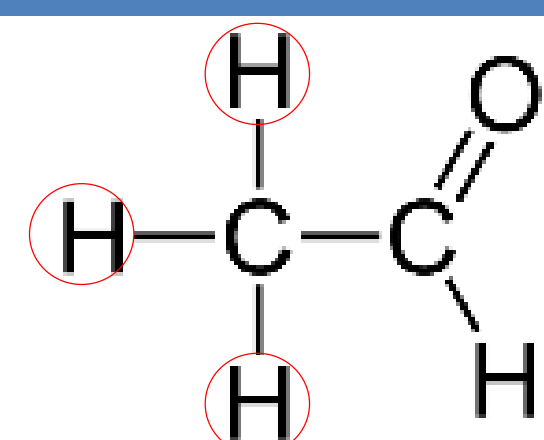


## INTRODUCTION

### Overview of haloacetaldehydes (HALs)

- Unregulated disinfection by-products (DBPs)
- 3<sup>rd</sup> most abundant DBP class (after THMs and HAAs)
- High cytotoxicity
- Promoted formation due to ozonation
- Limited availability of full-scale occurrence data
- In Québec City: 75% utilities apply O<sub>3</sub> – Cl<sub>2</sub> disinfection



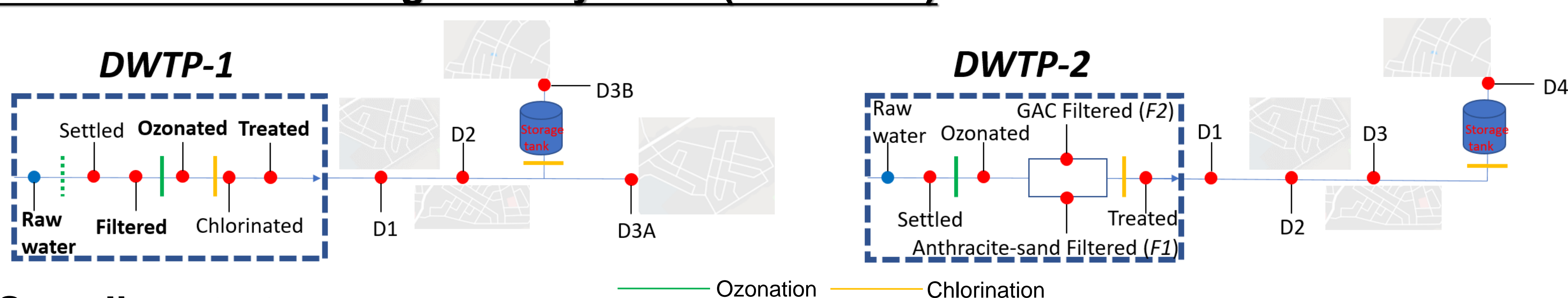
- HAL occurrence in Québec's tap water?
- Spatial and temporal variabilities of HAL?
- Effects of ozonation on HAL variability?

## OBJECTIVES

- Investigate the occurrence and spatio-temporal variability of HALs in two Canadian full-scale drinking water systems
- Identify factors (i.e., water quality, operational parameters) responsible for these variations
- Evaluate the impacts of different ozonation strategies on water quality parameters (e.g. indicators of DBP precursors)
- Assess the effects of different disinfection scenarios (post-chlorination in the presence or absence of ozonation) on the occurrence and speciation of DBPs in a full-scale drinking water treatment plant (DWTP)

## METHODOLOGY

### Two full-scale drinking water systems (S1 and S2)



### Sampling strategy

#### i) Monthly/fortnightly sampling program: November 2017 – October 2018

- Pre-ozonation not applied in DWTP-1
- 16 campaigns during one year
- > 300 samples analyzed



#### ii) 5- week intensive sampling program: December 2018 – January 2019

Table 1. Four phases applying different disinfection strategies in DWTP-1

	Phase 1 (P1)	Phase 2 (P2)	Phase 3 (P3)	Phase 4 (P4)
Pre-O <sub>3</sub> (0.5 mg/L)		✗		✗
Post-O <sub>3</sub> (0.8 mg/L)	✗	✗		
Cl <sub>2</sub>	✗	✗	✗	✗

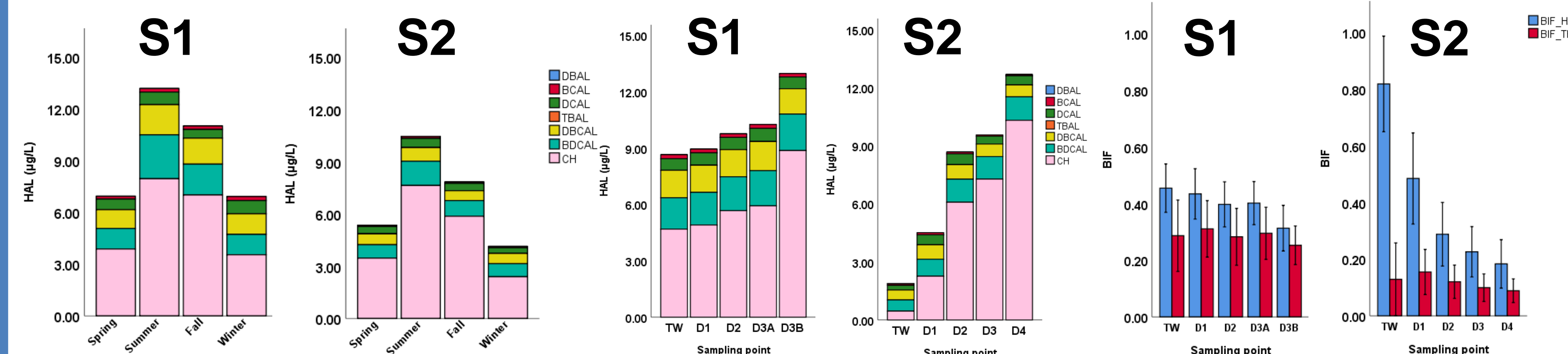
- **4 phases** chronologically considered: P1, P2, P3 and P4
- During each phase, **one sampling/day**: raw water (RW), treated water (TW)
- During the days of transition between phases, **6 samplings/day**: RW, TW
- Sampling points only during **P2**: sand-filtered water (FW), post-ozonated water (OW)

### Chemical analysis

- Water quality parameters: water temperature, pH, conductivity and turbidity
- Indicators of DBP surrogates: total organic carbon (TOC), total nitrogen (TN), UV-254 and bromide
- DBP quantification: THMs (SPME-GC/MS) and HALs (LLE-GC/ECD)

## RESULTS & DISCUSSION

### Occurrence and speciation of DBPs in S1 and S2 during one year

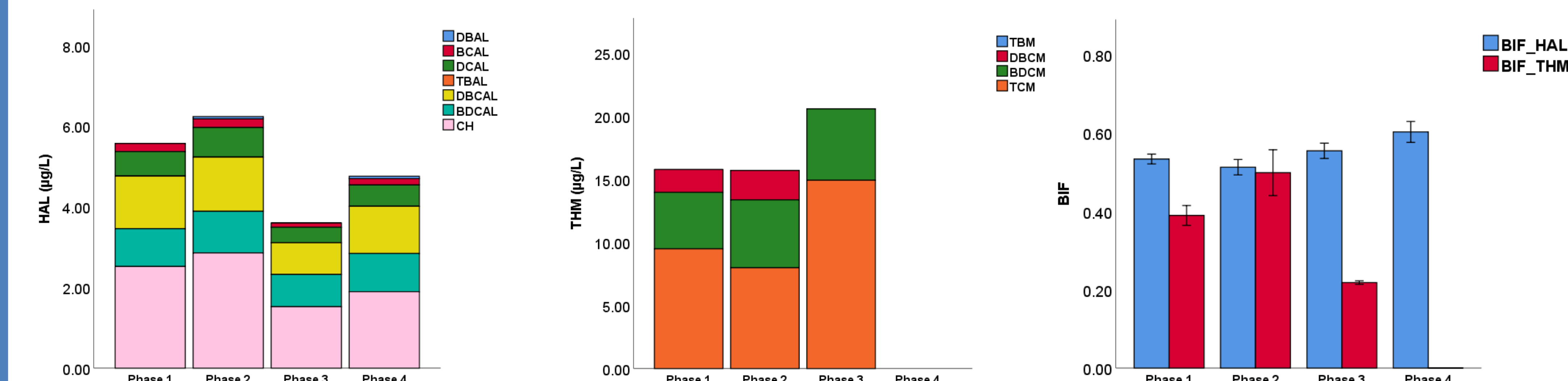


Seasonal variability of HALs

Spatial variability of HALs

Spatial variability of DBP speciation

### Effects of ozonation on the formation and speciation of DBPs (treated water of DWTP1)



Variability of HALs according to different ozonation strategies

Variability of THMs according to different ozonation strategies (data unavailable for Phase 4)

Variability of bromine incorporation factors (BIFs) according to different ozonation strategies (BIFs of THMs unavailable for Phase 4)

## CONCLUSIONS & PERSPECTIVES

- CH accounted for >50% of the total HALs (HAL7) whereas dihalogenated acetaldehydes (DHALs) represented <10% of HAL7 in both systems. Due to the low bromide levels in source water (~20 µg/L), no DBAL or TBAL were observed in either distribution system.
- Higher HAL7 levels were generally observed in warmer water (summer, fall).
- In the presence of residual chlorine, HALs generally increased as water residence times also increased.
- With increasing water residence times, the BIF of HALs decreased considerably, whereas the BIF of THMs remained generally stable during water transit in both systems. This suggests that the bromine-containing HALs are less stable than the bromine-containing THMs in distribution systems.
- Water temperature was the most highly correlated factor to the formation of HALs in this full-scale occurrence study.
- Total **ozone** dosage (Pre-O<sub>3</sub> + Post-O<sub>3</sub>) was shown to be a contributing factor of HAL formation. A strong correlation between ozone dose and HAL7 levels confirms the importance of ozonation on the formation of HALs.
- Pre-O<sub>3</sub> appeared to be crucial for the formation of **DBAL** in the DWTP under study, whereas the mechanism needs to be further investigated.
- Ozonation lowered significantly the level of total **THMs** while higher ozone dosage promoted the formation of brominated THMs (e.g., **DBCM**) and contributed to increasing **BIF** for THMs.

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