Preventing Disinfection By-product Formation

What are some Affordable Alternatives?

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RES'EAU-WaterNET

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Mission

RES'EAU-WaterNET is dedicated to maximizing benefits to small and rural communities by becoming the nation's premier solution provider for the drinking water treatment industry

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"RES'EAU WaterNET's partners leverage their expertise and passions towards affordable technologies and sustainable best practices that will make safe drinking water readily available to all Canadians."

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An NSERC Small Water System Strategic Network

DBPs

What is the problem?

Concern over possible human health risk (epidemiologic studies):

- Risk of bladder cancer; some cause cancer in laboratory animals
- Recent concerns about possible reproductive & developmental effects

Vancouver Sun (Oct. 15, 2011)

DBPs

What are they?

More than 600 DBPs identified

Halogenated DBPs

- Halomethanes
- Haloacids
- Haloaldehydes
- Haloketones
- Halonitriles
- Haloamides
- Halonitromethanes
- Halopyrroles
- Haloquinones
- Halofuranones (e.g., MX)
- Oxyhalides (e.g., bromate)
- Many others

Non-halogenated DBPs

- Nitrosamines
- Aldehydes
- Ketones
- Carboxylic acids
- Others

DBPs

Only 11 DBPs are regulated in U.S.

DBPs	MCL (µg/L)
•Total THMs	80
•5 Haloacetic acids	60
•Bromate	10
•Chlorite	100

Note: No evidence of *regulated* DBPs causing bladder cancer in animals

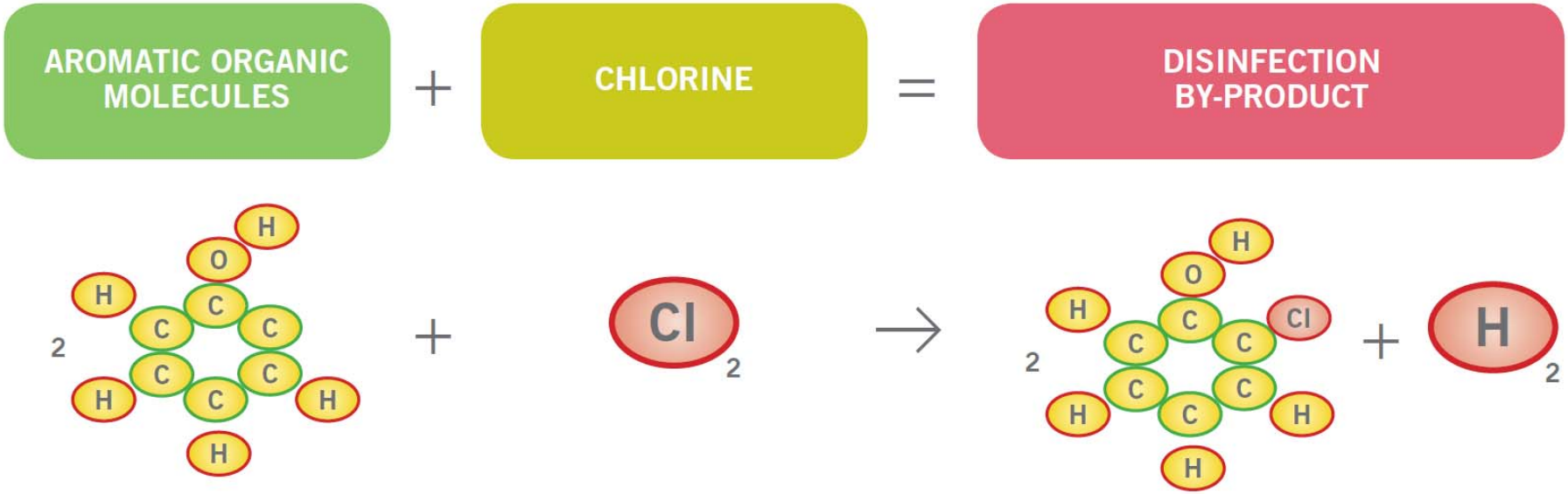
Little known about occurrence, toxicity of *unregulated* DBPs

A few *unregulated* DBPs are animal carcinogens

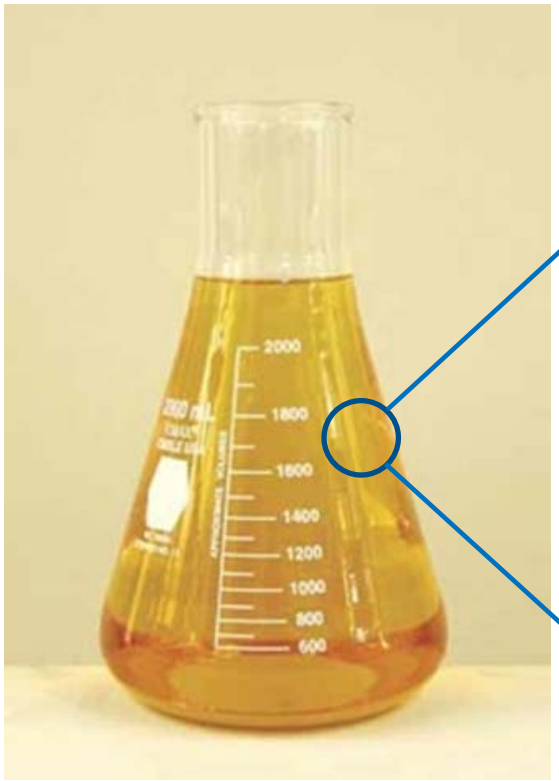
DBPs

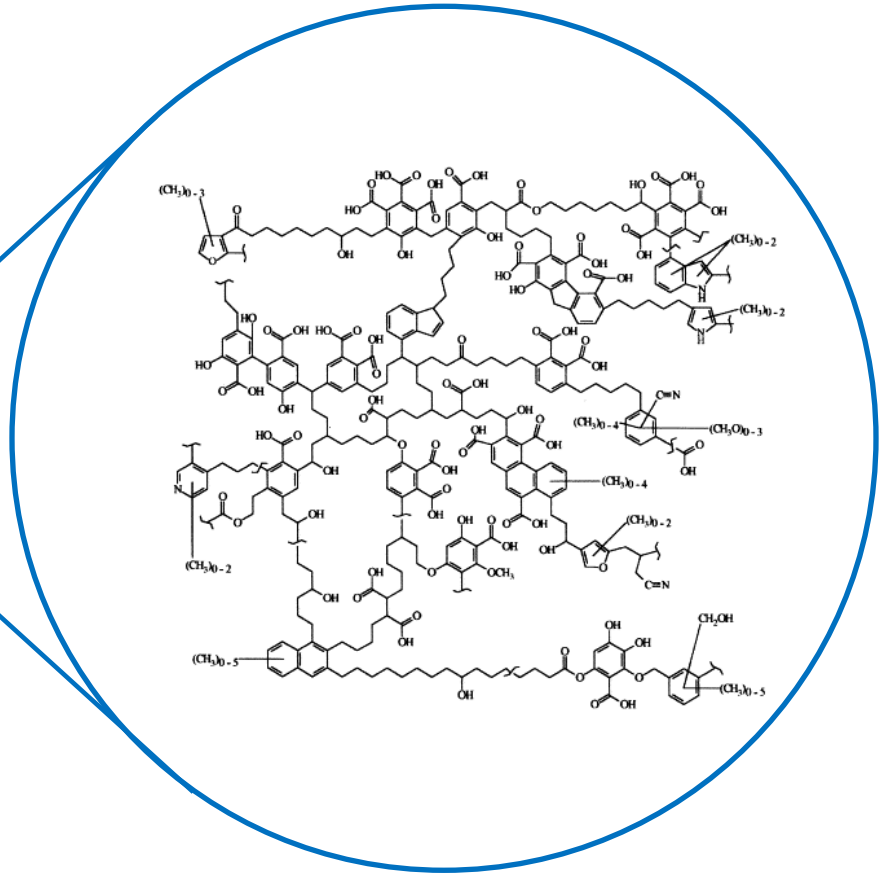
How are they formed?

DBP Formation



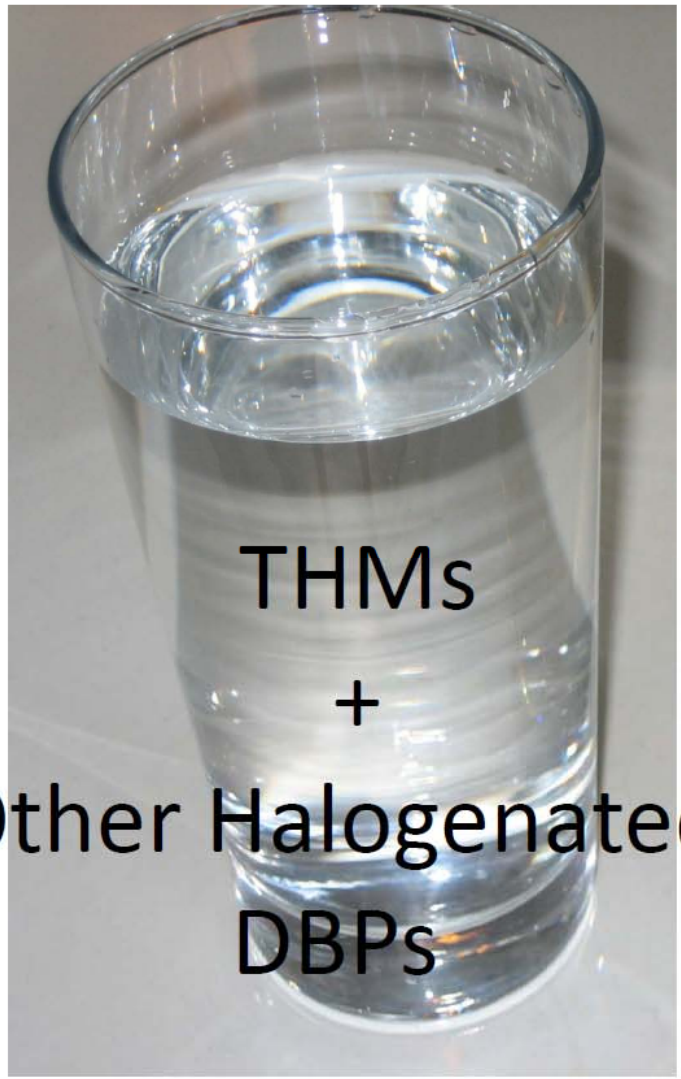
Natural Organic Matter (NOM)





A possible structure of NOM

+ Cl_2



NOM

What is NOM?

- Detritus generated by biological processes
- Complex, highly variable composition

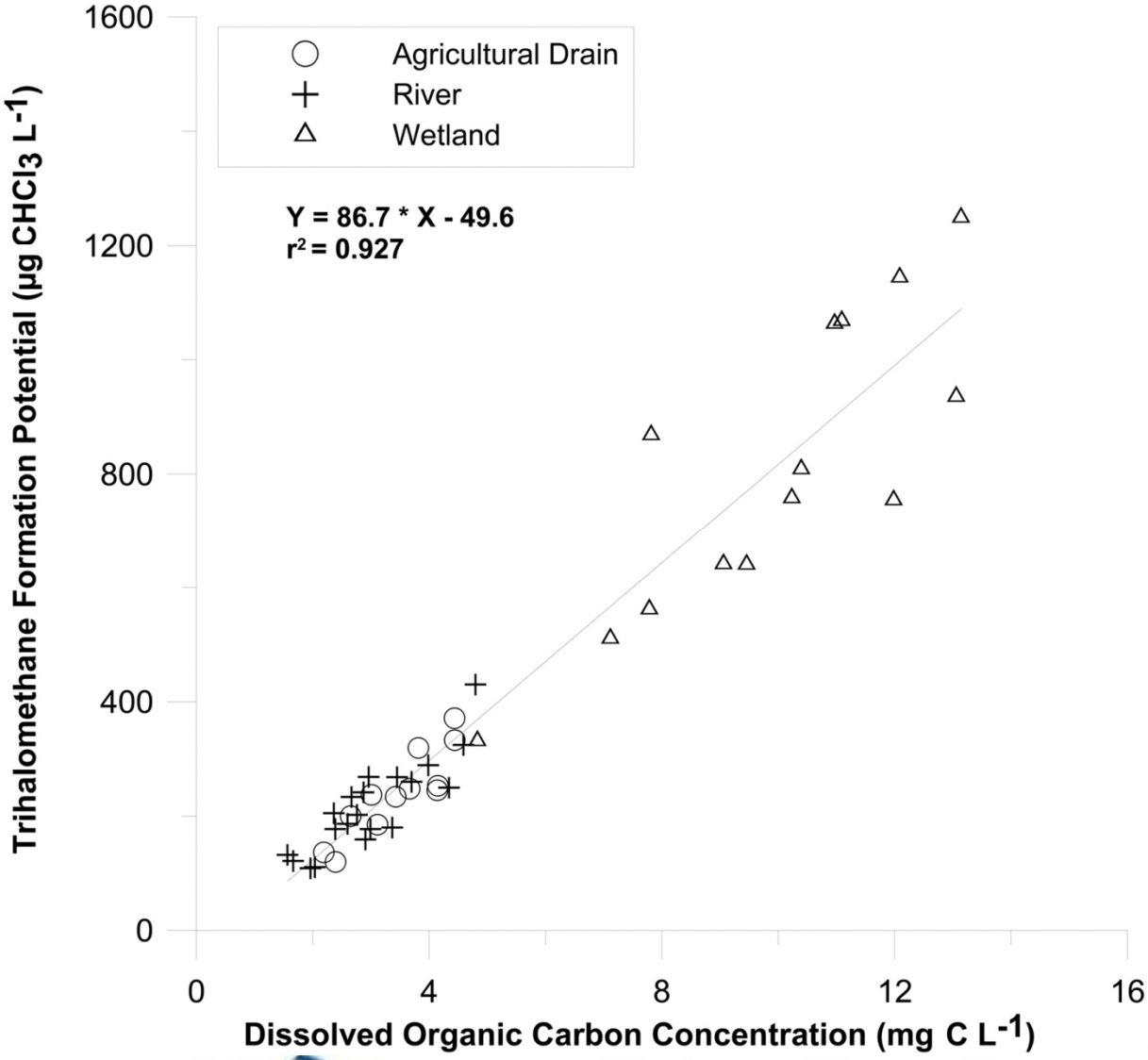
Implications for drinking water treatment

- Precursors to chlorination DBPs
- Bacterial regrowth potential

Implications for advanced processes

- Screening of UV
- Membrane fouling

DBPs and DOC content



Engelage et al. (2009)

DBP Formation Factors

Temperature: Increasing temperature results in increased DBP formation rate

pH: THMs increase somewhat with pH, HAAs increase with decreasing pH

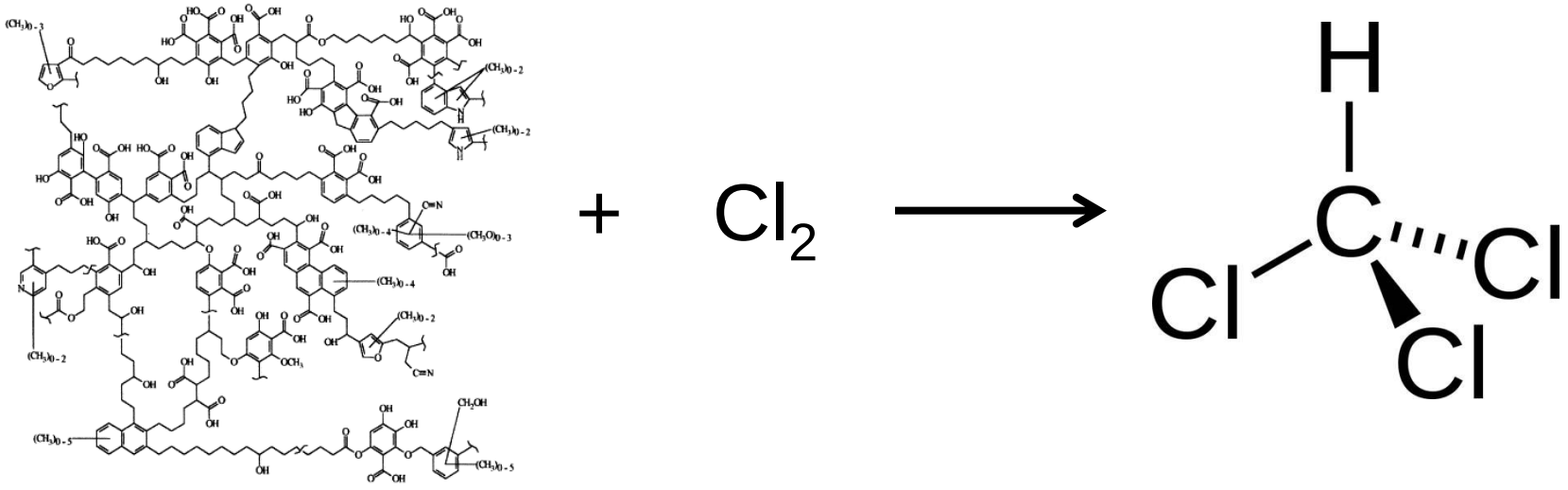
Time: Reaction is rapid for the first few hours and then decreases. Reaction will continue as long as there is disinfectant and precursors

Disinfectant Dose: Increasing dose results in increasing DBP formation

Type and concentration of NOM

What are the alternatives?

- Minimize the use of Cl_2
- Remove NOM

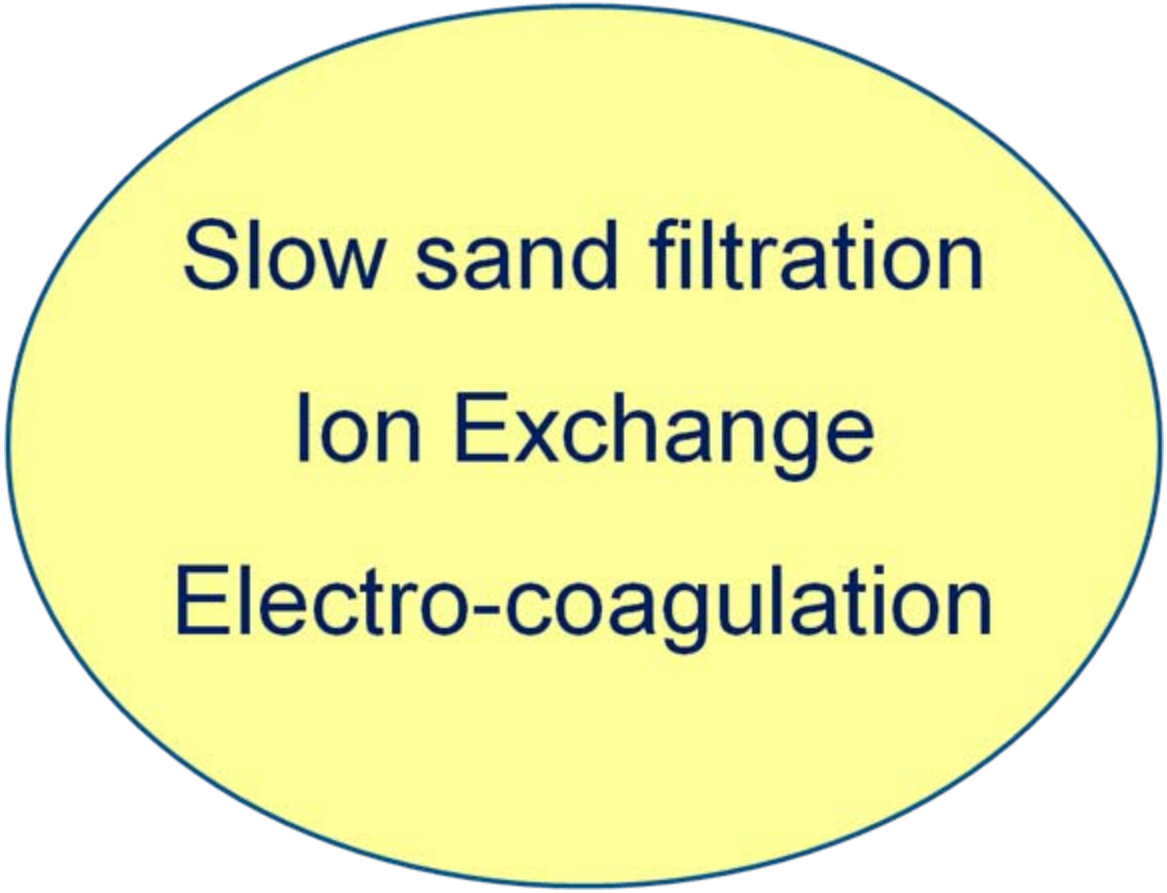


Requirements

NOM Removal Technologies

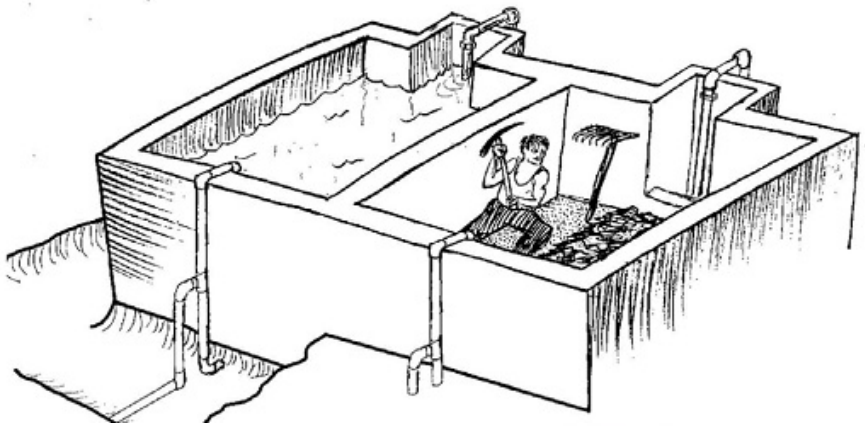
1. Applicable to a range of raw water qualities
   - *Small systems are widely distributed and each has its unique source water that varies seasonally and with climate*
2. Operator-friendly
3. Robust
4. Affordable and cost-effective to operate
5. Low in maintenance
6. Easily serviced with the assistance of remote expertise

Potential Alternatives

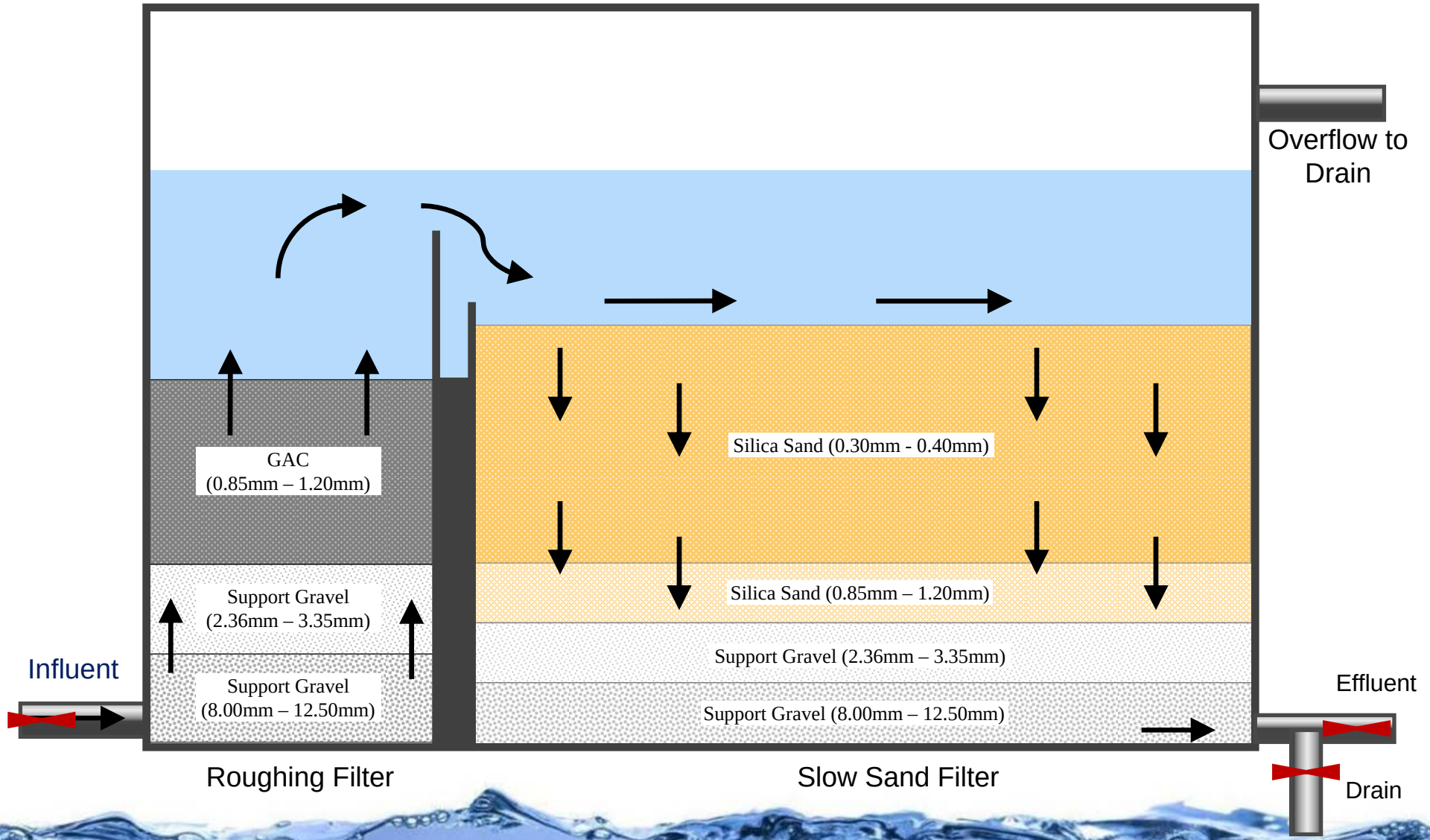


Slow Sand Filter

- Used for more than 150 years for water treatment
- Many advantages
  - Simple technology
  - Low cost
  - Low maintenance
  - Passive treatment
  - No chemicals used
  - Green technology



Multistage Slow Sand Filter



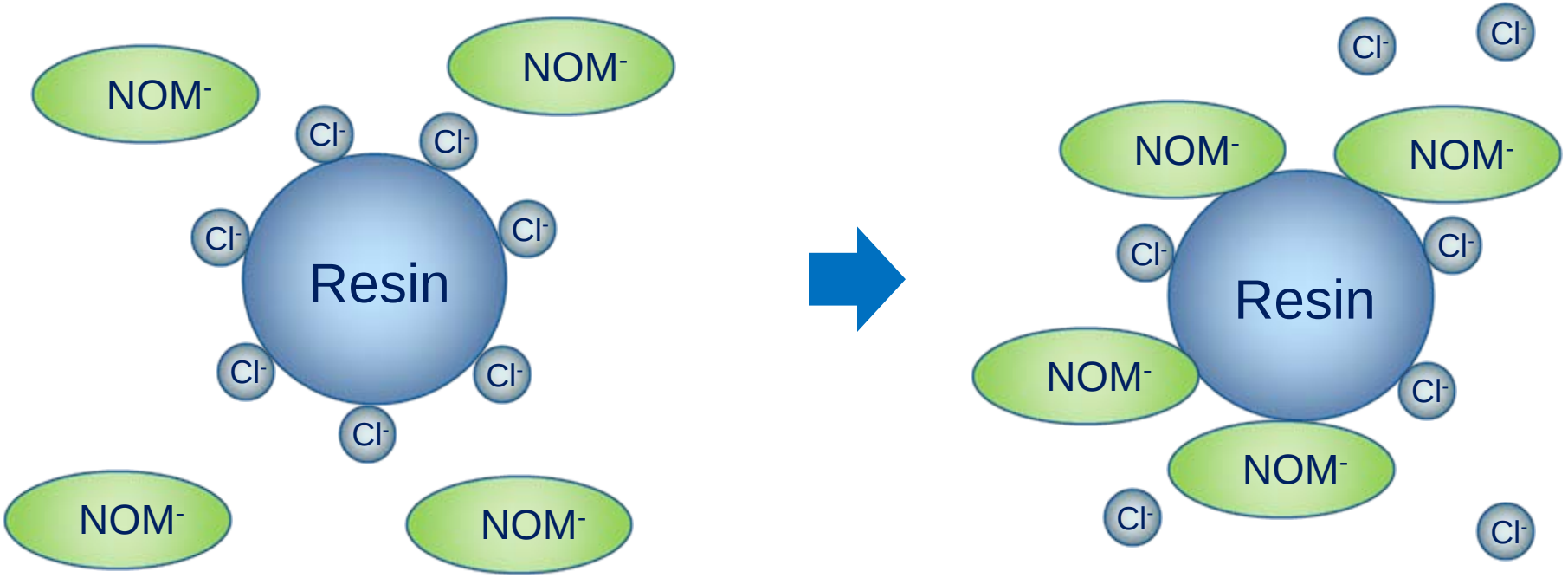
Ion Exchange Resins (IEX)

- Emerging as effective alternatives for the removal of NOM from raw surface water

- Show great promise as pre-treatment to reduce the formation of DBPs and increase the efficiency of many advanced treatments (e.g., H_2O_2/UV, ozone, and membrane)

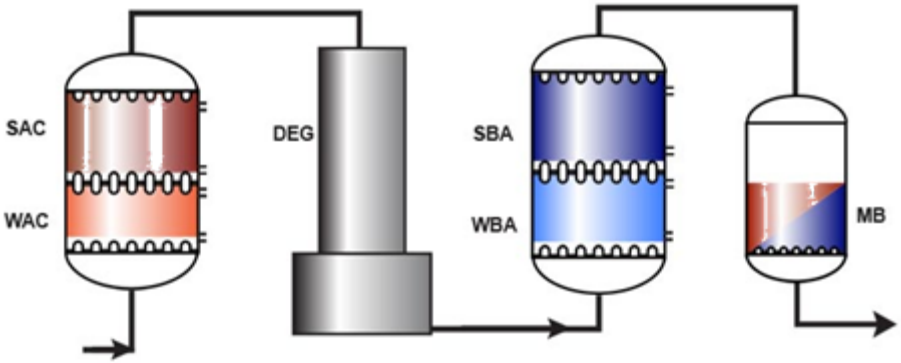
Ion Exchange Resins (IEX)

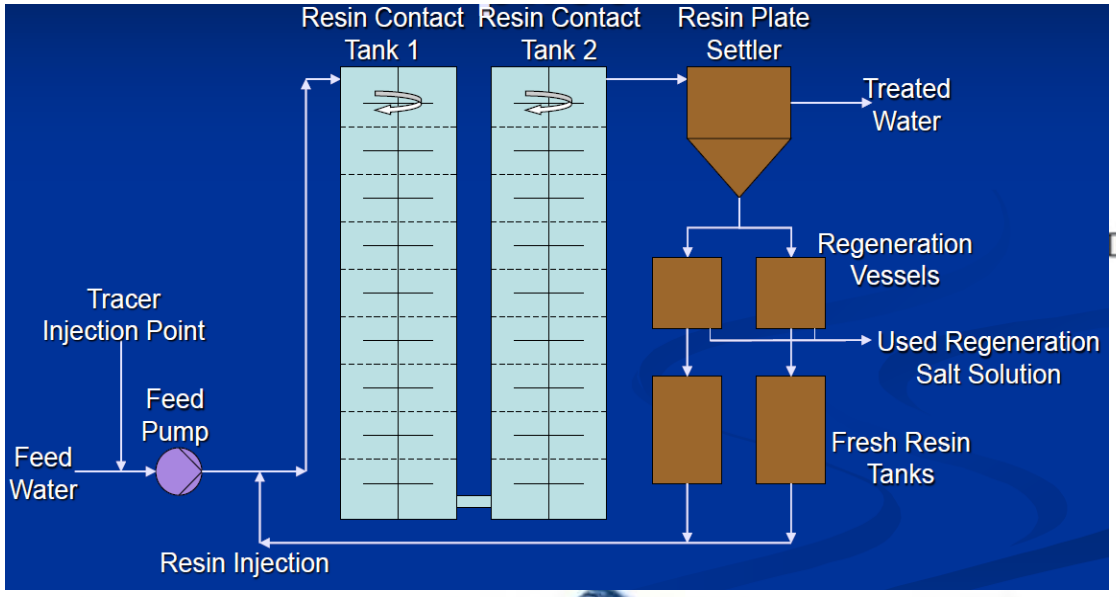
- Removal mechanisms:
  - Ionic exchange of negatively charged NOM
  - Adsorption of neutral NOM

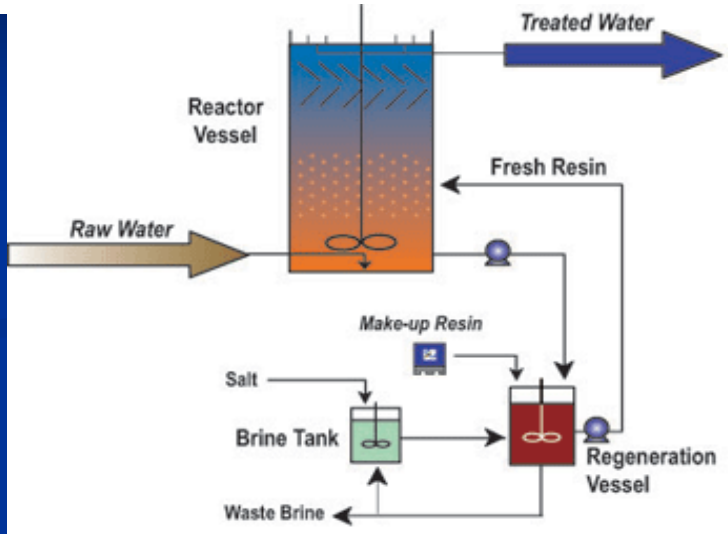


Operational Aspect

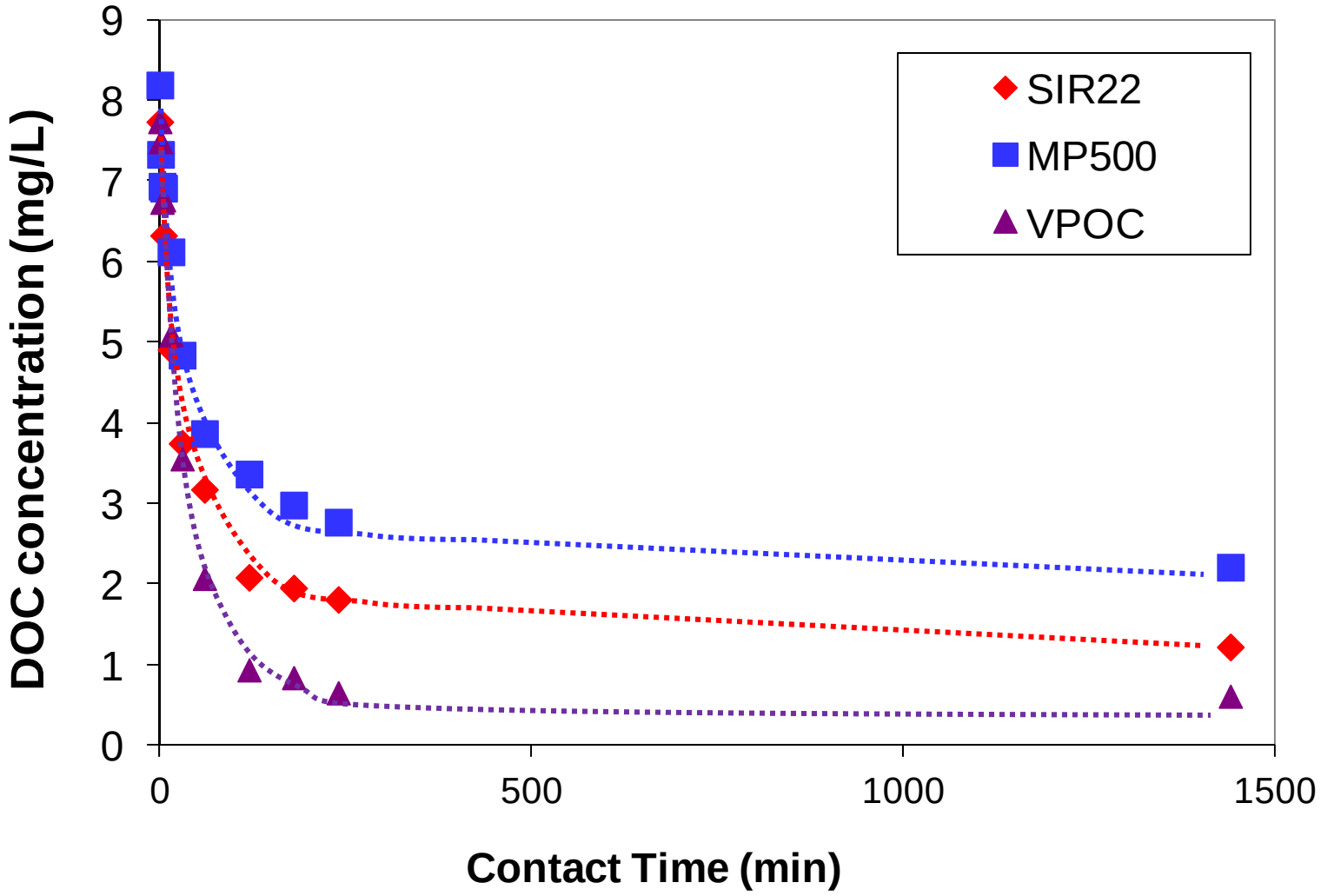
- **Column Operation**
  - Co-flow regeneration
  - Counter flow regeneration
- **Well-mixed**
  - MIEX, other IEX resins
- **Fluidized or Suspended**
  - MIEX or any other IEX resin







DOC removal with IEX - Batch

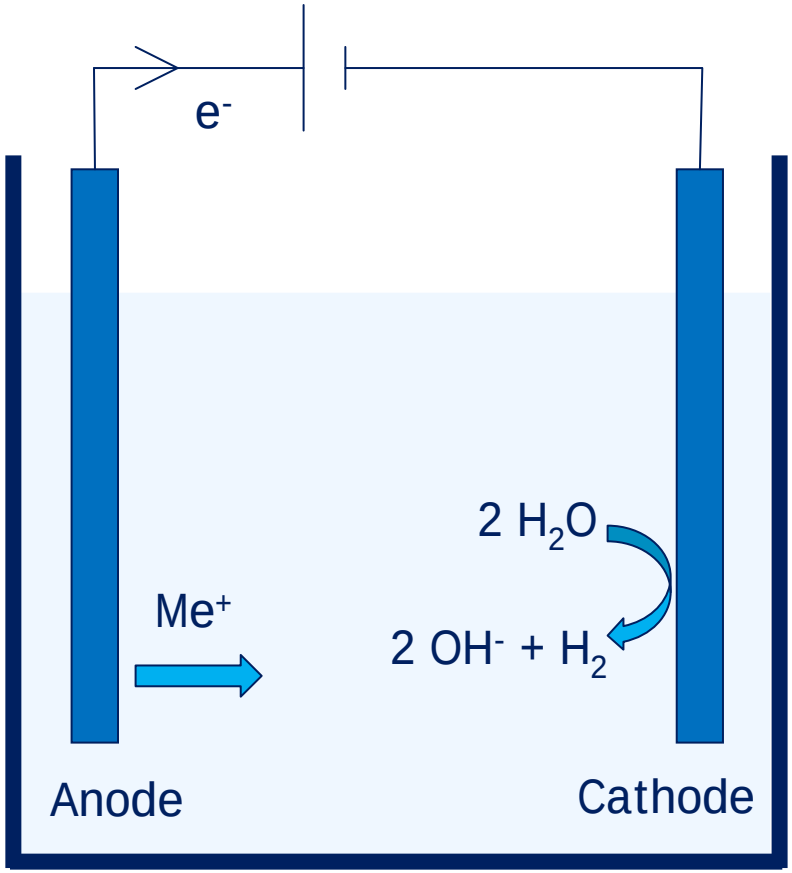


Practical limitations

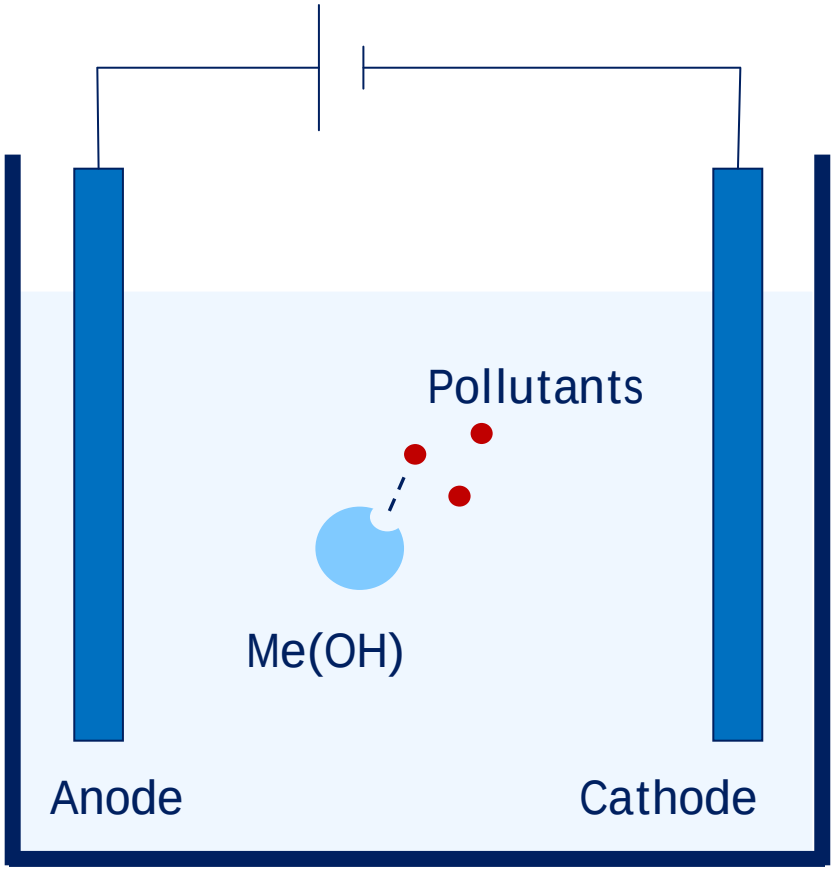
- Affinity difference
- Effective for low concentrations (brackish or sea water)
- Only ionized targets can be eliminated
- **Regeneration (cost, environmental burden)**

Electro-coagulation (EC)

1) Generates coagulant



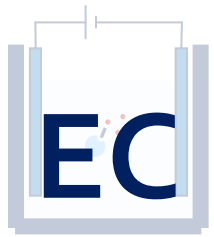
2) Destabilizes and adsorbs pollutants



Electro-coagulation (EC)

Advantages:

1)No chemical supply chain
2)No chemical handling
3)No addition of sulfates or chlorine anions
4)Minimal service: one electrode change per year
5)No pH control necessary
6)Possible flotation removal
7)Tunable to quality, dose changing is electronic
8)Very compact and small footprint



vs

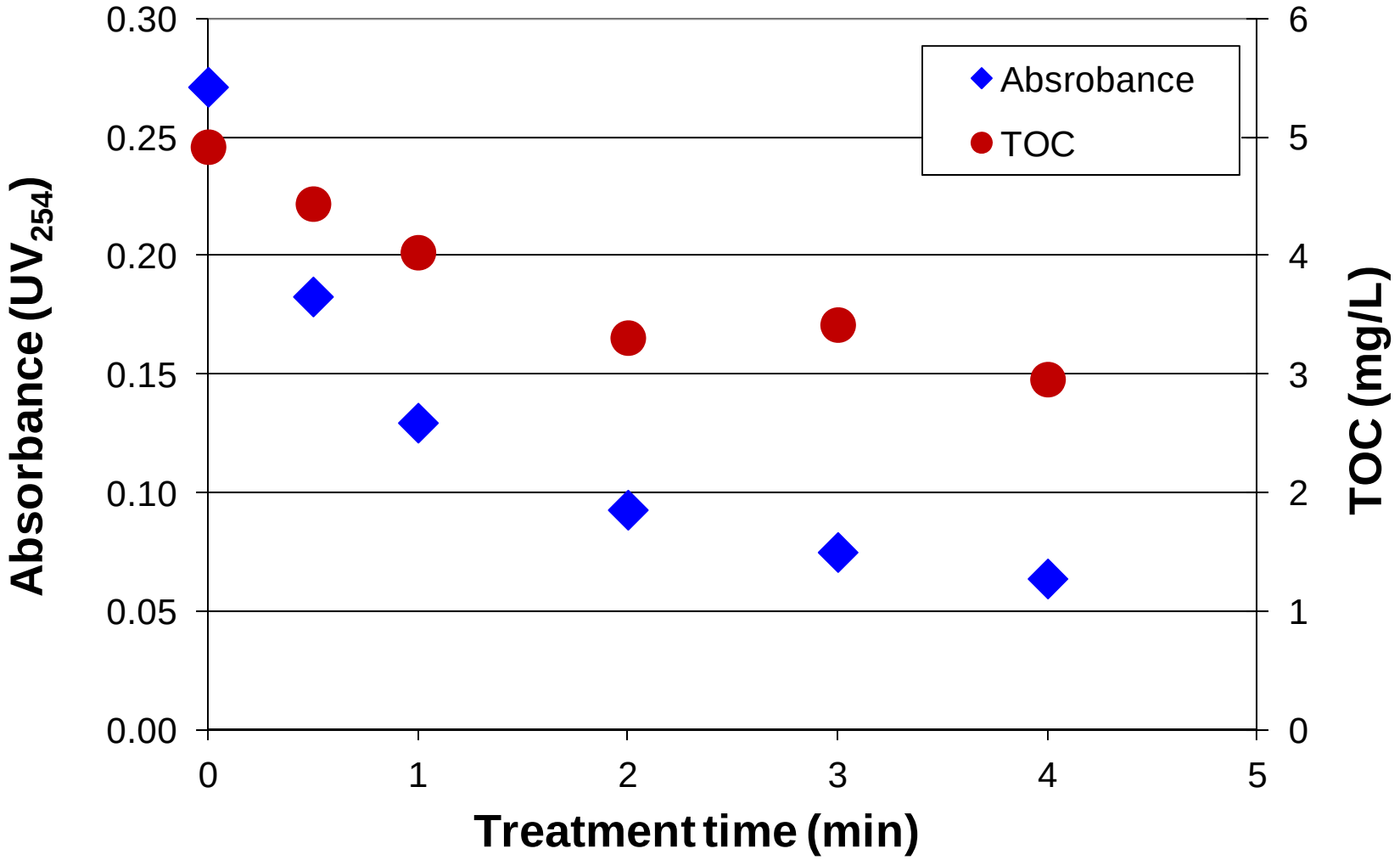
Alum

Disadvantages:

1)Electricity + water?
2)Passivation

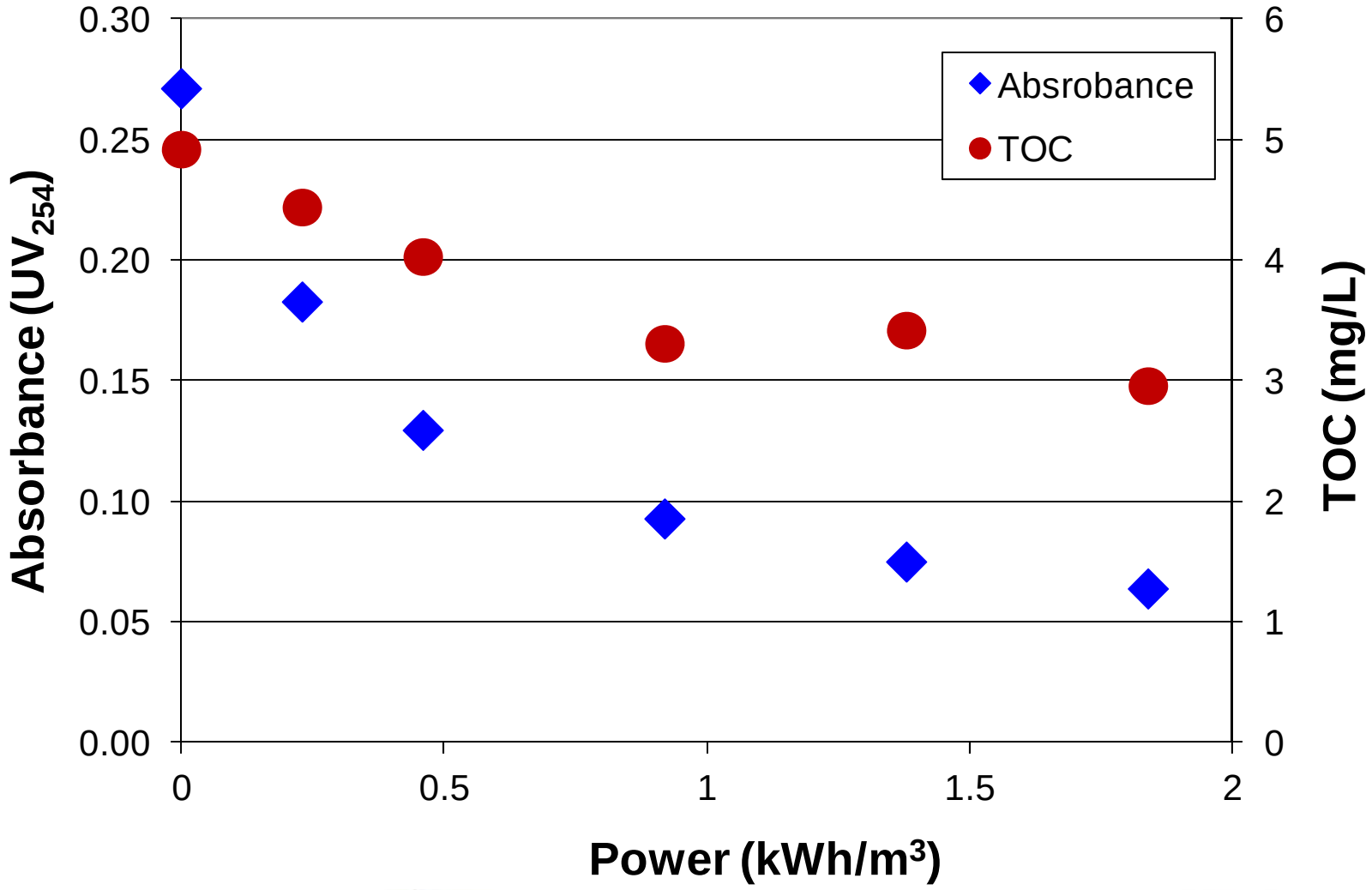
EC for NOM Removal

River Water



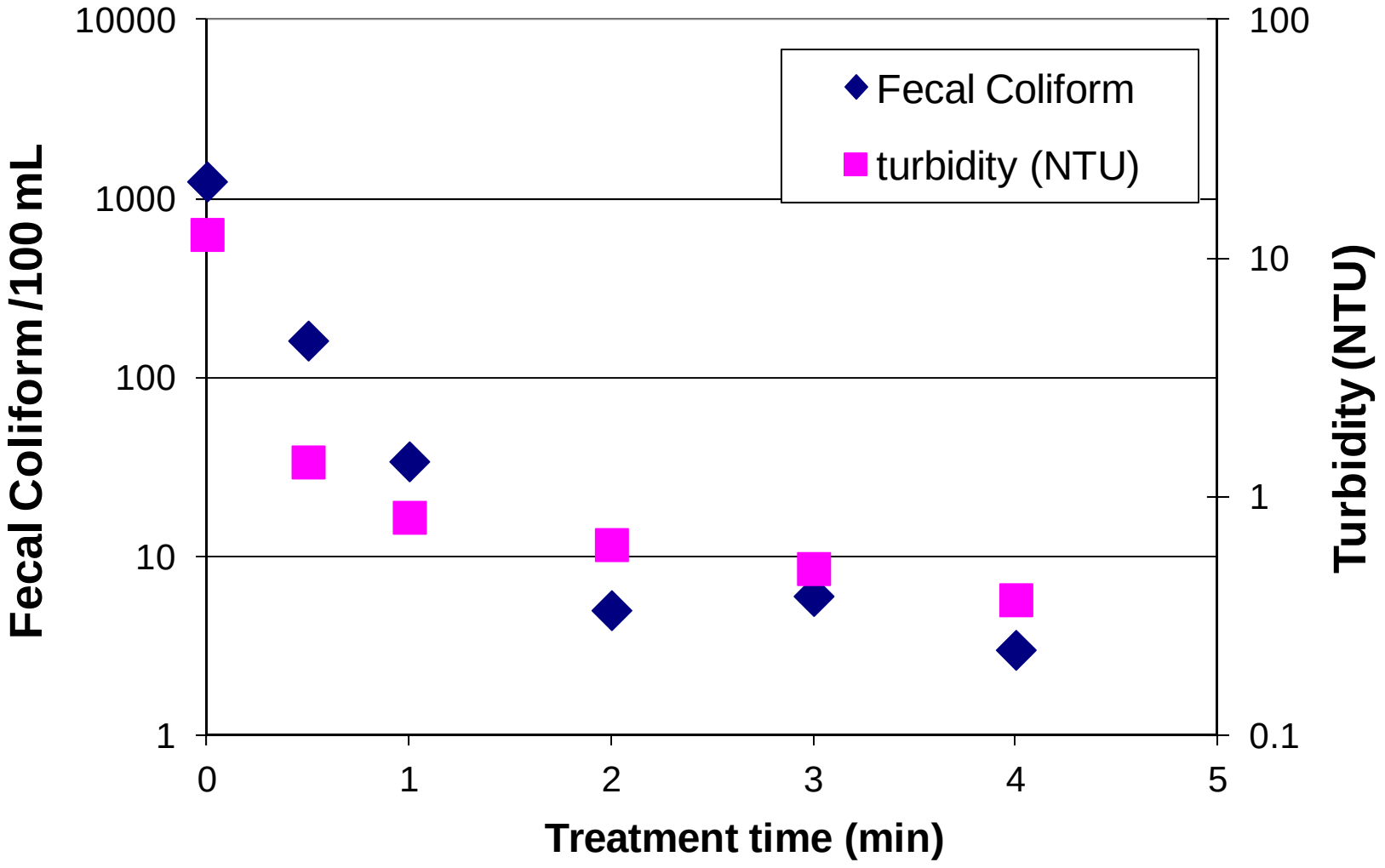
EC for NOM Removal

River Water – energy consumption



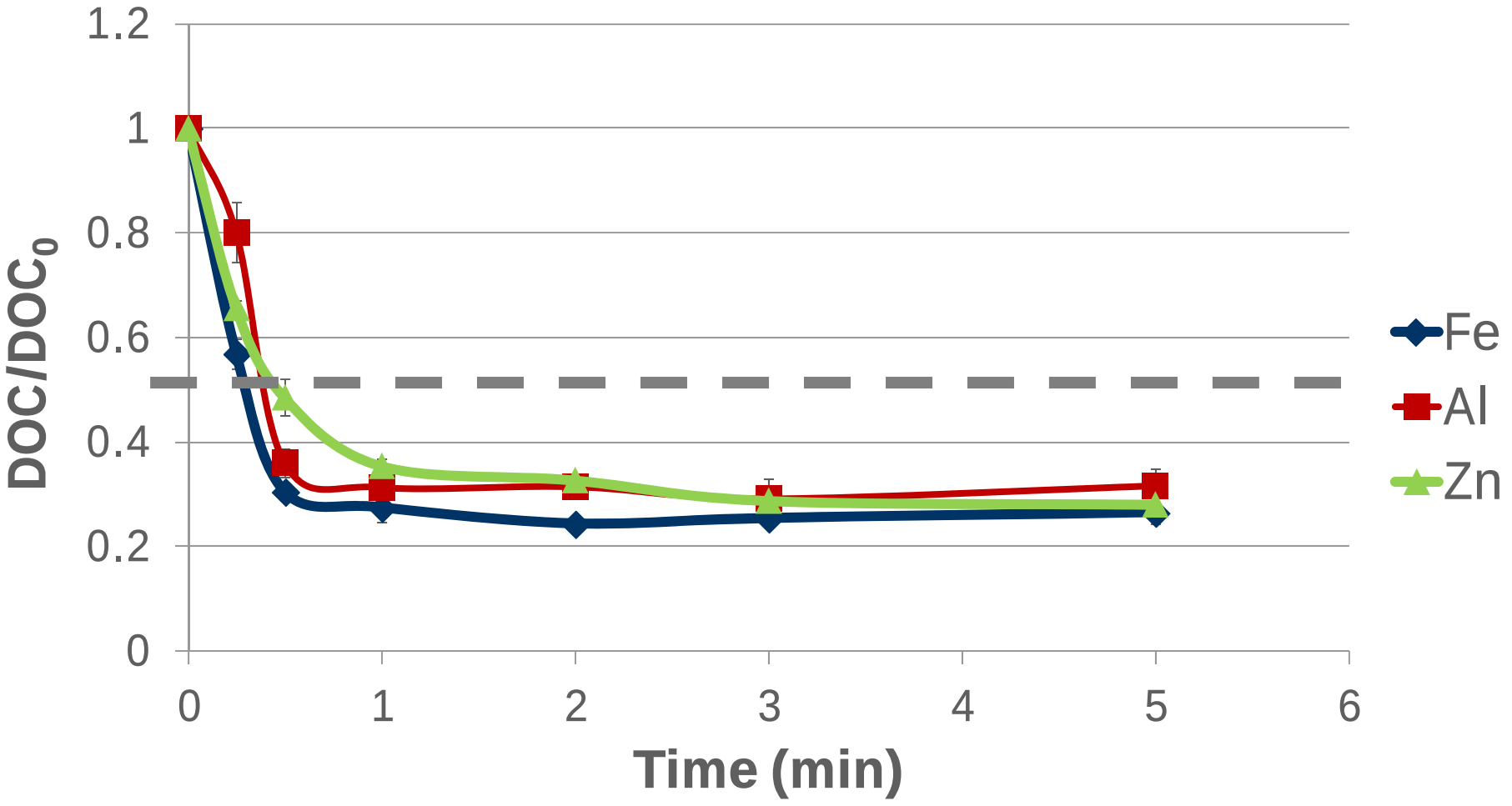
EC for FC and Turbidity Removal

River Water



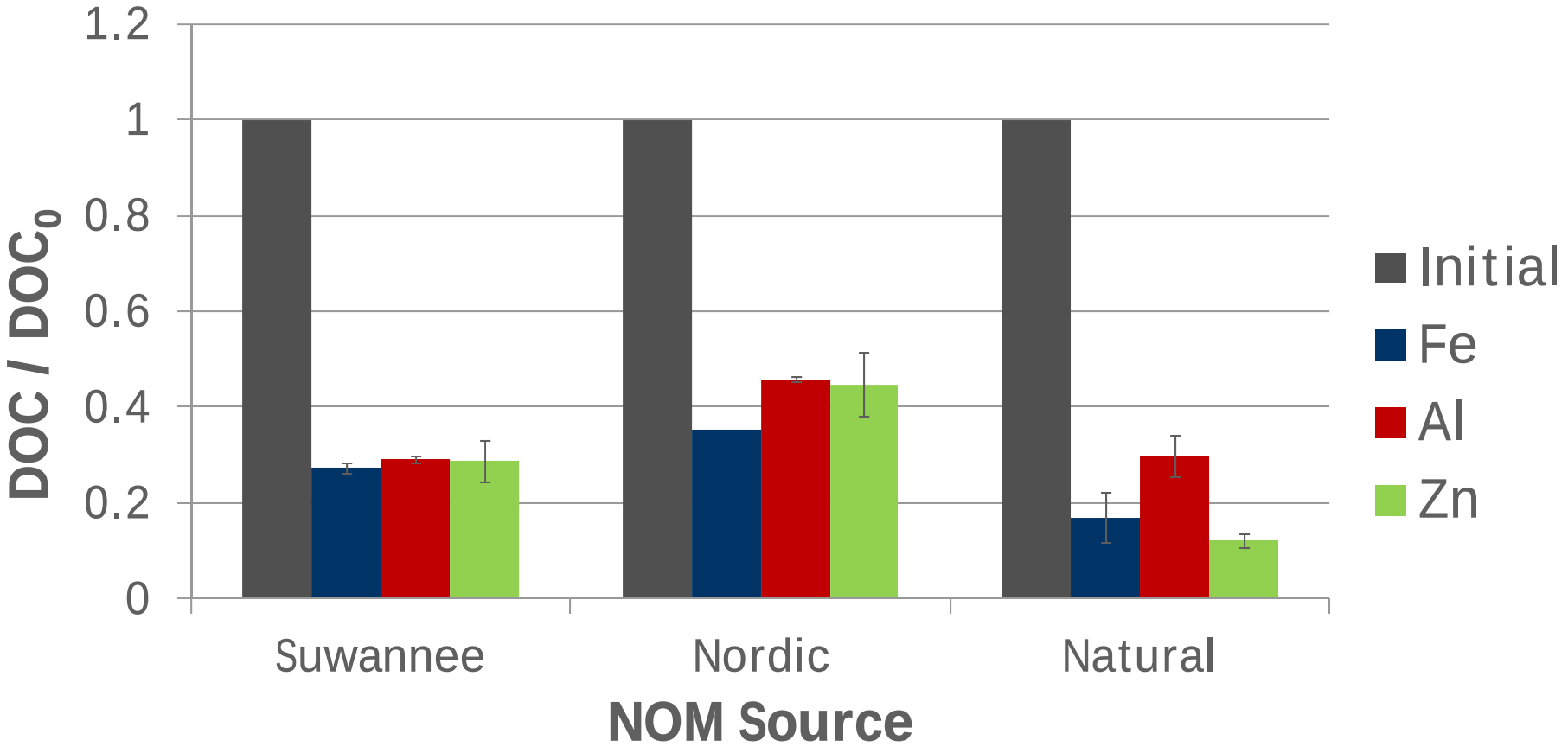
EC for NOM Removal

Comparison of Metals



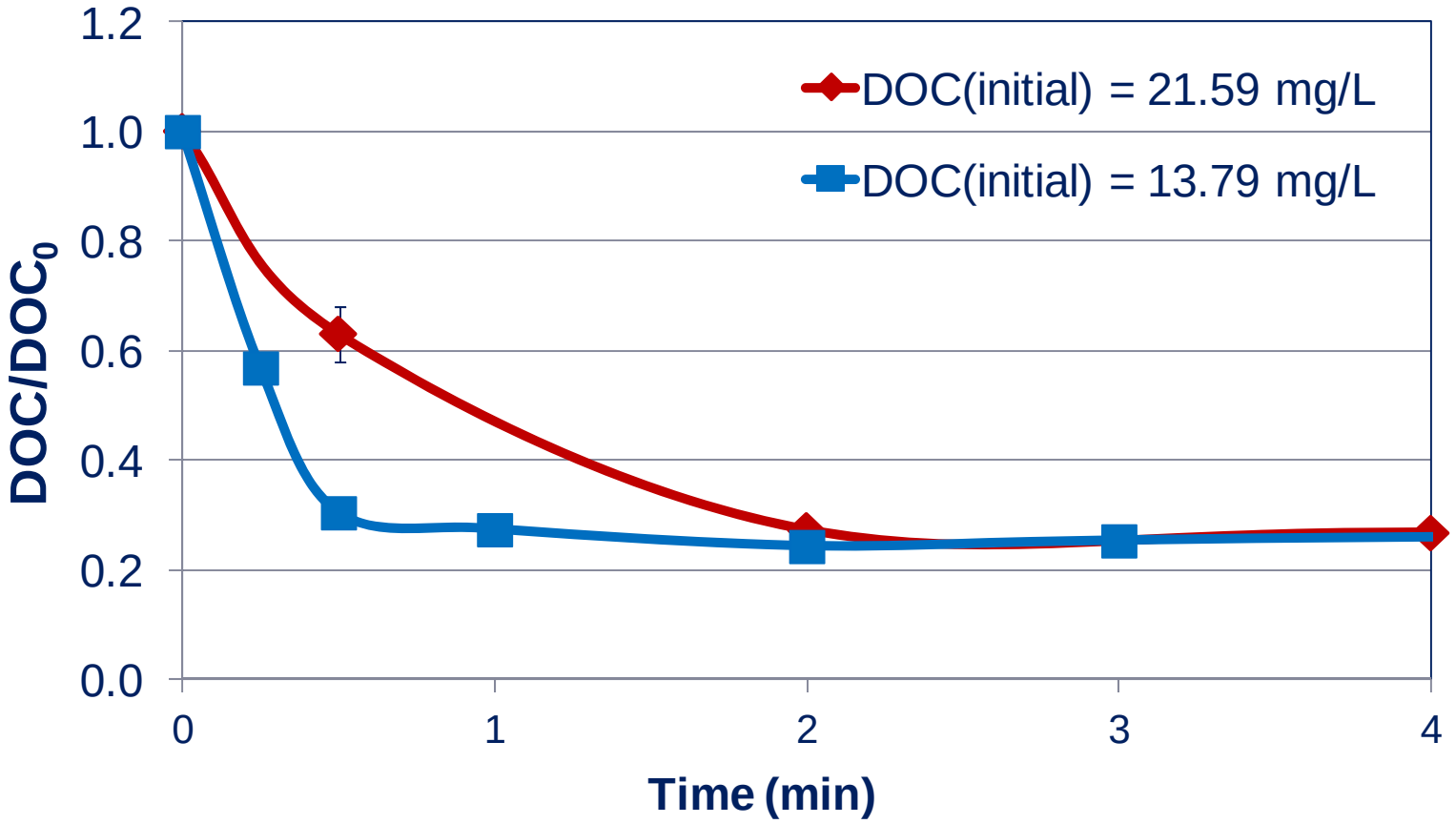
EC for NOM Removal

Comparison of Metals for different waters



EC for NOM Removal

Effect of NOM Concentration



Fraction of NOM that cannot be removed

Take Home Message

Removal of NOM

- Reduces the formation of undesirable by-products
- Increases the efficacy of many water treatment processes (filtration, chlorination, UV-disinfection)
- Saves significant energy associated with downstream processes
- EC and IEX are easily retrofitted to existing facilities

NSERC CRSNG strategic network

RES'EAU WATERNET

UBC a place of mind

University of Victoria

UNIVERSITY OF CALGARY

ÉCOLE POLYTECHNIQUE MONTRÉAL

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Thank You!

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