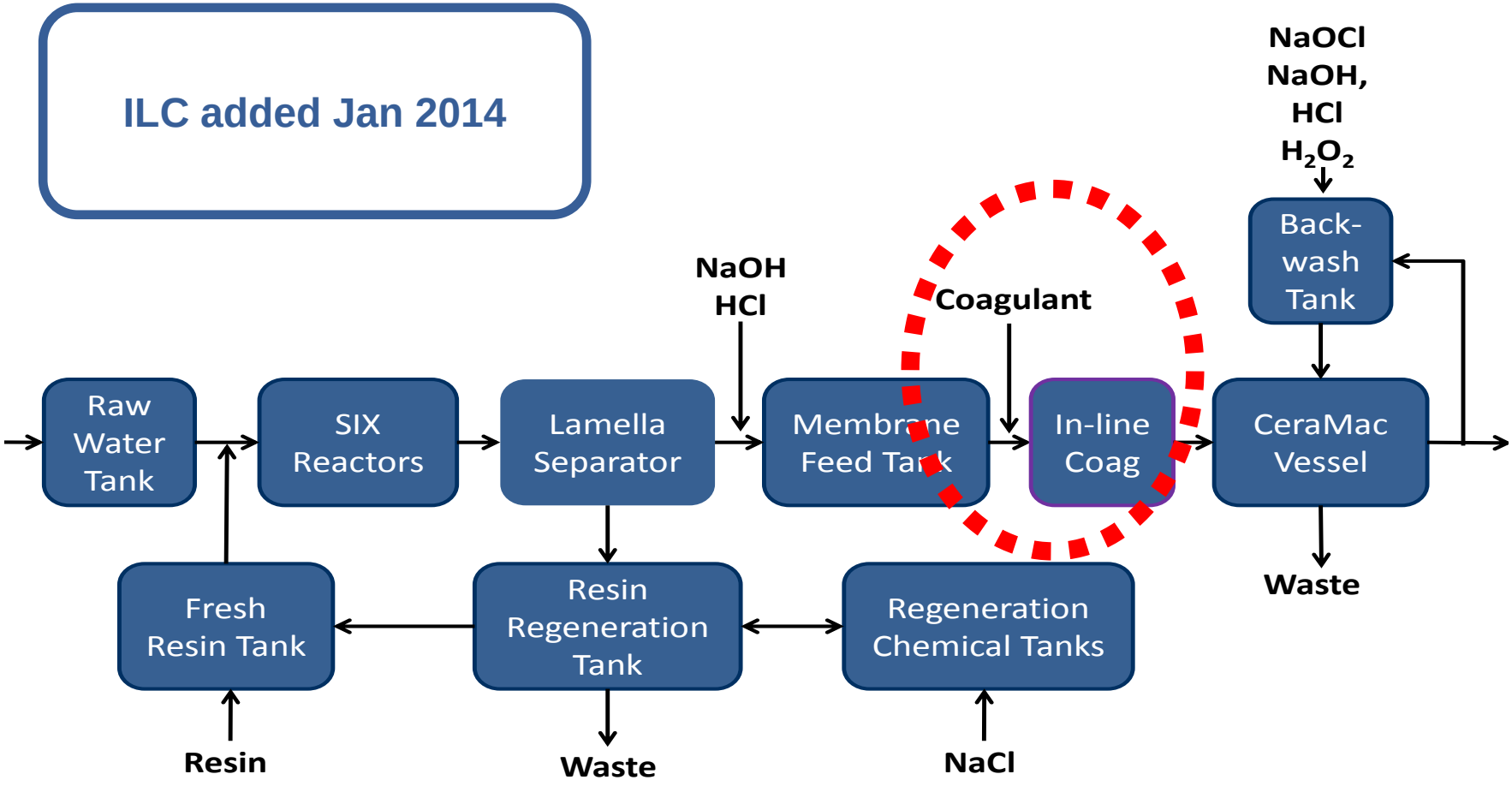
Coagulation...



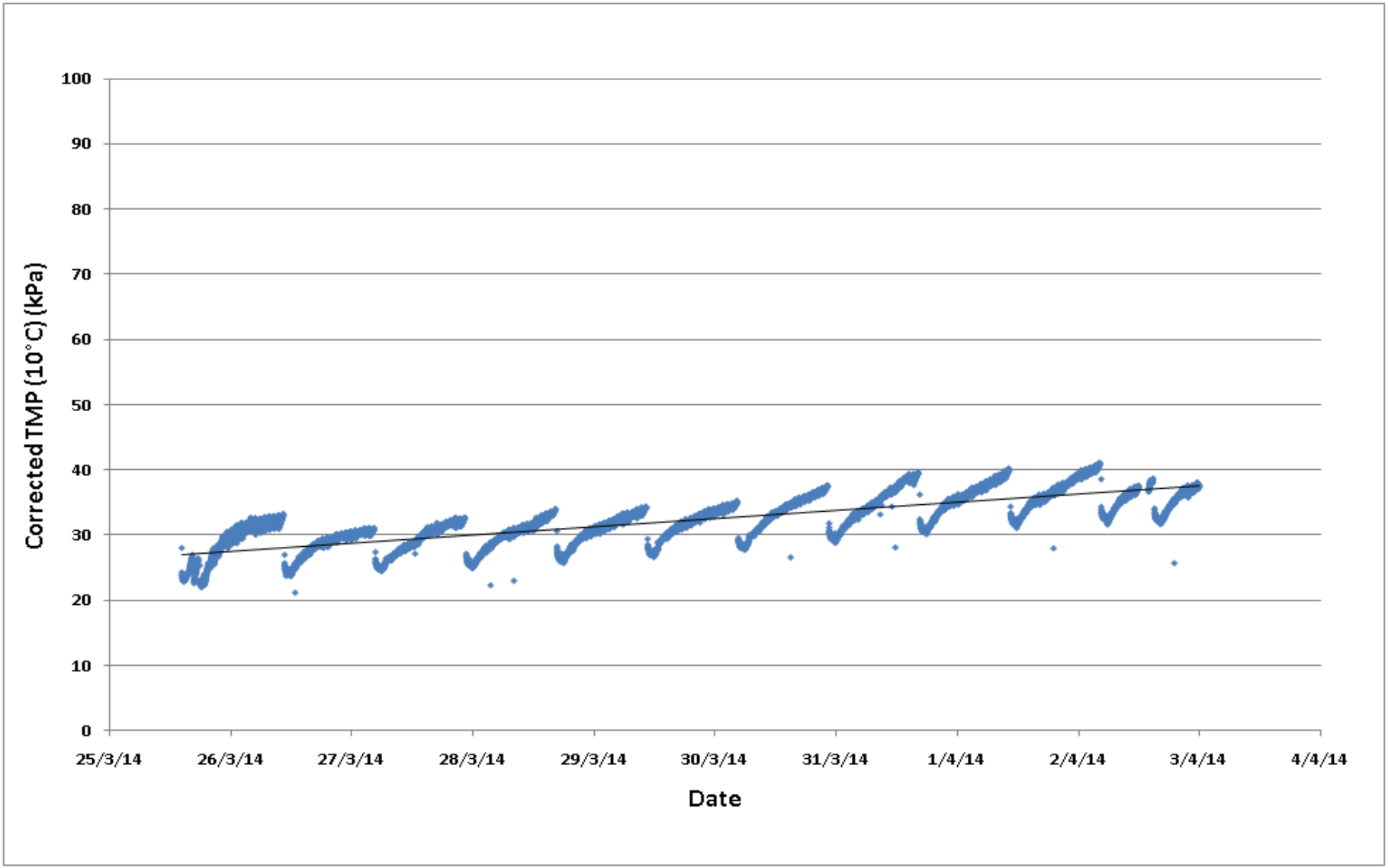
Coagulant addition post SIX



Revised pilot process train

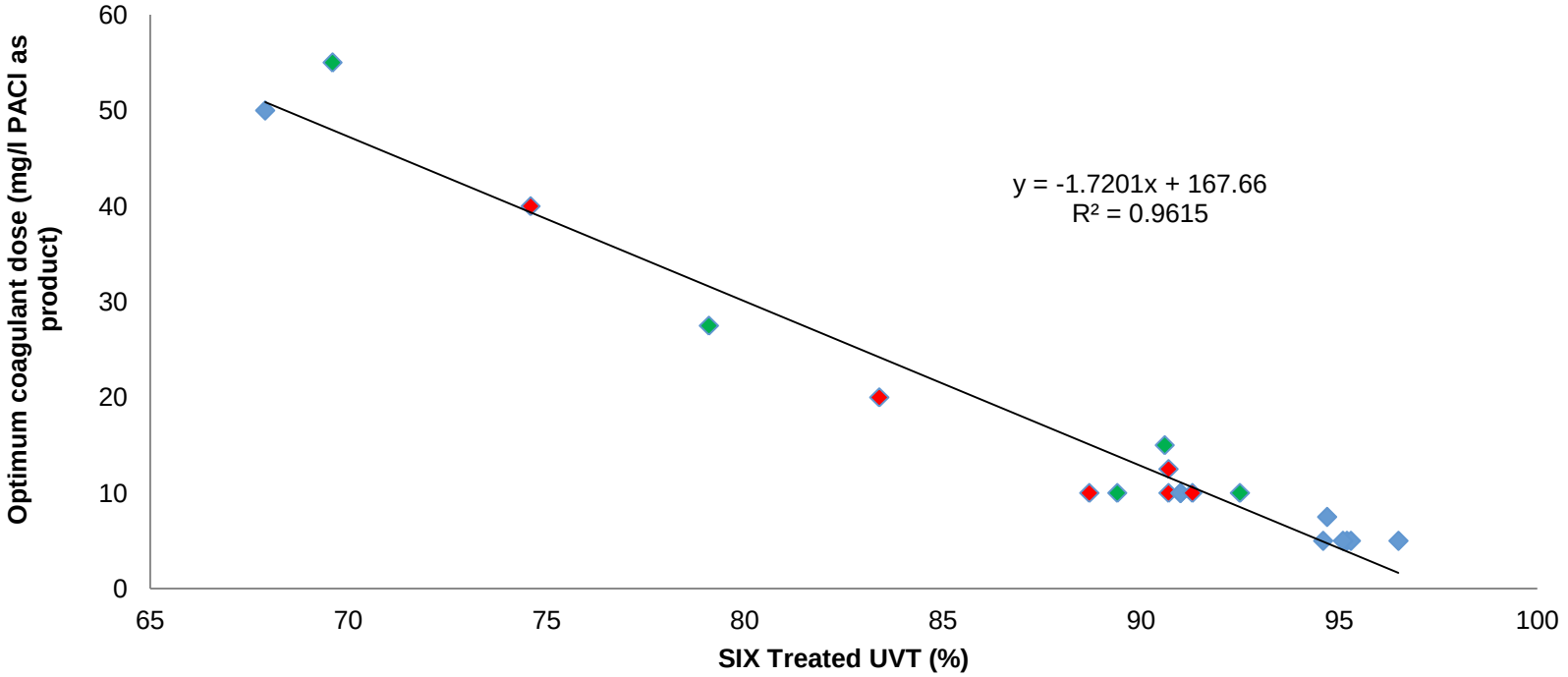


SIX / ILCA pre-treatment

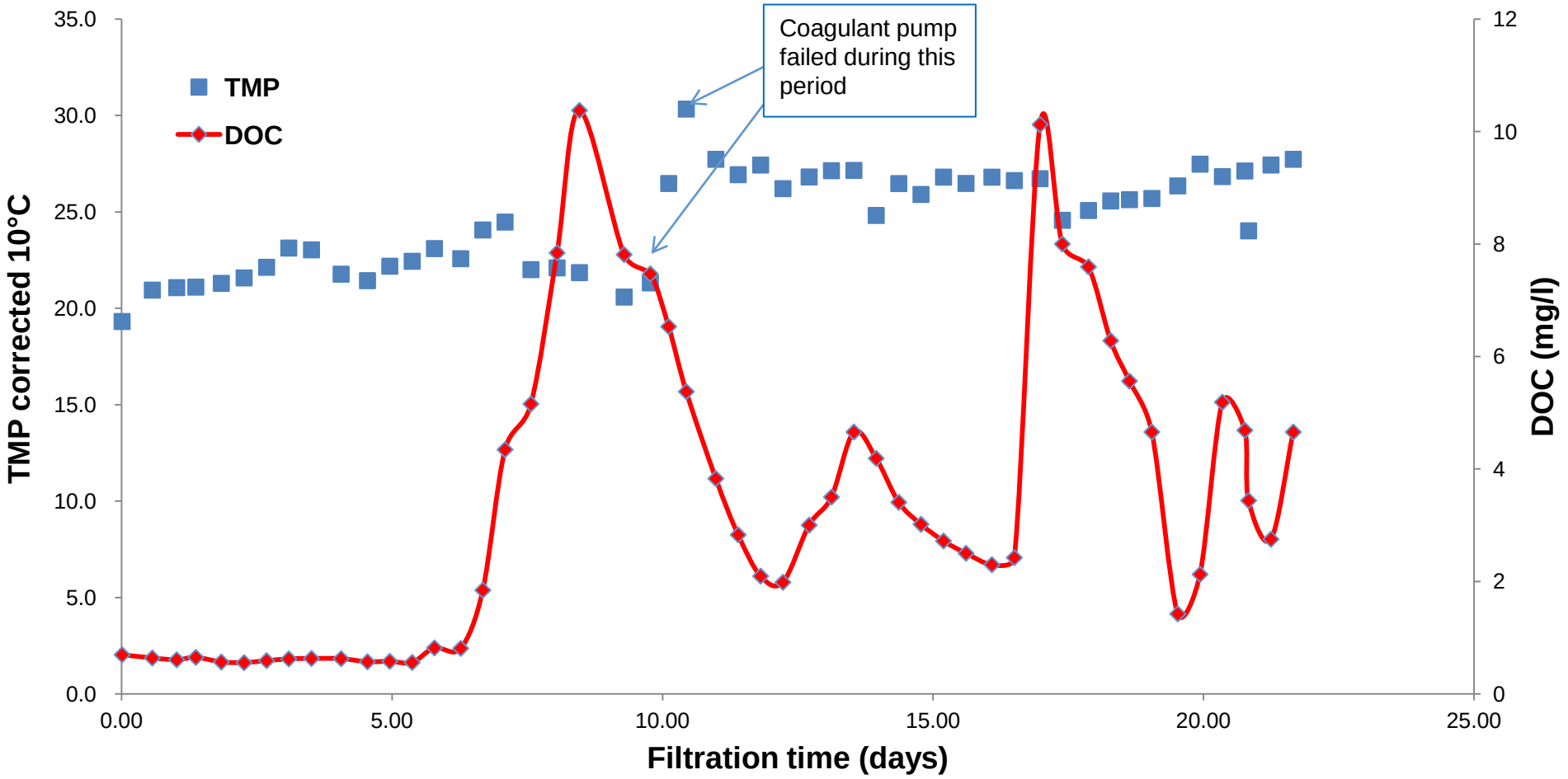


Coagulant optimisation for MF

- New jar test method - less subjective + optimises organics removal
- 20 Jar tests on 3 sources + variable WQ
- Excellent correlation – r2 – 0.96



Optimised membrane operation during spates



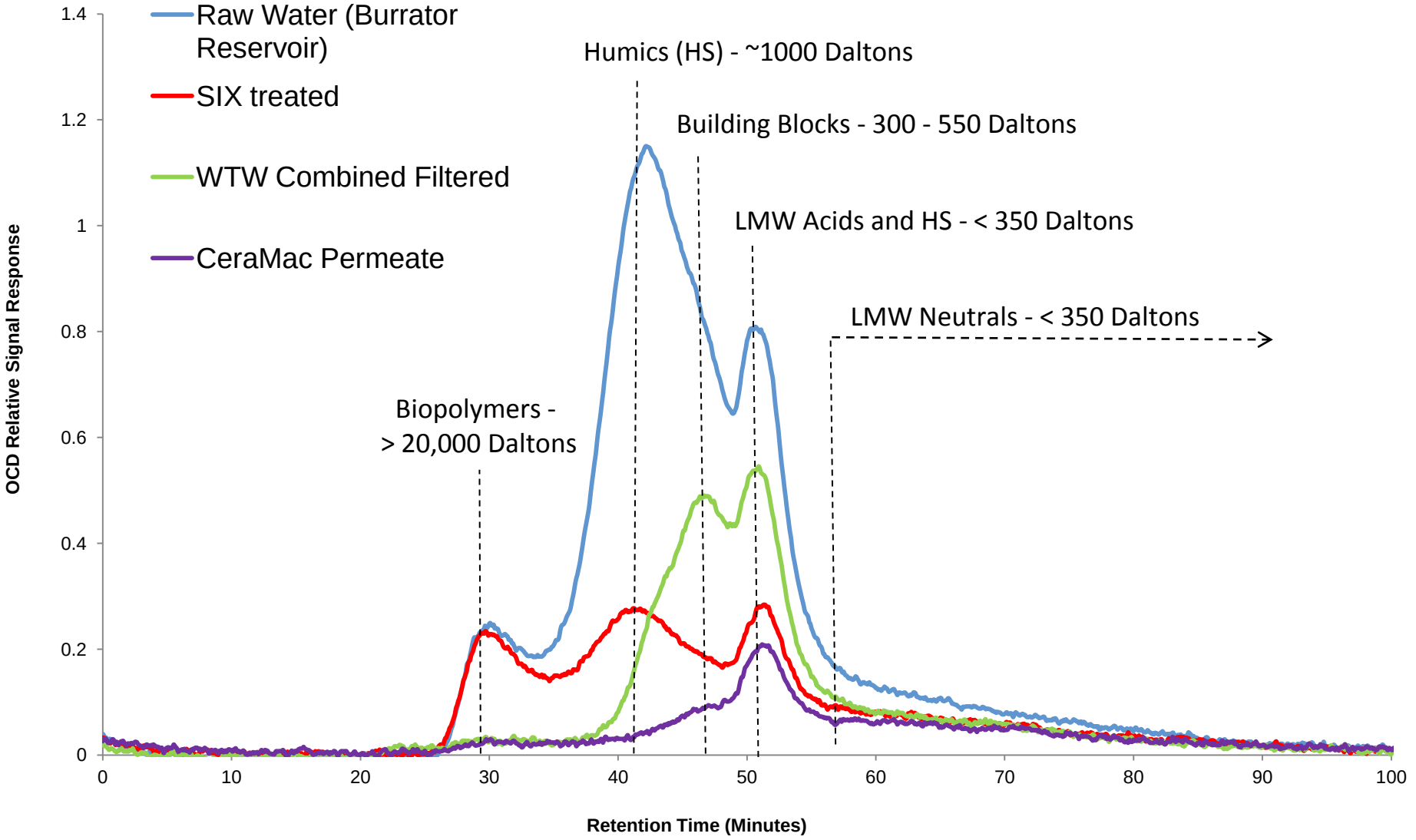
Optimised inline coagulation was critical to stable membrane operation. Using an automated coagulant control system it was possible to run at very high flux (185 LMH), during periods of extremely variable raw water quality (river spate conditions), with very low membrane fouling

Membrane fouling / sustainable flux

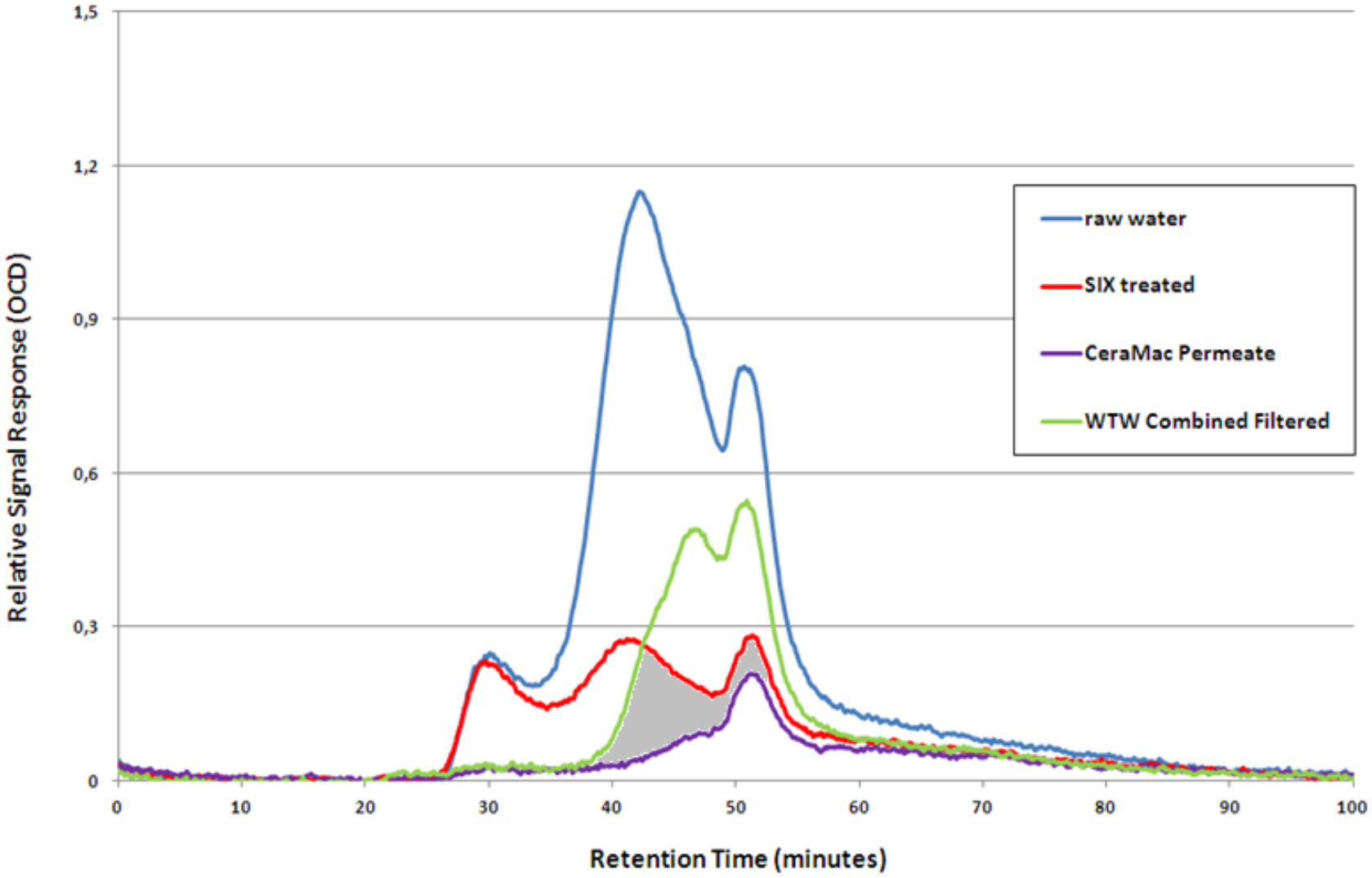
SOUTH WEST WATER

- Higher flux (SLR) = less membranes = lower cost
- Low fouling = simplifies operation, lowers pumping pressure, reduces frequency of chemical cleans
- A years worth of tests - All waters / conditions
- Sustainable flux determined as 185lmh max / 112lmh nominal – pilot info used for design
- Automation of coagulation and pH = improved performance

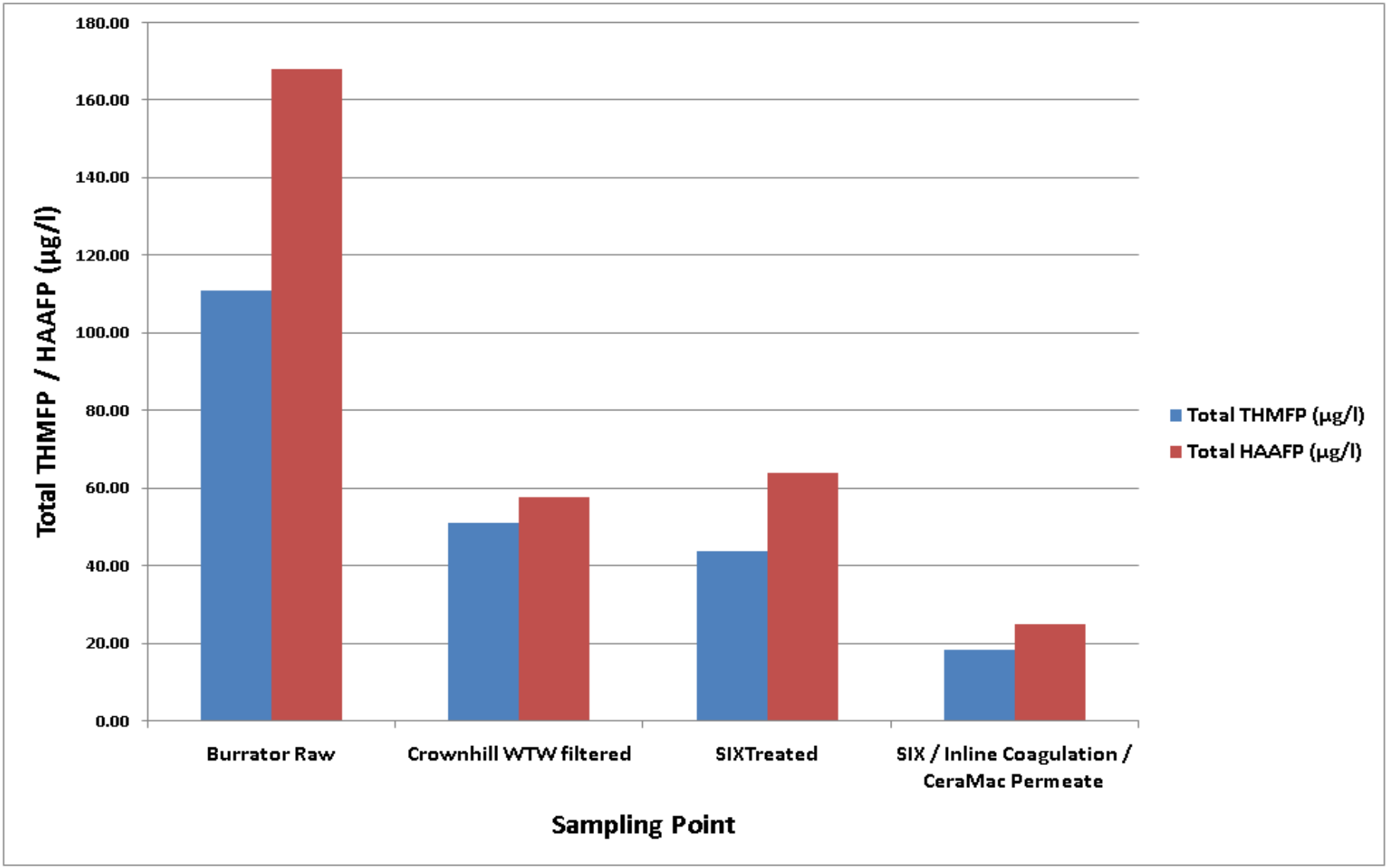
Enhanced organics removal



Organics removal



By products


180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Total THMFP / HAAFP (µg/l)
Burrator Raw
Crownhill WTW filtered
SIXTreated
SIX / Inline Coagulation / CeraMac Permeate
Sampling Point
Total THMFP (µg/l)
Total HAAFP (µg/l)

Mean % removal SIX/ILCA vs. conventional

Parameter	SIX/ILCA/CeraMac additional removal relative to conventional treatment (%)
DOC (% Reduction)	50
UVA (% Reduction)	62
THMFP (% Reduction)	62
HAAFP (% Reduction)	62
THMFP Reactivity (% Reduction)	22
HAAFP Reactivity (% Reduction)	18
Brominated DBPFP (% Reduction)	47

- DBPFP reduction was not only due to enhanced DOC removal, but also to reduced concentrations of Br-DBPs and selective removal of reactive organic compounds

Publications

SOUTH WEST WATER

CRANFIELD UNIVERSITY

David Christopher Metcalfe

Application of Suspended Ion Exchange, In-line Coagulation and Ceramic Membranes for Surface Water Treatment

School of Applied Science
MSc by Research

Master of Science
Academic Year: 2014 - 2016

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Removal of disinfection by-product precursors by coagulation and an innovative suspended ion exchange process

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Keywords:
Ceramic membrane filtration
Disinfection by-products
Ion exchange
Natural organic matter

ABSTRACT

This investigation aimed to compare the disinfection by-product formation potentials (DBPFPs) of three UK surface waters (1 upland reservoir and 2 lowland rivers) with differing characteristics treated by (a) a full scale conventional process and (b) pilot scale processes using a novel suspended ion exchange (SIX) process and inline coagulation (ILCA) followed by ceramic membrane filtration (CMF). Liquid chromatography-organic carbon detection analysis highlighted clear differences between the organic fractions removed by coagulation and suspended ion exchange. Pretreatments which combined SIX and coagulation resulted in significant reductions in dissolved organic carbon (DOC), UV absorbance (UVA), trihalomethane and haloacetic acid formation potential (THMFP, HAAFP), in comparison with the SIX or coagulation process alone. Further experiments showed that in addition to greater overall DOC removal, the processes also reduced the concentration of brominated DBPs and selectively removed organic compounds with high DBPFP. The SIX/ILCA/CMF process resulted in additional removals of DOC, UVA, THMFP, HAAFP and brominated DBPs of 50, 62, 62, 62% and 47% respectively compared with conventional treatment.

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Pre-treatment of surface waters for ceramic microfiltration

D. Metcalfe [a], P. Jarvis [b], C. Rockey [a], S. Judd [b,c,*]

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[c] Qatar University, Doha, Qatar

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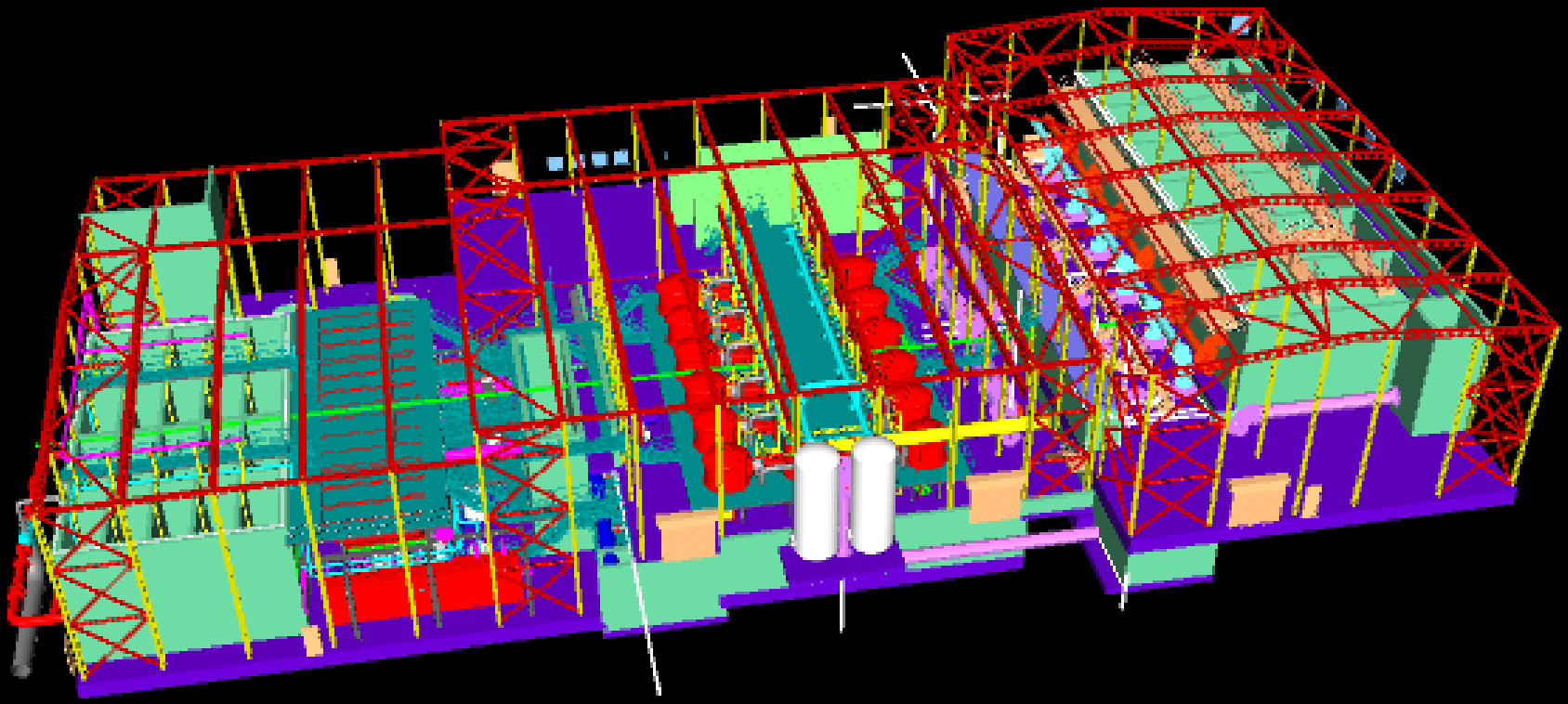
Keywords:
Ceramic membrane
Pretreatment
Ion exchange
Coagulation
Organic fouling

ABSTRACT

The influence of pre-treatment on the suppression of irreversible (IR) fouling of ceramic membranes challenged with three UK surface waters has been studied at pilot scale. An initial scoping study compared the efficacy of suspended ion exchange (SIX) and clarification (coagulation followed by sludge blanket clarification) individually and in combination. Direct membrane filtration following in-line coagulation (ILCA) was also investigated with and without SIX. The impact on the various organic fractions, specifically high molecular weight (HMW) biopolymers (BPs) and humic substances (HSs), and lower molecular weight (LMW) building blocks (BBs) and neutrals, was studied using liquid chromatography-organic carbon detection (LC-OCD).

Results revealed SIX and coagulation to preferentially remove the LMW and HMW organic fractions respectively. Residual HMW organic matter (primarily BPs) following SIX pre-treatment were retained by the membrane which led to rapid irreversible fouling. Coagulation pre-treatment provided stable membrane operation and the residual LMW organics were not significantly retained by the membrane. Combining clarification and SIX resulted in significantly increased removal of organics and lower mem-


RWA
FFL 179.00
SCR
GAC
FFL 179.00
UVB
SCB
CBT
FFL 179.00
TUR
GEN
CSB
OFF
FFL 172.31
WPD
TPS
TWB
FFL 171.00
Reservoir
(Covered)
TWA
WAA
FFL 171.00
LLM
179.8m
Path (fum)
PILOT PLANT
EXISTING LEAT
LANDSCAPING ZONE
1 : 500
PRELIMINARY
NOT TO BE USED FOR CONSTRU
DRAFT FOR CONSULTATION
SOUTH WEST WATER
K5 PROGRAMME
NORTH PLYMOUTH
NORTH PLYMOUTH W
PROPOSED SITE LAY
NPLY-ARC-ROW-XX-DR-C-10120
30006373



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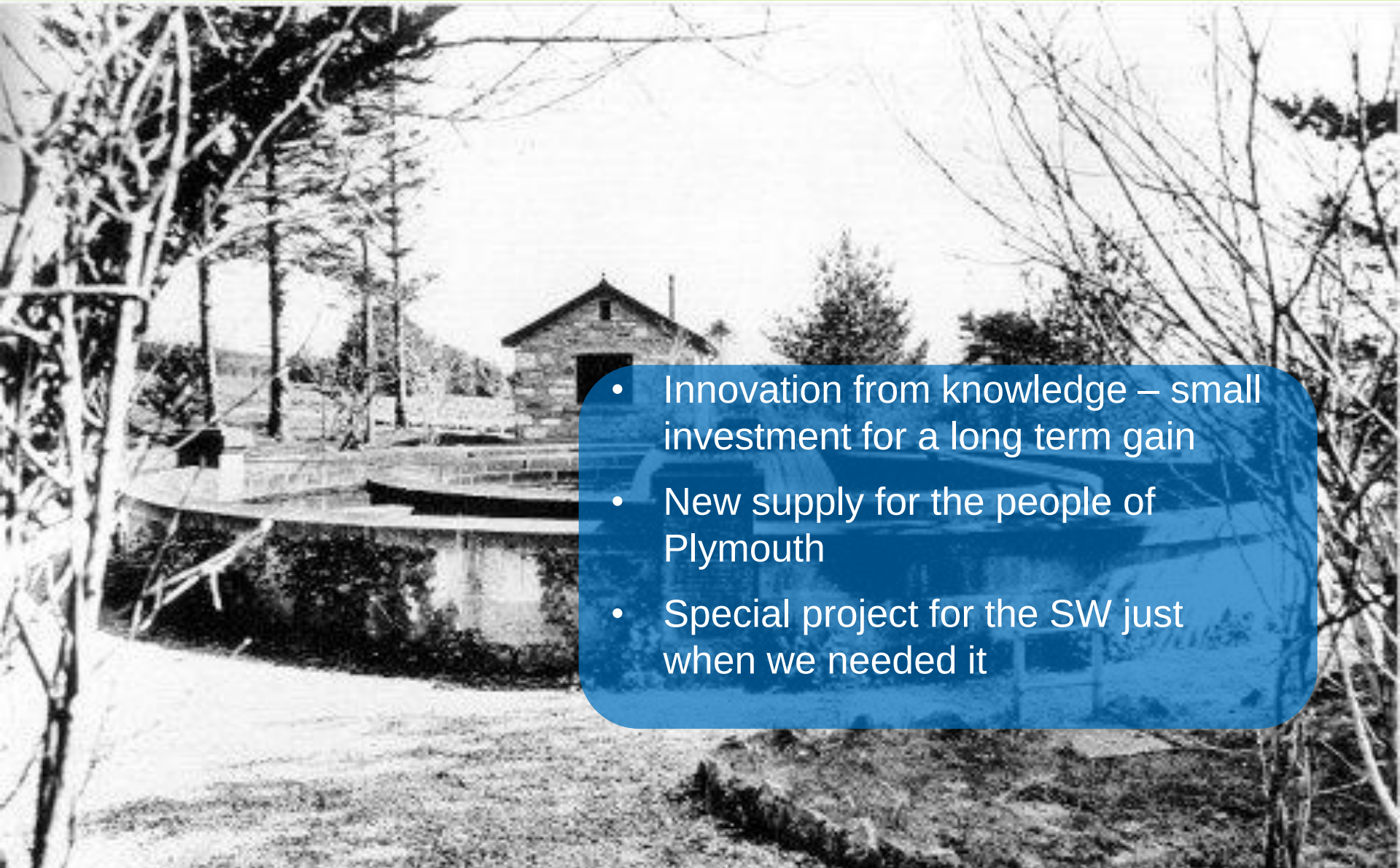
Summary



- Innovation from knowledge – small investment for a long term gain
- New supply for the people of Plymouth
- Special project for the SW just when we needed it

Acknowledgments...

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Cranfield UNIVERSITY

Rwb waterservices

HET WATERLABORATORIUM

Interreg
2 Seas Mers Zeeën
DOC2C's
European Regional Development Fund

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De Watergroep
Université de Lille
TU Delft

Thank you

When trying to protect your membranes…

‘…dubbel genaaid houdt beter!’