



The background of the slide is a detailed map of Southern Ontario, Canada, showing numerous watersheds delineated by black lines. Major cities and towns are labeled, including Ottawa, Kingston, Peterborough, Barrie, Guelph, and Hamilton. Key geographical features like Georgian Bay, Saugeen And Cape Croker Fishing Islands No. 1, and the Niagara Peninsula are also indicated. Major highways such as 400, 60, 27, 81, 4, and 390 are marked with their respective shields. The map is rendered in a light grey and white color scheme.

Next-Generation Tools for Protection of Surface Water Quality and Public Health

Amber Park, PhD

Senior Research Program Manager

University of Guelph



Canada faces significant challenges to surface water quality

1. Climate change & extreme weather events, e.g. flooding
2. Urbanization, land use changes, population growth
3. Aging infrastructure
4. Inputs from wildlife, agricultural & industrial sources

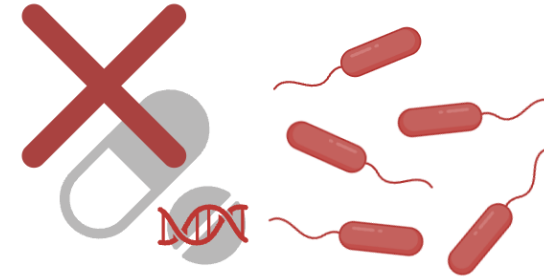
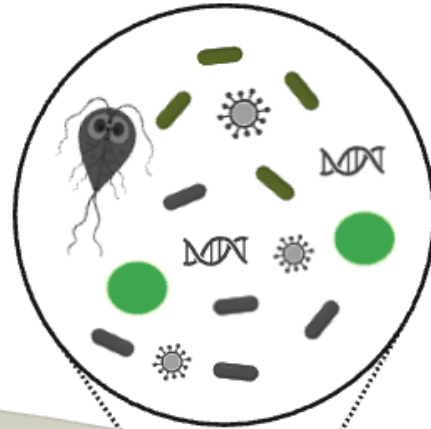


These pressures increase the risk of waterborne disease and spread of antimicrobial resistance (AMR)

WARNING

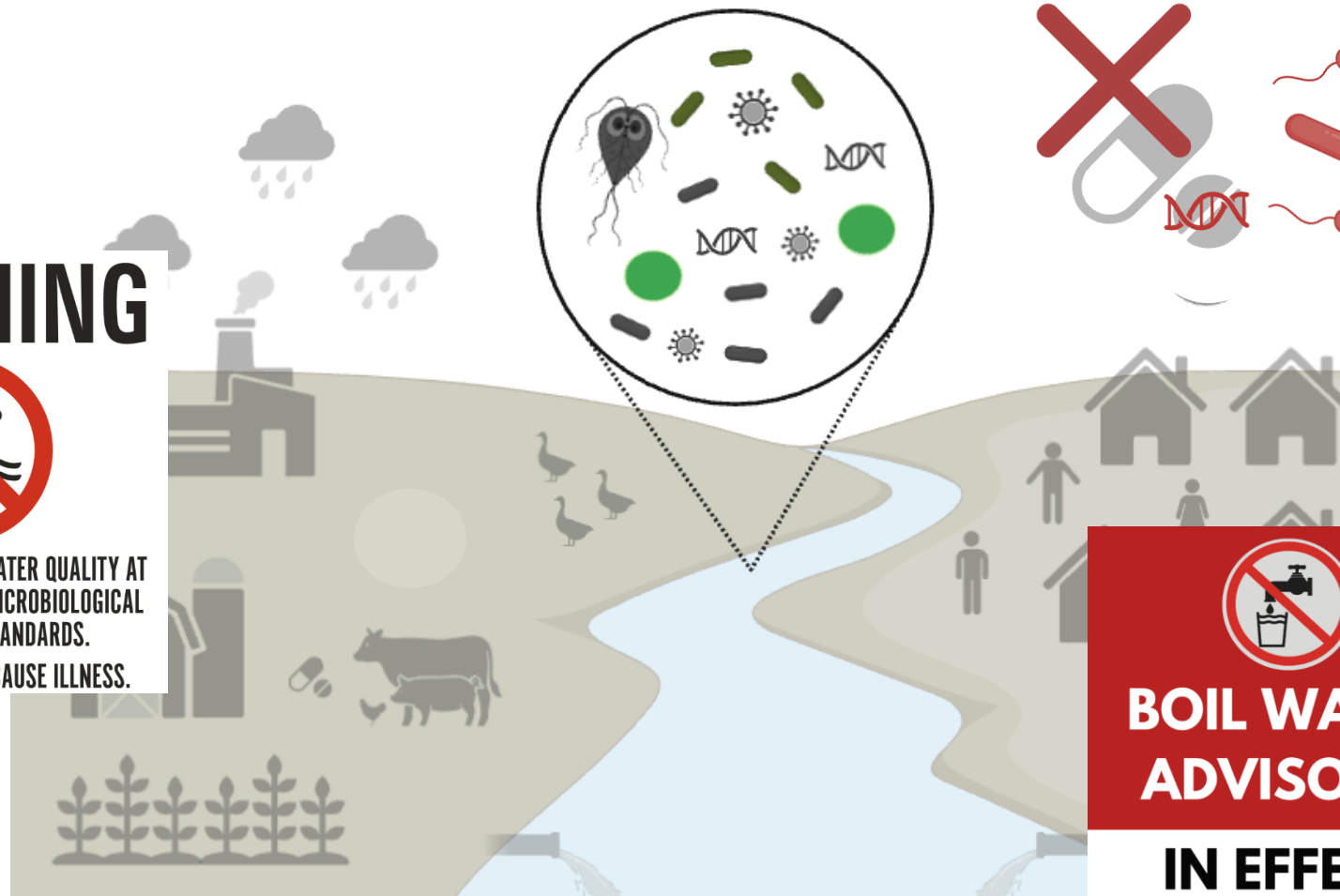


RAINFALL CAUSES THE WATER QUALITY AT THE BEACH TO EXCEED MICROBIOLOGICAL WATER QUALITY STANDARDS. WATER CONTACT MAY CAUSE ILLNESS.

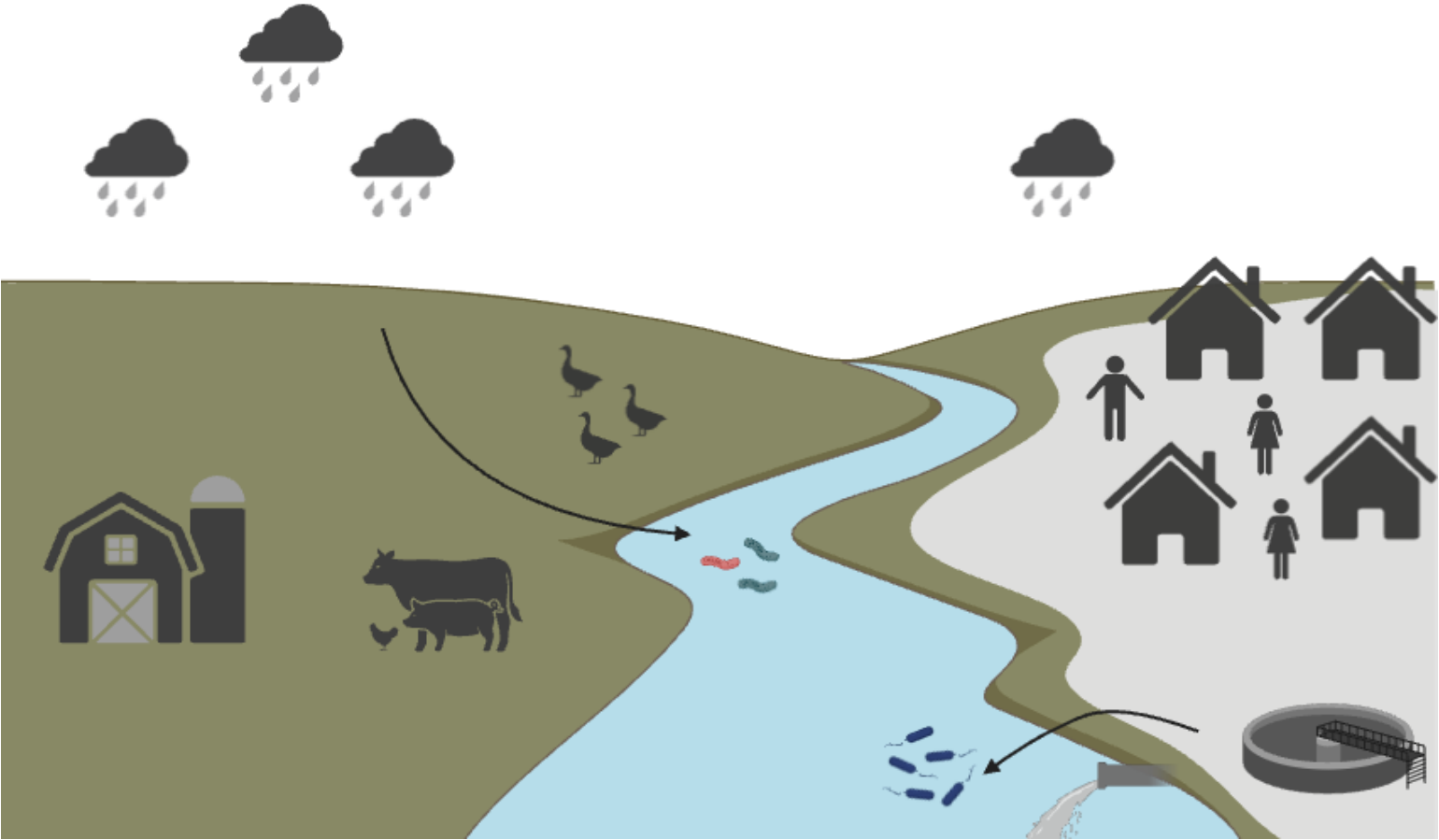


**BOIL WATER
ADVISORY**

IN EFFECT

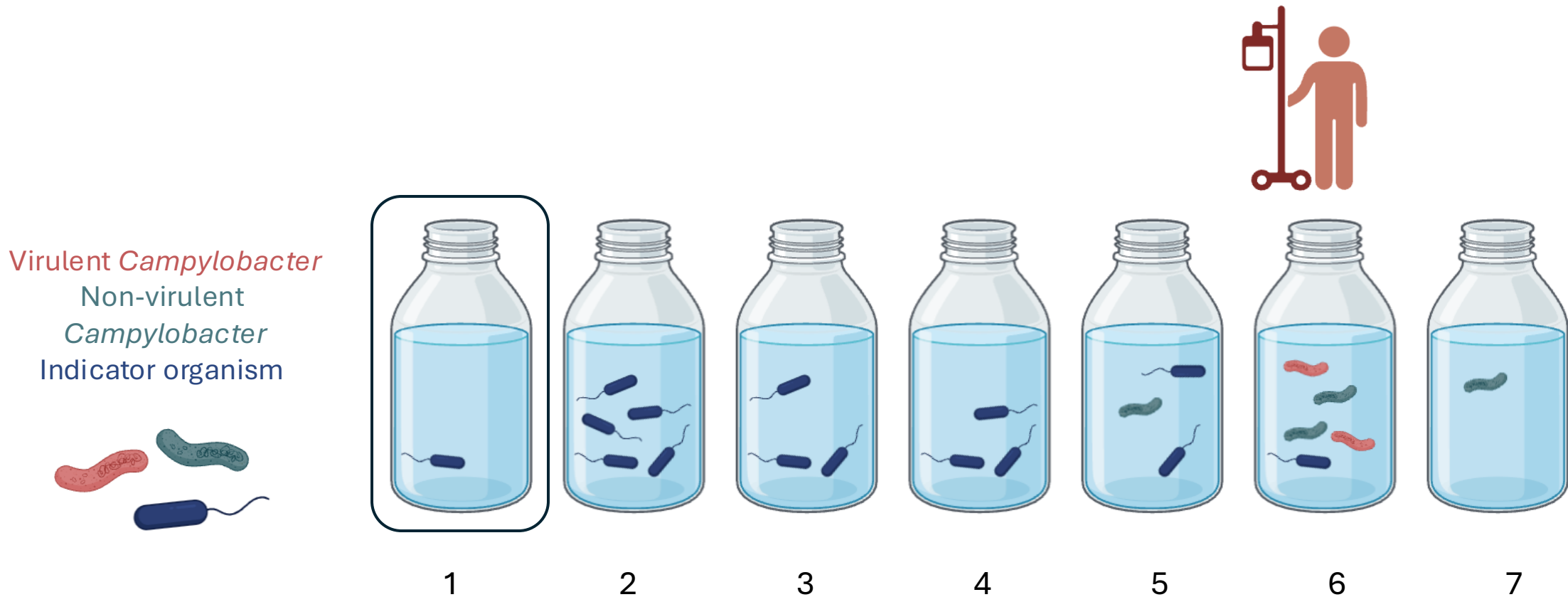


Scenario: Heavy rainfall



Current limitations in surface water quality surveillance

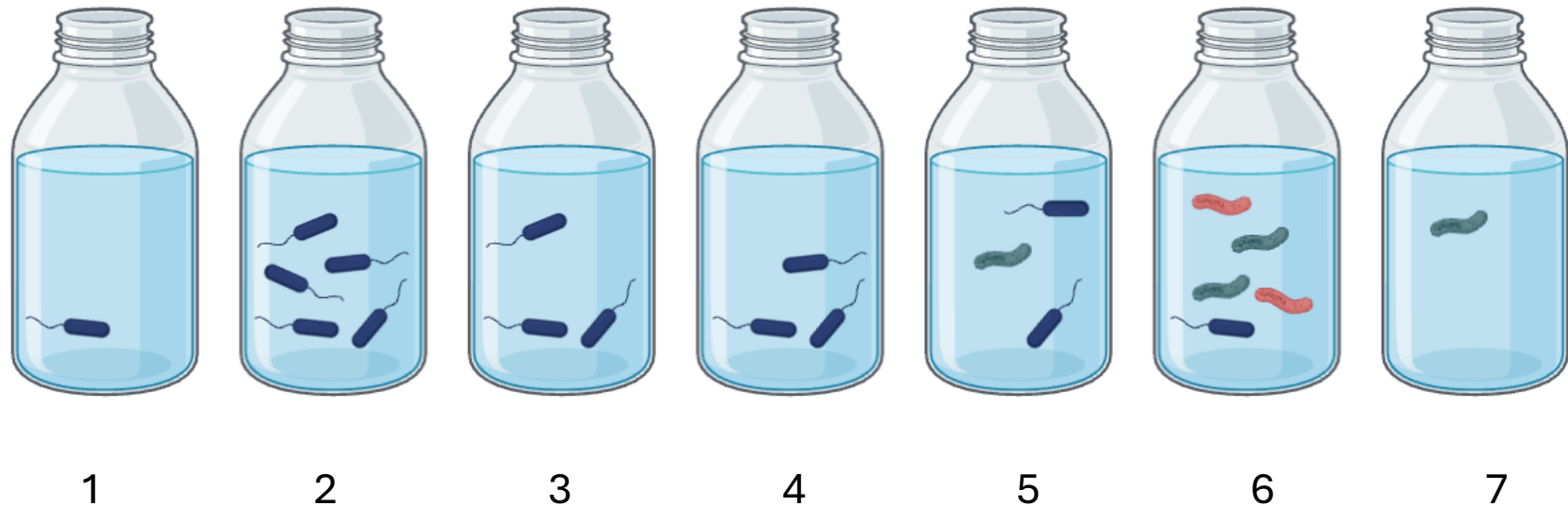
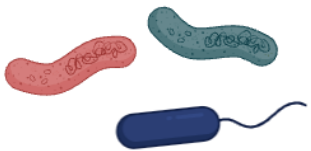
- Inadequate or cost-prohibitive tools, resulting in low #'s of sampling sites or frequency



Current limitations in surface water quality surveillance

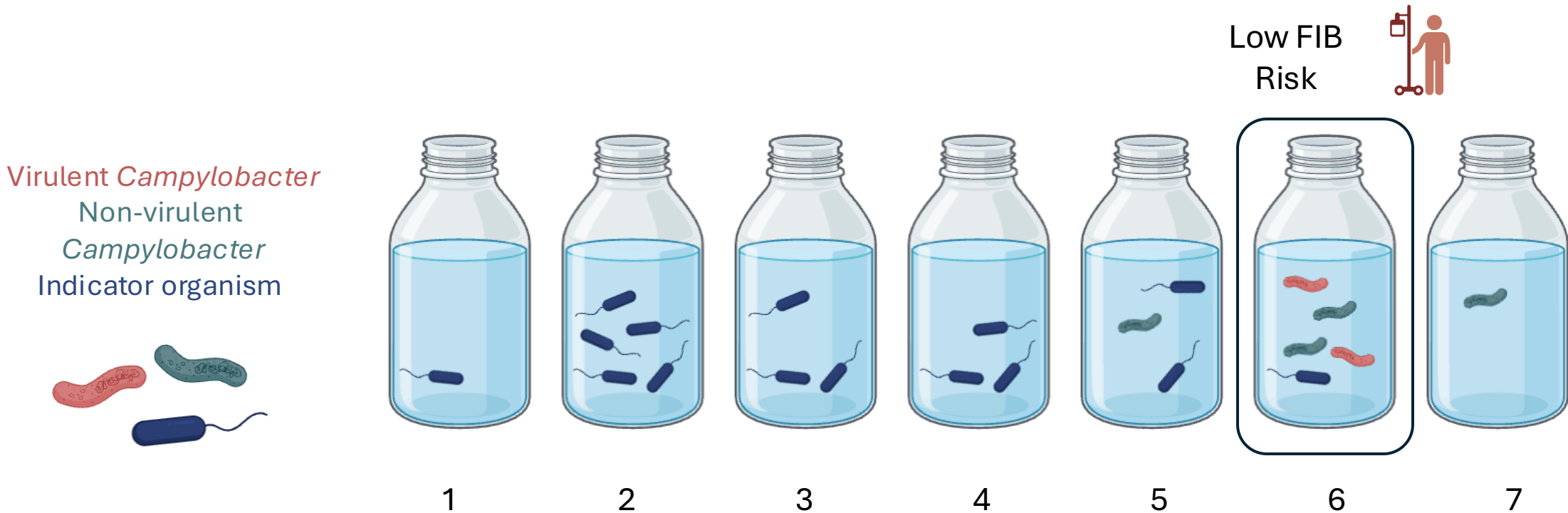
- Inadequate or cost-prohibitive tools, resulting in datasets with low #'s of sampling sites or frequency, or the wrong targets
- Lab-based detection methods with long processing times

Virulent *Campylobacter*
Non-virulent
Campylobacter
Indicator organism



Current limitations in surface water quality surveillance

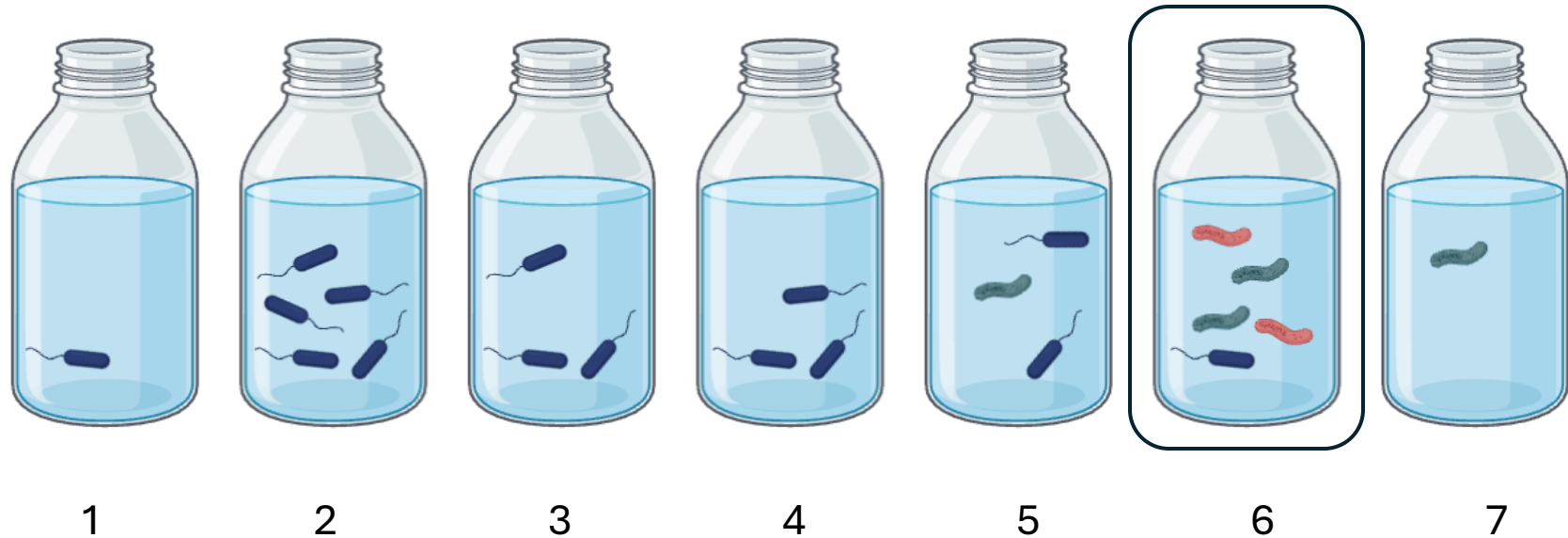
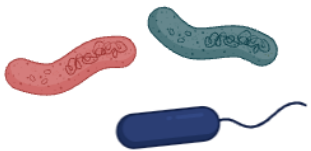
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- Relying on indicator organisms that do not correlate with health outcomes



Current limitations in surface water quality surveillance

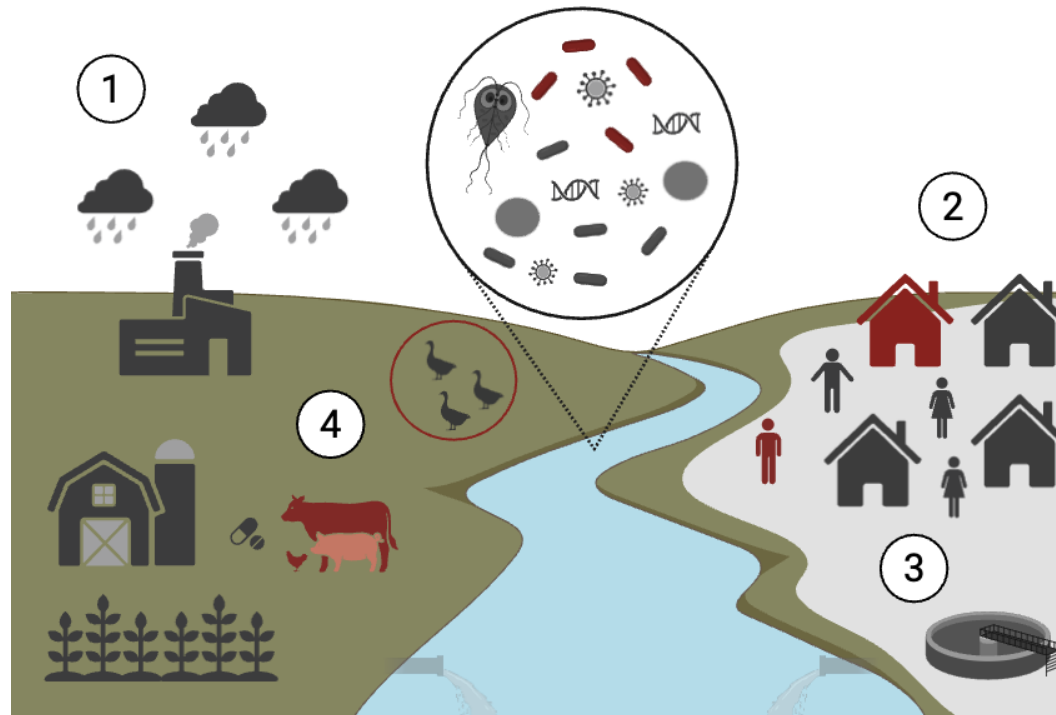
- Inadequate or cost-prohibitive tools, resulting in datasets with low #'s of sampling sites or frequency, or the wrong targets
- Lab-based detection methods with long processing times
- Relying on indicator organisms that do not correlate with health outcomes
- **Challenges with accurately assessing risk via QMRA**

Virulent *Campylobacter*
Non-virulent
Campylobacter
Indicator organism



Current limitations in waterborne disease mitigation

- Surveillance challenges mean inadequate data for evidence-based decisions
- Low resolution contaminant source attribution
- Limited knowledge on use or optimization of sustainable treatment solutions that minimize negative impacts on the environment



Canadian Excellence Research Chair (CERC)

- CERC in Waterborne Pathogens: Surveillance, Prediction and Mitigation
- Objectives of the CERC program are to attract the top researchers in Science Technology and Innovation priority areas;
- To help build a critical mass of expertise;
- Establishing Canada as a location of choice for world-leading research, science and technology development
- Chair started September 2024; 8-year program



Canada Excellence
Research Chairs

Chaires d'excellence
en recherche du Canada

How did we get here? Passive Samplers

- Words first passive sampler for Wastewater Surveillance
- Manufactured and deployed in over 30 countries
- Featured in WHO guidelines for for “Environmental surveillance for SARS-COV-2 to compliment public health surveillance”

Wastewater surveillance of viruses

Traditional sampling



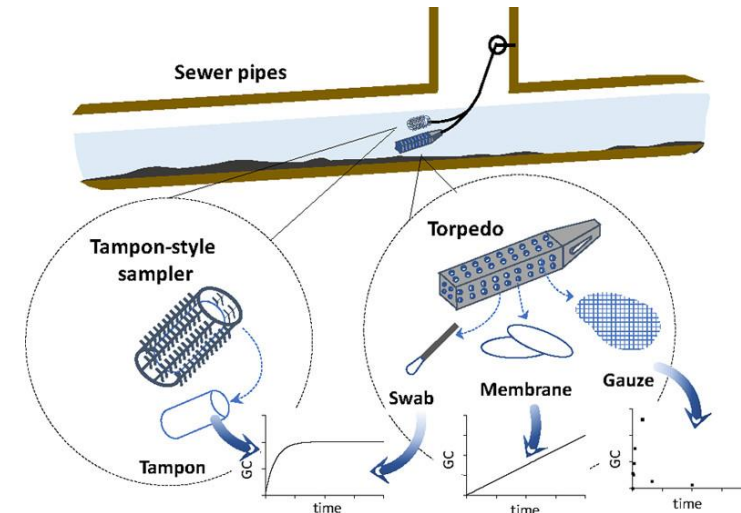
\$\$\$, complex, power, bulky



Passive sampling

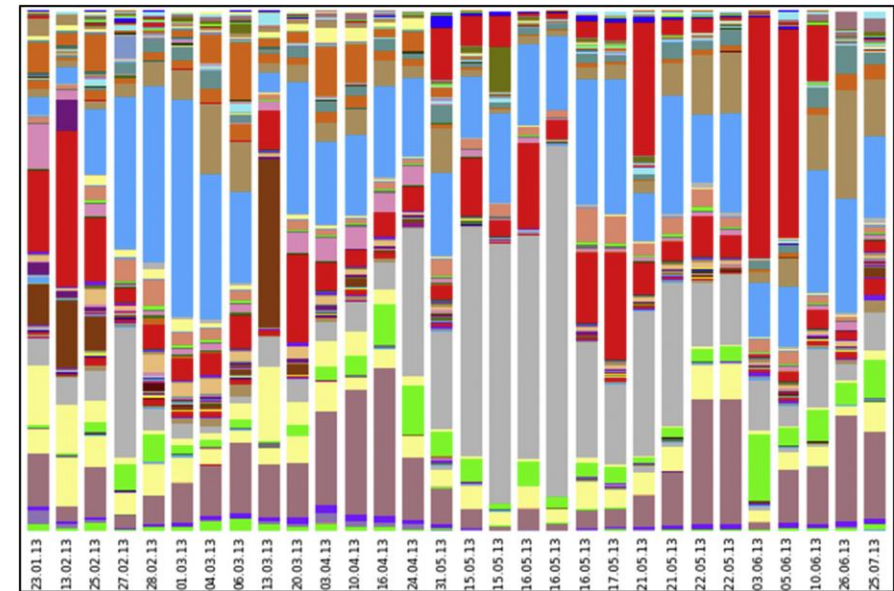
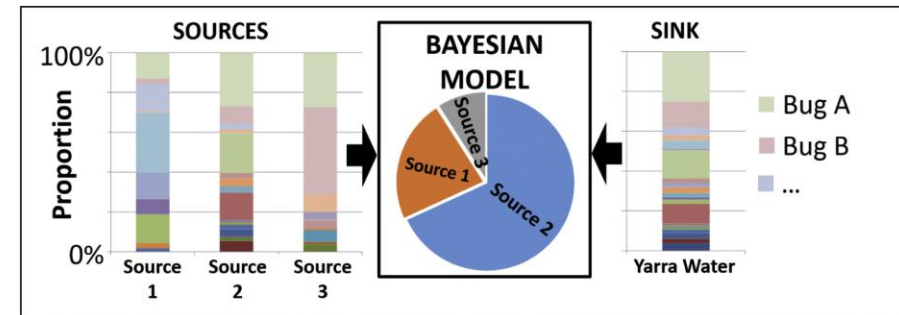


\$, simple, no power, small



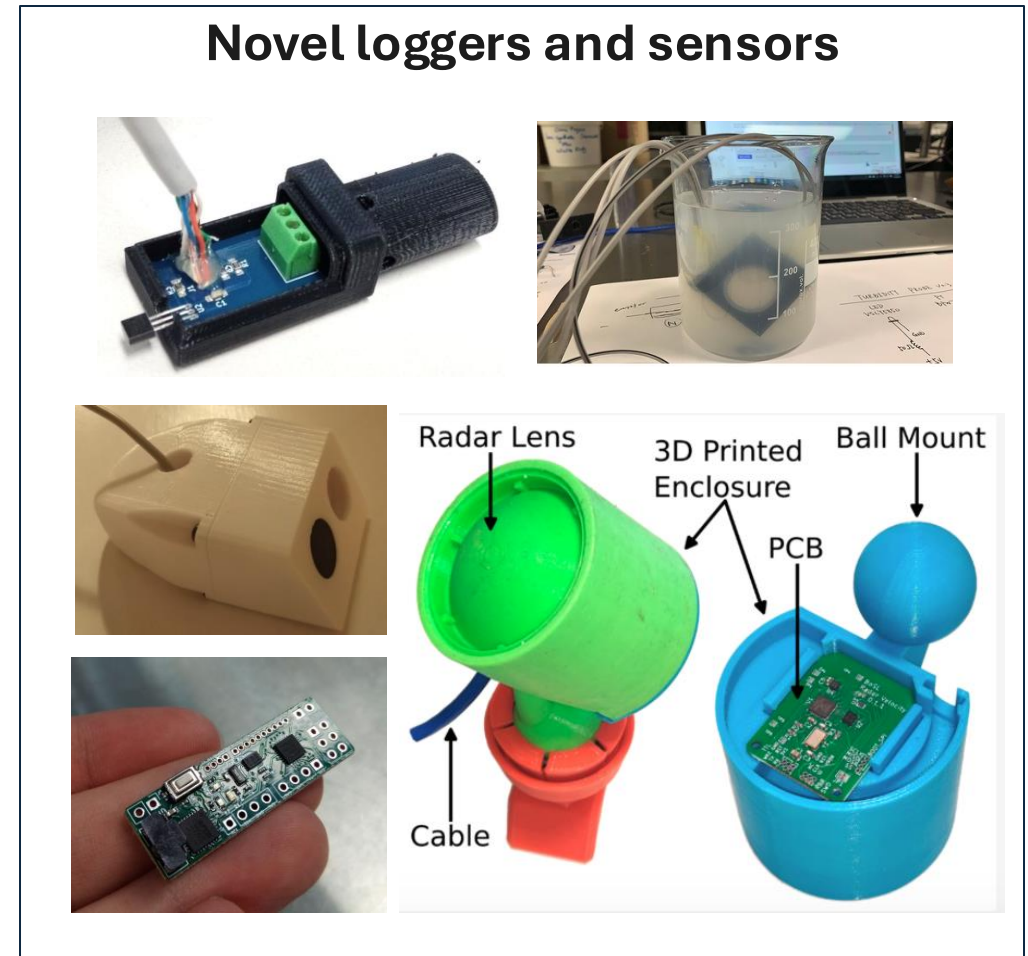
Community-based Microbial Source Tracking

- A novel microbial source tracking (MST) method using microbial community fingerprints
- Case studies in Yarra River Estuary¹ & Port Phillip Bay² (costal) demonstrated microbial community-based MST has the potential to become a powerful tool to identify contamination from both diffuse & point sources



Low-cost sensors, boards & samplers

- Depth, temperature and EC sensor
(Shi et al., *MDPI*. 2021)
- Turbidity Sessor (Wang et al., *Sensors*. 2024)
- In-water and non-contact velocity sensors
(Catsamas et al., *Sensors*. 2022 & 2023)
- Low-power-consumption BoSL boards
- Automated sampling devices, e.g. 3D-printed peristaltic pump



Open-source and Open-IP bosl.com.au



Main Wiki Page

MONITORING

FAQ in field

Troups

EoDC

Stony

RTC

RTC Manual

PUBLICATIONS

Publications

PASSIVE SAMPLING

for SARS-CoV-2 in WW

WATER SAMPLERS

BoSL Pump

Cheap MAD-AS

Eski sampler

TRAINING COURSE

BoSL Training

EoDC Teaching

Program

SOFTWARE & CODE

CODE

Design Library

BoSL Programmer

BoSL Code

Image Analyser

BOARDS

BoSL Board v0.3

BoSL Board v0.4

BoSL Board v0.5

Page Discussion

BoSL FAL Pump

Contents [hide]

- 1 Overview
- 2 Journal Paper describing the pump
- 3 3D print files, code and original datasets
- 4 Test together with microBoSL board - 3rd Feb 2020

Overview

Water sampling is an essential undertaking for water utilities and agencies to protect and enhance our natural resources. The high variability in water quality, however, often necessitates a spatially distributed sampling program which is impeded by high-cost and large sampling devices. This paper presents the BoSL FAL Pump - a low-cost, easily constructed, 3D-printed peristaltic pump which can be made from commonly available components and is sized to suit even the most space constrained installations. The pump is 38mm in height and 28mm in diameter, its components cost \$16 AUD and the construction time is just 12 minutes (excluding 3D printing times). The pump is driven by a direct current motor which is commonly available, cheap and allows for flexibility in the energy supply (5-12 V). Optionally, the pump has a Hall effect sensor and magnet to detect rotation rates and pumping volume to improve the accuracy of pumping rates/volumes. The pump can be easily controlled by commonly available microcontrollers, as demonstrated by this paper which implements the ATmega328P on the Arduino Uno R3. This paper validates the pump for long-term deployments at flow rates of up to 13r per minute in 0.14mL volume increments at accuracy levels of greater than 99%. The pump itself is scalable, allowing for a wider range of pumping rates when, for example, large volume samples are required for pathogen and micropollutant detection.

Journal Paper describing the pump

<http://dx.doi.org/10.13140/RG.2.2.35486.77123>

<https://doi.org/10.1016/j.ohx.2021.e00214>

3D print files, code and original datasets

See our repository here: <https://data.mendeley.com/datasets/prb2wzr77y/1>

Test together with microBoSL board - 3rd Feb 2020

A test was conducted to see how the microBoSL was able to perform in a pumping environment. To do this the BoSL FAL pump was connected to a water reservoir and an empty water container. The pumping program was uploaded to the microBoSL with parameters: PumpEveryXMin = 1, DurationOfRun = 180, NumberOfSpins = 10. The microBoSL and pump were powered with a 4.2V li-ion battery. The hall effect sensor was connected directly up to the ports on the microBoSL. The pump was connected on the positive side through 4.2V and on the negative side to the MOSFET integrated into the microBoSL. The test was ended at the 3 hour and 9 minute mark as the microBoSL had not finished on its own. It is uncertain if this was because of the inaccuracies of the internal clock. At the end of the a volume of 260 mL was pumped. Given that over this time the pump underwent approximately 189 rotations the volume per rotation is 0.14 mL. This is in accordance with proper operation of the pump.

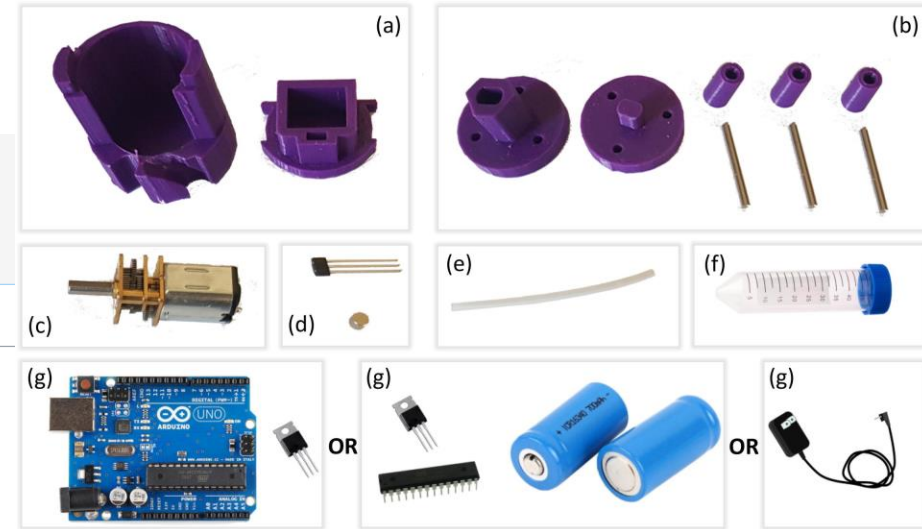


Image: McCarthy et al., HardwareX. 2021



Slide 14

microSCAPE: Surveillance & Control of AMR and Pathogens in Environments

IoT Monitoring Networks

- Low-cost sensor networks and AI-driven anomaly detection systems for water pollution monitoring
- Real-time data uploading, storage, and visualization frameworks; algorithms that identify pollution patterns
- Monitoring systems are now being trialled in seven catchments, five of which are in Australia, one in the USA and one in the Netherlands

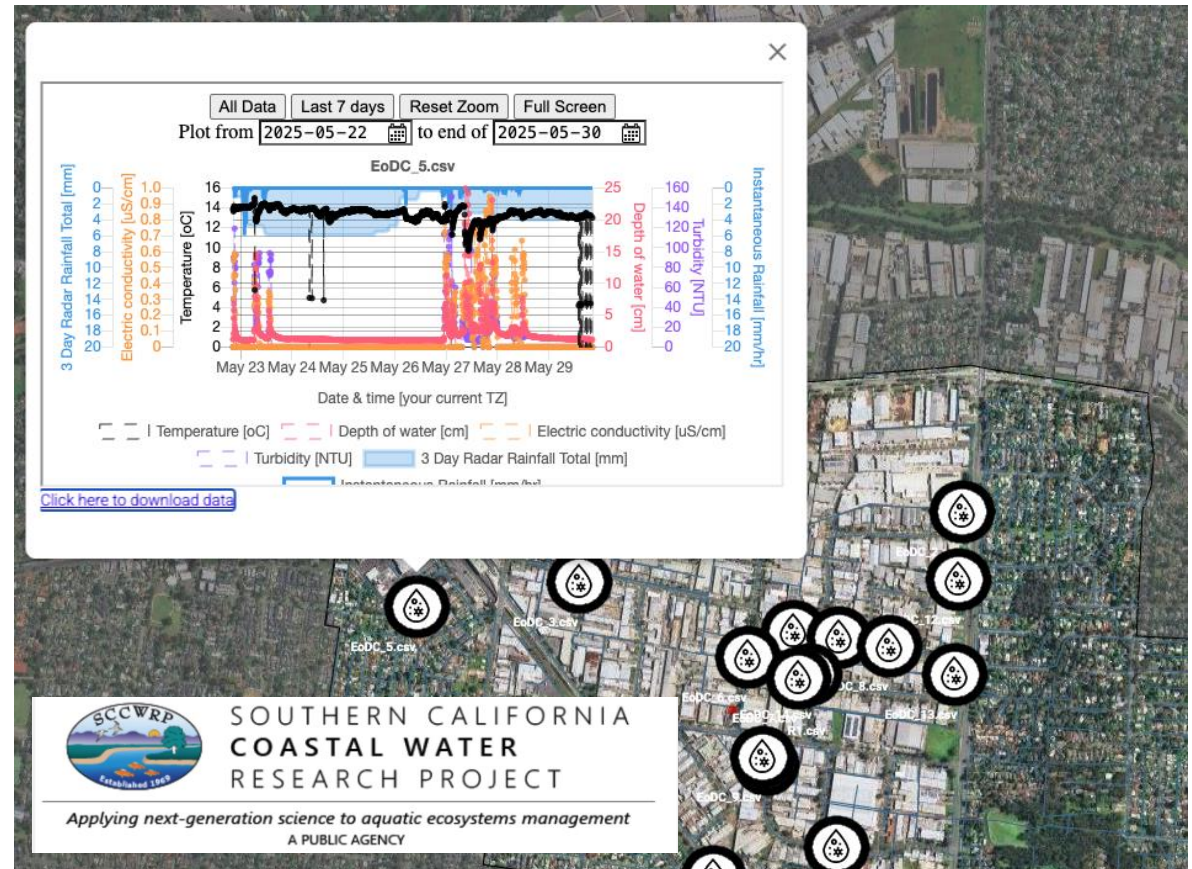
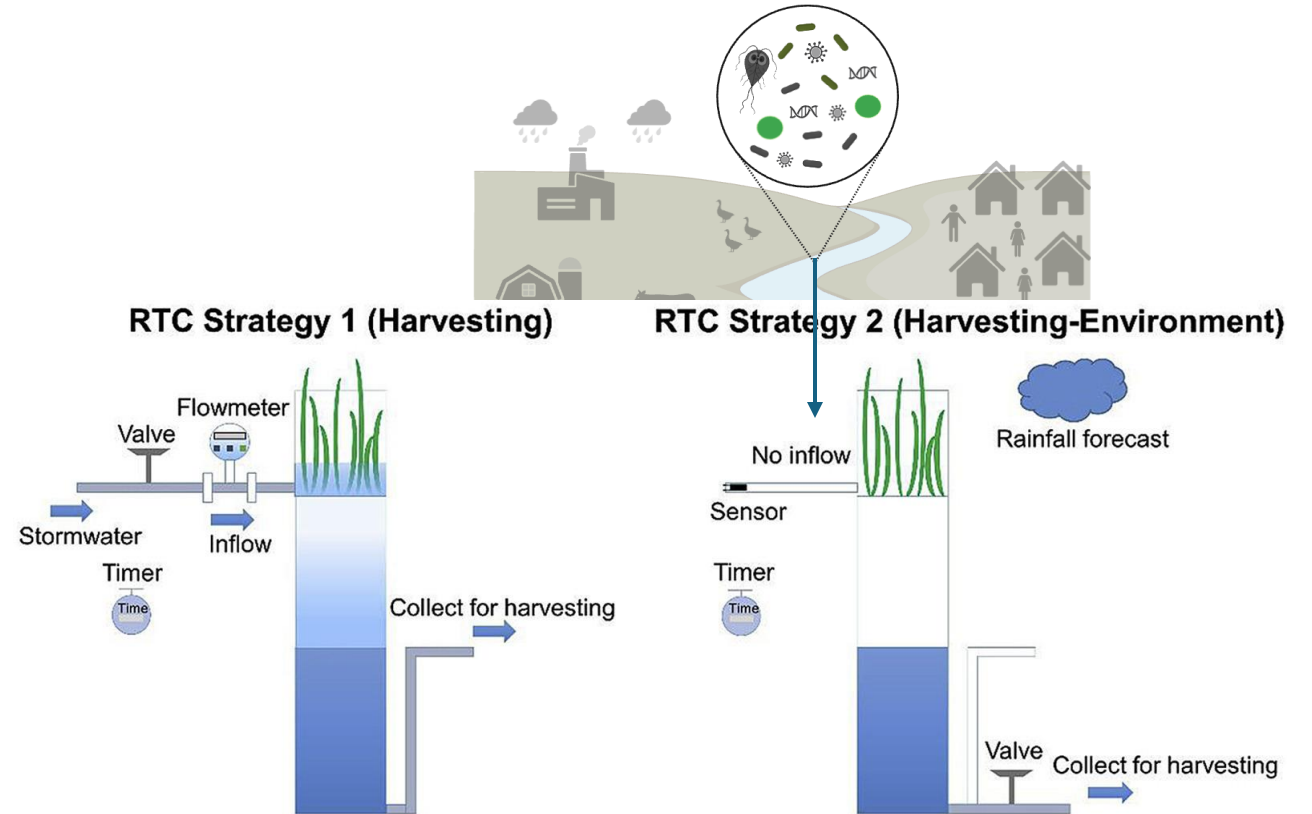


Image: bosl.com.au



NBT & RTC

- Nature-based treatment (NBT) solutions for pathogen removal
- Real-time control (RTC) of biofiltration: biofilters and wetlands
- Implications for stormwater harvesting and reuse



- 28.4 % of stormwater could meet the requirement for :
 - secondary contact recreation in Australia
- Environment pollution is exacerbated due to bypass

- 5.4 % of stormwater could meet the requirement for:
 - dual reticulation with indoor and outdoor use or irrigation of commercial food crops
 - secondary contact recreation in Australia
- Environment could be well protected



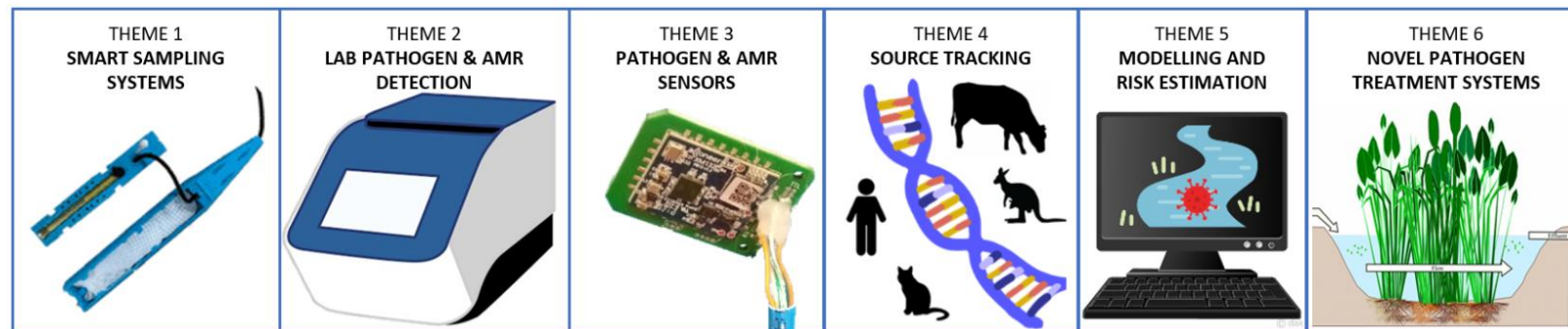
Images: BioRender.com; Shen et al., Water Research.2020



CERC in Waterborne Pathogens Research Themes



1. Smart Sampling Systems
2. Lab-based Pathogen and AMR detection
3. *In Situ* Sensors and In-field Pathogen Detection
4. Source Tracking of Pathogens and AMR
5. Models for Real-time Prediction and Scenario Testing
6. Treatment Systems for Waterborne Pathogens



Building our team

UNIVERSITY OF
GUELPH

Ontario
Agricultural College
School of Environmental Sciences

- 3 PDFs
- 5 PhD
- Undergrad students
- Ongoing recruitment



Surveillance of local water systems

- To determine the viable concentration of fecal-derived pathogen(s)- which bug is likely causing issues in our region?
- 12 sites in summer 2025; key waterbodies and storm drains
- Sampling: Passive and Grab
- Paired with water flow and quality data, which is necessary to contextualize pathogen and AMR detection

Map: grandriver.ca/our-watershed/maps-and-data

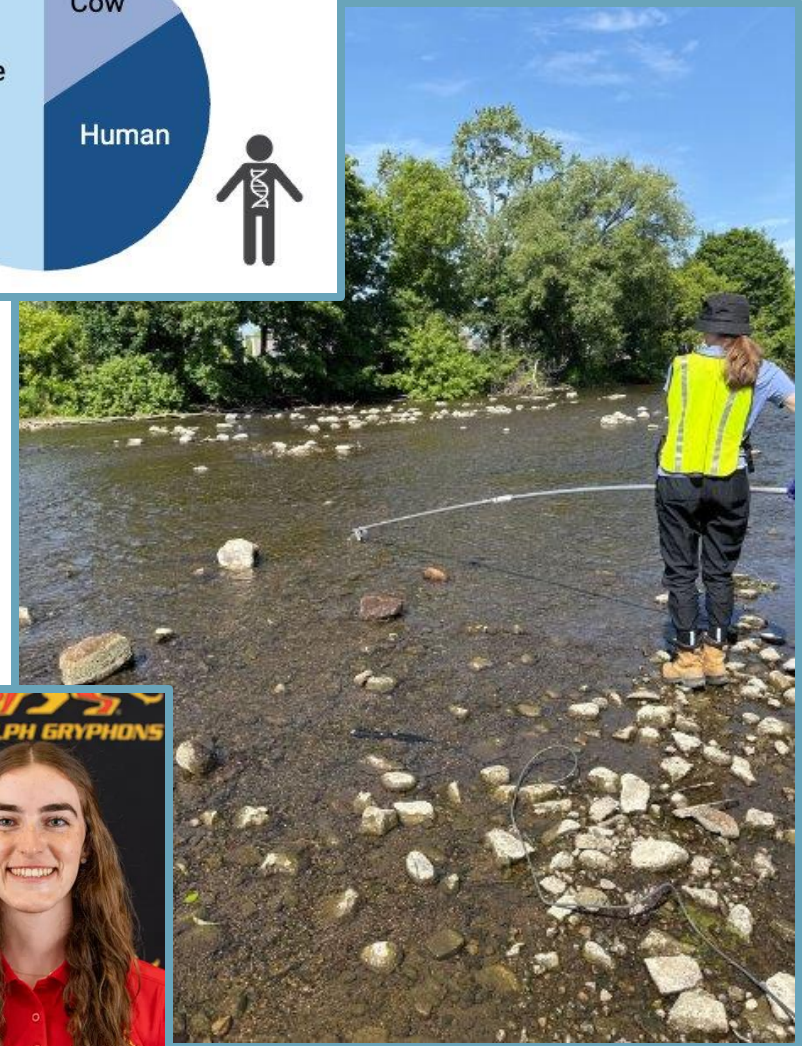
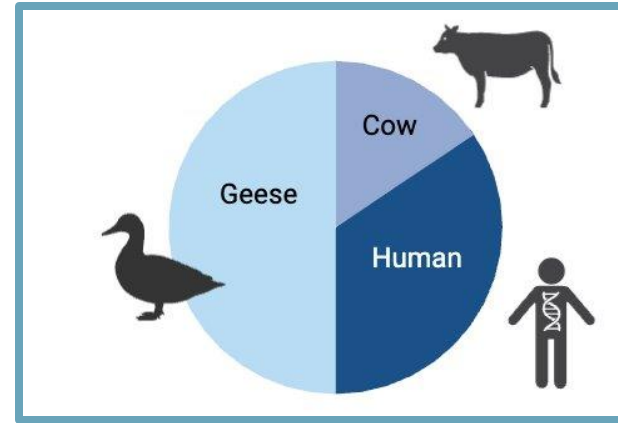


Student projects

Microbial risks of Water-based Recreation in Guelph

Summer Student, Jacqueline Giles

- Scat-a-log: collection of fecal material from potential contamination sources (agricultural, wildlife, wastewater)
- Molecular detection of pathogens in water samples using TaqMan array cards

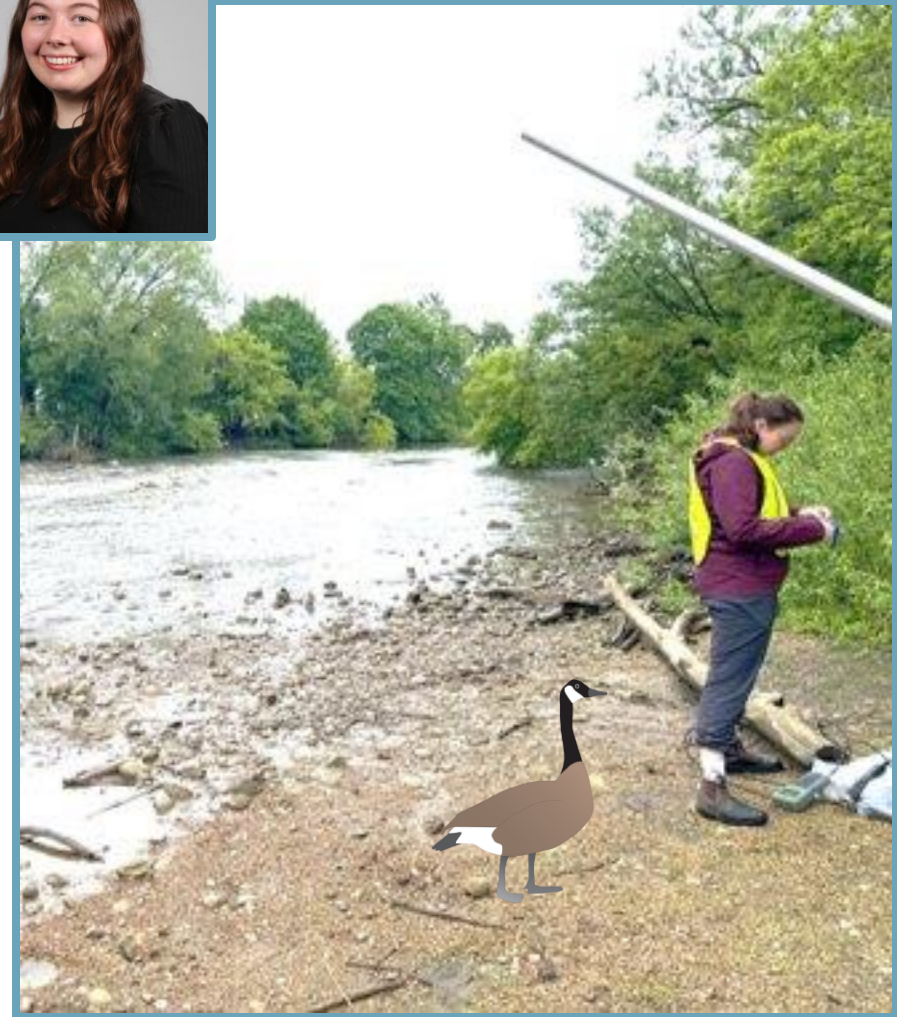


Student projects

Understanding human health risks associated with fecal contamination from Canadian Geese

Thesis project, Rachael Young, BSc

- Quantify *Campylobacter* and antimicrobial resistance genes (ARGs) in goose feces and surface waters
- Inform risk assessments and identify priority areas for further surveillance and interventions

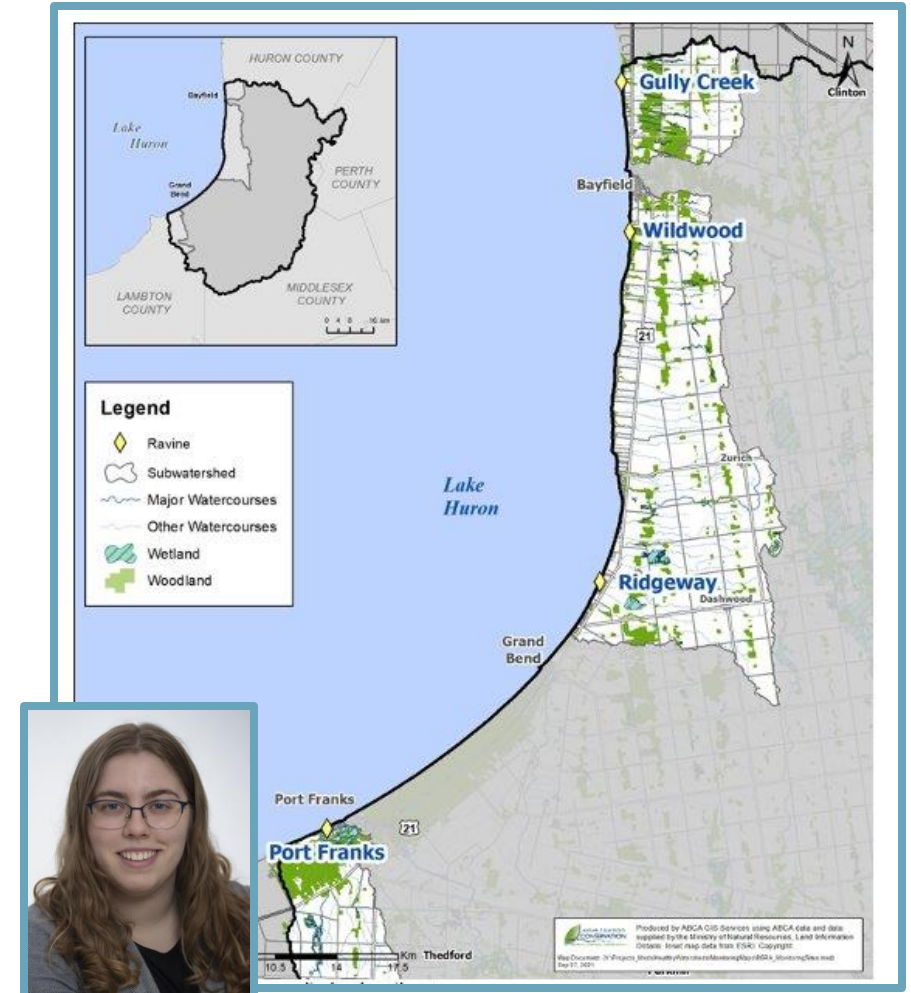


Surveillance in Ausable Watershed



Water Quality (WQ) testing of beach and ravine samples from Lake Huron

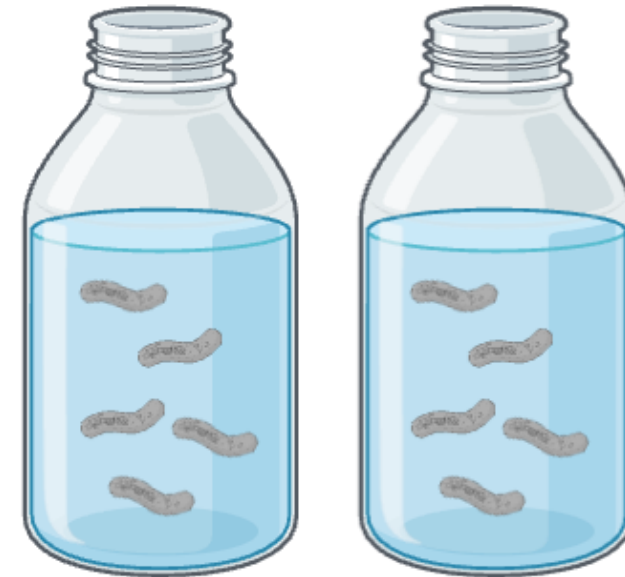
- Collaboration with Ausable Bayfield Conservation Authority (ABCA)
- Project: Microbial Source Tracking (MST) to identify sources of fecal pollution
- Goal: Build on current ABCA microbial analysis that is currently limited to *E. coli* to better understand sources of contamination



Assessing risk: Can we do better?

- From a public health perspective, we want to be able to accurately assess the risk of infection when utilizing or occupying contaminated water

Exposure dose = (source concentration) x (dose ingested)

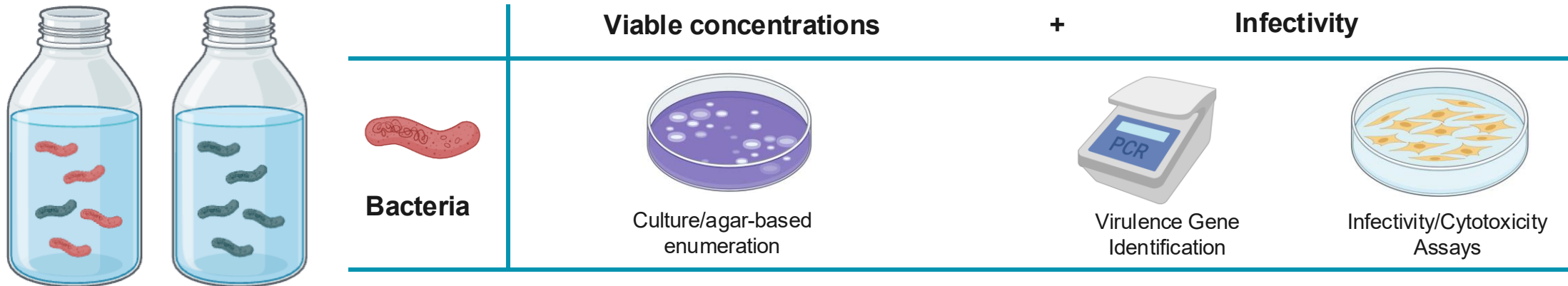


Virulent *Campylobacter*
Non-virulent *Campylobacter*



Diagnostic platforms for pathogen infectivity

Exposure dose = (source concentration) x (% infective) x (dose ingested)



- What are research groups currently doing? Systematic review coming soon!
VanLoon & Young, 2026, in preparation



Stormwater management and harvesting

Innovative stormwater management and harvesting systems for water-resilient farmers and improved ecosystems



Kari Dunfield , U of G



Mari Veliz, ABCA



Mel Luymes, LICO



Kevin McKague, OMAFA



Bahram Gharabaghi, U of G



Heather Murphy, U of G



Safer stormwater on farms



Understand Barriers to use of water monitoring technologies and stormwater reuse on farms to generate tailored solutions



Demonstrate the potential for using digital sensing and control technologies to better manage and recycle stormwater



Demonstrate Green Stormwater Infrastructure (GSI) system use on farms to better manage water flows and quality



Help farmers better understand real-time water budget with short-term forecasts, including soil moisture



Safer stormwater on farms: Timeline

1



Fall 2025

Identifying field sites; identifying barriers

2



2026

Set-up: site monitoring season 1

3



2027

Infrastructure: site monitoring season 2

4



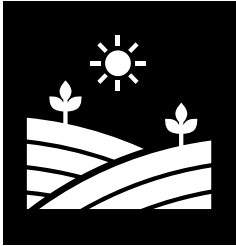
2028

Site monitoring season 3 & Knowledge Transfer

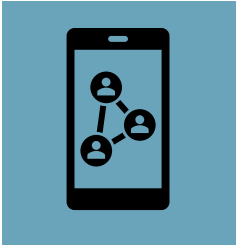
Photos: UofG, Elora Research Station; credit D. McCarthy; Smartwetlands.farm; Illinois sustainable agriculture



Safer stormwater on farms: Get involved



Reach out if you are interested in stormwater monitoring and/or infrastructure on your farm



Follow us on social media for updates on the study



Participate in our survey: coming winter 2026



Stay tuned for lunch-and-learn and other educational events



Thank you for listening

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Dave McCarthy
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LinkedIn: CERC Lab in Waterborne Pathogens

Website: microscope.ca



Advancing Waterborne Pathogen Surveillance and Mitigation: Next-Generation Tools for Protection of Surface Water Quality and Public Health

- With climate change, population growth, urbanization, and aging water infrastructure, Canada faces mounting challenges in managing waterborne disease risks and antimicrobial resistance (AMR). The Canada Excellence Research Chair (CERC) in Waterborne Pathogens addresses these challenges through an integrated research program spanning six themes: smart environmental sampling systems, laboratory-based pathogen detection, in-situ sensors and field detection, source tracking methodologies, predictive modeling, and green infrastructure treatment systems.
- This presentation will discuss the water management research and technologies that lead to the establishment of the CERC program at University of Guelph, and how the program is leveraging these advanced tools to transform how we monitor and mitigate waterborne pathogen risks to protect precious water resources. Projects that are currently in progress under the broader program will be discussed including: current water quality sampling campaigns in the Grand River and Ausable watersheds; agricultural initiative that examine best management practices for on-farm stormwater collection through both passive and activated Green Infrastructure (GI) solutions; and the development of diagnostic platforms that assess both pathogen presence and infectivity for improved Quantitative microbial risk assessment (QMRA).
- By developing open-source, field-deployable technologies that enable high-resolution spatiotemporal monitoring of water quality parameters this program aims to provide actionable information for real-time risk management. This integrated approach exemplifies One Health principles by addressing human health risks, agricultural sustainability, and environmental protection through coordinated surveillance, source tracking, and treatment strategies that span from farm to watershed scales.

