City of Toronto, University of Waterloo & Wilfrid Laurier University – Working Together on Corrosion Control

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National Water & Wastewater Conference 2022

Halifax, Nova Scotia

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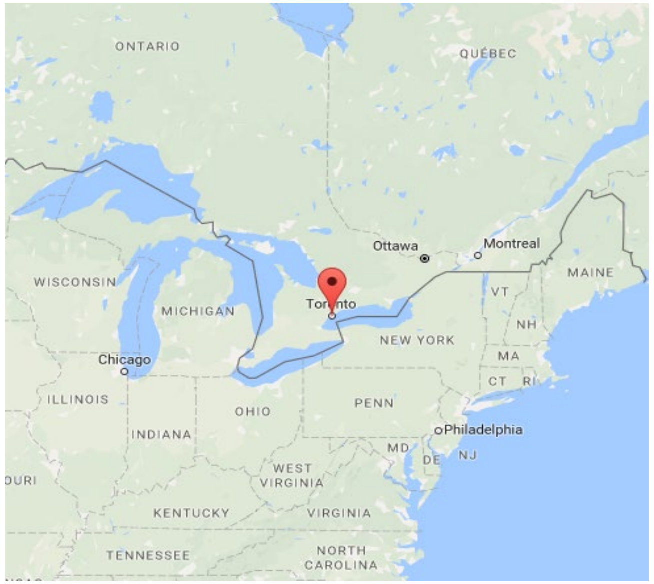
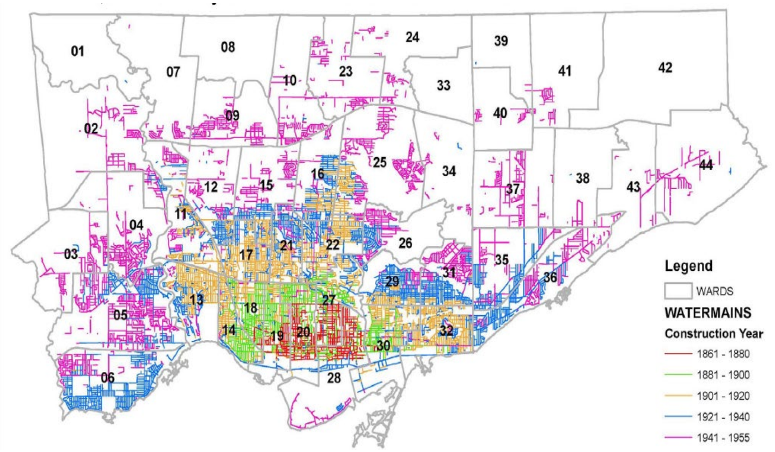
TORONTO Water



- Serves 3.6 million residents and businesses in Toronto, and portions of York
- Average production: 1,400 ML/d
- Operates and maintains:
  - 4 drinking water treatment plants,
  - 18 pumping stations,
  - 11 underground reservoirs
  - 4 elevated tanks and
  - more than 6,000 km of watermains

Toronto's Lead Problem

- In 2008, Toronto estimated that 65,000 lead service lines (LSLs) existed on City property
- Wide geographic distribution
- No control over lead sources on private property
- >10% of lead samples exceeded the ODWQS of 10 ug/L in 2 of 4 sampling rounds
- Under O.Reg 170/03, Toronto Water was required to prepare a Corrosion Control Plan




Final Report

Corrosion Control Plan for Toronto Water

Prepared for
Toronto Water

October 2010

Prepared by
CH2MHILL

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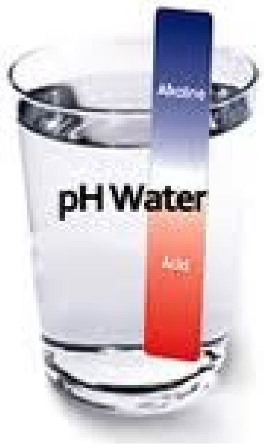
Corrosion Control Plan (2010)

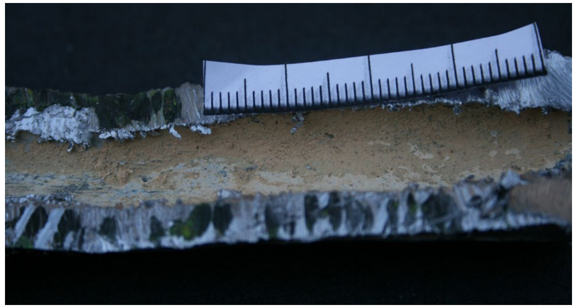
- Lead mitigation options identified:
  1. **Lead source reduction**
     - Lead Service Line replacement
  2. **Upward pH adjustment**
     - Add Sodium hydroxide to raise pH to 8.5 or greater
  3. **Phosphate based inhibition** (zinc phosphate, phosphoric acid, poly-phosphates)
     - Forms a protective coating inside all pipes/fixtures and reduces potential for lead to enter drinking water



Chosen Option for Lead Mitigation

3. Phosphate based inhibition using phosphoric acid

- Regulatory compliance can be achieved quickly
- Reduces lead in drinking water regardless of lead source
- LSL replacement to continue
- Adopted by City Council
- Supported and endorsed by Toronto Public Health as safe way to reduce lead levels



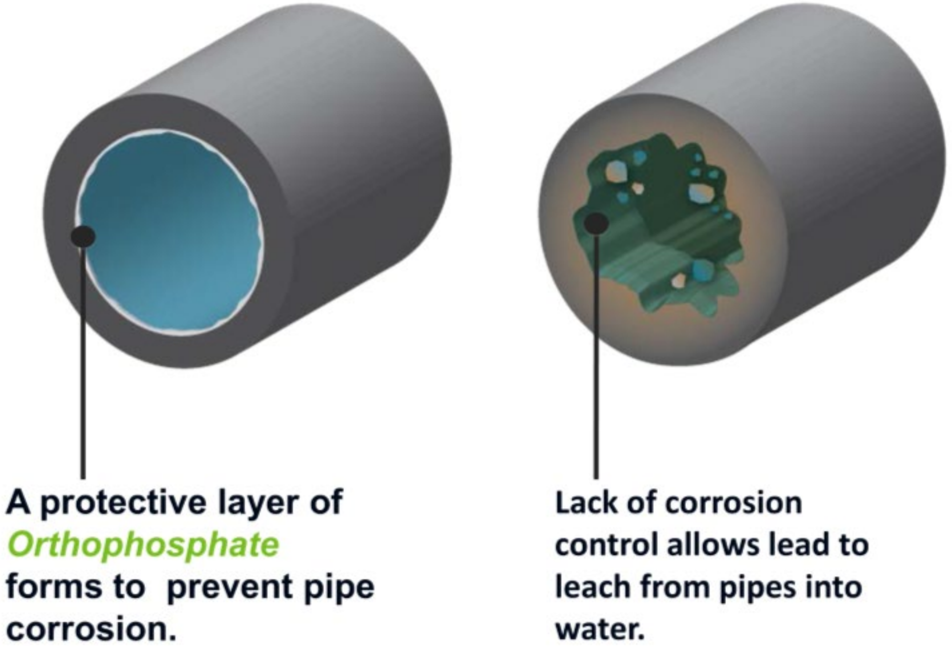
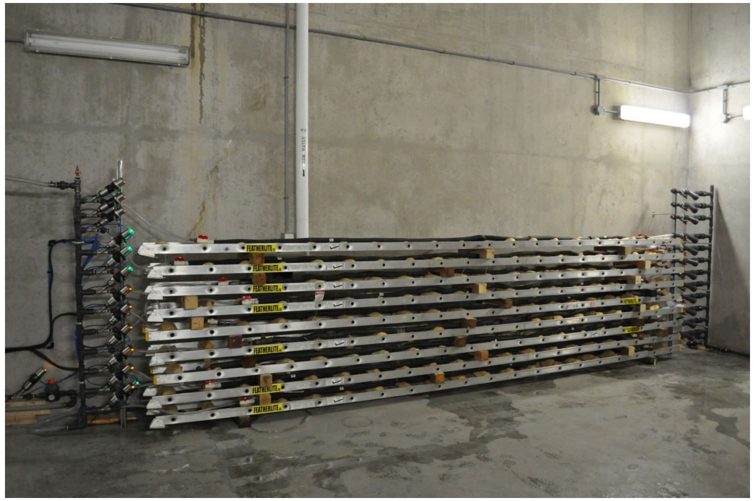


Image: Pittsburgh Water and Sewer Authority (PWSA) https://lead.pgh2o.com/understanding-lead-and-water/orthophosphate/

Corrosion Control Implementation

- Literature review completed on use of phosphate in chloraminated systems
    - Very limited information found

- Testing completed on harvested lead pipe rigs to investigate and confirm:
    - Lead level reductions to be achieved
    - Phosphate dosages required
    - Any potential water quality changes following corrosion control implementation



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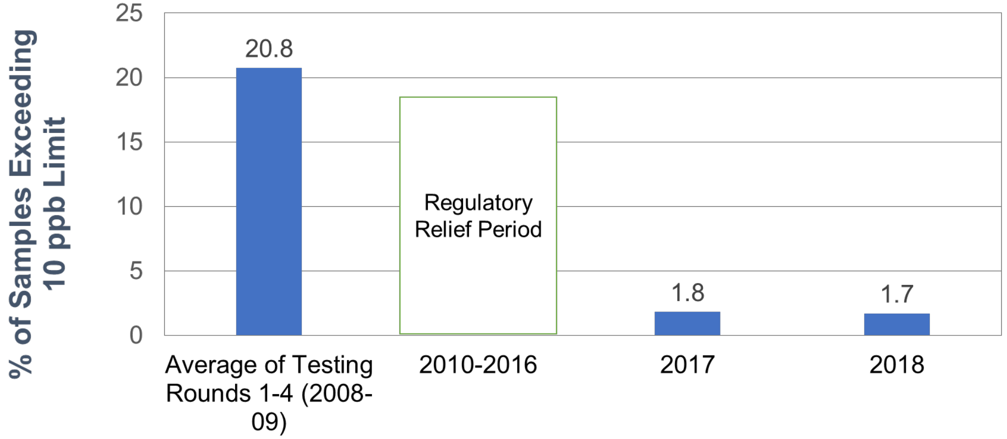
Corrosion Control Implementation

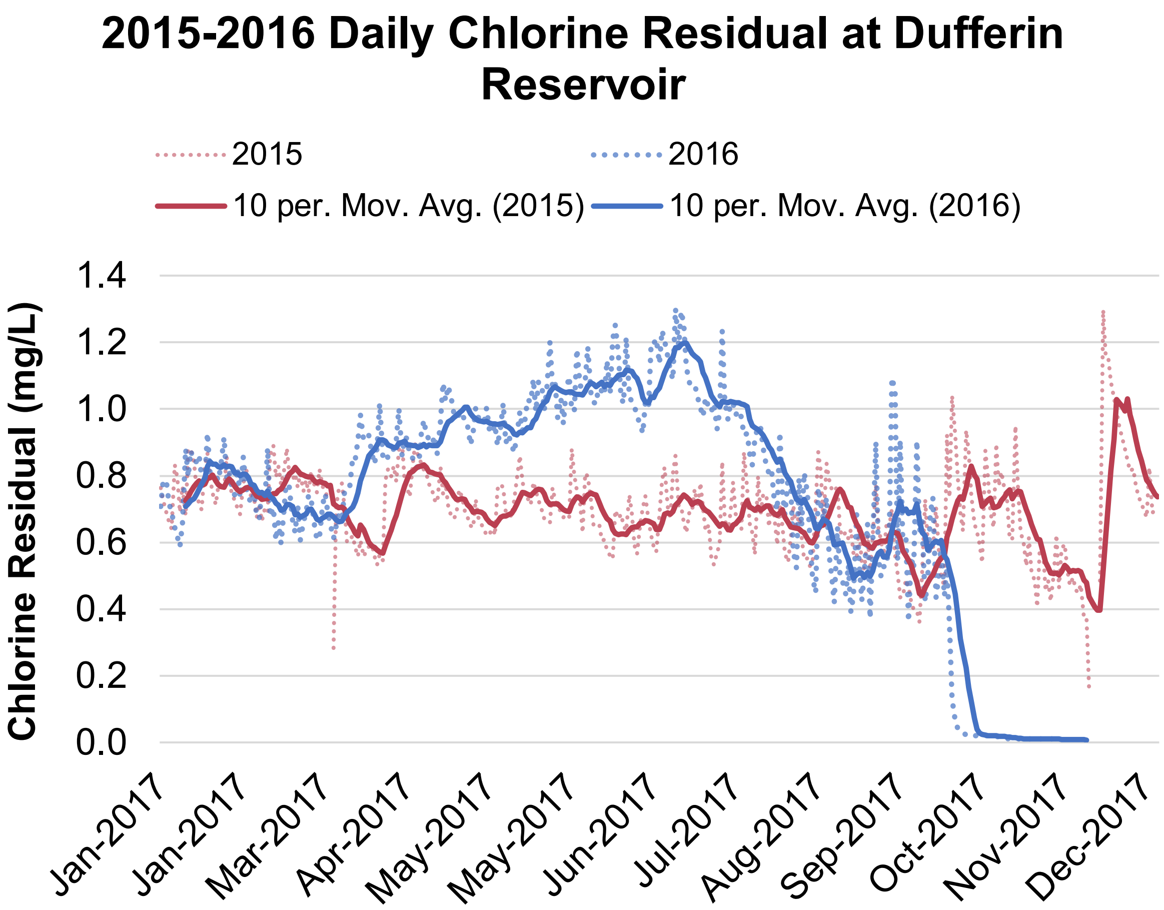
- Corrosion control systems commissioned at all 4 WTPs over the course of 2014
  - Year 1 and 2: Conditioning dose (3 mg/L as PO_4)
  - Year 3 and onwards: Maintenance dose (1-2 mg/L as PO_4)

- **SUCCESS STORY!** Significant reduction in lead levels was achieved with implementation of corrosion control treatment using phosphate



Nitrification Event Occurs

- October, 2016: City experienced a nitrification event at one of its reservoirs
- First documented event in Toronto's transmission system



- Sampling confirmed nitrification event in progress with nitrite levels >0.01 mg/L
- Chlorine residual could not be maintained despite every effort taken

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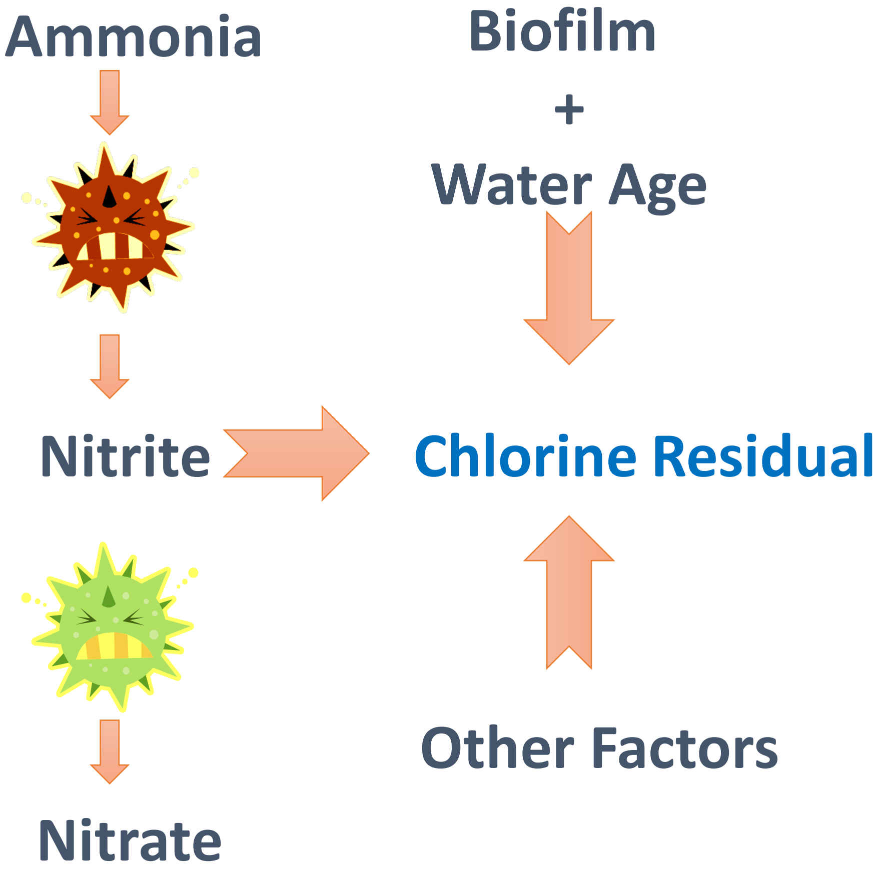
What is Nitrification?

- Nitrification is the biologically mediated process of converting ammonia to nitrate
- Can occur in chloraminated systems
- Ammonia is released through chloramine degradation which serves as a nutrient for nitrifying bacteria



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What Conditions Promote Nitrification?

Conditions promoting nitrification

- "Low" chlorine residuals (<1 mg/L)
- pH range
- Water temperature >14^{o}C
- High water age: lack of turnover, high hydraulic retention = lower chlorine residuals, higher water temp, increased free ammonia
- Presence of nutrients (C:N:P)

Potentially impacted by addition of phosphate for corrosion control

Research Partnership

- Long-term partners: City of Toronto and NSERC Chair led by Dr. Peter Huck at University of Waterloo
- Research team expanded to include microbiology team led by Dr. Robin Slawson at Wilfrid Laurier University
- **Research Project:** Examine the impacts of phosphoric acid addition for corrosion control on chlorine residual maintenance in the distribution system

UW's NSERC Industrial Research Chair in Water Treatment

- 6^{th} term research focus (2018-2023)
  - Managing raw water quality changes (robustness)
  - Green and innovative treatment processes
  - Distribution system corrosion (lead)
- Multi-disciplinary – engineering, microbiology, chemistry
- 9 researchers
- 16 partners (include larger and smaller systems)

Our Partners

Region of Waterloo

Lake Huron Primary Water Supply System

Elgin Area Primary Water Supply System

Toronto

Hamilton Water

The Corporation of the City of Brantford

Durham Region

Oxford County Growing stronger together

City of Guelph

Barrie

EPCOR

Ottawa

Niagara Region

OCWA Ontario Clean Water Agency Agence Ontarienne des Eaux

GHD

The District Municipality of Muskoka Managing Our Legacy Together

Associated Engineering

NSERC CRSNG

University of Waterloo

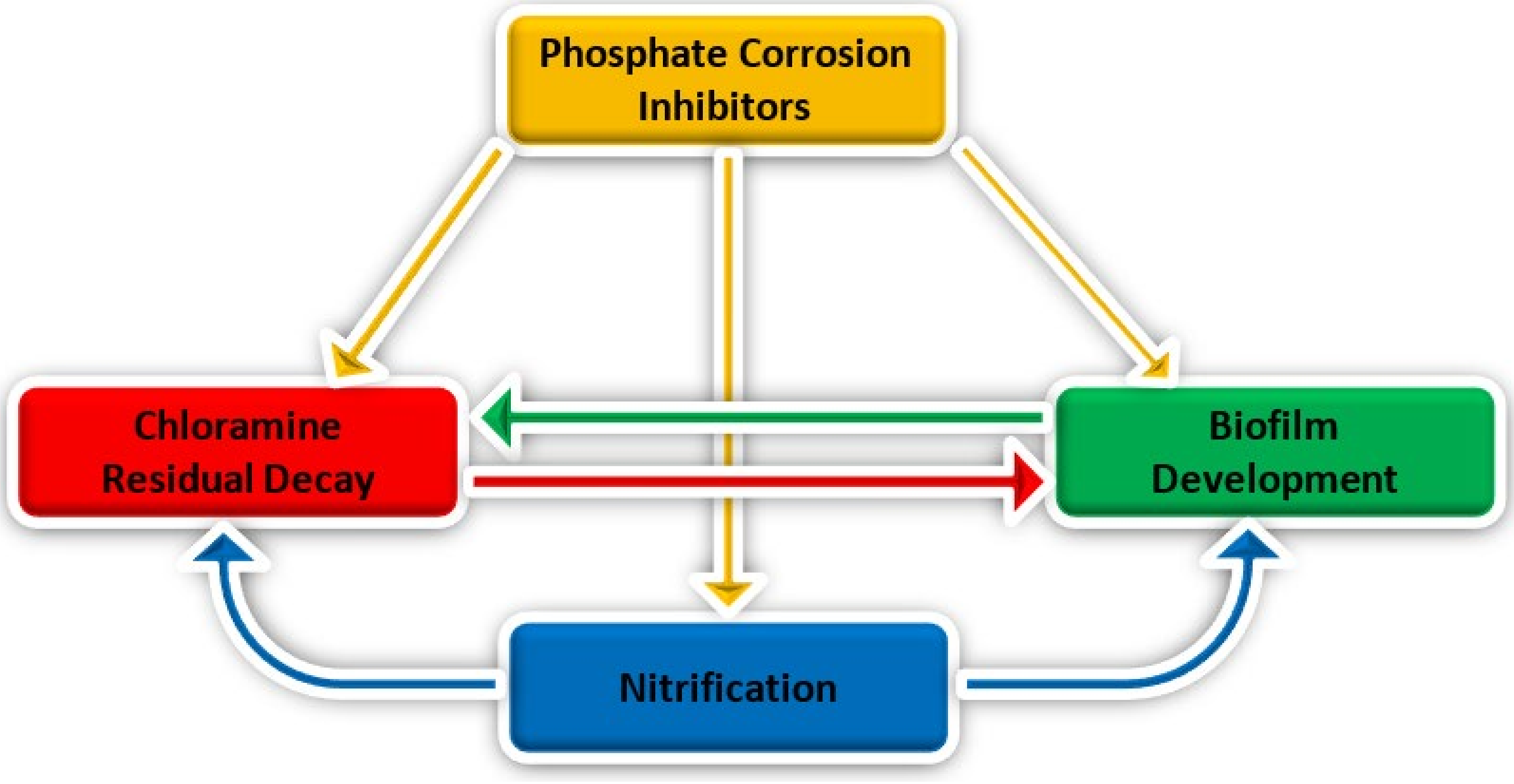
Laurier Applied and Environmental Microbiology Lab (Prof. R. M. Slawson)

- Water microbiology focus since 2003
  - Waterborne pathogen persistence
  - Microbial community robustness
  - Factors supporting remedial communities in engineered and natural environments
- Multi-disciplinary research focus – (microbiology, biochemistry, aquatic biology) and collaboration (engineering, analytical chemistry)
- Multi-faceted research approach with extensive field sampling experience brought to the bench for both culture-based and molecular assessments

Project Objectives

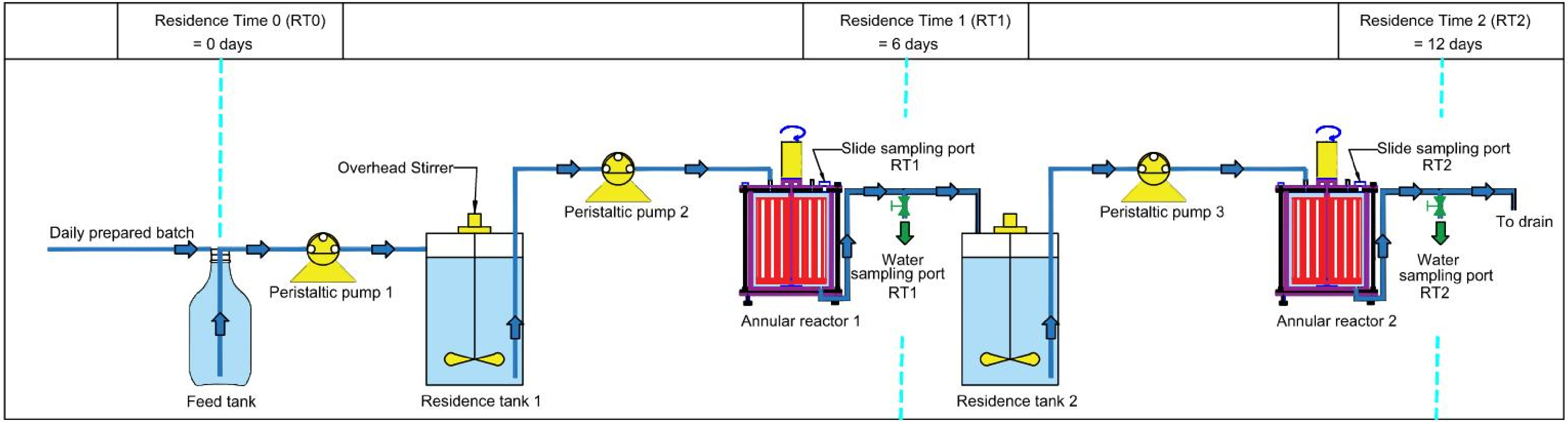
- Investigate the interrelationships between orthophosphate corrosion inhibitors, chloramine residual, biofilm development, and nitrification in distribution systems
  - Study the effects of different orthophosphate dosages and chloramine initial concentrations
  - Understand the relationship between biofilm development and chloramine decay in the presence of orthophosphate
  - Explore the impact of residence time and orthophosphate presence
  - Study the applicability of key results to other waters (starting soon)

Relationships



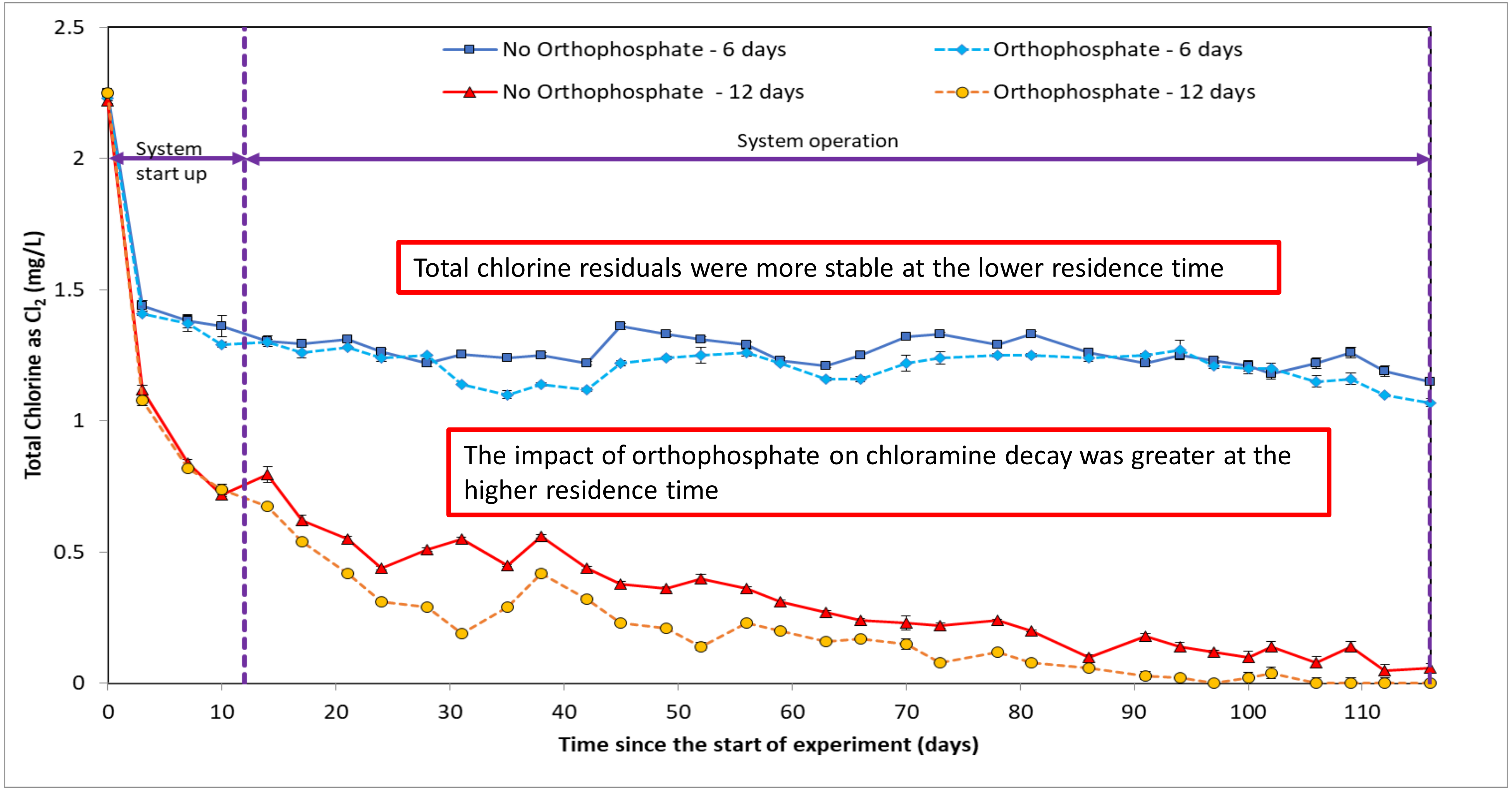
Test Procedure

- Two bench-scale systems in parallel (4 months)
  - Control (without OP) and with OP
  - Fed with treated Toronto water prior to disinfection
- pH of the feed water adjusted to 7.4 for all systems
- Temperature: 20°C



FT= feed tank, P= Pump, RT= retention tank, AR= annular reactor, DT= disposal tank

Example Result: Total Chlorine Decay



Error bars included, however they are not always visible due to being smaller than the data point symbol

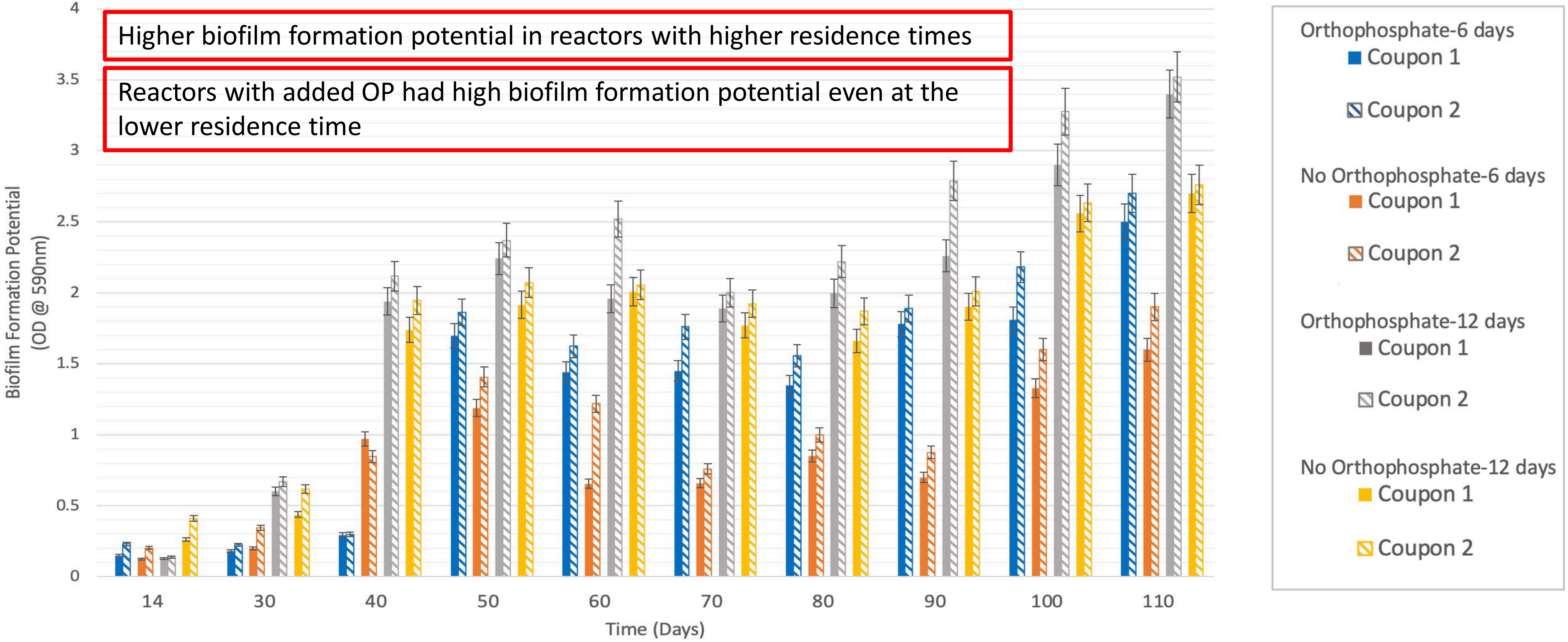
Conclusions - Physico-Chemical Results

- Free ammonia concentrations and monochloramine decay rates were higher at the higher residence time
- Orthophosphate increased monochloramine decay (more noticeably at the higher residence time)
- Nitrite levels increased at the higher residence time, especially in the presence of orthophosphate, though they remained stable at the lower residence time
- Greatest variation in monochloramine decay, ammonia release and nitrite formation was between residence times rather than orthophosphate presence/absence

Biofilm Formation Potential of Biofilms Removed From Coupons

Higher biofilm formation potential in reactors with higher residence times

Reactors with added OP had high biofilm formation potential even at the lower residence time



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Conclusions - Microbiological Results

- Microbial biofilm communities monitored every 10-12 days throughout the flow-through experiments
- Microbiological analyses used to create functional and genetic profiling of biofilm community present in annular reactors
- Determined that the addition of orthophosphate impacted microbial growth potential, biofilm formation potential and metabolic diversity
- Results from microbial and physio-chemical analyses may explain changes in disinfectant decay and potential for nitrification

Project Recommendations for Water Utilities

- To reduce the water quality impacts of orthophosphate addition:
  - Reduce orthophosphate dose to the extent possible
  - Increase pH
  - Apply biofilm control strategies
  - Reduce residence time
  - Increase chloramine concentrations at network extremities
  - Increase initial chloramine concentration

What the collaboration has meant for UW and Laurier

- Excellent opportunity for faculty and students involved to experience research as it directly supports real-world problems
- Detailed interactions with Toronto Water staff – learning their approach and perspectives

Project Participants

- University of Waterloo
  - Dr. Peter Huck, Dr. Sigrid Peldszus, Mahmoud Badawy, Kimia Aghasadeghi
- Wilfrid Laurier University
  - Dr. Robin Slawson, Mitchell Cooke, Vedika Bakshi
- Toronto Water
  - Liza Ballantyne, Gary Che, Alireza Anvari, Sarah Wilson

Thank you!

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