

Efficacy of Magnetized Ion Exchange versus Ballasted Flocculation as a Pre-Treatment for the Removal of Organic Carbon

Robert Wiersma, P. Eng.
April 2009

NEWWA Spring Joint Regional Conference
Worcester, MA



One Team. Infinite Solutions.



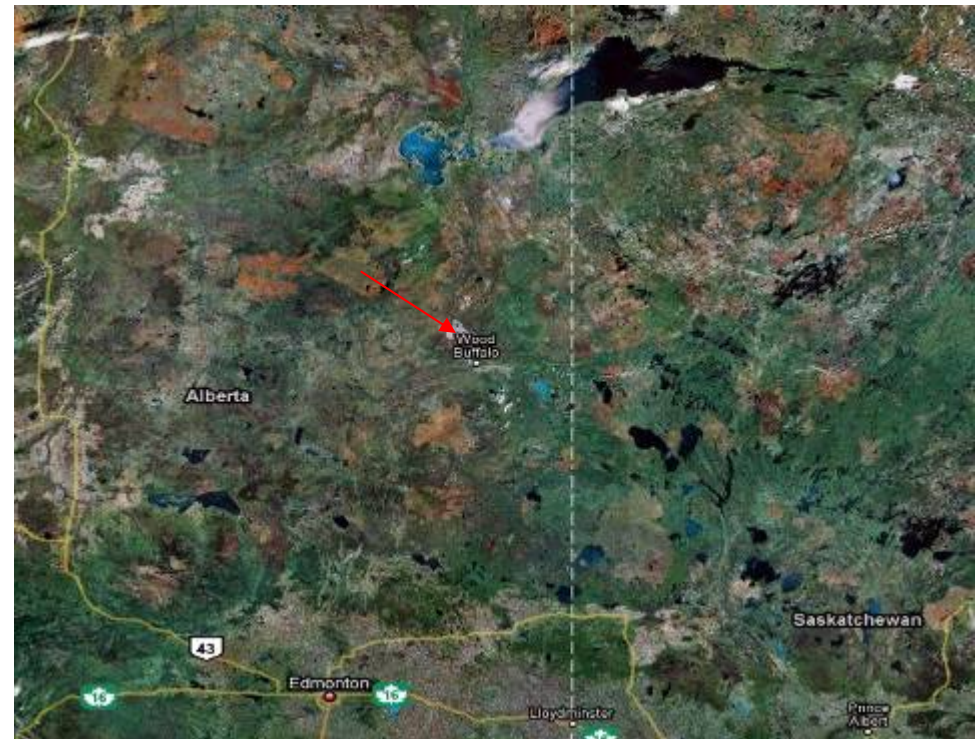
Efficacy of Magnetized Ion Exchange versus Ballasted Flocculation as a Pre-Treatment for the Removal of Organic Carbon

- Engineers aren't boring people, we just get excited over boring things.
--Anon.

Background

Project Context

- Stantec was retained to provide detailed engineering design services to Lockerbie & Hole (L&H) in a design build, own, operate (DBOO) project to construct a Water Treatment Plant (WTP) for a petrochemical firm in Fort McMurray, Alberta
- The preferred treatment technology identified for the facility was a package microfiltration (MF) membrane system supplied by Pall Corporation, with UV-based primary disinfection



Background

Raw Water Source

- The facility will utilize a large raw water storage “pond” fed from the Athabasca River as its raw water source
- This source is characterized by the following specific parameters of concern:
 - High turbidity with periodic extreme events up to 200 NTU
 - High organic carbon concentration
 - High colour
 - Elevated iron

Design Considerations

Raw Water Quality

Parameter	Range	Design	50%	90%	95%	99%
Temperature, °C	0.5 - 25	0.1				
pH	7.0 – 8.1	8.1				
Alkalinity, mg/L C _a CO ₃	45 – 205	187	133	184	187	200
Total Suspended Solids, mg/L	0 – 1,040	360	15	233	360	598
Total Organic Carbon, mg/L	2.6 – 14	11	7.2	10.2	11.0	13.2
UV Transmittance, %	60 - 85	75				
Colour, TCU	-	95	36	72	95	294
Total Iron, mg/L	0 – 1.2	0.866	0.100	0.212	0.275	0.866
Total Aluminum, mg/L Al ₂ O ₃	-	2.5				
Turbidity, NTU	1.7 – 300	55	6.5	42	133	270

Design Considerations

Impact on Preferred Treatment

- A desktop level evaluation of the raw water quality highlighted the following potential limitations to the membrane filter system:
 - operation (e.g., maximum acceptable turbidity)
 - performance (i.e., incapacity to remove dissolved species)
- The impacts of the raw water on the membrane were categorized in terms of priority as follows:
 - 1) Organic Matter (DOC and TOC, respectively)
 - 2) Turbidity
 - 3) Colour
 - 4) Iron

Treated Water Quality Criteria

- Treated water quality was required to meet the following key objectives:

Parameter	Objective/ Limit
Viruses, Log-Inactivation	4
Giardia, Log-Inactivation	5.5 ¹
Cryptosporidium, Log-Inactivation	5.5 ¹
Fecal Coliforms, cfu/100mL	0
Turbidity, NTU	0.1 ²
TDS, mg/L	<500
Particle Counts, No./mL	20 ^{3,4}
Colour, TCU	<15
Iron, mg/L	0.3
Manganese, mg/L	0.08
Aluminium, mg/L	0.1
Disinfectant Residual, mg/L	0.1 – 2.5
Disinfection Byproducts, µg/L:	
<ul style="list-style-type: none"> Trihalomethanes (four species; THM) Bromodichloromethane Haloacetic acids (five species; HAA5) 	100 <16 80 ⁵
1. Due to lack of information on cysts / oocysts concentration in the raw water, the worst-case scenario was assumed. 2. Exceedance of this limit is allowed up to 0.3 NTU for a cumulative period of 15 minutes per day into the clearwell. 3. Exceedance of this limit is allowed up to 50 particles/mL for a cumulative period of 15 min/d, for discharge into the clearwell. For those membranes that operate under vacuum, where air entrainment may be a problem, exceedance of this limit is allowed up to 200 particles/mL for a cumulative period of 30 min/d. 4. Particles larger than 2µm. 5. CGDWQ proposed MAC.	

Design Considerations

Design Flows

- Based on the pre-design report prepared by Bantrel Inc. (2006), the following WTP flows were adopted by Stantec:

Average Day	518 m ³ /day	(95 USgpm)
Maximum Day	1,363 m ³ /day	(250 USgpm)
Design Flow	2,045 m ³ /day	(375 USgpm)

- To account for losses in pre-treatment and the membrane treatment process, a design flow of 2,300 m³/day was set for the pre-treatment equipment

Design Considerations

Performance Criteria for Pre-Treatment

- The following performance criteria were required for the pre-treatment process:

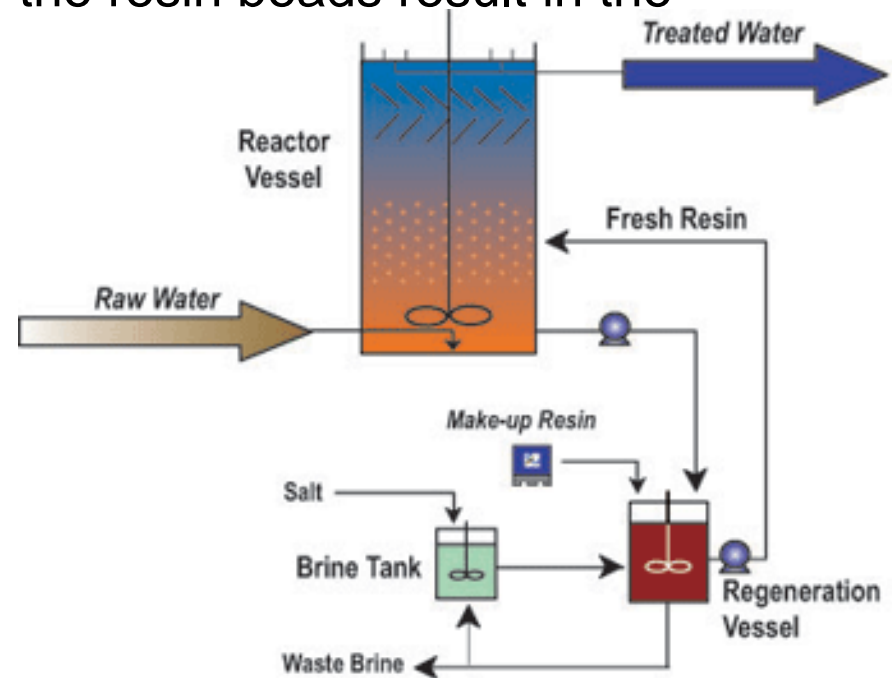
Quality Parameter	Acceptable Performance Criteria	Operating Goals
pH	>6	6.5 – 8.5
Raw Water Turbidity ¹		
<25 NTU	< 3	< 1
25 NTU < Turb. < 100 NTU	< 5	< 3
> 100 NTU	< 10	< 5
Colour, TCU	< 10	< 5
TOC Reduction, %	> 55	> 60
Polymer Carryover, mg/L	<0.1	<0.1

Pre-Treatment Technologies

Magnetic Ion Exchange (MIEX[®])

- The process is “designed specifically to be used in a continuous ion exchange process that utilizes the high surface area of the resin beads to provide ion exchange in mixed or fluidized bed reactors at very low resin concentrations and short detention times. The magnetic properties of the resin beads result in the beads forming agglomerates that will settle rapidly or fluidize at high hydraulic loading rates...”

Description and image: Orica Watercare



Pre-Treatment Technologies

Ballasted Flocculation (Actiflo[®])

- Ballasted flocculation is a process that works on the premise that better flocculation is achieved with a higher number of suspended particles and the large diameter particles represent the higher proportion.
- Microsand is added along with coagulant and polymer to create sites for floc to form.

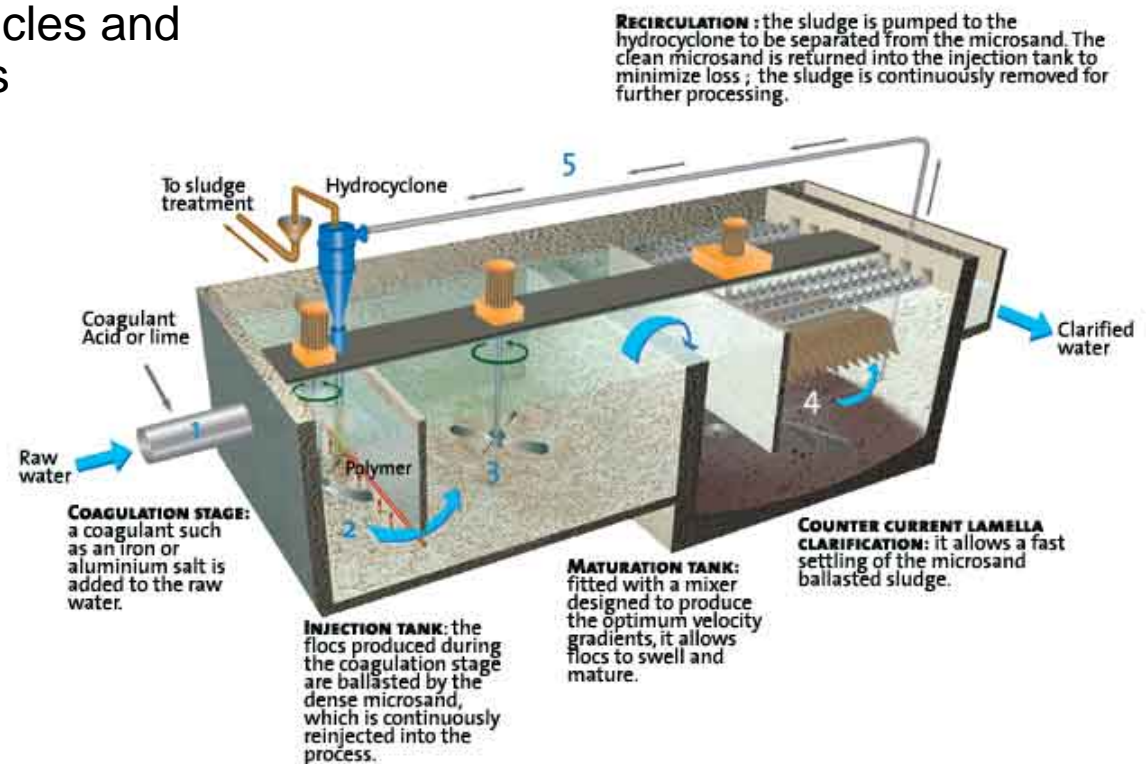


Image: Veolia Water

Description: Scott Alpert, PE, HDR Engineering (AWWA, 2002)

Pre-Treatment Technologies

Suitability for the Proposed Application

- Both MIEX and Actiflo are applicable for water treatment applications with high organics where smaller footprint is required relative to other conventional processes
- Both technologies are capable of treating low temperature water
- MIEX allowed for a minimum of chemical additions to the treatment process
- Actiflo further provides for consistent removal of turbidity, oxidized iron and colour

Pre-Treatment Technologies

Bench-Scale Testing

- Orica Watercare (MIEX) and John Meunier Inc. (Actiflo) undertook bench-scale testing of the raw source water as part of the initial process selection
- Notes:
 - The bench-scale evaluations did not reflect the treatment efficiency during worst-case conditions, but provided a comparative evaluation of the treatability of the Athabasca River water by MIEX and BF systems
 - As the tests were conducted by the vendors, there was no standardized methodology, so the test parameters differ
 - Turbidity criterion not applicable to MIEX

MIEX

Bench-Scale Testing

- Orica Watercare tested samples of the source water for organics removal under two temperature conditions: 5°C and 20°C
- DOC:
 - 66% removal @ 5°C
 - 70% removal @ 20°C

Parameter	Raw Water	Treated Water	
		600 BV	800 BV
pH	8.2	7.8	8.0
Temp, °C	NA	5	5
UV Abs. 254nm, cm ⁻¹	0.163	0.043	0.049
UV Transmittance, %	68.7	90.1	89.3
DOC, mg/L	5.59	1.7	1.9
Turbidity, NTU	82.6	-	-
True Colour, Pt-Co	29	25	22
Alkalinity, mgCaCO ₃ /L	100	80	-
Sulfate, mg/L	29.8	12	-
Chloride, mg/L	5	55	
Total iron, mg/L	0.035		

MIEX

Bench-Scale Testing

- Simulated distribution system (SDS) tests were performed.
- A sample was collected from an equivalent 800 bed volumes (BV) and SDS tests were carried under the following conditions:
 - Incubation temperature: 20°C
 - Incubation pH: approximately 8 (unadjusted)
 - Incubation period: 3 days
 - Target chlorine residual: 0.5 – 1.0 mg/L
- Samples were dosed with chlorine and tested for HAA and TTHM

Sample	TOC (mg/L)	DOC (mg/L)	Chlorine Dose (mg/L)	Chlorine Res. (mg/L)	SDS-HAA5 (µg/L)	SDS-TTHM (µg/L)
Raw	5.7	5.6	7.0	0.8	190	283
Treated	-	1.9	3.5	1.1	28	51

MIEX

Bench-Scale Testing

- Results:
 - MIEX successfully reduced the DOC to acceptable concentrations
 - The UVT of the pre-treated water was increased
 - HAA and TTHM is reduced
 - No pH impacts were observed
 - As expected, no iron removal or turbidity treatment is provided
- Process Concerns:
 - Lack of iron removal and turbidity reduction will impact downstream membrane equipment sizing and performance

Actiflo

Bench-Scale Testing

- John Meunier Inc. (JMI) tested samples of the raw source water to evaluate the Actiflo process as a pre-treatment alternative
- The samples were tested under the following conditions:
 - Simulated rise rate – 40 m/h
 - Sand concentration – 10 mg/L
 - Test temperature – 5°C
 - Hydraulic residence time – 2 minutes (with two additional tests performed at four and six minutes, respectively)
- Additionally, different combinations of coagulants and polymers were tested at different concentrations

Actiflo

Bench-Scale Testing

- The results obtained from JMI were summarized as follows:

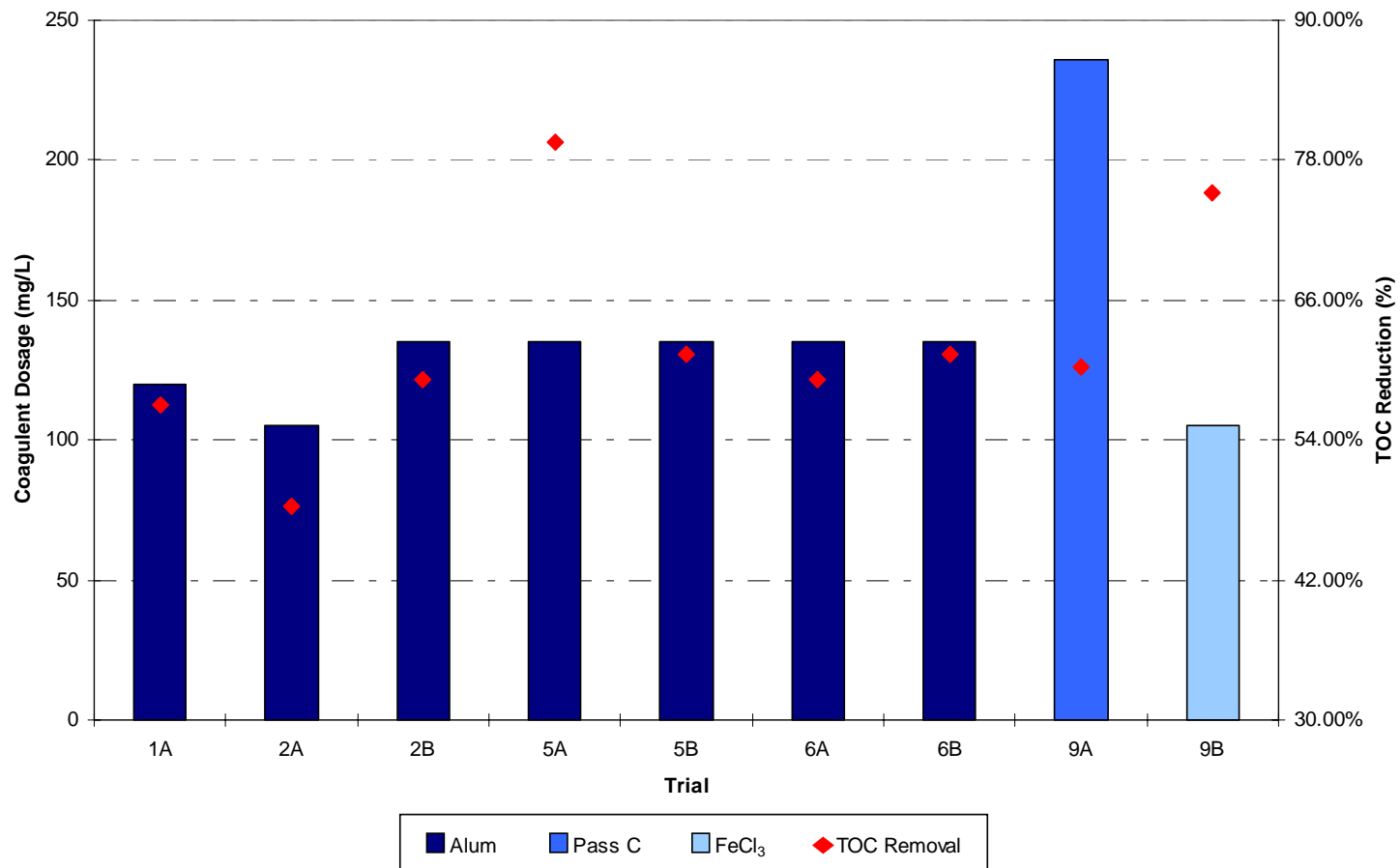
Sample	Coagulant		Polymer		pH	Turb. (NTU)	TOC (mg/L)	Colour		UV		Iron (mg/L)	Al (mg/L)
	Type	Dose mg/L	Type	Dose mg/L				App.	True	Abs. (cm ⁻¹)	Trans (%)		
Raw	-	-	-	-	8.2	7.1	9.3	88	39	0.286	51.8	0.232	0.007
1A*	Alum	120	LT22S	0.2	6.5	1.3	4	10	<2	0.056	87.9	0.012	>0.275
1B*	Alum	105	LT22S	0.2	6.7	2.5	4.8	19	<2	0.059	87.3	0.036	0.080
5A*	Alum	135	LT22S	0.25	6.2	1.4	1.9	11	2	0.050	89.1	0.016	>0.275
6B**	Alum	135	LT22S	0.25	6.3	1.2	3.6	11	3	0.050	89.1	0.017	>0.275
9A*	PassC	200	LT27A G	0.25	5.6	0.8	3.7	12	4	0.058	87.5	0.027	0.166

* 2 minutes contact time
 ** 6 minutes contact time

Analysis

Actiflo Data

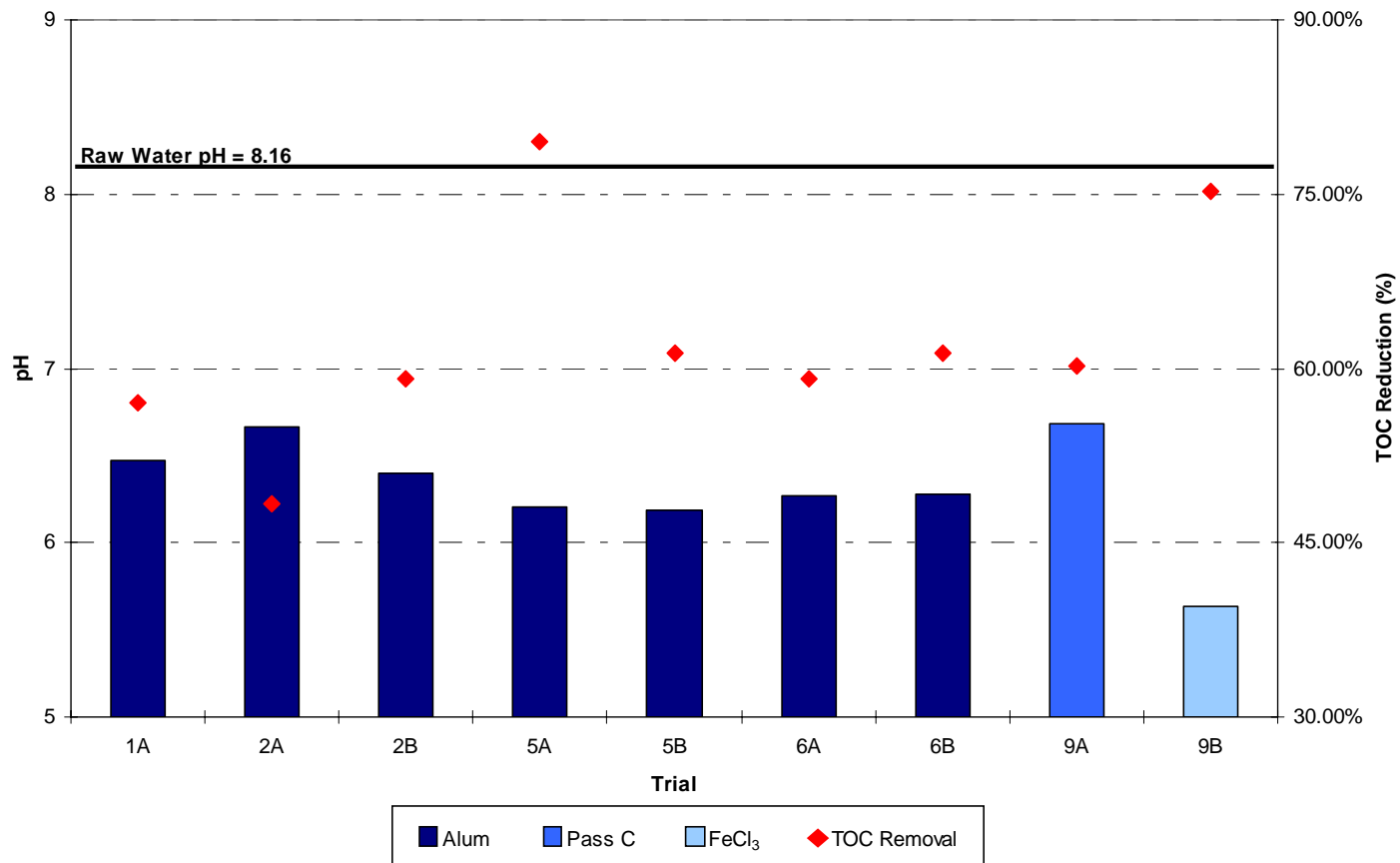
Coagulant Dose & TOC per Run



Analysis

Actiflo Data

pH & TOC per Run



Actiflo

Bench-Scale Testing

- Results for alum in combination with polymer:
 - Actiflo effectively removed TOC
 - The UVT of the water was effectively increased
 - Iron from the raw source water was effectively reduced
 - pH lowered (range of 6.2 – 6.7)
 - Aluminum concentration elevated above the Operational Guideline (with one outlying event)

Actiflo

Bench-Scale Testing

- Results for polyaluminum chloride in combination with polymer (one test):
 - Actiflo effectively removed TOC
 - The UVT of the water was effectively increased
 - Iron from the raw source water was effectively reduced
 - pH sharply reduced (5.6)
 - Increase in residual aluminum, but not above the OG

rw23

Slide 22

rw23

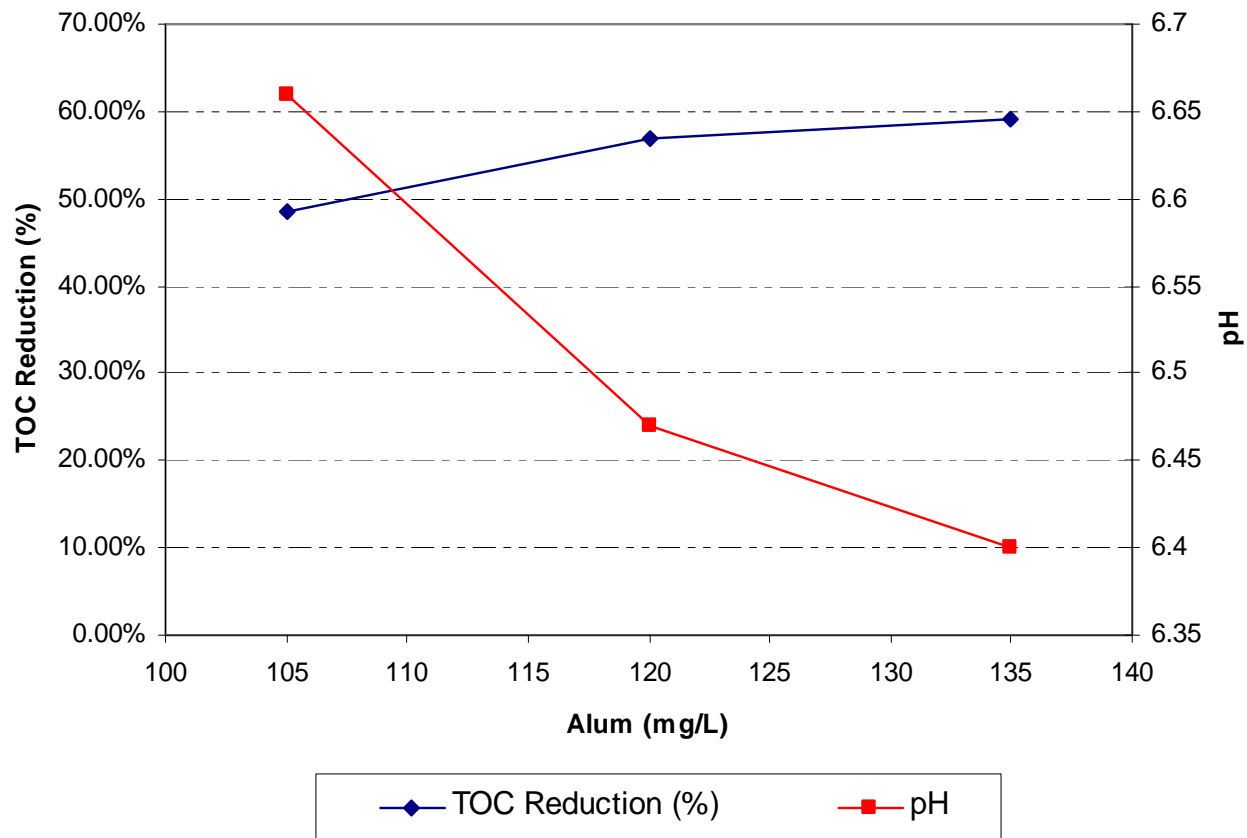
find OG for aluminum in Alberta.

rwiersma, 4/22/2008

Analysis

Actiflo Data

TOC & pH per Coagulant Dose



Actiflo

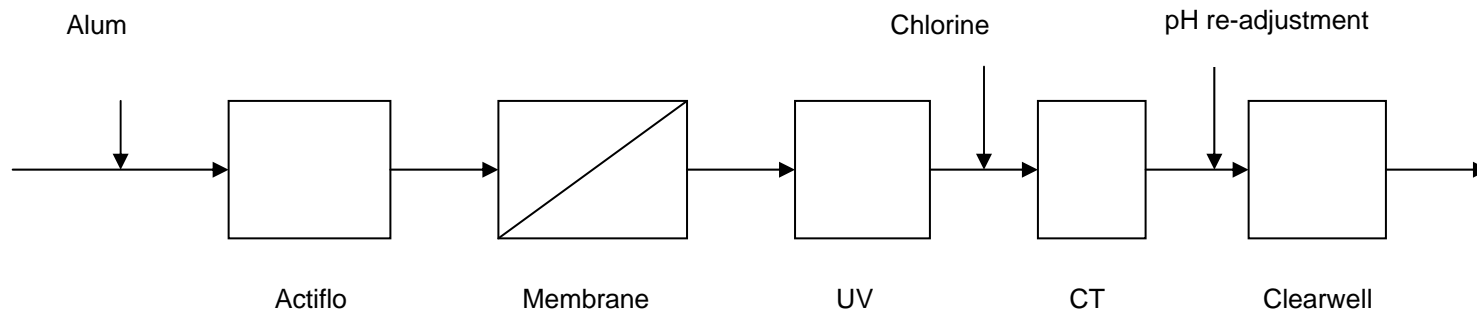
Bench-Scale Testing

- Process concerns:
 - High coagulant doses are required to achieve the desired removal of organics (TOC and colour)
 - Impact of polymer carryover to the membrane treatment system
 - Treated water pH
 - Filterability of the residual aluminum present in effluent

Design Considerations

Impacts to the Preliminary Design

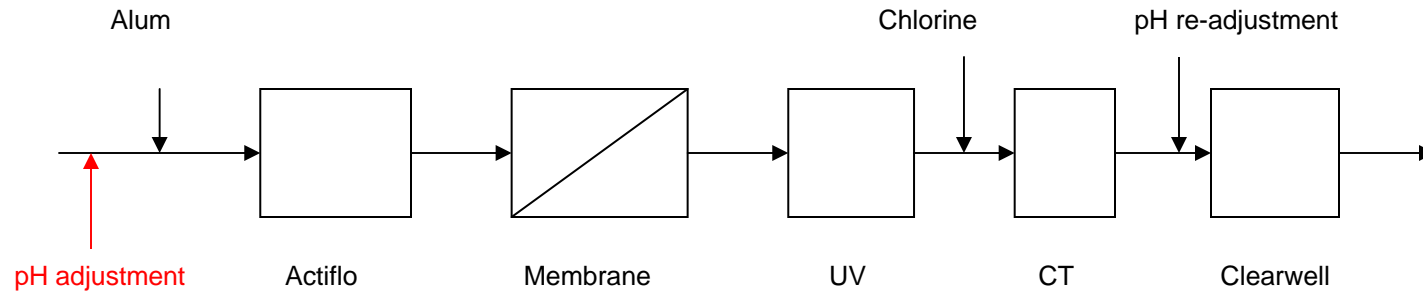
- Since pH reduction of the raw water is required for the desired TOC removal in the Actiflo process, the impact on the overall process chemistry is that two pH adjustment steps must be introduced into the PWTP design
- Option 1:



Design Considerations

Impacts to the Preliminary Design

- Option 2:



Conclusions

Fort McMurray WTP Project

- **Both** technologies were capable of meeting the required removal targets for TOC/DOC
- The Actiflo system achieved additional removals of iron and turbidity at the cost of high coagulant doses and increased residual aluminum in the treated effluent
- The MIEX system is not designed to treat either iron or turbidity, but achieves organics removal without requiring large inputs of chemical

Conclusions

Fort McMurray WTP Project

- Based on the constraints of this particular DBOO project, the MIEX system was recommended over the Actiflo system as follows:
 - Fewer chemical inputs were required
 - The additional chemical inputs would necessitate additional floorspace within the proposed building
 - On the basis of the existing information, it was not yet determined whether residual aluminum would be reduced to acceptable levels after membrane treatment
 - While the MIEX system did not provide any turbidity reduction, the specified membranes had sufficient redundant capacity to treat the turbidity

Conclusions

Actiflo vs. MIEX

- Based on the information obtained for this project, the following general conclusions can be drawn:
 - Actiflo provides a broader spectrum of removals for source water such as that found in the Athabasca River
 - MIEX could be considered a targeted treatment technology for organics
 - The following additional testing would be helpful in other future projects considering Actiflo:
 - Affect of pH adjustment in the reduction of required coagulant
 - Ability of proposed filtration to remove residual aluminum

Post Script

Pre-Treatment Equipment Selection

- Equipment pre-selection was conducted for the pre-treatment process.
- The DBOO owner instructed Stantec to forward RFPs to vendors of the following technologies:
 - 1) Magnetized Ion Exchange (MIEX)
 - Orica Watercare
 - 2) Ballasted Flocculation (BF)
 - Actiflo, John Meunier Inc.
 - 3) Dissolved Air Flotation (DAF)
 - AquaDAF, Infilco Degremont
 - ClariDAF, ITT / F.B. Leopold Co.

Pre-treatment Technologies

Initial Selection

- Initial screening was based on capital cost and overall process footprint
- AquaDAF by IDI and MIEX by Orica Watercare were selected for further comparative investigation
- Actiflo was not capital cost competitive
- AquaDAF required a significant building expansion and required comparatively higher operational costs in terms of chemicals and electricity
- MIEX by Orica Watercare was recommended as the pre-treatment technology for this PWTP project

Acknowledgments

- A. Cristina Fonseca, Ph.D., PE, Stantec
- Leigh McDermott, P. Eng., Stantec
- Kelly Kennedy, EIT, Stantec
- Lockerbie-Hole
- EPCOR
- Orica Watercare
- John Meunier Inc.



Efficacy of Magnetized Ion Exchange versus Ballasted Flocculation as a Pre-Treatment for the Removal of Organic Carbon

Robert Wiersma, P. Eng.
April 2009

NEWWA Spring Joint Regional Conference
Worcester, MA

For additional information contact Robert.Wiersma@stantec.com

questions and answers