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WCWC Walkerton Clean Water Centre
An agency of the Government of Ontario
CWAE Centre de Walkerton pour l'assainissement de l'eau
Un organisme du gouvernement de l'Ontario

Reducing organics and Disinfection By-Products in Ontario's drinking water systems through pilot studies

Land Acknowledgement

The Centre acknowledges the aboriginal and treaty rights of First Nations, Inuit and Métis communities as recognized and affirmed in section 35 of The Constitutions Act, 1982. In the spirit of truth and reconciliation, the Centre acknowledges that the land Ontarians inhabit today and on which the Centre operates its services and provides training across Ontario, are traditional territories of Indigenous Peoples. The Centre recognizes the history, spirituality, and vibrant culture and respectfully acknowledges all Indigenous Peoples who have stewarded this land and water since time immemorial. Those past generations of stewards have passed on the responsibility to all people to honour the sacred land and water that is integral to everyone's lives. As a source of life, nourishment, and cleansing, water offers many teachings, and the Centre hopes to incorporate those teachings into its training and services. This acknowledgement is a reminder of the Centre's commitment to growing new relationships, partnerships and understanding so that we may move forward in a spirit of reconciliation and collaboration.

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WCWC is committed to supporting the owners, operators and operating authorities of Ontario’s drinking water systems

- Hands-on training
- Public & on-site courses
- Helpline
- Pilot testing
- Drinking Water Resource Library
- Virtual and e-learning courses

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Pilot study 1- Using fixed bed Ion-Exchange process to reduce organics and DBPs

Background

- A small drinking water system serving a population of approximately 5,000 in Northern Ontario
- Source water – River
- Water Treatment Plant – Flow rate approximately 10,000 m^3/day
- Current WTP
  - Enhanced coagulation (Alum dose-200 mg/L)
  - Hydraulic flocculation tanks
  - Settling tanks
  - Anthracite (600 mm) and sand (350 mm) filters
  - Chlorine & Chloramination as primary and secondary disinfectant respectively

Issues

- Raw water organics (DOC) level -16.5 mg/L

- Filtered water DOC level – 5.73 mg/L

    - DOC level of filter effluent > AO - DOC : 5 mg/L

- Exceedance of THMs - MAC : 100 µg/L

Pilot Objectives

- To evaluate

  - a fixed bed ion exchange (IX) system with the aim of additionally reducing organic matter and THMs & HAAs in the treated water

  - the overall effect of the ion exchange process on treated water quality

  - the effect of varying flow rates through the ion exchange systems on organic matter reduction

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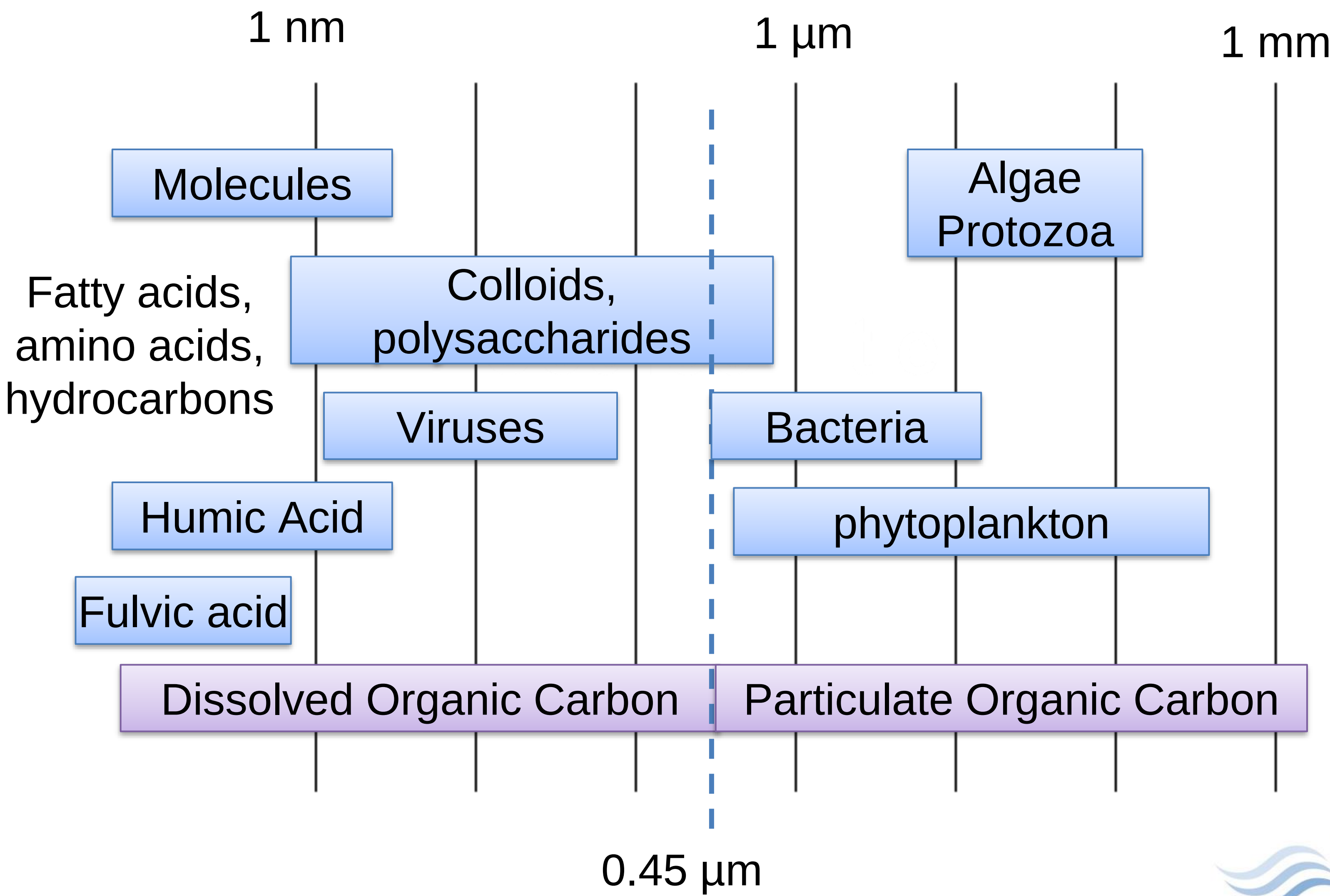
Raw Water Quality Characteristics

Parameters	Average (Experiment 1 & 2)
DOC (mg/L)	16.5
UV absorbance at 254nm (cm^{-1})	1.011
SUVA (L/mg-m)	6.14
Alkalinity (mg/L $CaCO_3$)	69
True colour (Pt- Co)	146
Apparent colour (Pt- Co)	203
Turbidity (NTU)	7.56
pH	7.61

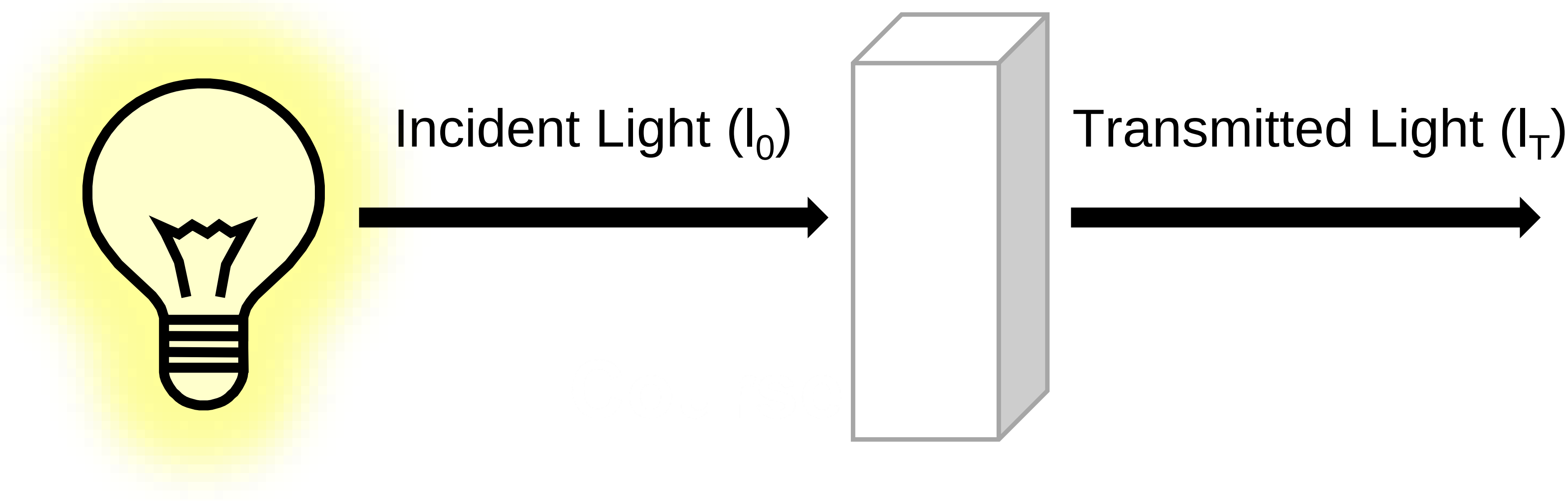
Scale of Particulate and Dissolved Organic Carbon in Natural Waters



UV Absorbance (UV_{254})

- UV_{254} is widely used in water treatment plants to monitor natural organic matter
- Specific structures in the NOM (chromophores) absorb UV light
- UV absorbing chromophores are associated primarily with the humic fraction of NOM

UV_{254} Analysis



T%: the percent transmittance in the medium when the path length is 1 cm and the wavelength is 254 nm

$$UV\ \ Abs. = 2 - log_{10}(T\%)$$

Specific UV Absorbance (SUVA)

- The ratio of UV absorbance and DOC
- An estimate of chemical characteristics of dissolved NOM
- SUVA is a good indicator of the hydrophobic fraction (humic acids) of NOM

$$\mathbf{SUVA}\ \frac{\mathbf{L}}{\mathbf{mg \cdot m}} = \frac{\mathbf{UV_{254}(cm^{-1})}}{\mathbf{DOC}\ (\frac{\mathbf{mg}}{\mathbf{L}})} \times \mathbf{100}\ \frac{\mathbf{cm}}{\mathbf{m}}$$

SUVA

SUVA L/mg·m	Composition	Coagulation	DOC Removals using enhanced coagulation with Alum
> 4	Mostly Aquatic Humics, High Hydrophobicity, High Molecular Weight	Good DOC Removals.	> 50%
2 - 4	Mixture of Aquatic Humics and Other NOM, Mixture of Hydrophobic and Hydrophilic NOM, Mixture of Molecular Weights	DOC Removals should be Fair to Good.	24-50%
< 2	Mostly Non-Humics Low Hydrophobicity, Low Molecular Weight	Poor DOC Removals.	< 25%

Edzwald et al. 1999

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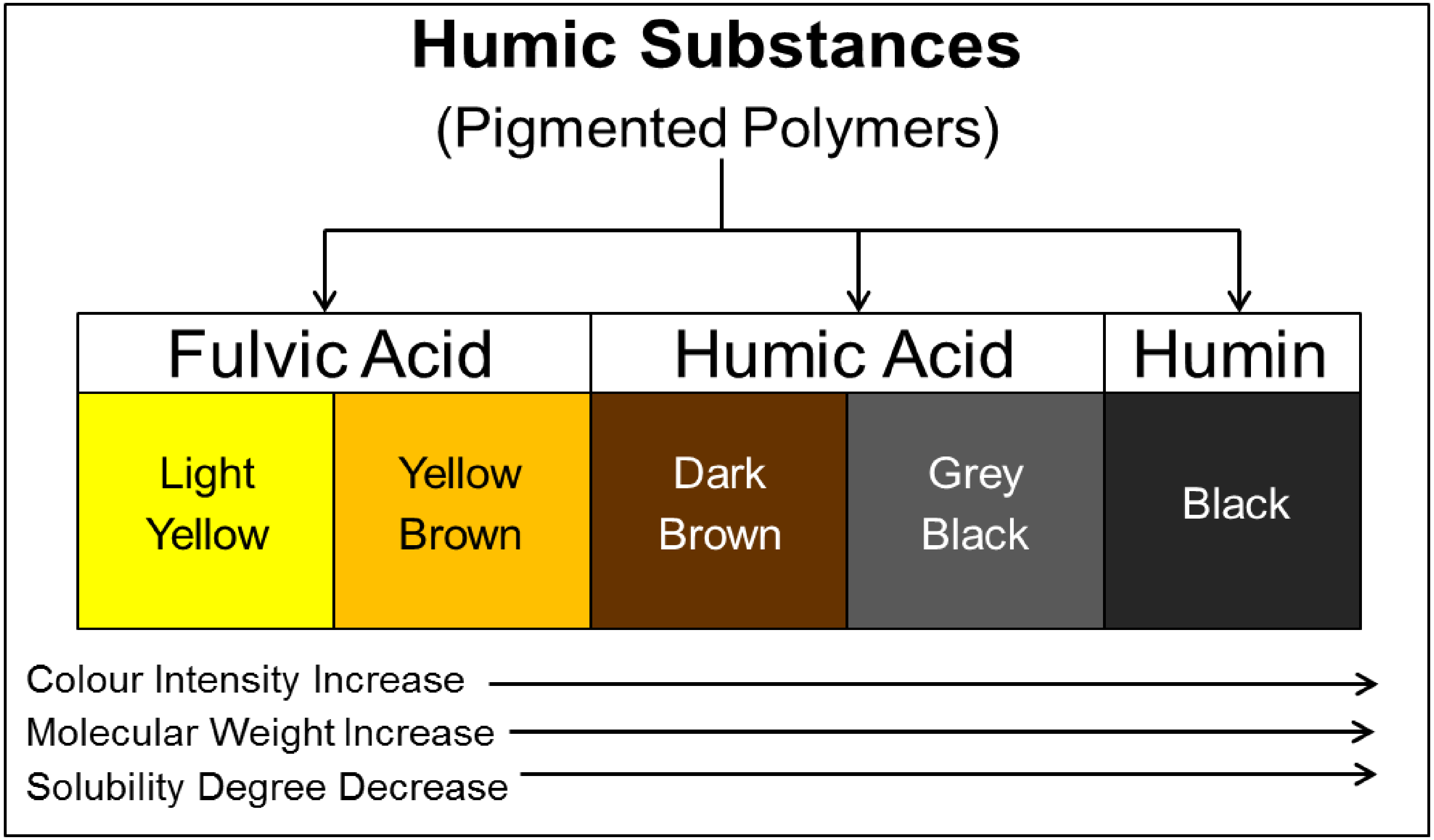
Guideline of TOC Removal By Enhanced Coagulation (US EPA,1999)

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0 - 60	61-120	>120
> 2 - 4	35%	25%	15%
> 4 - 8	45%	35%	25%
> 8	50%	40%	30%

Colour- A surrogate for Organic matter



THMs & HAAs Formation

Chlorine **+** **Natural Organic Matter (NOM)** ➡ **THMs & HAAs**

The formation of THMs and HAAs depends on:

- ✓ Chlorine concentrations
- ✓ Chemical make-up of NOM and their concentrations
- ✓ Contact time, and
- ✓ Temperature

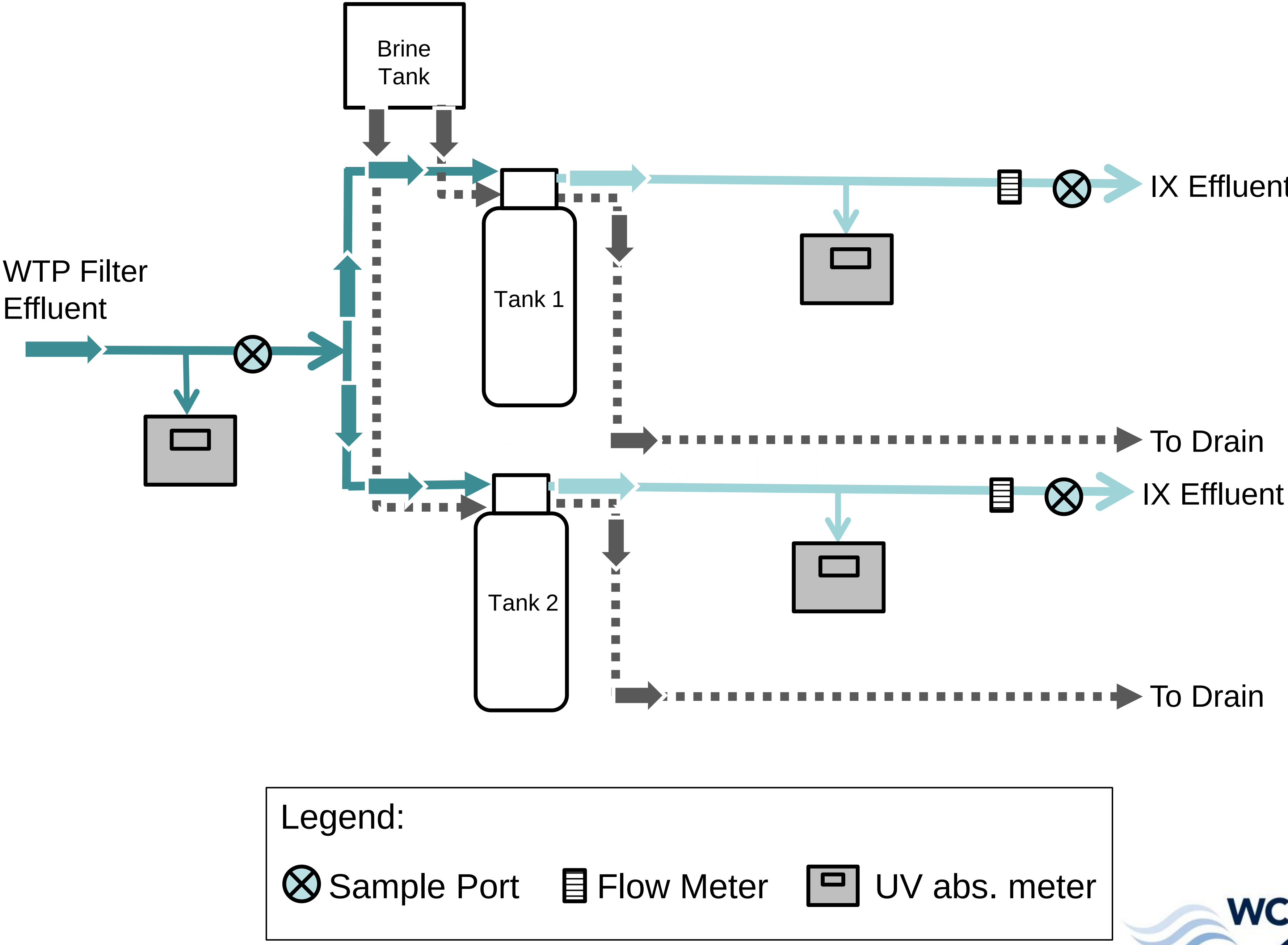
Reducing NOM concentrations prior to chlorination can effectively lower THM and HAA levels

Experimental Conditions

Experiment	Train	Train Flow	Sampling Frequency	Remarks
1	1	23 L/min	After 1 , 3, 5 and 7 hours	EBCT= 2.5 min (3.0 gpm/cubic ft)*
	2	23 L/min	After 1, 2, 3 and 4 hours **	EBCT= 2.5 min
2	1	11 L/min	After 1, 3, 5 and 7 hours	EBCT= 5.2 min (1.5 gpm/cubic ft)*
	2	11 L/min	After 1, 3, 5 and 7 hours	EBCT= 5.2 min

* Design flow rate :1-10 gpm/cubic ft

** Sampling time changed due to desludging operations at the WTP and power failure issues


Brine Tank
WTP Filter Effluent
Tank 1
Tank 2
IX Effluent
IX Effluent
To Drain
To Drain
Legend:
Sample Port
Flow Meter
UV abs. meter
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SDS-THMs/HAAs conditions

- Chlorine dose: 6 mg/L
- Detention time: 2 days @ room temperature
- Conducted at the Centre
- THMs/HAAs analysis conducted by an accredited private laboratory

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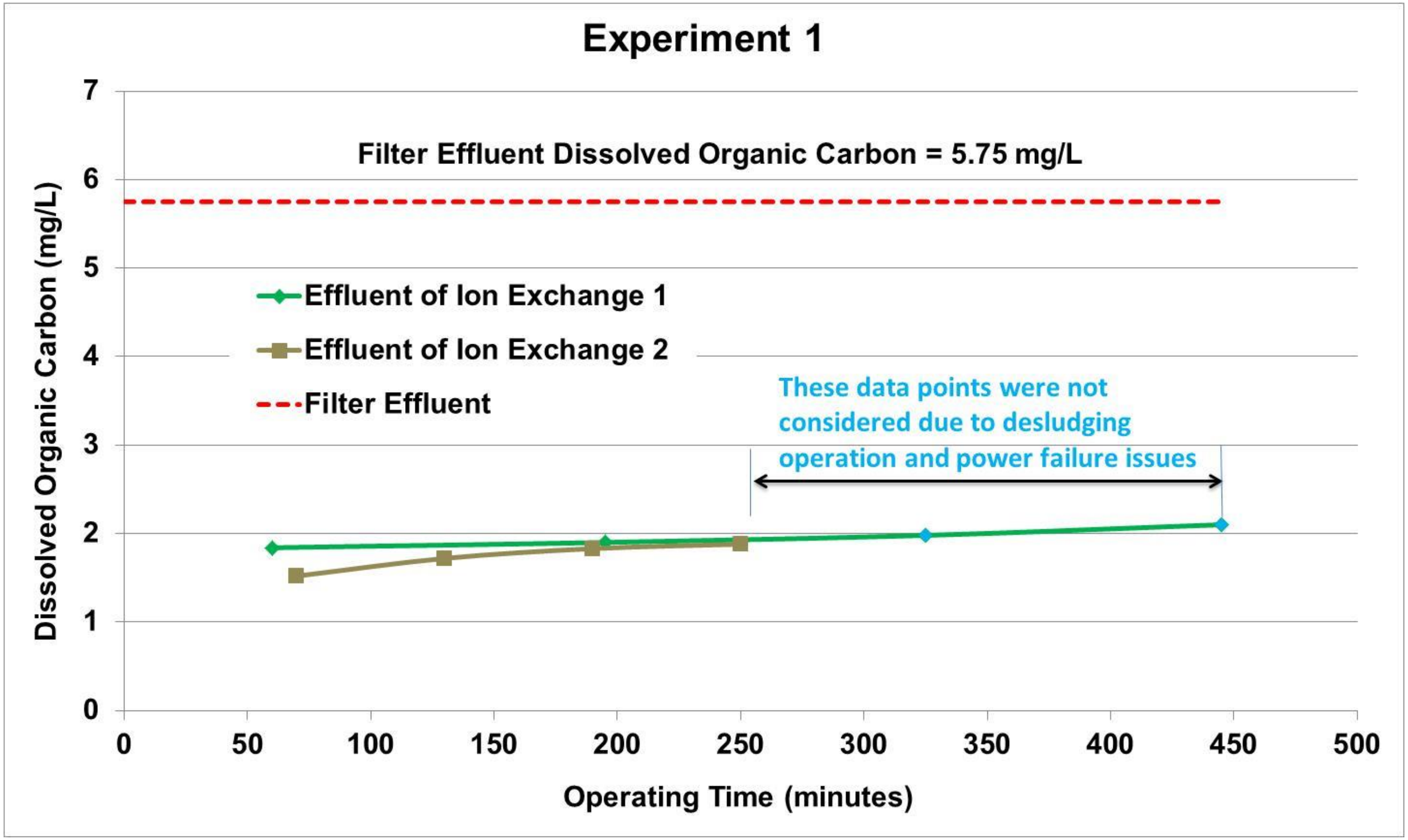
Additional DOC Reduction with EBCT - 2.5 min



- Raw water :16.4 mg/L and Filtered effluent: 5.75 mg/L
- IX treated water: 1.84 -1.90 mg/L
- Additional DOC reduction: 68%

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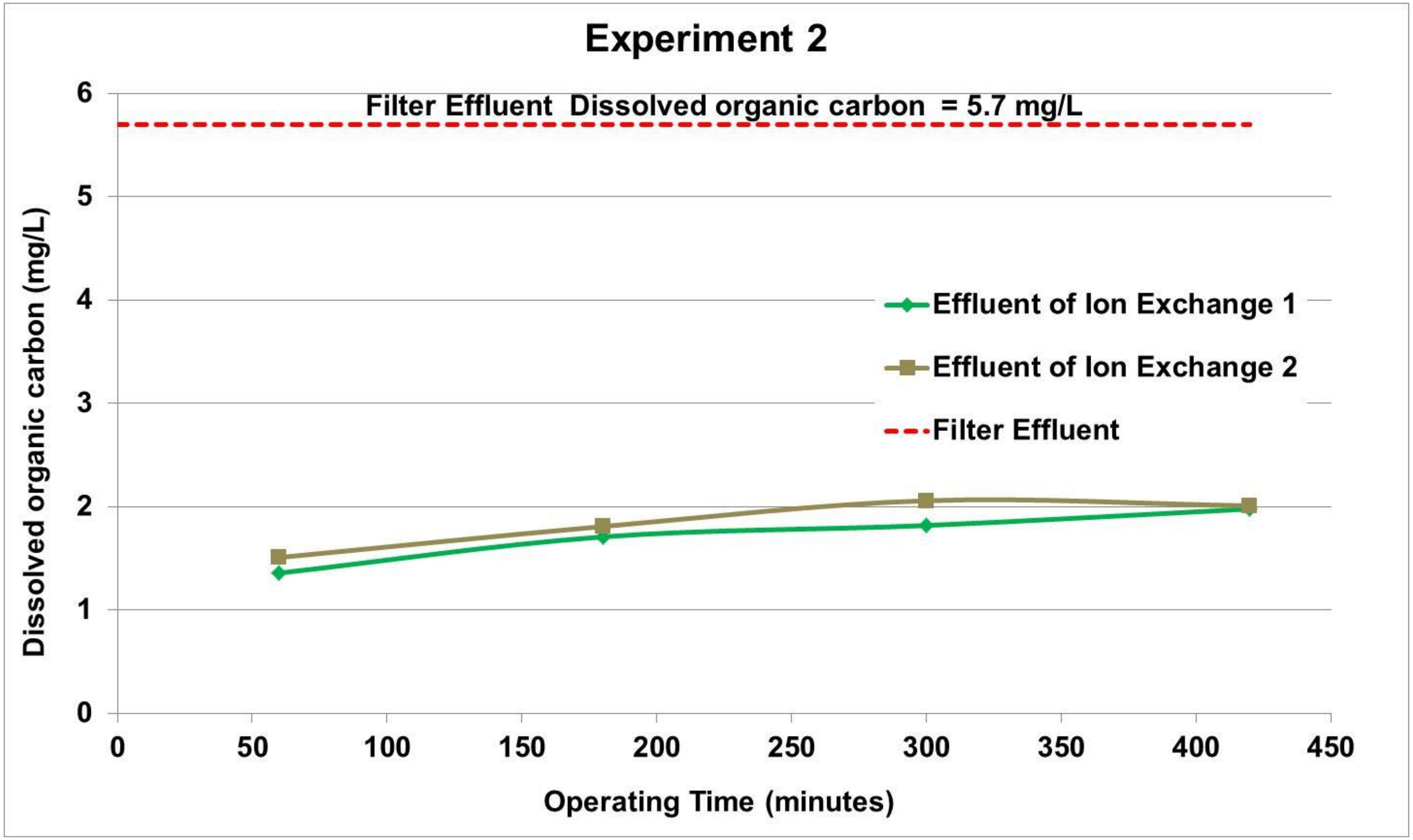
Additional DOC Reduction with EBCT – 5.2 min



- IX treated water: 1.36 - 2.06 mg/L,
- Additional DOC reduction: 69%
- Treated water DOC level increases with time

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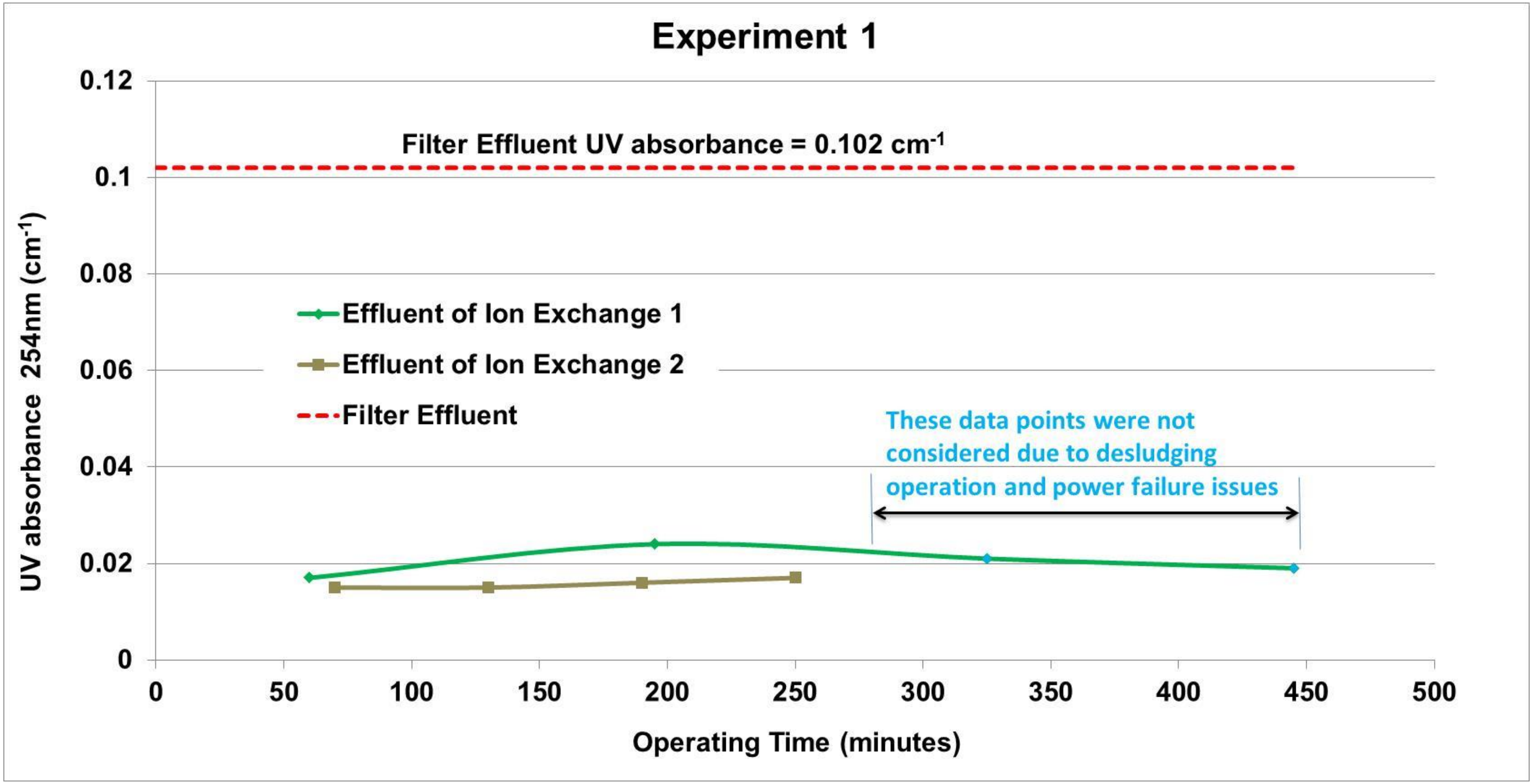
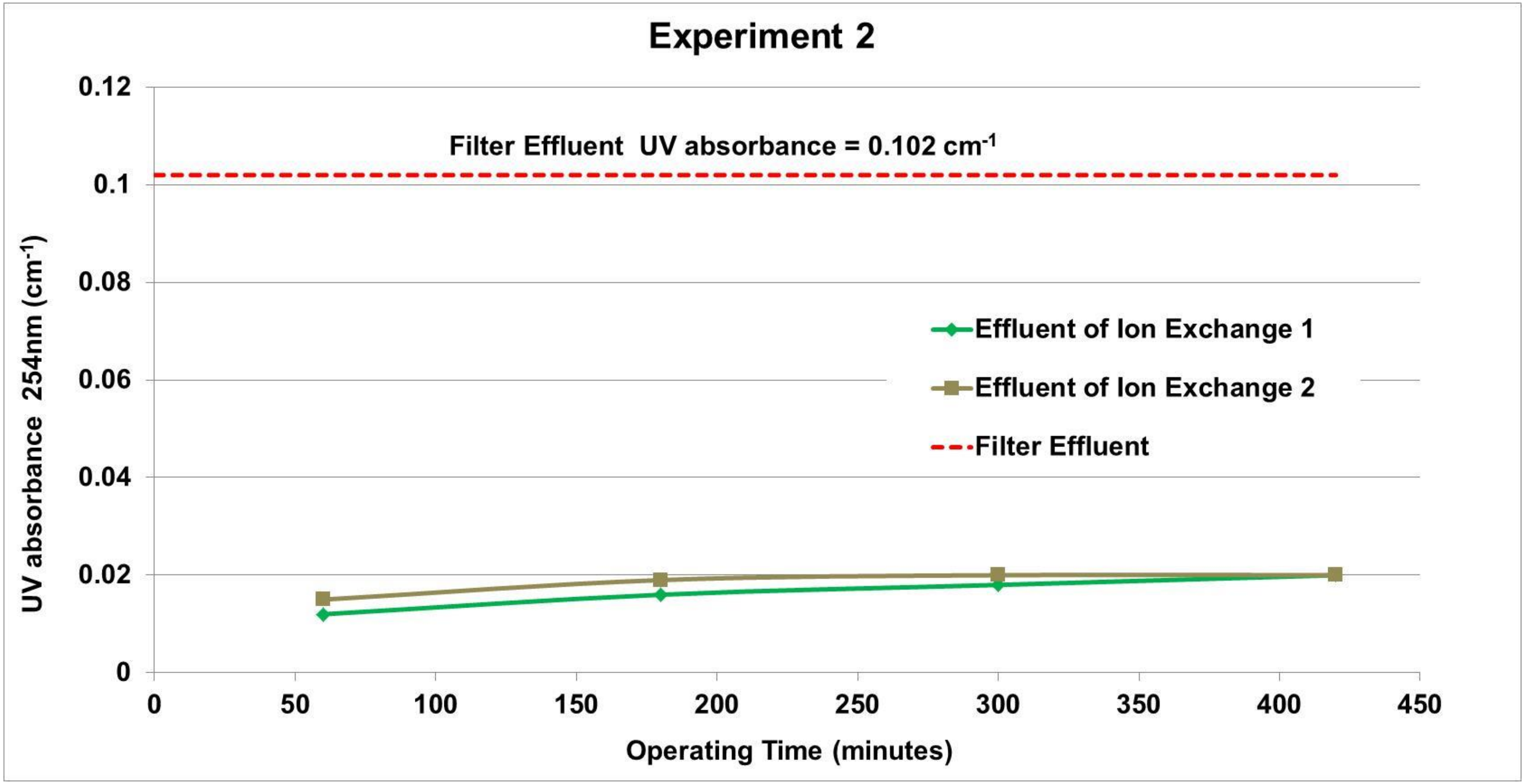
Additional UV absorbance Reduction with EBCT – 2.5 min



- Reduction up to Filtered effluent: 90%
- Additional UV absorbance reduction by Ion-exchange process: 84%

Additional UV absorbance Reduction with EBCT – 5.2 min

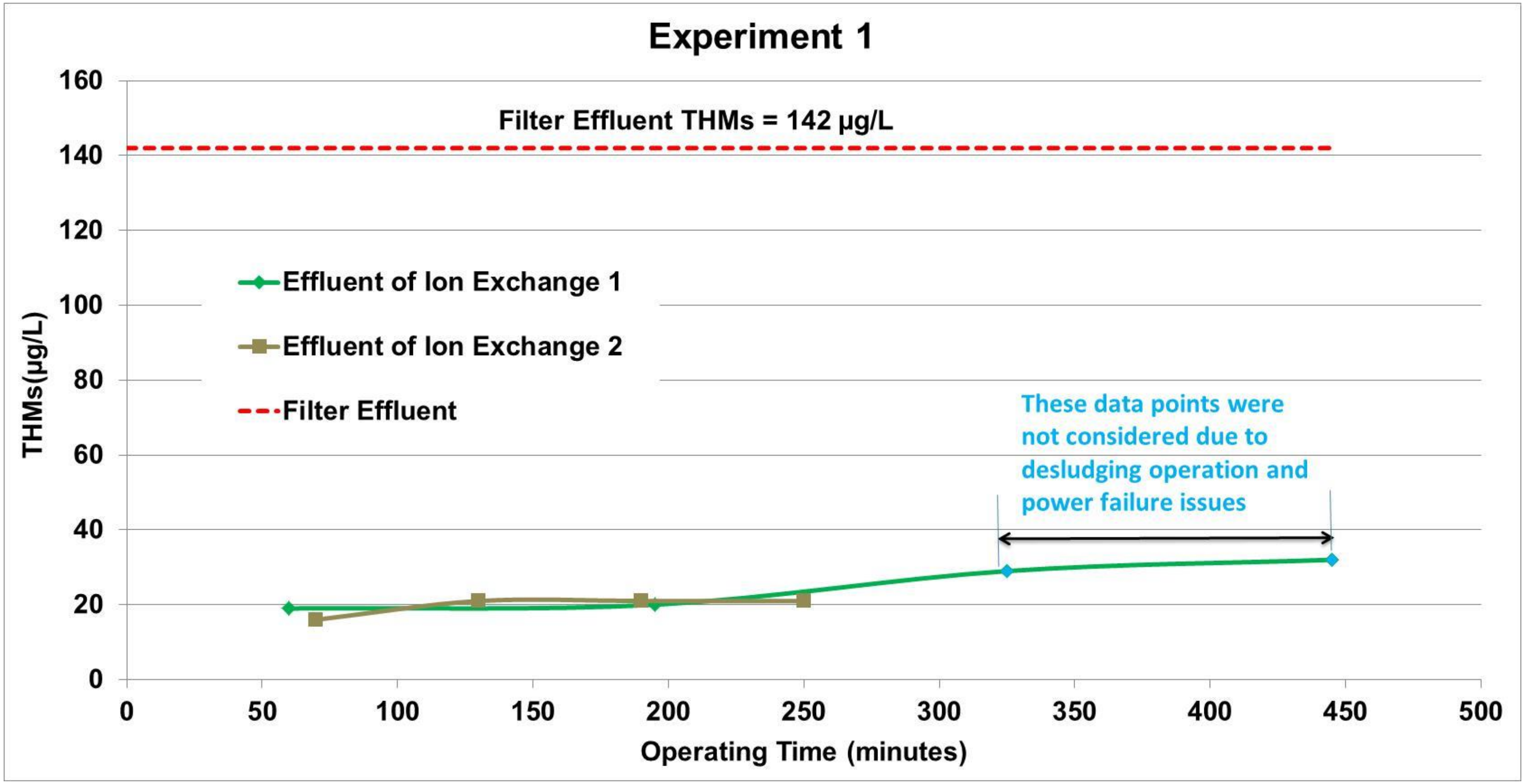


- Additional UV absorbance reduction by Ion-exchange process: 82%

Conclusion

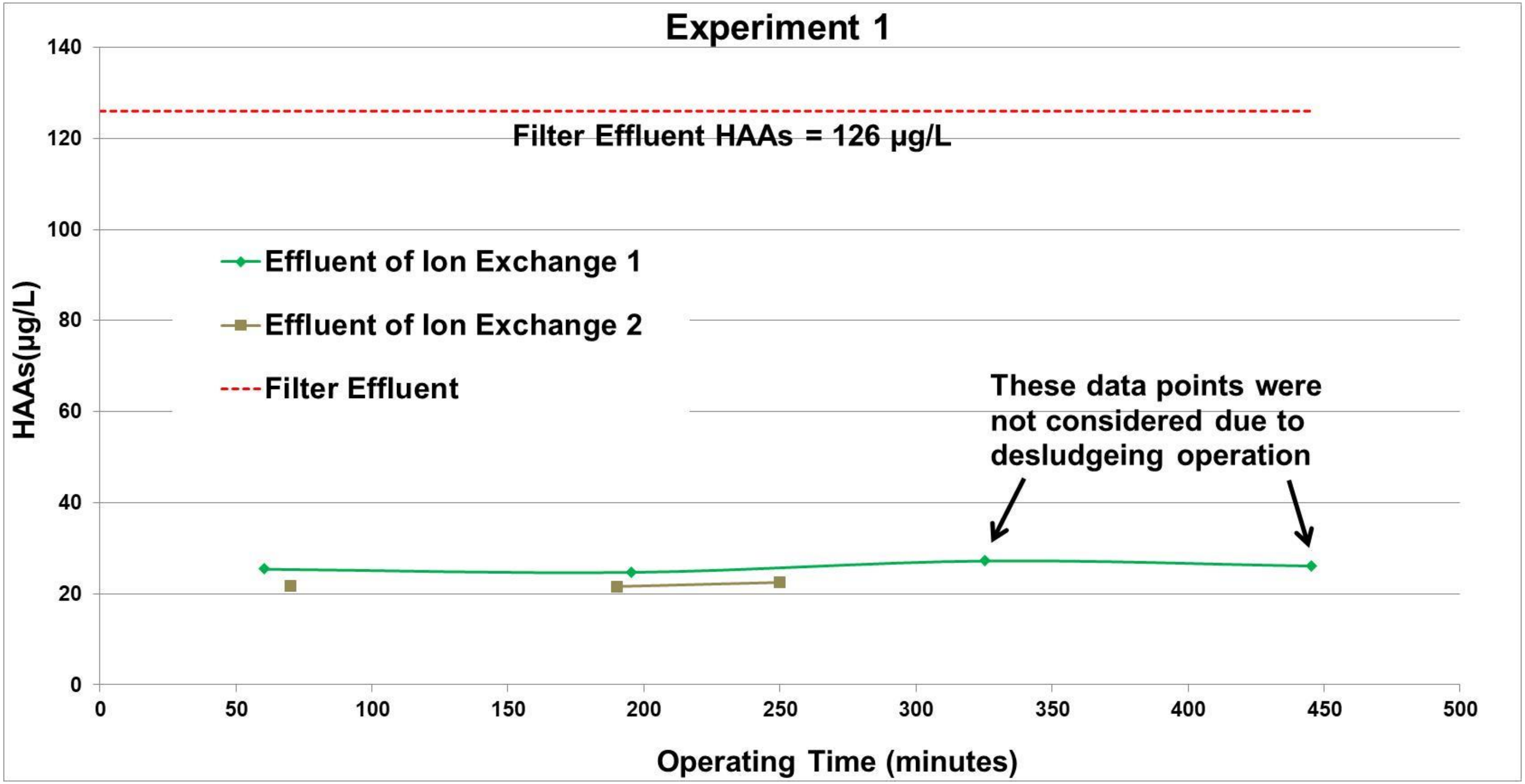
- Additional DOC and UVA removal by IX process: 69% and 83%
- IX process reduces more aromatic fraction
- Because two different EBCTs showed similar performance within a range of flows which indicate that EBCT can be decreased or flowrate can be increased.
- On-line UV absorbance meter can be used as a monitoring tool for DOC
- Performance decreases as runtime increases and therefore UV absorbance can be used for regeneration frequency

Additional THMs Reduction by IX process



- SDS-THMs conditions: 6.3 mg/L chlorine and 2-day detention time
- Raw water : 238 µg/L, Filtered water : 142 µg/L
- Average IX treated water : 20 µg/L
- **Additional THMs reduction by IX process: 86%**

Additional HAAs Reduction by IX process



- Raw water : 185 µg/L, Filtered water : 126 µg/L
- Average IX treated water : 23 µg/L
- **Additional HAAs reduction by IX process: 82%**

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Impact of IX process on general water quality

Parameters	Raw water	After filtration	After IX process *
Alkalinity in mg/L as $CaCO_3$	69 (The town add soda ash to increase alkalinity)	33	8
pH	7.6	6.4	5.0

* Needs adjustment to maintain stability in Distribution System

Pilot study 2- Comparing DAF and Conventional sedimentation performance in organics reduction

Background

- A community in Northern Ontario
- 300 residents
- Water source: Lake water
- Raw water:
  - High DOC: 8.2 – 14.2 mg/L

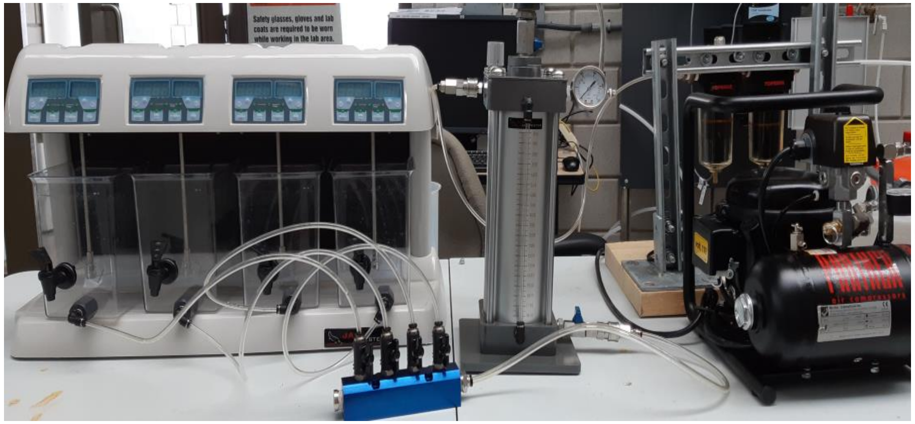
    → High potential to form DBPs
  - Low turbidity: 0.7 – 2.9 NTU
  - Low alkalinity: 49 – 71 mg/L $CaCO_3$

    → Challenging to form flocs for conventional treatment

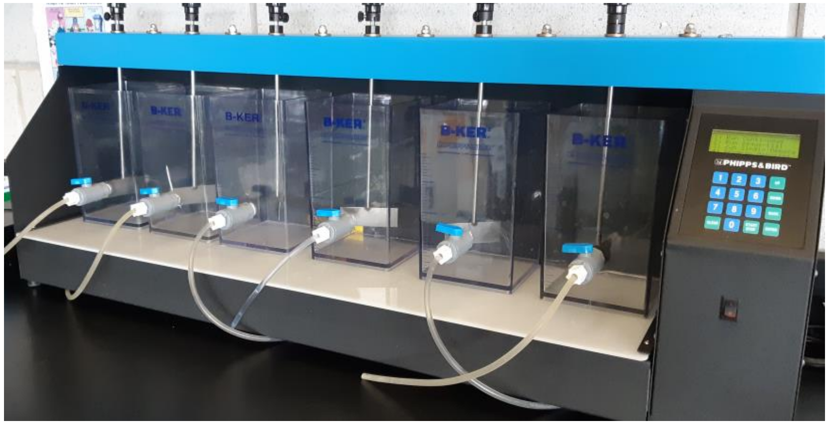
Pilot objectives

- To investigate if enhanced coagulation is sufficient to removal organics under cold water conditions
- To compare the performance of two clarification processes: conventional sedimentation and dissolved air flotation (DAF) following enhanced coagulation under cold water conditions

DAF vs. Conventional Sedimentation



DAF Jar Tester



Conventional Jar Tester

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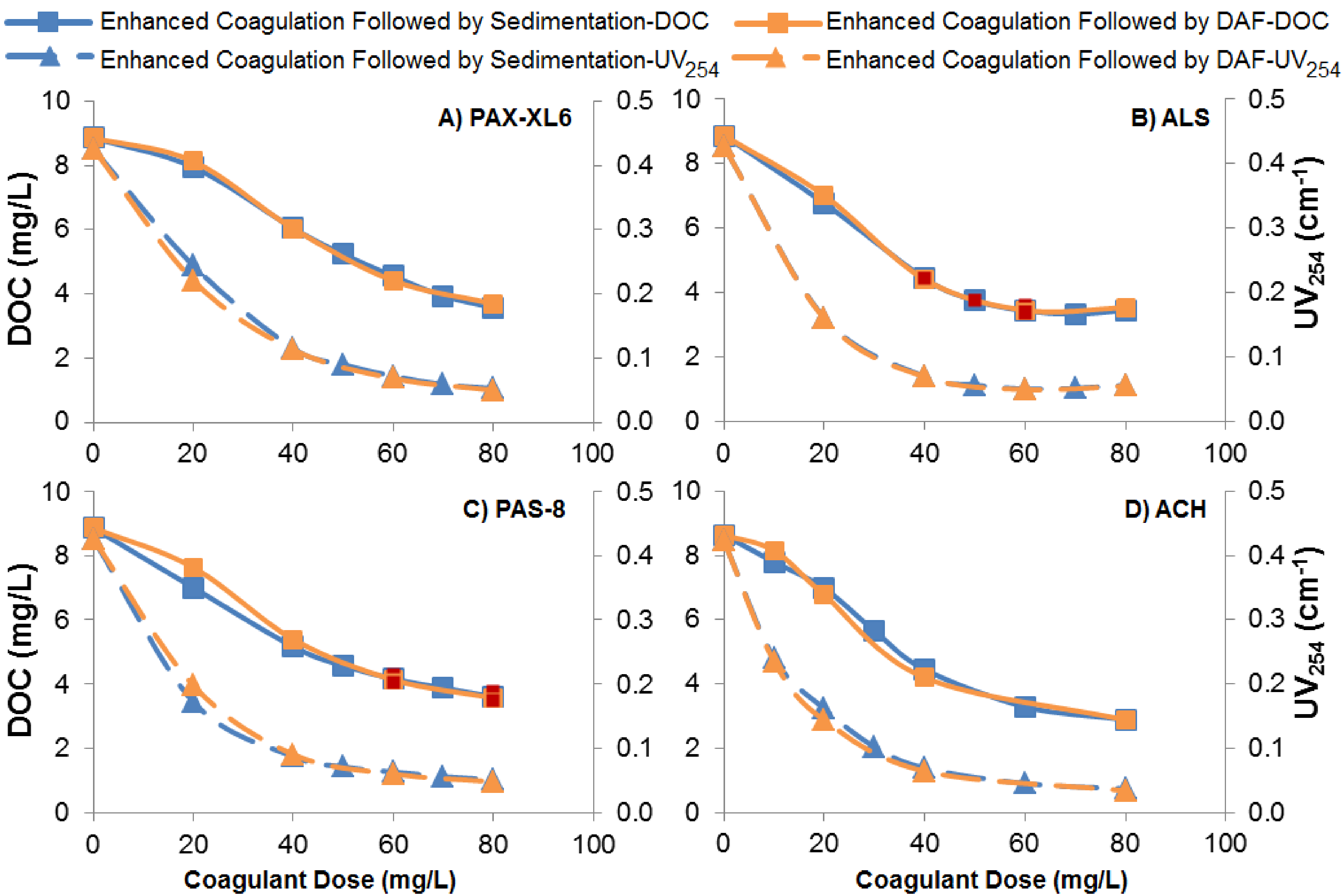
Coagulants

Product Name	Major Ingredients	Details (Gebbie, 2006 and product technical data sheets)
PAX – XL6	Aluminum chloride hydroxide sulphate	Reduced sludge production, less pH adjustment, improved cold water performance.
ALS	Aluminum sulphate	Alum is generally lower cost. Raw waters that are coloured, low turbidity, low pH/alkalinity may require lime, soda ash or caustic soda to improve coagulation.
PAS-8	Aluminum hydroxide sulphate	Reduced sludge production, less pH adjustment, improved cold water performance.
ACH	Aluminum chlorohydrate	Compared to alum, ACH generally requires 1/3 of the dose and lower sludge production, but is more costly. Reduced sludge production, less pH adjustment, improved cold water performance. Short shelf-life.

Jar Test Conditions

Stage	Enhanced Coagulation Followed by Sedimentation		Enhanced Coagulation Followed by DAF	
	Speed (rpm)	Detention Time (min)	Speed (rpm)	Detention Time (min)
Coagulation (Rapid Mixing)	100	1.5	100	1.5
Flocculation 1	50	4.5	50	4.5
Flocculation 2	25	25.5	25	6.5
Application of Air	N.A.	N.A.	Saturation Pressure: 600 kPa	
			Recycle Rate: 8%	
Clarification	0	30	0	12.5



Conclusion: Enhanced coagulation followed by either conventional sedimentation or DAF removed over 50% of DOC and over 85% of UV_{254}

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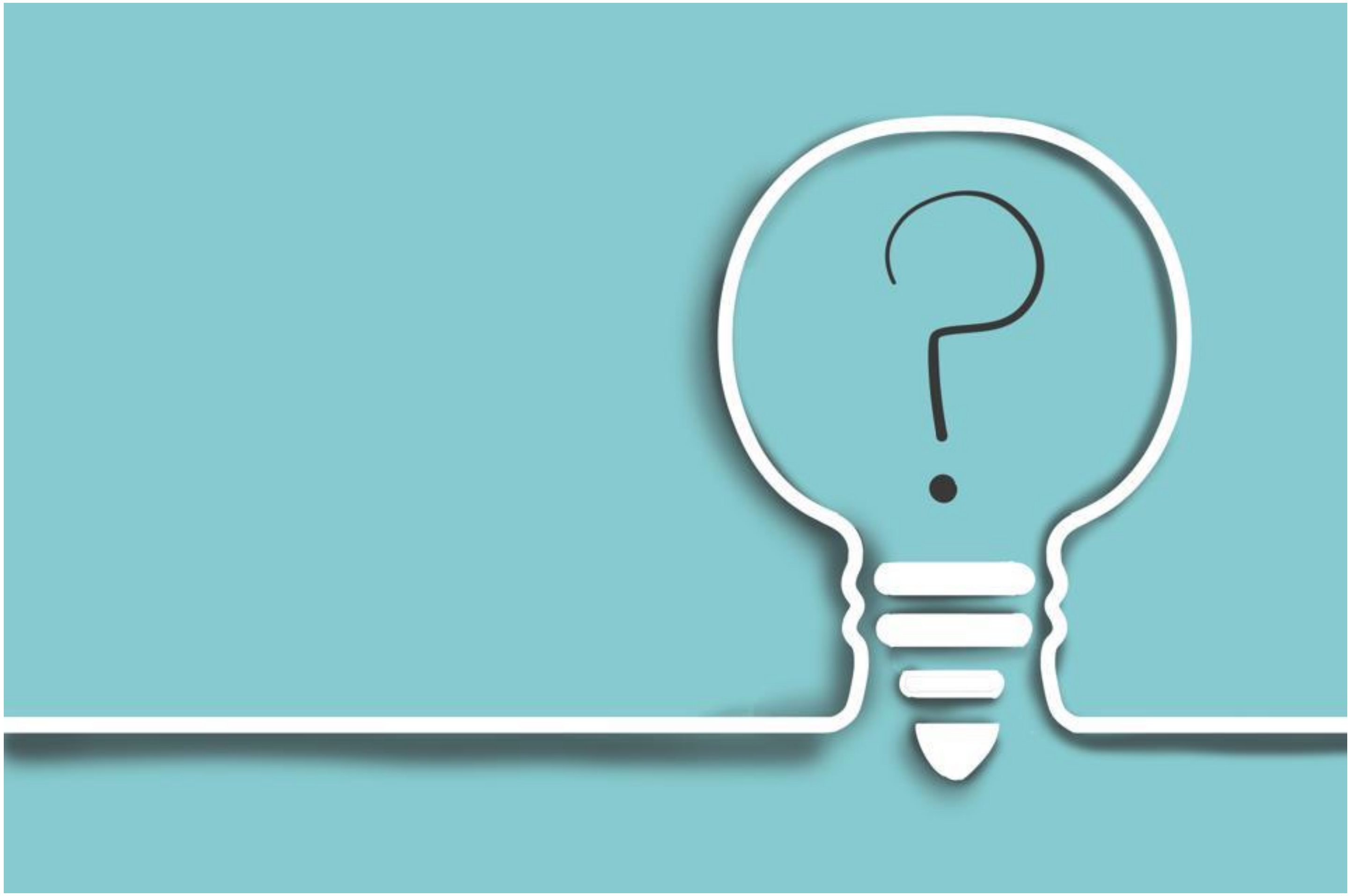

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