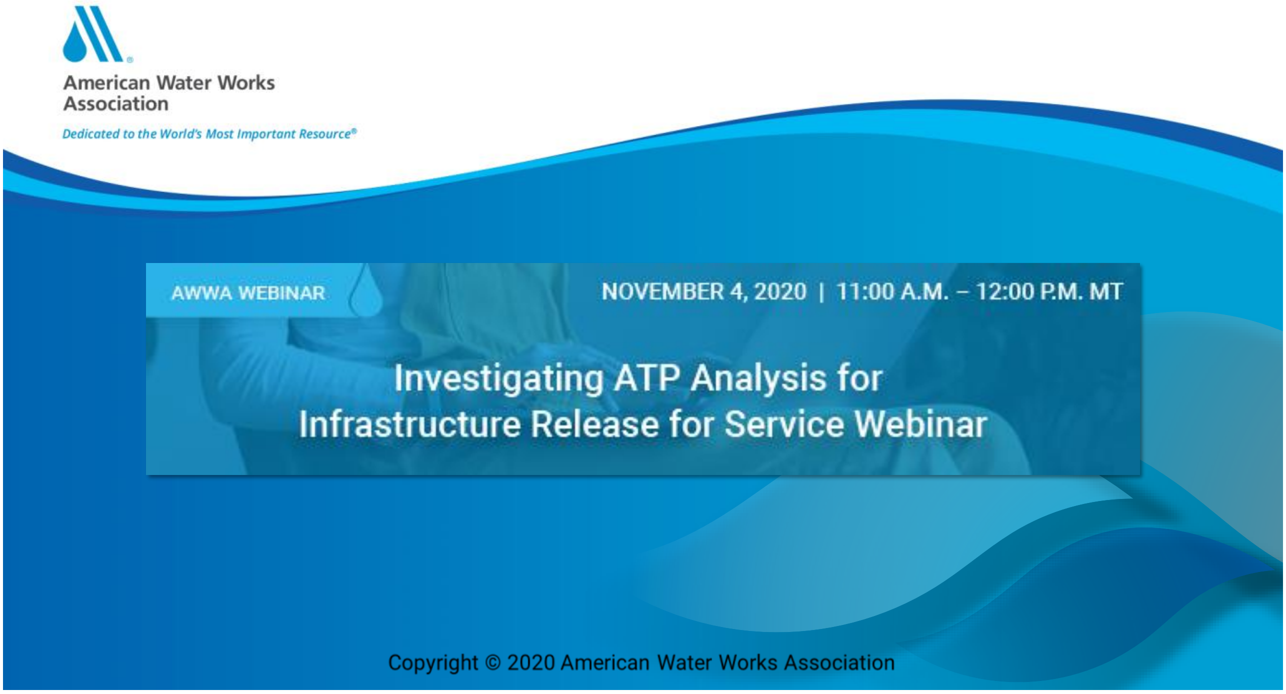
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AWWA WEBINAR
NOVEMBER 4, 2020 | 11:00 A.M. – 12:00 P.M. MT
Investigating ATP Analysis for Infrastructure Release for Service Webinar
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WEBINAR MODERATOR

Nathan Edman

Standards Methods Manager

American Water Works Association

Nathan oversees and manages the content production of Standard Methods for the Examination of Water and Wastewater compendium and is in charge of a majority of the AWWA chemical standards committees.

Nathan received his Bachelor of Science Degree in Chemistry from the University of Arizona.

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PANEL OF EXPERTS

Brad MacIlwain, PE, MASc
Application Engineer
LuminUltra Technologies

Amina Stoddart, PhD, PE
Assistant Professor
Dalhousie Univeristy

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AGENDA

I. Microbial Monitoring in Drinking Water Distribution Systems Using ATP — Brad MacIlwain, PE, MASc

II. ATP Dynamics in Drinking Water Distribution Systems — Amina Stoddart, PhD, PE

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ASK THE EXPERTS

Brad MacIlwain, PE, MASc
LuminUltra Technologies

Amina Stoddart, PhD, PE
Dalhousie Univeristy

Enter your **question** into the **question pane** on the right-hand side of the screen.
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LUMINULTRA microbial monitoring

MICROBIAL MONITORING IN DRINKING WATER DISTRIBUTION SYSTEMS USING ATP

Brad McIlwain, P.Eng., MASc.
Application Engineer
LuminUltra

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MICROBES IN WATER DISTRIBUTION SYSTEMS

- In drinking water, we often focus on specific microorganisms or groups of microorganisms
  - *E. coli* + total coliforms
  - Giardia
  - Crypto
- Often limited to regulated parameters
- Many operational issues caused by other microorganisms

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MICROBES IN WATER DISTRIBUTION SYSTEMS

Non-pathogenic microbes can cause several issues within a system:

- Consume disinfectant residual
- Promote biofilm formation
- Promote corrosion
- Contribute to taste and odour issues
- Cause nitrification

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MICROBES IN WATER DISTRIBUTION SYSTEMS

Complaints

Waste

Health Risks

Labour demands

Microorganisms cause costly problems. Time and resources can be saved by preventing or responding more quickly to microbiological growth.

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MECHANISMS FOR CONTROLLING GROWTH

- Treatment and Disinfection
  - Reduce nutrients
  - Remove, inactivate, or kill microorganisms
- Distribution
  - Maintain disinfectant residual
  - Maintain pH
  - Manage water age
  - Biofilm removal

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MONITORING DISTRIBUTION SYSTEM MICROBIOLOGICAL GROWTH

- When testing is needed
  - Routine testing – identify need for actions
  - Troubleshooting – identify problem
  - Follow-up – Verify corrective actions
- Common parameters
  - Temperature & pH
  - Turbidity
  - Disinfectant residual

What about biological content?

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BACTERIAL INDICATOR TESTING

- Examples include *E. coli* and total coliform testing
- Indicates a system breach
- Important for monitoring integrity and sanitary quality
- Impractical for operational monitoring

Typically no detections

Represent a portion of population

Delayed results

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GENERAL MICROBIOLOGICAL MONITORING IN DRINKING WATER

Heterotrophic Plate Count (HPC)

- HPC is an attempt at a total microbial count (CFU/mL)
- Drawbacks for field-use:
  - Only captures small proportion of community (0.1-1%)
  - Requires at least 48 hours for results.
- Many utilities choose not to do many HPCs since they do not isolate pathogens.

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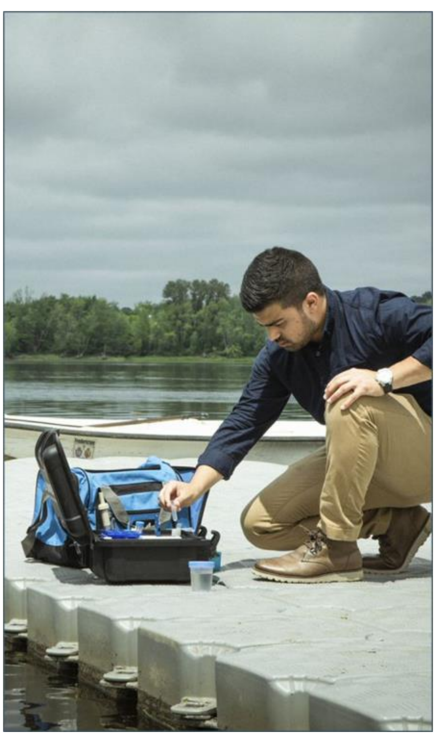

ATP TESTING

- ATP testing provides a rapid, non-specific measure of total microbial content.
- Advantages:
  - Real-time feedback (< 5 minutes)
  - Complete results (all cells contain ATP)
  - Field-ready
- Decisions can be made on-the-spot enabling same-shift troubleshooting
- Compliant with ASTM D4012.

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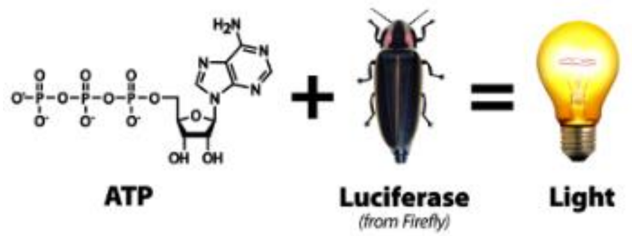
WHAT IS ATP?



- ATP = Adenosine Triphosphate
- Molecule associated with cellular energy in all living cells
- Contained in all living cells, so quantifying it allows you to quantify the size of the total population
- Measured via firefly luciferase reaction
  - ATP + luciferase = light = **microbes**
- Measurement takes only minutes.
- ATP testing has been used in food & medical hygiene for decades.

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HOW DO THESE TESTS COMPARE?

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HOW DO THESE TESTS COMPARE?

Legend:

E. coli

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HOW DO THESE TESTS COMPARE?

Legend:

E. coli

Total Coliforms

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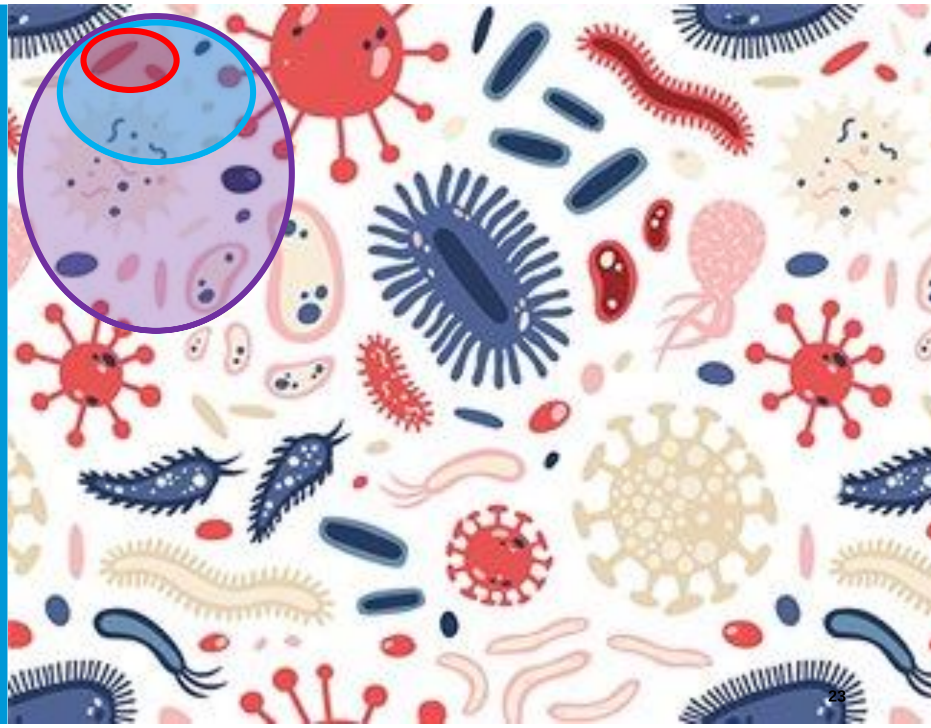
HOW DO THESE TESTS COMPARE?

Legend:
E. coli
Total Coliforms
HPCs



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HOW DO THESE TESTS COMPARE?

Legend:
E. coli
Total Coliforms
HPCs
ATP

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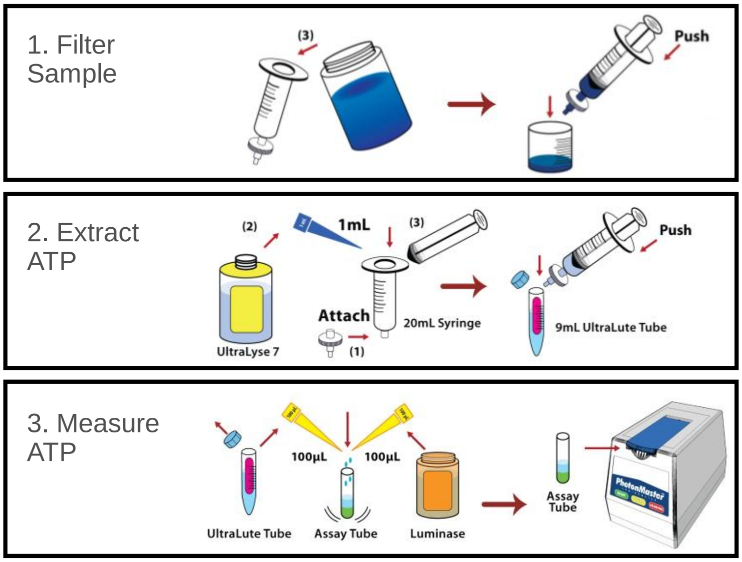
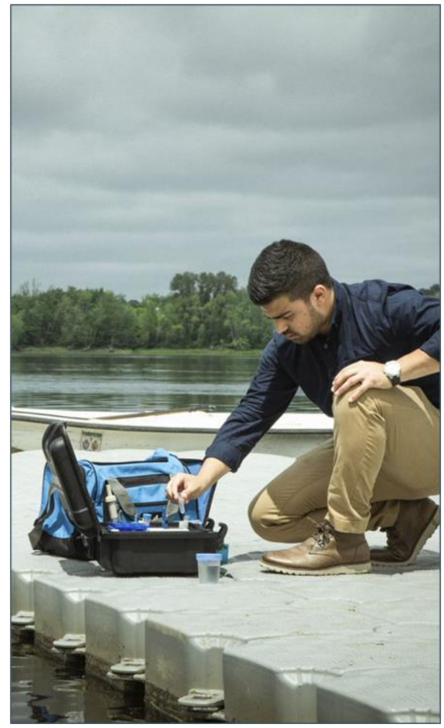
RUNNING ATP TESTS





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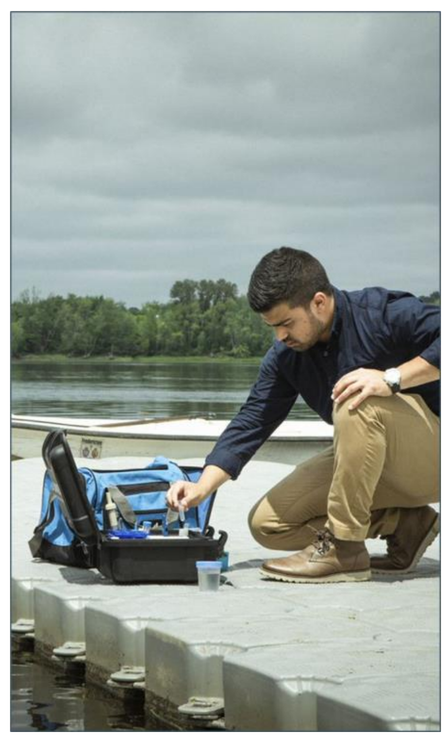
RUNNING ATP TESTS

Measurements are obtained in relative light units (RLU) and converted to concentration of ATP (pg/mL) using a standard calibration.

Typical Interpretation Guidelines

Action Level	
Good Control	< 1 pg/mL
Preventive Action	1 – 10 pg/mL
Corrective Action	> 10 pg/mL



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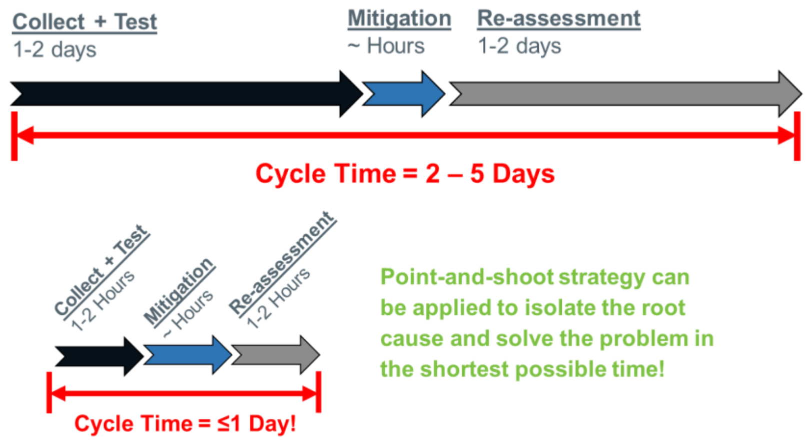
IMPLEMENTATION

Traditional Culture Tests

2nd Generation ATP Testing



Point-and-shoot strategy can be applied to isolate the root cause and solve the problem in the shortest possible time!

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HOW CAN ATP BE USED?

Distribution Monitoring

- Routine monitoring for growth
- Trace up the line to find the source of issues
- Flush (not too much, not too little)
- Boost disinfectant/burnout
- Managing storage tank operations
- Confirm water quality before completing regulatory and compliance tests
- Confirm water quality on-site immediately after line repairs

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HOW CAN ATP BE USED?

Other Applications

- Source water monitoring (algae, cyanobacteria)
- Biofiltration
- Membrane filtration pre-treatment
- Monitor growth as part of water management program for building water systems

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CASE STUDY

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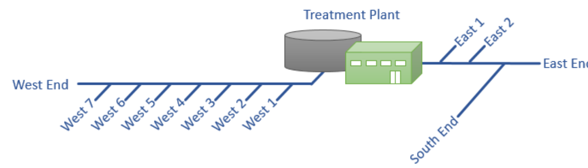
CASE STUDY – CROSS CONNECTIONS

- Naegleria fowleri amoeba found in a Louisiana drinking water distribution system
- Action taken to raise total chlorine residual to emergency rule level
- Samples collected and analyzed for total chlorine and ATP to establish a baseline



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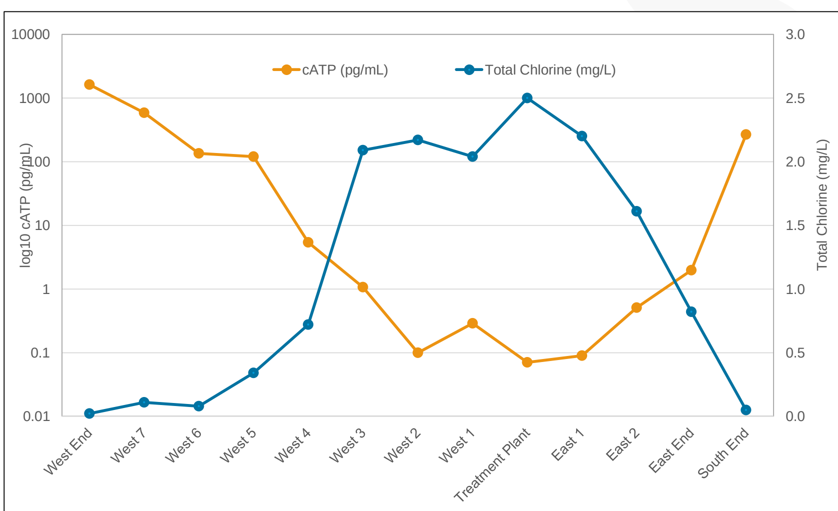
CASE STUDY – CROSS CONNECTIONS

- High ATP and low chlorine at ends of system
- ATP spike and chlorine drop between West 4 and West 5



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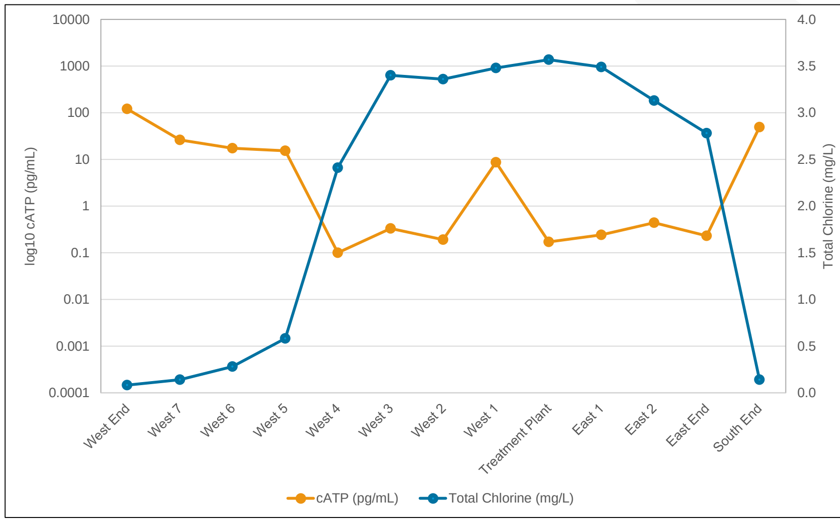
CASE STUDY – CROSS CONNECTIONS

- Investigation around West 4 identified cross connection with dead end
- ATP and chlorine improved after removal
- Target residuals still not met



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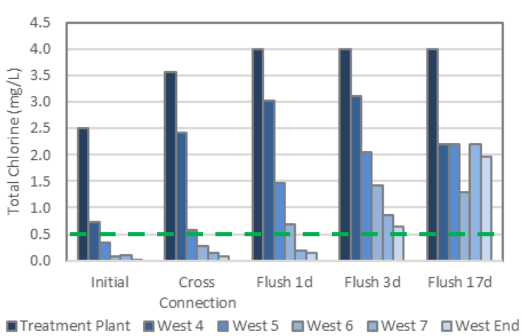
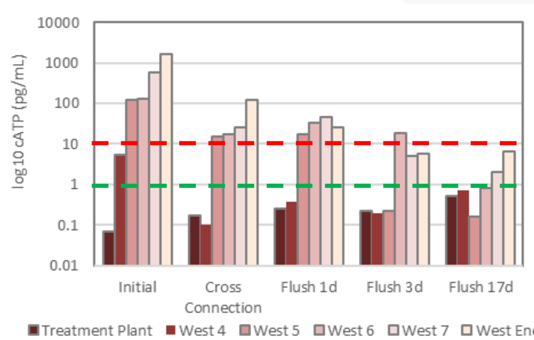
CASE STUDY – CROSS CONNECTIONS





- Operators increased residual and conducted flushing
- Chlorine residual and ATP concentrations improved, meeting targets within 17 days

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SUMMARY

- ATP provides a rapid method for measuring total bioburden in water samples at any stage of the water supply process – supply, treatment, and distribution
- Tests are designed specifically for field-use, providing results on the spot
- Not dependent on incubation – test is rapid and measures all active cells, not just those capable of growing on media
- Can be used for routine monitoring, troubleshooting, and assessing corrective actions

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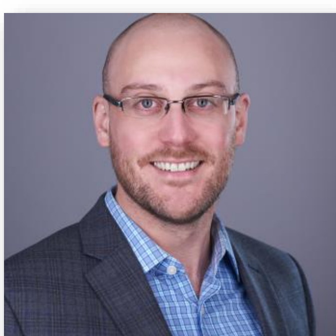
ASK THE EXPERTS



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Dalhousie Univeristy

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DALHOUSIE UNIVERSITY

ARCADIS Design & Consultancy for natural and built assets

ATP DYNAMICS IN DRINKING WATER DISTRIBUTION SYSTEMS

Amina Stoddart
Assistant Professor
Dalhousie University

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AWWA TEC PROJECT

ATP & Coliform Analysis Comparison For Infrastructure Release For Service

Acknowledgements

DALHOUSIE UNIVERSITY

- **Amina Stoddart, PhD**
- **Graham Gagnon, PhD**
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- Toni Mullin

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- **Ashley Evans, PE**
- Rebecca Slabaugh, PE
- Brent Alspach, PE

American Water Works Association

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- **Technical Educational Council**
- **Distribution System Committee**

Project Advisory Committee

- Richard Giani
- Corinne Bertoia
- Laura Meteer
- Theodore Nicholas
- Randy Easley
- Dave Tracey

Participating Utilities

- Halifax Water
- Greater Cincinnati Water Works
- Ann Arbor
- Newmarket
- City of Bethlehem
- Valley Water
- York

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PROJECT MOTIVATION

- **Total coliform testing** is routinely used as a key determinant of when distribution system infrastructure can be released for service following:
  - Installation of a **new main**
  - Repair of a **main break**
  - Cleaning, disinfection, and/or maintenance of a **treated water storage reservoir**
- **Total coliform testing can take 20-30 h** from time of collection to result
- Use of an **alternative indicator** to coliform testing could have economic, conservation, customer, environmental and community benefits

Water main break (HalifaxToday, 2020)

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PROJECT OBJECTIVE

Investigate the use of **adenosine triphosphate (ATP)** as a risk assessment indicator for operational guidance that may be used as an alternate method to total coliform testing for distribution system events

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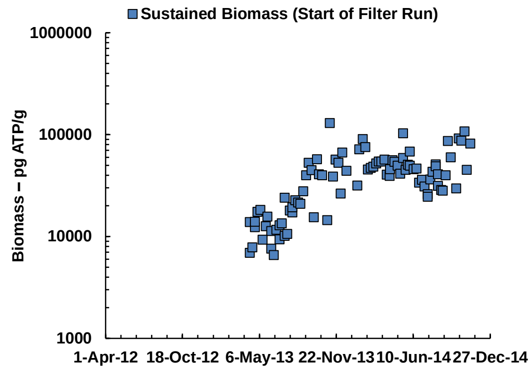
ADENOSINE TRIPHOSPHATE (ATP)

- ATP is an energy carrying molecule found in all living cells
- ATP concentration can provide an indication of biomass quantity in a laboratory or field setting within minutes
- Measurement of ATP content in microorganisms has found use in the water industry for:
  - Microbial monitoring in distribution systems
  - Biofilters



Stoddart, A.K., Schmidt, J.J. & Gagnon, G.A. 2016. Biomass evolution in full-scale anthracite-sand drinking water filters following conversion to biofiltration. *J Am Water Works*, *108*(12), 615-623.

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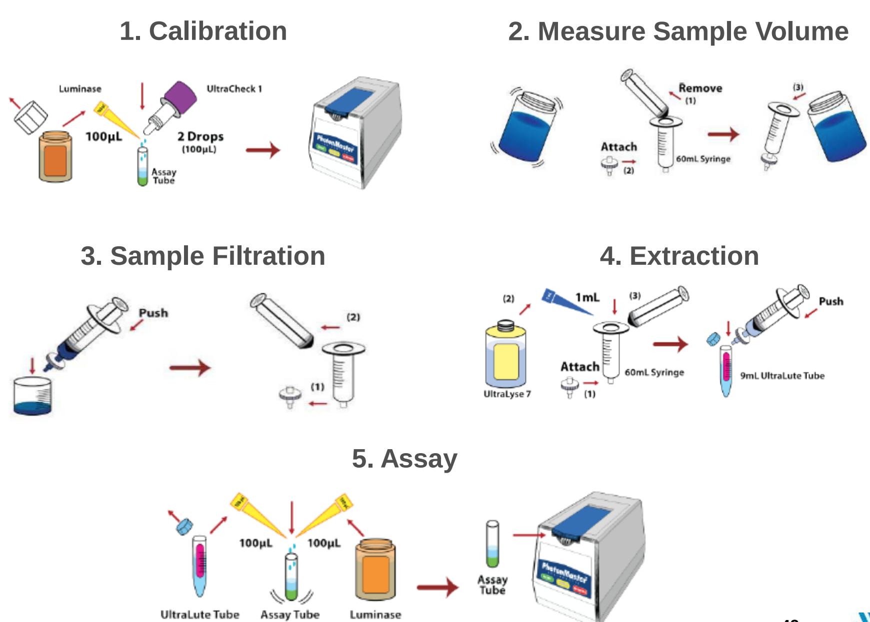
ADENOSINE TRIPHOSPHATE (ATP)



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GENERAL ATP ADVANTAGES

- Sample turnaround time of minutes (~15 mins) as compared to hours (20-30 h) for total coliform testing
- Suitable for in-field testing
- Non-specific

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POTENTIAL ATP ADVANTAGES FOR DISTRIBUTION SYSTEM INFRASTRUCTURE

Distribution System Targeted Event Type	Disadvantages of Coliform Analysis due to 20-30 Hour Analysis Turn-Around-Time	cATP Analysis Considerations
Releasing newly installed water mains for service NEW MAINS	• Increased construction time and costs and lost production • Excess water released during flushing	• Sample turnaround time of approximately 15 minutes • True total non-specific biomass measurement rather than a specific biological assay • On-site testing as opposed to laboratory testing, allowing for rapid decisions
Releasing mains for service after breaks MAIN BREAKS	• Customer/community impacts due to Boil Water Advisory/Boil Orders or suspended service	
Releasing treated water storage reservoirs for service after cleaning, disinfection, and/or maintenance RESERVOIRS	• Negative distribution system water quality impacts • Temporary loss of storage and/or reduced pressure in the distribution system	

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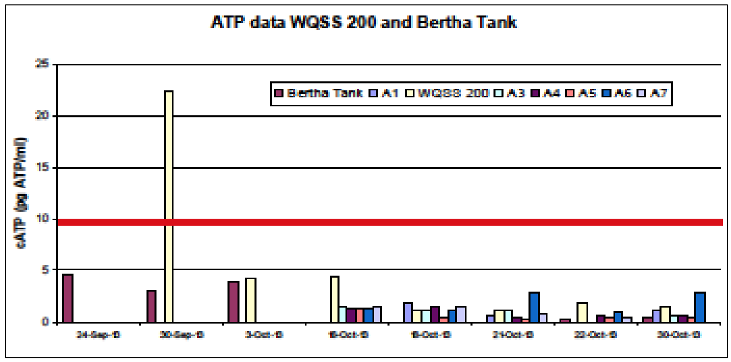
EARLY ATP STUDY IN LITERATURE:

PORTLAND WATER BUREAU



Gupta, K. (2014) Evaluation of the ATP Test for Nitrification Monitoring at the Portland Water Bureau. Pacific Northwest Section Conference.

- A routine distribution system sample came back positive for total coliforms, along with multiple resamples
- Extensive water quality monitoring in combination with total coliform sampling was conducted
- ATP was added to monitoring list (with chlorine and temperature)
  - TC sampling could have led to a resampling loop
  - HPC found to be too time consuming
- For this event, ATP in conjunction with other parameters, provided extra confidence

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APPROACH

Utility	Disinfectant Type	Size
A	Chloramines	>100,000 Customers
B	Free Chlorine	>1 million Customers
D	Free Chlorine	>300,000 Customers
E	Chloramines	<100,000 Customers
F	Chloramines	>1 million Customers
I	Free Chlorine	<50,000 Customers

- Partnered with utilities across North America to collect **historical and new ATP and total coliform distribution system data**
- Selected utilities with with different disinfectant type and service size

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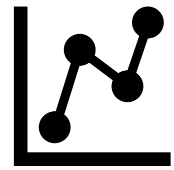
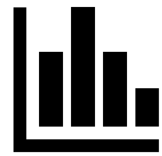
APPROACH:

HISTORICAL DATA

- Where available, utilities provided historical ATP and coliform distribution system water quality data
  - Data reflected normal operation and provided a baseline for each distribution system



- Also requested temperature, pH, turbidity, dissolved oxygen, total organic carbon, and heterotrophic plate counts where available



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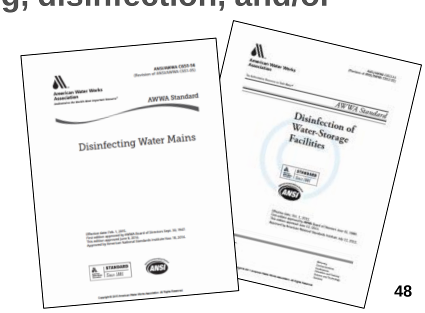
APPROACH:

EVENT SAMPLING

- Utilities followed standard sampling protocols when releasing water mains and/or water storage reservoirs for service

- Specific Events:
  - releasing **newly installed water mains** for service
  - releasing **mains for service after breaks**
  - releasing **treated water storage reservoirs for service after cleaning, disinfection, and/or maintenance**



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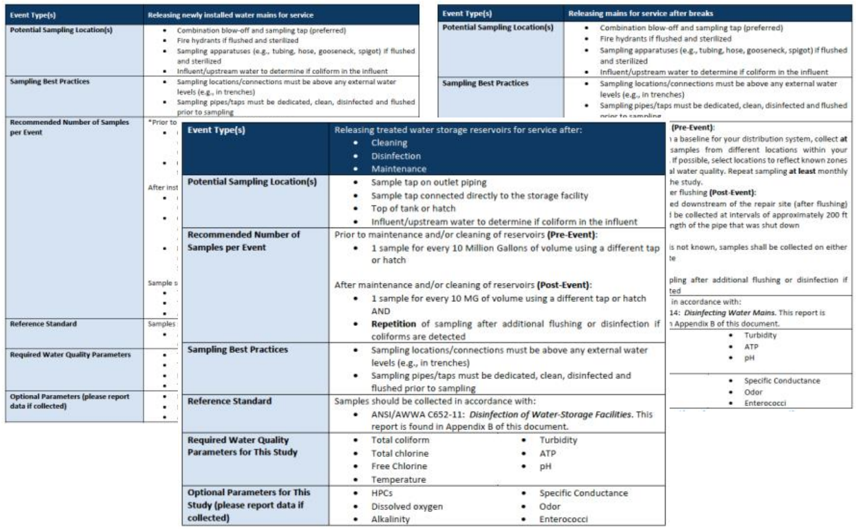
APPROACH:

EVENT SAMPLING



Event Type(s)	Releasing newly installed water mains for service
Potential Sampling Location(s)	• Combination blow-off and sampling tap (preferred) • Fire hydrants if flushed and sterilized • Sampling apparatuses (e.g., tubing, hose, gooseneck, spigot) if flushed and sterilized • Influent/upstream water to determine if coliform in the influent
Sampling Best Practices	• Sampling locations/connections must be above any external water levels (e.g., in trenches) • Sampling pipes/taps must be dedicated, clean, disinfected and flushed prior to sampling

Event Type(s)	Releasing mains for service after breaks
Potential Sampling Location(s)	• Combination blow-off and sampling tap (preferred) • Fire hydrants if flushed and sterilized • Sampling apparatuses (e.g., tubing, hose, gooseneck, spigot) if flushed and sterilized • Influent/upstream water to determine if coliform in the influent
Sampling Best Practices	• Sampling locations/connections must be above any external water levels (e.g., in trenches) • Sampling pipes/taps must be dedicated, clean, disinfected and flushed prior to sampling

Event Type(s)	Releasing treated water storage reservoirs for service after: • Cleaning • Disinfection • Maintenance	
Potential Sampling Location(s)	• Sample tap on outlet piping • Sample tap connected directly to the storage facility • Top of tank or hatch • Influent/upstream water to determine if coliform in the influent	
Recommended Number of Samples per Event	Prior to maintenance and/or cleaning of reservoirs **(Pre-Event)**: • 1 sample for every 10 Million Gallons of volume using a different tap or hatch After maintenance and/or cleaning of reservoirs **(Post-Event)**: • 1 sample for every 10 MG of volume using a different tap or hatch AND • **Repetition** of sampling after additional flushing or disinfection if coliforms are detected	
Sampling Best Practices	• Sampling locations/connections must be above any external water levels (e.g., in trenches) • Sampling pipes/taps must be dedicated, clean, disinfected and flushed prior to sampling	
Reference Standard	Samples should be collected in accordance with: • ANSI/AWWA C652-11: *Disinfection of Water-Storage Facilities*. This report is found in Appendix B of this document.	
Required Water Quality Parameters for This Study	• Total coliform • Total chlorine • Free Chlorine • Temperature	• Turbidity • ATP • pH
Optional Parameters for This Study (please report data if collected)	• HPCs • Dissolved oxygen • Alkalinity	• Specific Conductance • Odor • Enterococci

- Provided utilities with detailed sampling plans for each event type in addition to AWWA/ANSI resources

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APPROACH:

EVENT SAMPLING

- Additional sampling requested:
  - Pre-event, Event, Post-event
- Additional parameters requested:
  - Microbiological; General water quality

Required Water Quality Parameters	Optional Parameter
• cATP • Total Coliform (quantitative) • Disinfectant Residual • Temperature • Turbidity • HPC • pH	• Dissolved Oxygen • Alkalinity • Specific Conductance • Odor • Enterococci

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SUMMARY OF DATA COLLECTED TO DATE

Utility	Historical Data Provided	Events (N=#)		
		New Main	Main Break	Reservoir
A	✓	7	-	-
B	✓	7	3	-
D	✓	3	7	1
E	✓	1	-	-
F	✓	-	-	-

Note: Not all participating utilities had historical data or were able to collect data for the study at time of presentation

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PRELIMINARY FINDINGS:

HISTORICAL DATA

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PRELIMINARY FINDINGS:

HISTORICAL DATA

- Observed a larger range in ATP values than has been reported in literature
- Under normal operating conditions, ATP concentrations in the participating distribution systems ranged from **<1 pg/mL to >1000 pg/mL**

Sample Location	n	Average (pg/mL)	Range (pg/mL)	Source
Reservoirs and network pipes	7	1.8 ± 1.0	-	Lautenschlager et al., 2010
Water treatment plant effluent & distribution plumbing	243	2.5	1 – 8	Van der Kooij, 2003
Watermain pipes	-	2.7	-	Lui et al., 2014
Premise plumbing	200	11.7 (± 8.62)[1]	2.54 – 47.7[1]	Siebel et al., 2008
Water mains & storage reservoirs	**-**	**-**	**<1 – >1000**	**Current Study**

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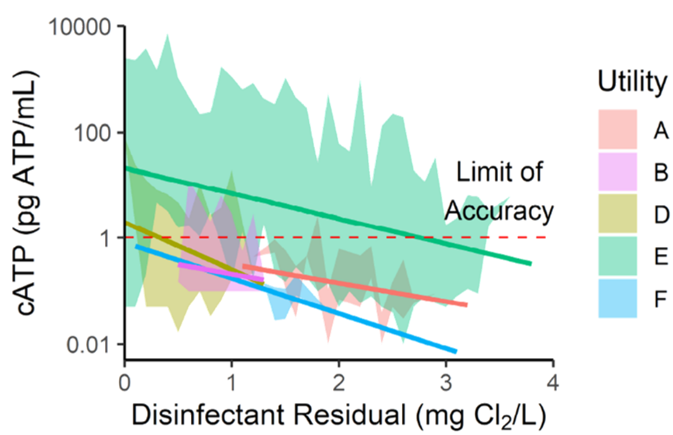
PRELIMINARY FINDINGS:

HISTORICAL DATA



- In general, **lower disinfectant residual** concentrations appeared to correspond to **higher ATP** concentrations
- Disinfectant residual appeared to have the greatest effect as compared to other water quality factors investigated (temperature, pH, etc.)

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PRELIMINARY FINDINGS:

EVENT DATA

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PRELIMINARY FINDINGS:

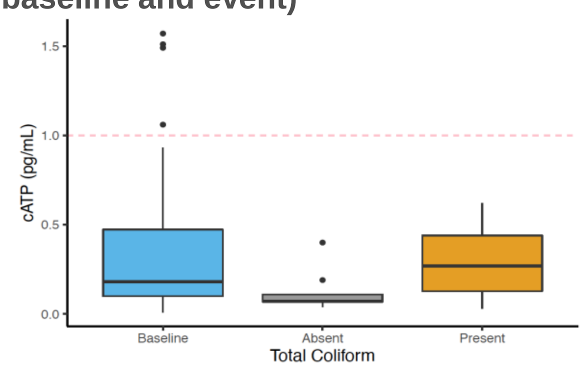
EVENT DATA

NEW MAIN

Utility A

(Chloramines, >100,000)

- Elevated average ATP observed when coliforms were present as compared to when absent
- ATP remained within distribution system baseline range during events sampling
- **ATP already well controlled within the system (<1 pg/mL baseline and event)**



Baseline samples (n=41)
Absent samples (n=9)
Present Samples (n=4)

Data represents one new main installation event

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PRELIMINARY FINDINGS:

EVENT DATA

NEW MAIN

Utility E

(Chloramines, <100,000)

- ATP was typically low (<10 pg/mL, often <1 pg/mL) during event sampling despite higher baseline ATP values
- In some cases, coliforms were identified in event samples when when ATP was low

Range Cellular ATP Values (pg/mL)		
Baseline	Total Coliform Absent	Total Coliform Positive
<1 – 7387 (n=1380)	<1 – 296 (n=10)	159 (n=1)

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PRELIMINARY FINDINGS:

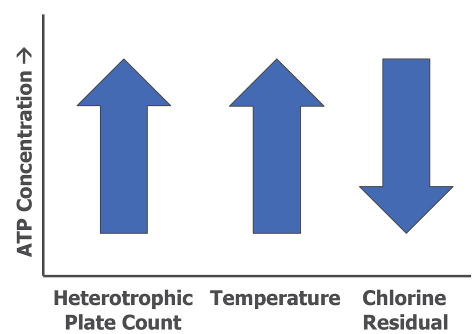
EVENT DATA

MAIN BREAK

Utility D

(Chlorine, >300,000)

- No positive coliform results across several (7) main break events
- Well controlled system
  - All event ATP results <10 pg/mL
- Higher event ATP appeared to correspond with higher HPC, higher temperature and lower chlorine residual



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CHALLENGES & LIMITATIONS

- Difficulty in coordinating sampling for main breaks given the unplanned nature of these events
- Difficulty in coordinating sampling when asking external contractors to add a new sample to their standard sample collection routine
- Challenges with measuring parameters in the field as field staff may not be equipped with necessary equipment and reagents
- Some utilities unable to revise standard procedures to allow for quantitative total coliform analysis
  - Comparing quantitative ATP to P/A coliform data a challenge

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PRELIMINARY TAKEAWAYS

- Baseline ATP concentration range is unique to each distribution system
  - When data was aggregated, higher baseline ATP was driven by lower chlorine residual more so than other water quality parameters
- ATP was typically well controlled (i.e., <10 pg/mL, often <1 pg/mL) during events across all utilities
  - Very few positive total coliform samples were observed during event sampling (all utilities following ANSI/AWWA Standards)
- Some preliminary evidence that higher ATP concentrations during event sampling may signal greater chance of a positive coliform result in certain distribution systems
  - Warrants further investigation

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THANK YOU!

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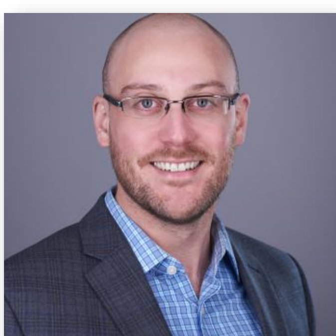
ASK THE EXPERTS



Brad MacIlwain, PE, MASc
LuminUltra Technologies

Amina Stoddart, PhD, PE
Dalhousie Univeristy

Enter your **question** into the **question pane** on the right-hand side of the screen.
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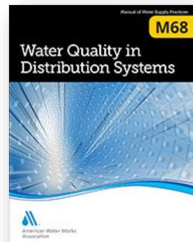
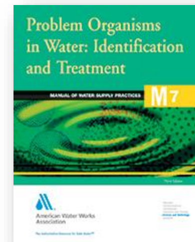
ADDITIONAL RESOURCES

- AWWA Water Quality Resource Community
- M68 Water Quality in Distribution Systems
  - AWWA catalog no: 30068
- M7 Problem Organisms in Water: Identification and Treatment
  - AWWA catalog no: 30007





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Nov 5 - FREE Webinar from SL Environmental Law Group: PFAS: Learn How to Navigate the Evolving Regulatory and Legal Landscape

Nov 12 - FREE Webinar from Hydromax USA: Pipeline Condition Assessment Technology - Innovative Solutions and Recent Field Applications

Nov 17 - FREE Webinar from Enchanted Rock: Industry Roundtable – Resilient Facility Design for the Water Utility Industry

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- Until next time, keep the water safe and secure.

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PRESENTER BIOGRAPHY INFORMATION

Brad McIlwain is an application engineer with LuminUltra, where he provides subject matter expertise in the development and implementation of LuminUltra's microbial monitoring technologies. Prior to joining LuminUltra, he worked as a consultant in the municipal water and wastewater industry. He holds a BASc and MASc in civil engineering.

Amina Stoddart is an Assistant Professor with the Centre for Water Resources Studies at Dalhousie Univeristy. Her group's research focuses on the development and application of tools to understand and optimize biological water treatment.

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