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Clean Water Centre**

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Pilot Testing Project Report

Reducing Disinfection By-Product Precursors to Control Trihalomethanes in a Large Municipal Residential Drinking Water System

Walkerton Clean Water Centre

Research and Technology

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Disclaimer

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List of Acronyms

AO	Aesthetic objective
CSMR	Chloride-to-sulphate mass ratio
DBPs	Disinfection by-products
DI	Deionized water
DOC	Dissolved organic carbon
DWS	Drinking water system
EBCT	Empty bed contact time
GAC	Granular activated carbon
HAAs	Haloacetic acids
HOBr	Hypobromous acid
HOCl	Hypochlorous acid
IX	Ion exchange
MAC	Maximum acceptance concentration
NOM	Natural organic matter
NTU	Nephelometric turbidity units
OG	Operational guideline
RAA	Running annual average
SDS	Simulated distribution system
TDS	Total dissolved solids
THMs	Trihalomethanes
UV ₂₅₄	Ultraviolet absorbance at 254 nm of wavelength

Executive Summary

Background

The Drinking Water System (DWS) has been experiencing increased trihalomethanes (THMs). The THM levels are approaching the maximum acceptable concentration (MAC) of 100 µg/L as a running annual average (RAA) of quarterly results (O. Reg. 169/03).

Disinfection by-products (DBPs) can form in chlorinated waters with organic precursors and the presence of bromide is a factor that influences THM formation. Although the organic levels in the water are not significantly high, the bromide level can increase the formation of brominated THMs. The reaction time with chlorine and organics can also cause an increase in THMs formation. In addition, the detention time of the distribution system can be up to 10 days.

Organic and bromide removal strategies can include membrane filtration (e.g. reverse osmosis or nanofiltration) or sorption processes (e.g. granular activated carbon (GAC) or ion exchange (IX) resins). This study compared the performance of GAC and IX filters.

Objective

The objective of this project is to investigate the effect of GAC and IX on the reduction of DBP formation by removing natural organic matter (NOM) and bromide, using groundwater.

Approach

The pilot-scale tests used raw water collected from groundwater and was conducted at the DWS. The selected GAC and IX resins were packed in two pressure filters and were operated for a 25-week period. A series of 10-day Simulated Distribution System (SDS) tests were conducted to monitor the change of THM formation throughout the test.

Key Findings

Through pilot testing it was determined that:

- The majority of the THMs are of the brominated species. THMs were above the MAC of 100 µg/L after 3 days of detention time when samples were dosed with 3.5 mg/L of chlorine. THMs increased with increasing detention time.
- Pilot-scale GAC filters ran for 25 weeks. The DOC was reduced by 68% and UV absorbance was reduced by 88%, compared to the raw water observed.
- Pilot-scale Bromide Plus/A860 IX ran for 25 weeks. The DOC was reduced by 66% and UV absorbance of 88%, compared to the raw.
- Both GAC and IX trains effectively reduced THMs below the MAC after 8 weeks, to 23.3 µg/L and 34.6 µg/L respectively, when dosed with 3.5 mg/L of chlorine and stored at room temperature for 10 days.
- The alkalinity results may indicate lower concern regarding lead galvanic corrosion for the GAC train effluent as compared to the IX train effluent.

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1. Introduction

The Drinking Water System (DWS) is located in Central Ontario. The DWS services a population of 510 and relies on three drilled wells. The groundwater that was tested in this study is the main source of raw water that feeds the distribution system and fills the reservoir. The DWS has been experiencing increased trihalomethanes (THMs) in the past few years. The THM levels are approaching the maximum acceptable concentration (MAC) of 100 µg/L as a running annual average (RAA) of quarterly results (O.Reg. 169/03).

Disinfection by-products (DBPs), such as THMs and haloacetic acids (HAAs), can form in chlorinated water with organic precursors. Although the level of organics is generally low in the community's source water (as quantified by dissolved organic carbon (DOC) of 1.5 mg/L), the bromide levels (0.34 mg/L) contribute to the formation of brominated DBPs.

The reaction pathways of brominated THMs (e.g., bromoform, dibromochloromethane and bromodichloromethane) and chloroform vary and have different factors that influence their formations (Saidan et al., 2015). When bromide is exposed to hypochlorous acid (HOCl) in water, the hypochlorous acid rapidly oxidizes bromide and forms hypobromous acid (HOBr) (Cooper et al., 1985; Watson, 2012; Saidan et al., 2015). The HOBr quickly reacts with natural organic matter (NOM) to form brominated THMs (Cooper et al., 1985; Watson, 2012; Saidan et al., 2015). HOBr is estimated to react 20 times faster with NOM than HOCl; therefore, bromine fills the available sites on NOM first and forms brominated THMs (Saidan et al., 2015). In addition, chlorinated THMs have been shown to shift to more brominated forms with increasing reaction time (Saidan et al., 2015). Brominated THMs are more cytotoxic and genotoxic than chlorinated THMs (Watson, 2012; Saidan et al., 2015; Soyluoglu et al., 2020).

Controlling bromide can ultimately reduce the formation of brominated THMs (e.g. bromoform, dibromochloromethane and bromodichloromethane) (Soyluoglu et al., 2020). Membrane filtration (e.g. reverse osmosis or nanofiltration) and sorption processes (e.g. granular activated carbon (GAC) or ion exchange (IX) resins) are regarded as the common bromide removal treatment technologies (Soyluoglu et al., 2020).

Pilot testing services from the Walkerton Clean Water Centre (Centre) were requested to test the impact of detention times and DBP precursors, such as bromide and organics, to ultimately control THMs and HAAs.

The objective of Phase 2 is to compare the removal of THM and HAA precursors, including NOM and bromide, pilot-scale fixed bed GAC and IX pressure filters, using groundwater.

2. Materials and Method

2.1 Raw Water Quality

Table 1. Groundwater Raw Water Quality

Parameter	Average Values \pm SD ¹ (n) ²	
	Collected August 2020	Collected February/March 2021 (Time of pilot testing)
Chloride (mg/L)	176.6 \pm 112.1 (6)	65.5 \pm 11.0 (25)
Conductivity (μ S/cm)	355.9 \pm 6.7 (8)	N/A
pH	8.2 \pm 0.1 (8)	8.5 \pm 0.7 (22)
Temperature ($^{\circ}$ C)	18.1 \pm 1.6 (8)	12.7 \pm 0.7 (22)
Total Dissolved Solids (TDS) (mg/L)	93.3 \pm 1.8 (8)	N/A
Turbidity (NTU)	0.57 \pm 0.56 (8)	0.4 \pm 0.6 (22)
Bromide (mg/L)	0.4 \pm 0.02 (4)	0.41 \pm 0.03 (17)
Alkalinity (mg/L as CaCO ₃)	127 \pm 7 (6)	137 \pm 12 (25)
UV ₂₅₄ absorbance (UV ₂₅₄) (cm ⁻¹)	0.042 \pm 0.001 (8)	0.041 \pm 0.001 (25)

DOC (mg/L)	1.76 ± 0.06 (5)	1.67 ± 0.06 (25)
Methane (L/m ³)	N/A	8 ± 6 (4)

¹SD = standard deviation

²n = number of samples

2.2 Water Quality Analysis

Water quality analysis was completed throughout the project using the methods described below (Table 2).

Table 2. Methods of Water Quality Analysis

Parameter	Preparation	Method	Range
In-House Analysis			
Alkalinity	N/A	Hach Method 8203	10 – 4000 mg/L as CaCO ₃
Chloride	N/A	Direct Measurement Method (Hach)	0.1 – 35,500 mg/L
Chlorine (free and total)	N/A	USEPA DPD Method	0.02 – 2.00 mg/L
Conductivity / TDS	N/A	Direct Measurement Method (Hach Method 8160)	0.01 µS/cm – 200 mS/cm
		Standard Method 5310C	
DOC	0.45 µm filtered	UV/persulfate oxidation with conductometric detection	0 – 10 mg/L
pH	N/A	Hach Method 8156	0 – 14
Turbidity	N/A	USEPA Method 180.1	0 – 1000 NTU
UV ₂₅₄	0.45 µm filtered	Real Tech UV ₂₅₄ Method	0 – 2 Abs/cm

Parameter	Preparation	Method	Detection Limit
Analyzed at a Licensed Laboratory			
Bromide	N/A	Ion Chromatography EPA300	0.05 mg/L
Haloacetic acids	3.5 mg/L chlorine dose for 10 days of contact times	EPA 552.3	5.3 µg/L
Methane	N/A	Lab Specific Method	0.02 L/m ³
Trihalomethanes	3.5 mg/L chlorine dose for 2 and 10 days of contact times	EPA 5030B/8260C	0.5 µg/L

2.3 Media Details

The pilot-scale tests were conducted using commercially available anion exchange resins and GAC products. Details of each filter media are summarized in Table 3.

Table 3. IX Resins and GAC Media Details

Category	Media	Material	Strong affinity for:
Anion Exchange Resin	Purolite® Bromide Plus	Gel polystyrene	Bromide
	Purolite® A860	Polyacrylic	Organic matter
GAC	Calgon Carbon Filtrasorb® 400	Bituminous coal	Organic matter

2.4 Pilot Plant Schematic

The pilot plant was installed at the DWS pumphouse on February 10, 2021 and commissioned on February 18, 2021. The pilot system used groundwater from the DWS. As shown in Figure 2, the pilot plant consisted of two pressure vessel trains. The pressure vessel in Train 1 was loaded with 0.75 ft³ of GAC and pre-soaked in DI water. Prior to

commissioning, the GAC filter was backwashed twice on-site to release trapped air bubbles and fines. The flow rate of Train 1 was regulated as 0.42 gpm (1.7 L/min) to achieve a 13 minute EBCT.

The pressure vessel in Train 2 was filled with 0.375 ft³ of Bromide Plus IX resin for bromide removal and 0.375 ft³ of A860 IX resin for NOM control, providing a total of 0.75 ft³ of IX resin. The flow rate in Train 2 was set as approximately 1.6 gpm (6.06 L/min) to achieve a 3.5 minute EBCT. The GAC manufacturer recommended 10 minutes of EBCT and the IX manufacturer recommended a flow rate of 3 – 3.5 gpm/ft³ of each resin and 2 – 3 minutes of EBCT. The IX manufacturer estimated the capacity as 2,500 bed volume per 1 ft³ of resin before a regeneration is required. The flow rates in the pilot test were slightly lower than the recommended flow rates from each manufacturer.

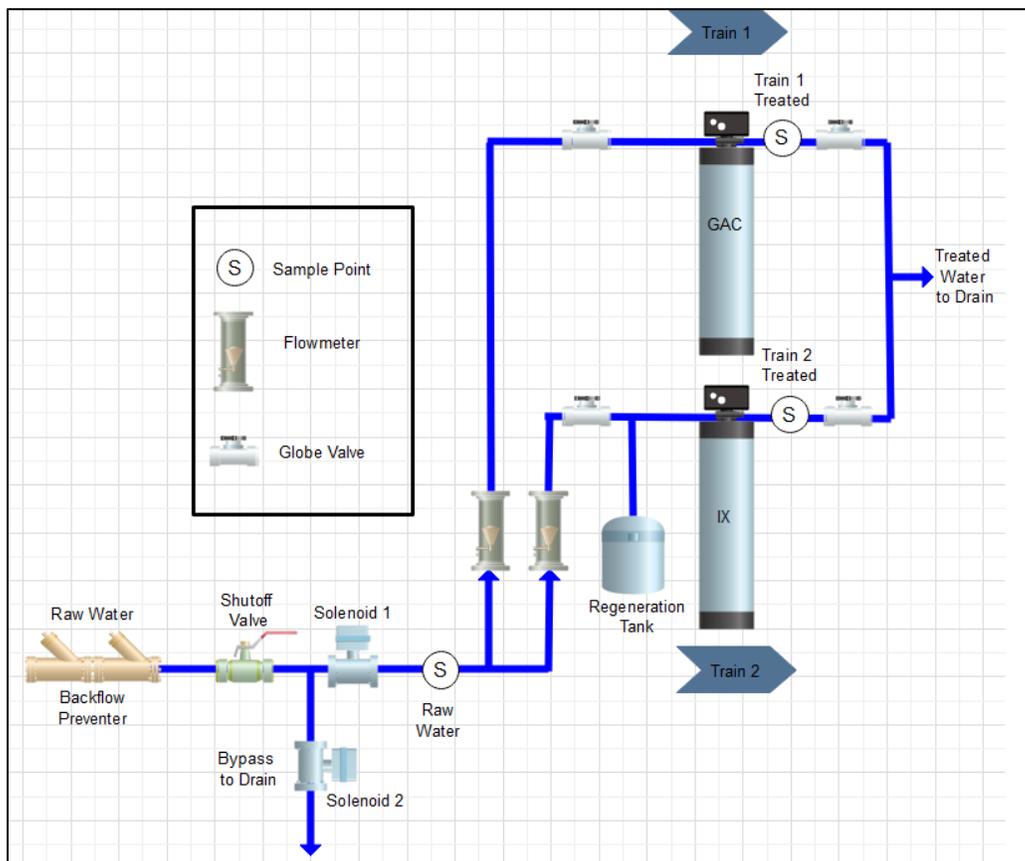


Figure 1. Pilot Plant Schematic

2.5 Water Quality Analysis

As shown in Figure 1, one flow meter was installed at each filter train to continuously monitor flow rates. Measurements of flow rate and UV₂₅₄ were recorded for every weekday during the first 22 weeks of on-site pilot testing by client staff. After week 22, the pilot trains continued to run, but daily sampling was no longer required.

Also, during that first 22-week period, grab samples were collected once or twice a week from raw water and filter effluents of each train. pH, temperature, and turbidity were measured immediately by client staff. From week 22 to the completion of the project, Centre staff grabbed samples from raw and filter effluents of each train during on-site visits. This was implemented to try and decrease the workload on client staff. The grab samples were then sent to the Centre for the analysis of DOC, UV₂₅₄, alkalinity and chloride and selected samples sent to accredited laboratory for bromide, sulphate, and methane analysis.

2.6 Simulated Distribution System (SDS)

During the period of pilot testing, six sets of SDS tests were conducted using the grab samples collected from Week 2, 3A, 3B, 4A, 4B, and 8. The SDS test was performed to investigate the removal of THMs and HAAs using IX and GAC filters. Grab samples collected from the pilot-scale plants were transferred into 250 mL chlorine demand free, amber glass containers. To achieve chlorine demand free bottles, the glassware was treated with 10 mg/L of chlorine solution for a minimum of 3 hours, rinsed with DI, and left to air dry.

Each SDS bottle was dosed with 3.5 mg/L of sodium hypochlorite, which was determined in a previous chlorine demand test. The bottles were then stored at room temperature and samples were collected and sent for THMs after 3 days and for THMs and HAAs after 10 days of contact times. Afterwards, THM and HAA samples were sent to an accredited laboratory for analysis.

3. Results and Discussions

3.1 Pilot-Scale Test Results

3.1.1. Turbidity

The raw water turbidity measured on average 0.43 ± 2.06 NTU. Both trains slightly reduced raw water turbidity, whereas the IX train (T2) had slight lower turbidity than the GAC train (T1).

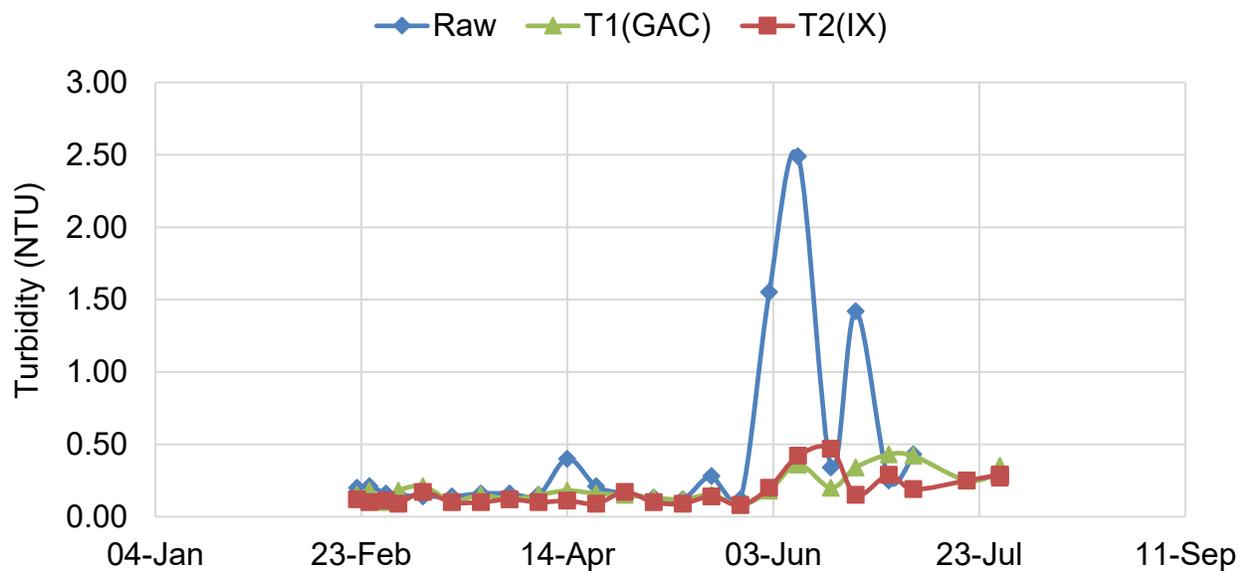
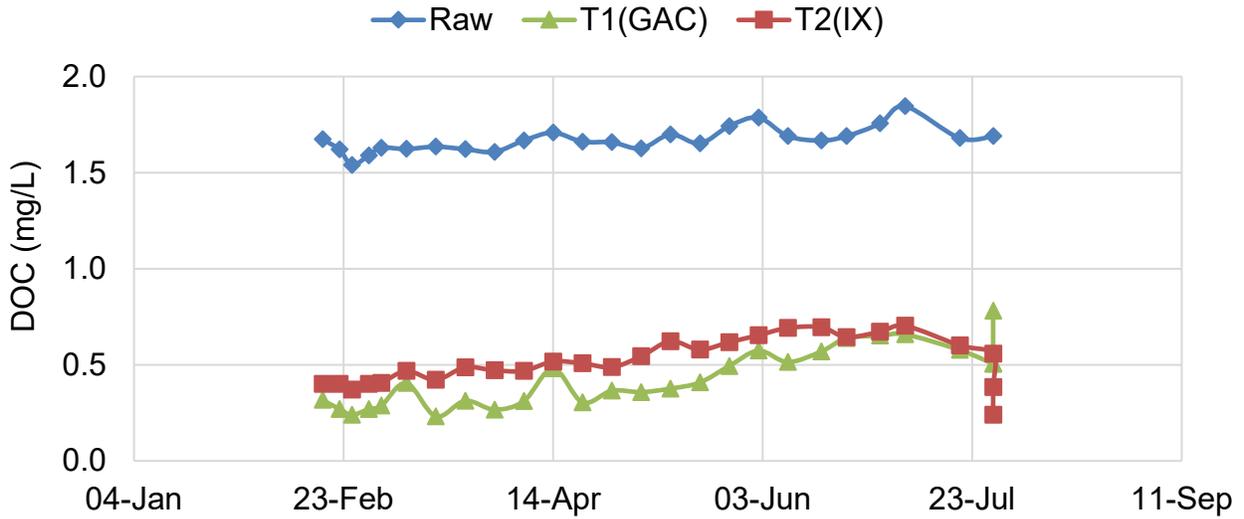


Figure 2. Turbidity Results

3.1.2. DOC and UV₂₅₄

The raw water DOC remained consistent at a level of 1.6702 ± 0.1748 mg/L. Initially, both filters effectively reduced DOC levels from raw water (over 50% removal), whereas the GAC train (T1) had approximately 0% - 15% better removal than the IX train (T2) (Figure 3).

A. DOC vs. Time



B. DOC Breakthrough

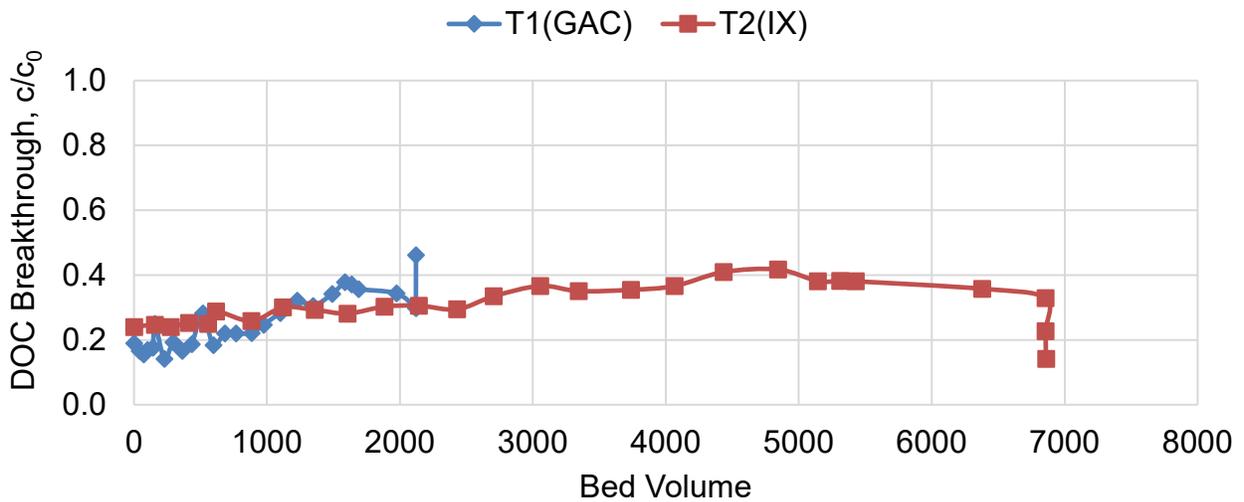
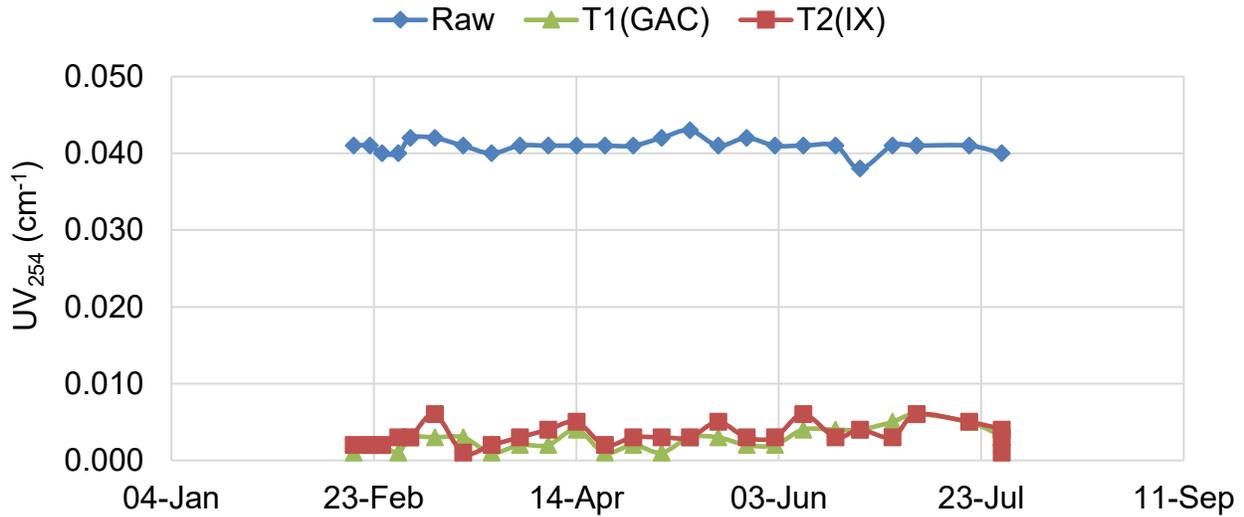


Figure 3. DOC Results

The UV absorbance of the raw water remained relatively stable during the test and was measured as $0.041 \pm 0.002 \text{ cm}^{-1}$. Both filters significantly reduced UV₂₅₄ (Figure 4), which could consequently reduce the THMs and HAAs.

A. UV₂₅₄ vs. Time



B. UV₂₅₄ Breakthrough

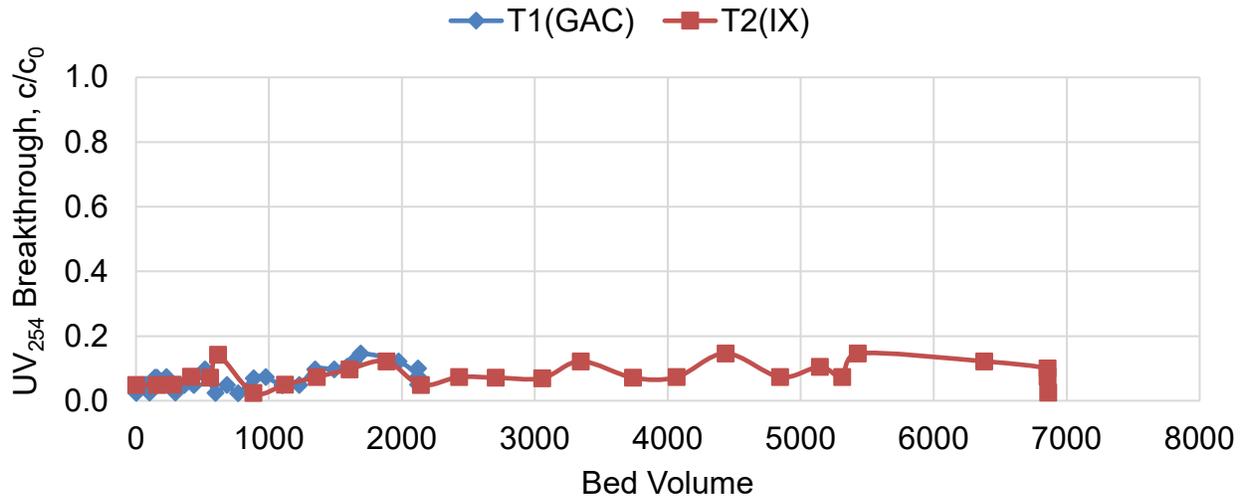


Figure 4. UV₂₅₄ Results

3.1.3. Bromide

The presence of bromide increases the formation of total THMs with higher formation of the brominated species (bromoform, bromodichloromethane and dibromochloromethane) but lower formation of chloroform (Soyluoglu et al., 2020). Therefore, controlling bromide can

ultimately reduce the formation of brominated THMs, which are the predominant species found in the WTP treated water.

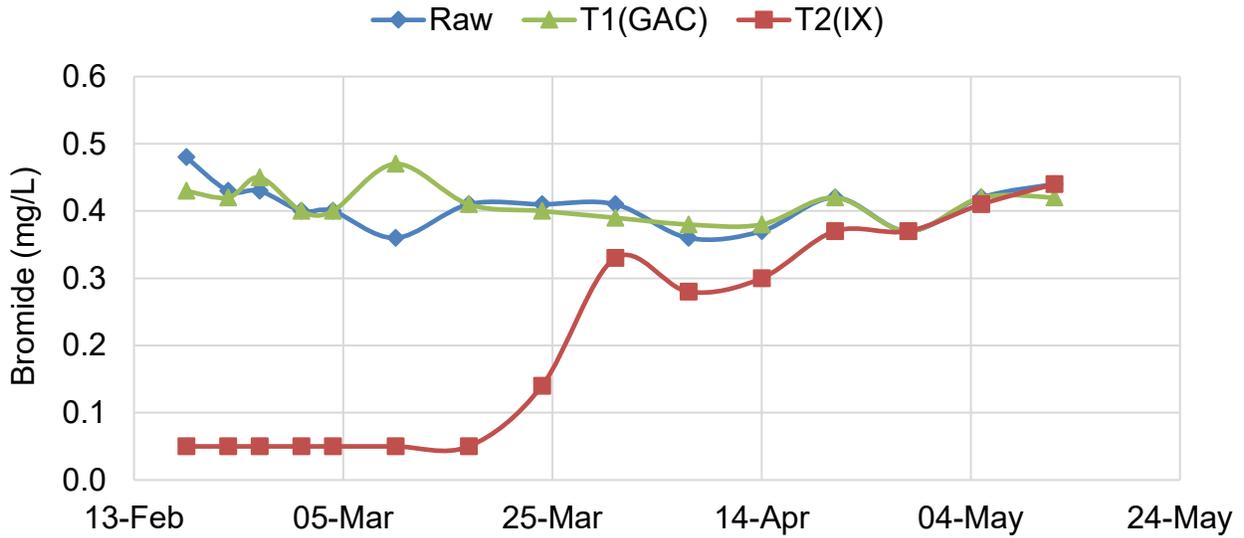
The raw water had bromide in a range of 0.41 ± 0.07 mg/L. The GAC filter (T1) had similar bromide levels as the raw water throughout the test, indicating that GAC was not able to remove bromide from raw water (Figure 5A).

The bromide levels of the IX filter (T2) remained undetectable (< 0.05 mg/L) during the first month of the test, but then rapidly raised to about 0.33 mg/L in two weeks of time, and eventually increased to a similar level as raw water, 0.44 mg/L (Figure 5A). The bromide trend of the IX filter indicated that the IX resin, potentially Bromide Plus, significantly removed bromide from raw water during the first month of operation (over 85% of removal) but was gradually exhausted over time. The IX resin was fully exhausted after 12 weeks of operation (Figure 5A).

Figure 5B shows the bromide breakthrough curves of the GAC and IX filters. The GAC filter (T1) had over 90% of bromide breakthrough during the run of 840 bed volumes, indicating that GAC can hardly remove bromide from raw water (Figure 5B). The bromide breakthrough of the IX filter (T2) remained about 10% for the initial 882 bed volumes of run, then quickly raised to 80% until 1,358 bed volumes, and eventually reached 100% at 3,055 bed volumes (Figure 5B).

As the bromide-removing IX resin was exhausted after 12 weeks of operation and GAC could not remove bromide, the Centre paused the weekly analysis of bromide afterwards.

A. Bromide vs. Time



B. Bromide Breakthrough

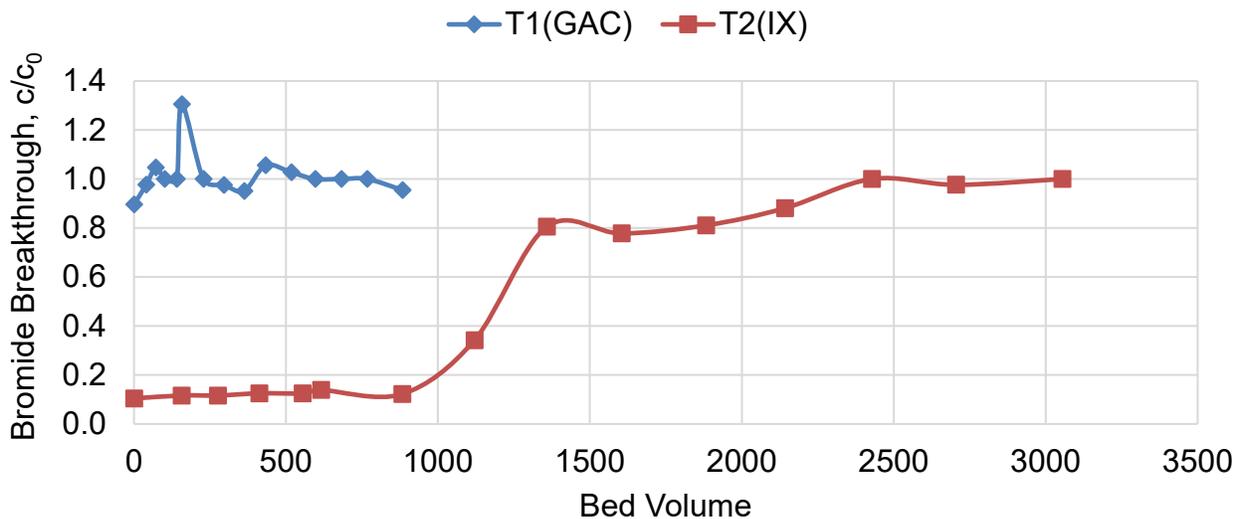


Figure 5. Bromide Results

(Note: Results below detection were plotted as the detection limit, 0.05 mg/L)

3.1.4. Methane

Methane can naturally occur in groundwater as a colourless and odourless gas. In Ontario, the AO of methane is 3 L/m³ (MECP, 2006). Methane can cause mechanical problems (e.g.

water hammer) and biological problems (e.g. microbial growth in the distribution system) in drinking water (MECP, 2006).

Methane was monitored for the first two weeks of the pilot-scale test. The raw water had methane measured as $8 \pm 5 \text{ L/m}^3$, whereas the methane levels of the GAC and IX filters were $9 \pm 3 \text{ L/m}^3$ and $12 \pm 2 \text{ L/m}^3$, respectively (Figure 6). Neither GAC nor IX filters removed methane from raw water.

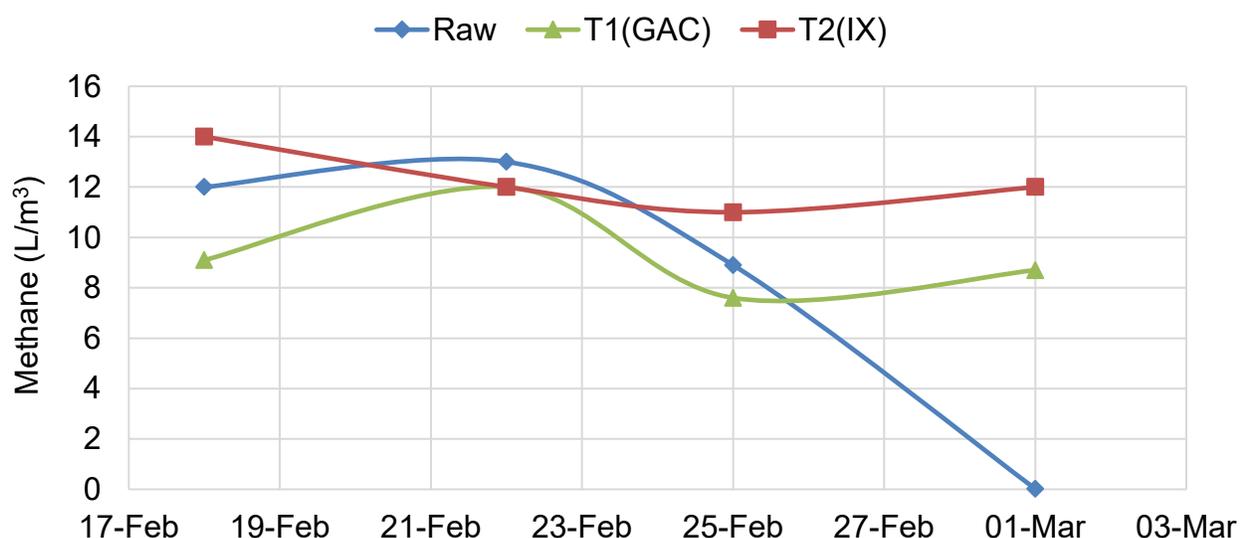


Figure 6. Methane Results of the Pilot-Scale Test

3.1.5. Alkalinity

Alkalinity is the buffering capacity of water and mainly consists of carbonates, bicarbonates and hydroxides in water (APHA, 2017). These alkalinity compounds can typically be removed through the IX process as they are negatively charged. The recommended operational guideline (OG) for alkalinity in Ontario is 30 – 500 mg/L as CaCO_3 (MECP, 2006). Low alkalinity can lead to corrosive water (MECP, 2006).

During the pilot-scale test, the raw water alkalinity remained relatively stable as $137 \pm 23 \text{ mg/L as CaCO}_3$ (Figure 7). Alkalinity results of both filters complied with Ontario OG. The GAC filter (T1) slightly reduced alkalinity for the first three weeks of operation. The alkalinity of the IX filter (T2) was initially about 40% lower than raw water but quickly increased to a similar level as the alkalinity of the GAC filter during the first week of test, and gradually

raised to a similar level as the raw water alkalinity after two weeks of operation. During the final week of operation, week 24, alkalinity decreased significantly in the effluent water of the IX train and remained low following the regeneration conducted in week 25 (Figure 7). The results of week 24 and 25 obtained from the IX unit closely follows known trends for anion exchange resins to remove alkalinity from raw water.

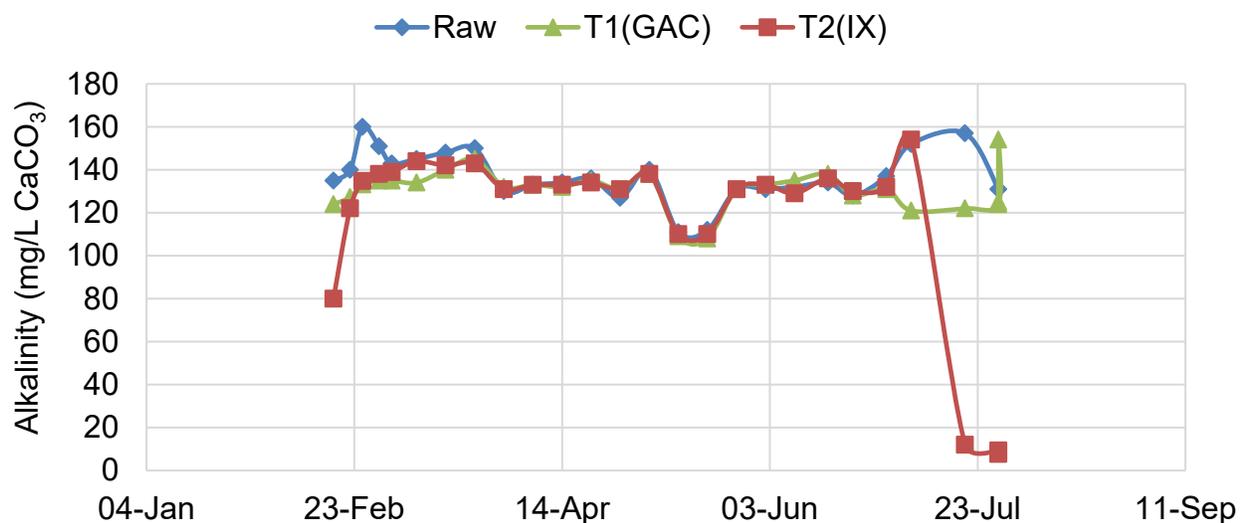


Figure 7. Alkalinity Results

3.1.6. Chloride-to-Sulphate Mass Ratio (CSMR)

3.1.6.1. Chloride

Chloride is not toxic in drinking water but can cause a salty taste above AO (250 mg/L) (MECP, 2006). During the pilot-scale test, the IX filter (T2) had increased levels of chloride that was about 2.4 times higher than the level found in raw water (Figure 8). The anion exchange process replaces negatively charged NOM and bromide ions with chloride ions and ultimately releases chloride in treated water. However, the chloride levels of the IX filter effluent dropped to a similar levels as raw water after the first 2 weeks of operation and remained low until week 24. In week 24 and week 25 following the regeneration, chloride levels remained high with one sample exceeding the AO (Figure 8). On the other hand, the GAC filter had similar chloride levels as raw water throughout the test, as adsorption process does not affect chloride levels (Figure 8).

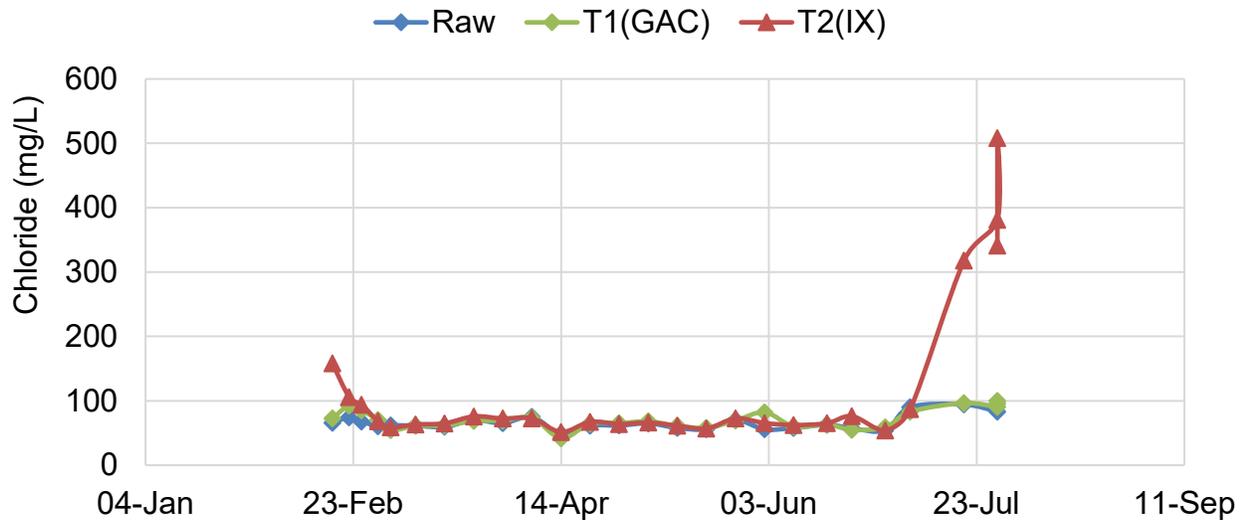


Figure 8. Chloride Results

3.1.6.2. Sulphate

Levels above 150 mg/L can affect taste. It can be reduced to sulfide causing odour problems (MECP, 2006). In Ontario, AO of sulphate is set as 500 mg/L (MECP, 2006). Sulphate was under detection (0.05 mg/L and 0.2 mg/L depending on test method) for both raw water and IX effluent (Figure 9). However, the GAC filter slightly increased sulphate levels during the first week of operation (Figure 9).

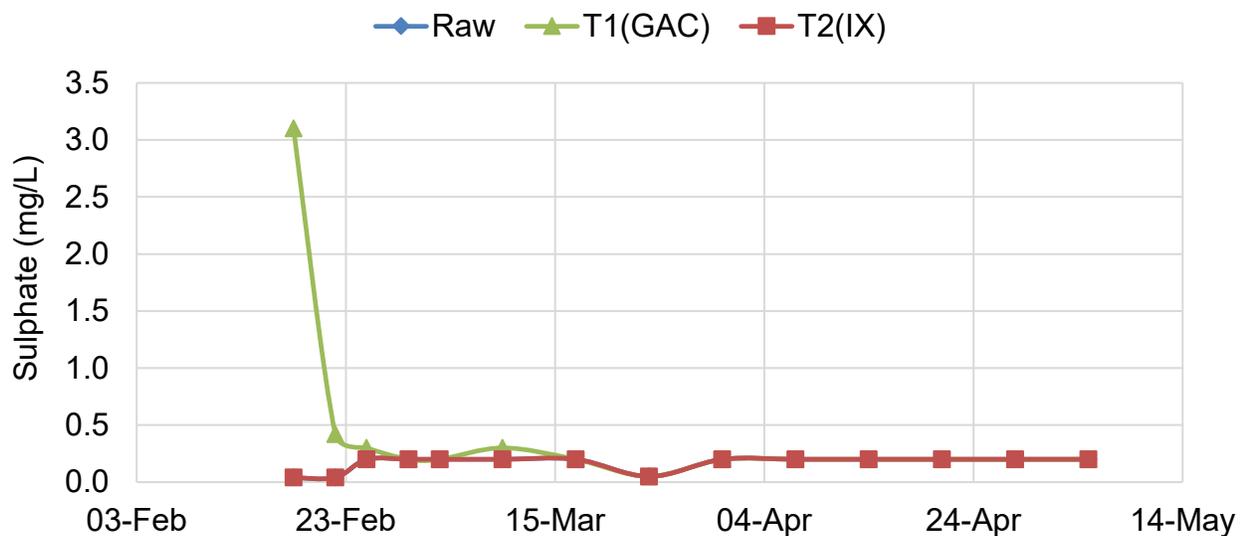


Figure 9. Sulphate Results of the Pilot-Scale Test

(Note: a. Results below detection were plotted as the detection limit, 0.05 mg/L and 0.2 mg/L depending on the test method; b. all sulphate results of raw water and IX effluent were under detection and were plotted as the detection limits that overlapped with each other in the figure)

3.1.6.3. CSMR

In water distribution systems or private plumbing systems, galvanic corrosion may happen at the lead/copper connections, where pH at the surface of lead materials would dramatically decrease in poorly buffered water causing lead leaching problems (WRF, 2010). Higher chloride concentrations in water tend to increase lead solubility, whereas higher sulphate concentrations tend to decrease lead solubility (WRF, 2010). Therefore, the corrosion rate of lead is related to the CSMR. High CSMR (> 0.5) could trigger lead galvanic corrosion problems in poorly buffered water (< 50 mg/L as CaCO₃) following treatment changes that increase the CSMR (WRF, 2010).

The results of chloride and sulphate indicate high CSMR values (>0.5). Samples from the GAC train consistently had alkalinity results greater than 50 mg/L as CaCO₃. Results obtained during week 24 and week 25 following the regeneration on the IX train is a value less than 10 mg/L as CaCO₃. These observations may indicate lower concern regarding lead galvanic corrosion for the GAC train effluent as compared to the IX train effluent.

3.1.7. SDS Test

The SDS tests were performed to determine if there was an impact of GAC or IX on the formation of THMs and HAAs. Based on the previous studies, the chlorine dose was determined as 3.5 mg/L. Samples collected from raw water and effluents of both filters were dosed with chlorine and held for 3 days and 10 days to simulate the detention time in the distribution system.

3.1.7.1. Chlorine Residuals

Free chlorine residuals were monitored while taking THM and HAA samples (Figure 10). Raw water had undetectable levels of free chlorine after 3 and 10 days of contact times.

However, all other samples were able to maintain over 0.8 mg/L of free chlorine residual for up to ten days of contact (Figure 10).

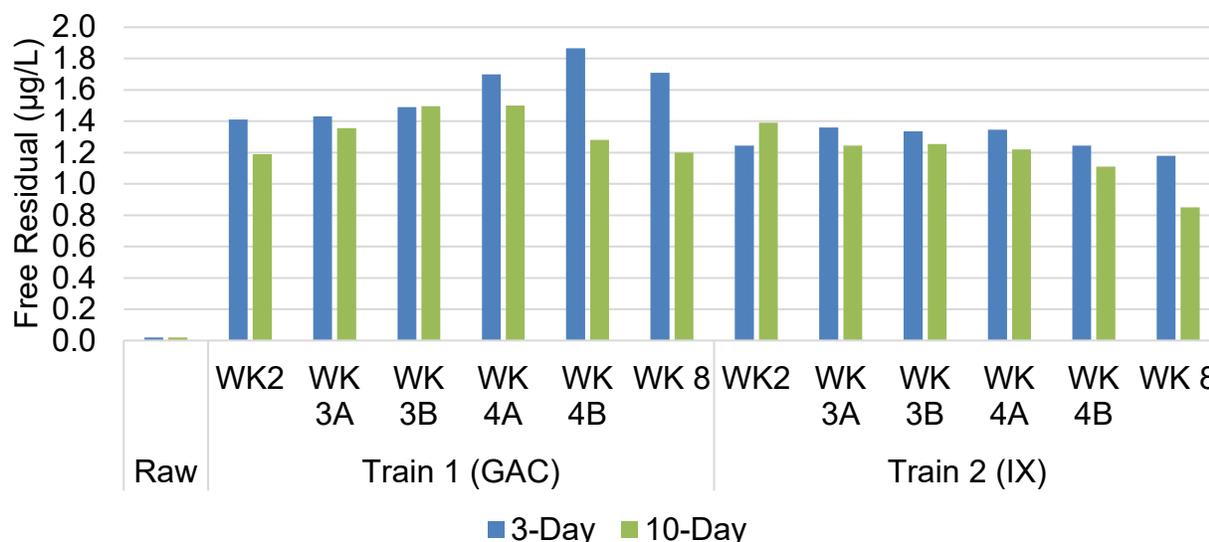


Figure 10. Free Chlorine Residuals of the SDS Test Using Samples Collected from the Pilot-Scale Test

(Note: Results below detection were plotted as the detection limit, 0.2 mg/L)

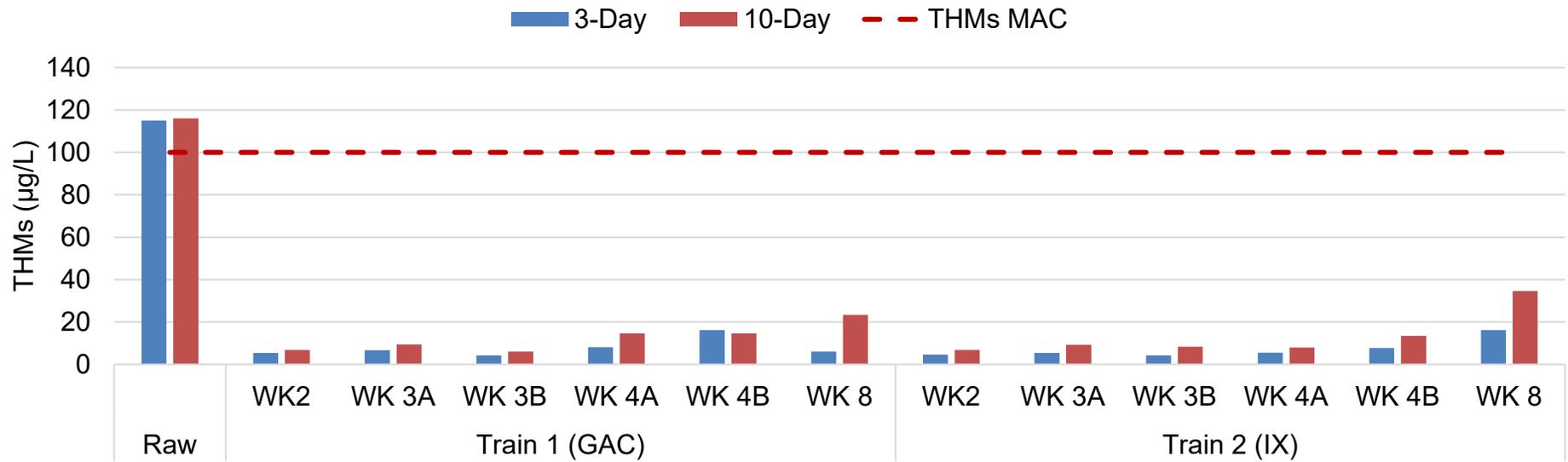
3.1.7.2. THMs

In Ontario, the MAC for THMs in drinking water is 100 µg/L as RAA (O.Reg. 169/03). Regardless of detention time, the THM levels of raw water were higher than the MAC, whereas both filters had THM levels well lower than the MAC (Figure 11A). The THM levels of both filters gradually increased as media exhausted over time. The THM concentrations of each sample increased with detention time (Figure 11A).

Among the four regulated THM species, the brominated species found in raw water, bromoform and dibromochloromethane, accounted for over 85% of total THM readings, regardless of detention time (Figure 11B). Similarly, bromoform and dibromochloromethane were found dominant in the GAC effluent, making up 75% - 90% of total THMs (Figure 11B). The composition of the two dominated THM species increased with detention time and filter run time.

Other than the brominated species, the chlorinated species, chloroform, was found dominant (over 55%) in the IX filter effluent until Week 8 (Figure 11B). This confirmed that the IX filter effectively removed bromide from raw water (Section 3.2.3) and consequently reduced the formation of brominated THMs. In addition, the chloroform levels of the IX filter decreased over filter run time (Figure 11B). As the bromide-removing IX resin exhausted, the composition of the brominated THMs increased. However, the NOM-removing IX resin exhausted much slower than the bromide-removing resin; therefore, the IX filter still had low levels of total THMs until Week 8.

A. THMs



B. THM Species

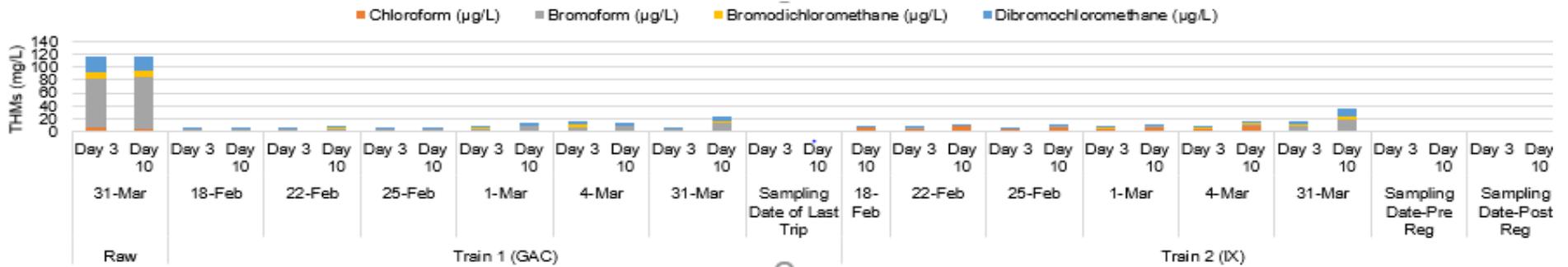


Figure 11. Total THM and THM Species Results of the SDS Test Using Samples Collected from the Pilot-Scale Test

(Note: Results below detection were plotted as the detection limit)

3.1.7.3. HAAs

HAAs were measured after 10 days of detention time for raw water and the effluents of the GAC and IX filters until Week 8 (Figure 12). All the HAA results were well under the Ontario MAC (80 µg/L as RAA). Therefore, HAAs analysis were discontinued after Week 8.

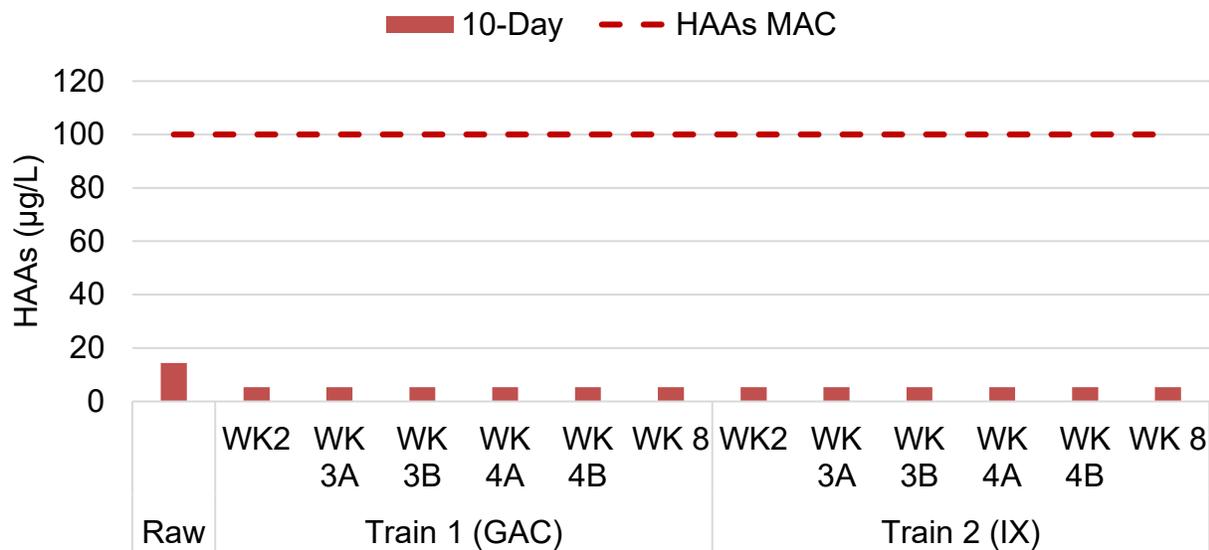


Figure 12. HAA of the SDS Test Using Samples Collected from the Pilot-Scale Test (Note: Results below detection were plotted as the detection limit, 5.3 mg/L)

4. Limitations and Considerations

The findings from this study did not consider the additional chlorine demand from the distribution system. All glassware was treated as chlorine-demand free, so the demand from the materials was not considered in the SDS tests. For a conservative approach, the samples were stored at an ambient room temperature; therefore, the rate of THM formation increased at higher temperatures. At the DWS, the well water is initially dosed with chlorine and then gets exposed to additional chlorine at the reservoir. This study did not include the second dose of chlorine.

To find scalable results for the IX media, it is recommended by the manufacturer to complete at least 5 full regeneration cycles. The manufacturer estimated the capacity as 2,500 bed volume per 1 ft³ of resin before a regeneration is required. It was estimated that provided

the organic levels and flow rate of the pilot plant and volume of resin, one regeneration cycle would be required after 14,026 gallons. Provided the run times, it was estimated to take 40 days to reach one regeneration cycle. The study lasted a total of 25 weeks, with the IX resin and GAC media treating a total of approximately 38,484 gallons and 11,882 gallons respectively. The client opted, at the agreement of Centre staff, to complete the project at week 25. Because the DOC and UV breakthrough results of both trains remained below 50%, and complete exhaustion had not been met, a final SDS-THM test was not completed, saving the utility time and resources. For this reason, the study only completed one regeneration cycle (week 25) with the understanding that the study is limited based on the information from one regeneration cycle.

Additionally, the GAC used in the pilot test were virgin GAC. The performance of virgin GAC is typically much better than aged GAC. Therefore, to obtain more representative results of full-scale, aged GAC performance, the GAC pilot plant would need to run for a longer period (up to a year). A backwash was conducted on the GAC train and a regeneration on the IX train in week 25 of testing. These results are not necessarily representative of full-scale performance as the process of full-scale filter backwashing/regeneration could not be perfectly simulated based on manufacturers specifications due to limitations in programming pilot equipment.

5. Conclusions

In conclusion, both treatment trains, GAC and the IX featuring a combination of Bromide Plus/A860 were able to reduce THMs and HAAs below the MAC of 100 µg/L and 80 µg/L respectively.

GAC, although unable to effectively remove bromide, continued to remove organics resulting in low DOC and UV absorbance results for the duration of the 25-week pilot testing experiment. The GAC media reduced the organic precursors affecting chlorinated THMs, thereby allowing it to produce effluent which when dosed with 3.5mg/L of chlorine and allowed to react for a 10-day detention period at room temperature, resulted in a THM formation of 23.3 µg/L (week 8). When compared to the results of SDS-THM formation in

the raw water undergoing the same conditions, with THMs above the MAC at 115 µg/L, GAC's organics reduction was effective. By week 25, the effluent from the GAC train provided a reduction in DOC of approximately 66%, and a reduction in UV absorbance of approximately 88% when compared to the raw water, confirming GAC continued to work effectively for the duration of the study.

During the first month of operation, the IX media was able to effectively reduce bromide concentrations in the raw water by over 85%, but steadily lost efficiency until complete exhaustion of bromide capacity by week 12. Prior to exhaustion, the IX media effectively removed bromide resulting in a reduction in the level of brominated THMs. Following this exhaustion of the Bromide Plus layer, the A860 media layer continued to effectively reduce DOC and UV absorbance. When compared to the results obtained for DOC from the GAC train, the IX on average produced an effluent with 0-15% higher results, but still well below the raw. By week 25, the IX train continued to work effectively resulting in a 64% reduction of DOC and an 88% reduction of UV absorbance when compared to the raw water. The alkalinity results may indicate a lower concern regarding lead galvanic corrosion for the GAC train effluent as compared to the IX train effluent.

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