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PHO Rounds: Wastewater Surveillance of COVID-19: Potential Applications, Challenges, and Experiences in Ontario

Doug Manuel, Bahar Aminvaziri, Ramsey D'Souza, Shinthuja Wijayasri

July 13, 2021

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FOCUS ON

Wastewater Surveillance of COVID-19

April, 2021

Key Findings

- Wastewater surveillance (WWS) for COVID-19 involves the testing of sewage for the presence of SARS-CoV-2 virus ribonucleic acid (RNA), which, if positive, suggests some level of COVID-19 presence in a source population.
- A key advantage of WWS is that a single test represents an independent signal from the entire population contributing to the sampled wastewater stream regardless of health status (symptomatic, asymptomatic, or recovered) or access/utilization of clinical testing.
- Limitations include that there are no standard methods for sampling or testing of wastewater and the data generated must be interpreted within the context of both the sites and sources being sampled, the testing methods and laboratories performing the testing and the clinical epidemiology of the catchment area being sampled. This requires significant collaboration between parties involved, e.g., utilities, laboratories, public health.

Search “wastewater” at PHO website

https://www.publichealthontario.ca/-/media/documents/ncov/phm/2021/04/public-health-measures-wastewater-surveillance.pdf?la=en

Outline

- What is Wastewater Surveillance (WWS)?
- How is COVID-19 Detected in Wastewater?
- How has wastewater surveillance for COVID-19 been used so far? (Ontario)
- What are the potential uses for covid-19 wastewater surveillance?
  - Population level surveillance/research
  - As “early warning system” or leading indicator
- Considerations when assessing wastewater data on COVID-19
  - A current lack of standardized testing methodology
  - Shedding dynamics and potential for under-reporting/over-reporting
  - Challenges in test interpretation
- Application of WWS Data to Public Health Decision Making

Wastewater-based surveillance of SARS-CoV-2

Doug Manuel

Senior Scientist, The Ottawa Hospital Research Institute
Distinguished Professor, The Department of Family Medicine and School of Epidemiology and Public Health, uOttawa

Conflicts of interest

- Consulting for World Bank in Latin America and the Caribbean
- Funding from CIHR CoVaRRNet – Canadian Open Wastewater Database
- Potential funding from the Public Health Agency of Canada – to support the Ottawa Data Model and Ontario Ministry of the Environment, Conservation and Parks to support the Ontario Wastewater Initiative

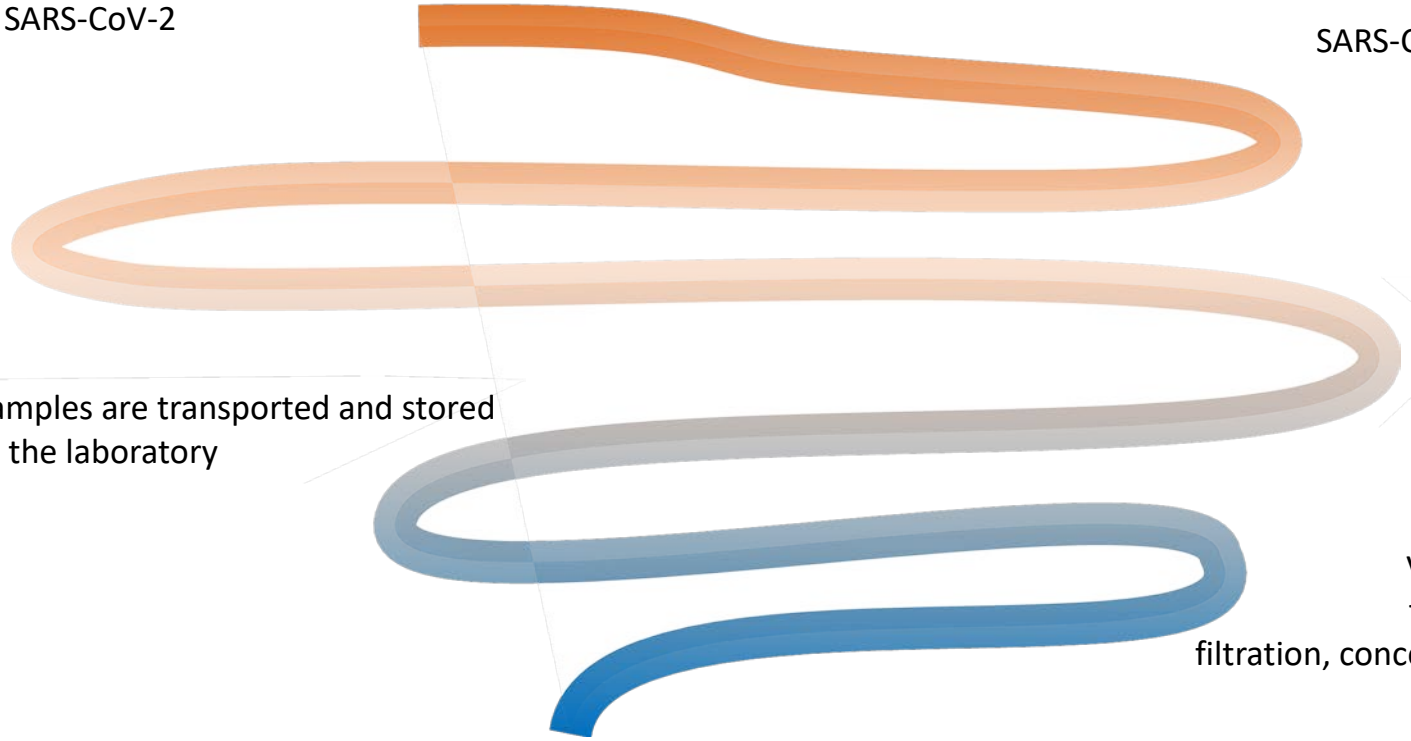
Overview

- What is wastewater-based surveillance?
- SARS-CoV-2 surveillance gaps – and role for WBS for filling those gaps
- Four uses
- Future uses and considerations
- Three challenges

People become infected with SARS-CoV-2

SARS-CoV-2 in stool gets flushed down the toilet

Virus particles travel through the sewages system



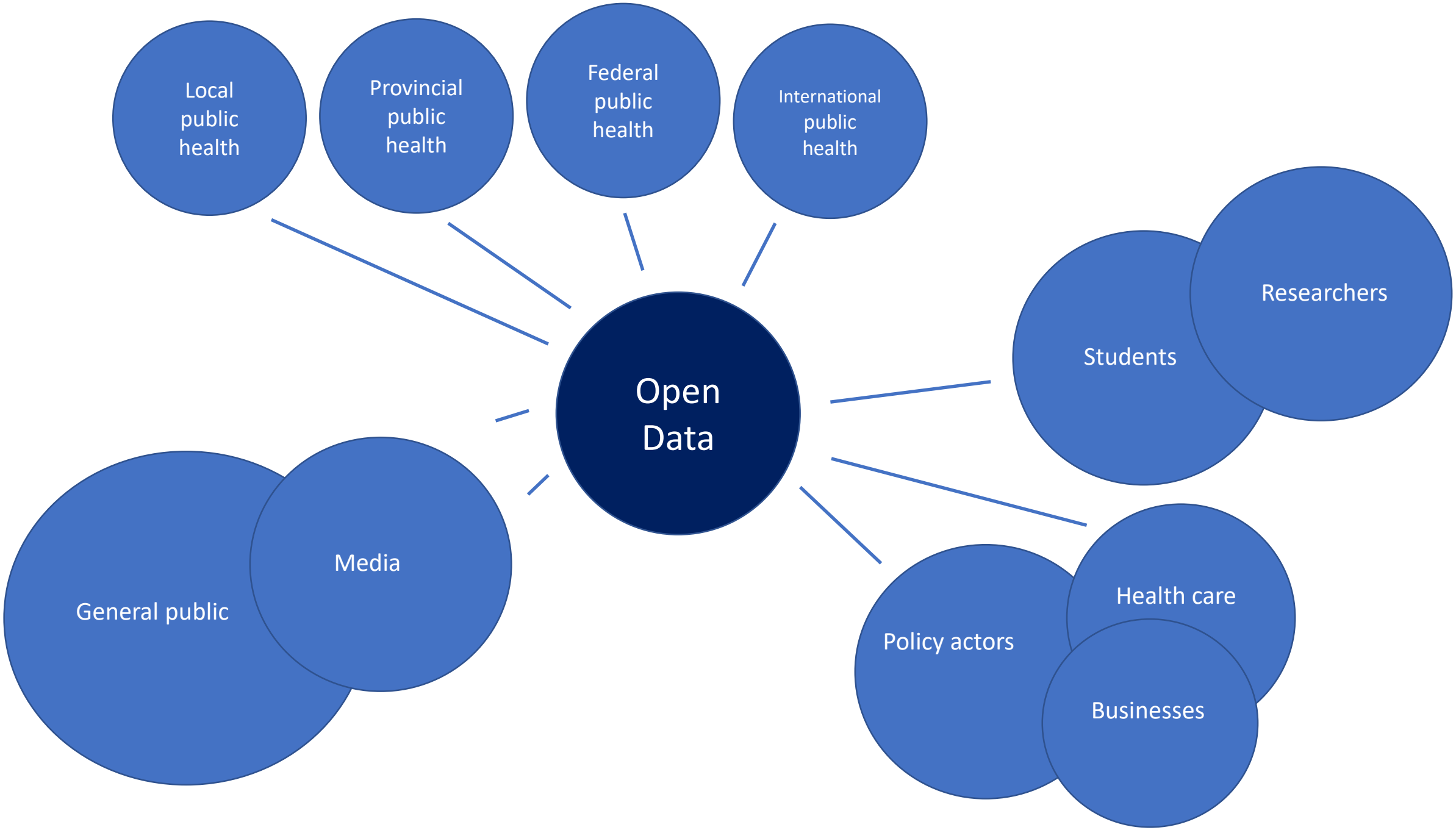
Sewage sample is taken along the sewage shed or at the treatment facility

Samples are transported and stored at the laboratory

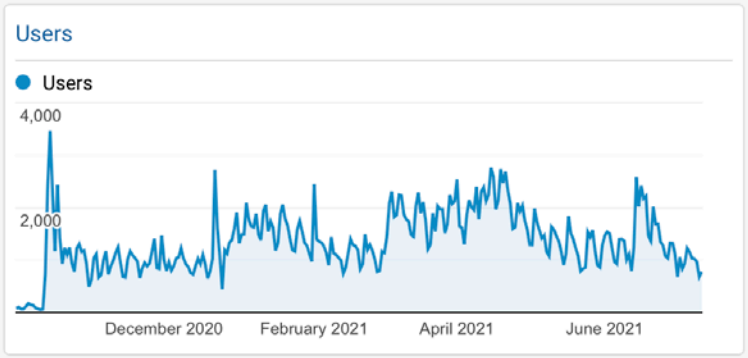
Viral and other measures are taken at the laboratory, after filtration, concentration, and RNA isolation

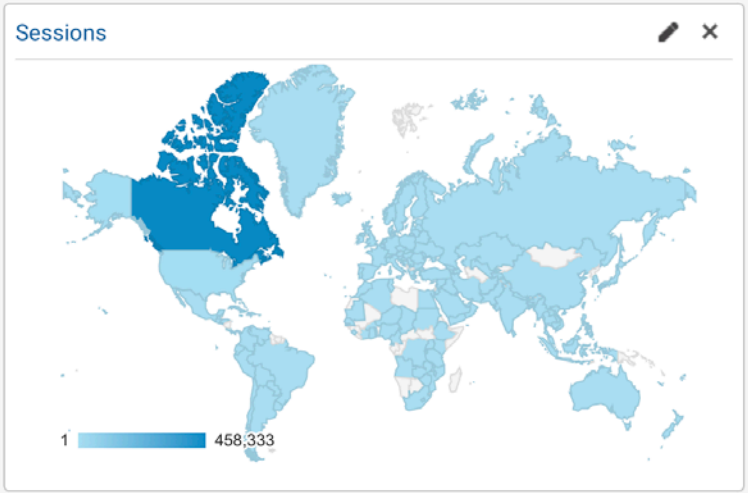
Public health action is informed by sharing data and reports

Openly and transparently shared with the engage the public in prevention and control measures	Interpret results alongside other surveillance data	Advance wastewater science and our understanding of Covid19
Public, policy actors and journalists	Local, regional, national, and international public health along with environment and wastewater collaborators	Researchers, students and informed public


Local public health
Provincial public health
Federal public health
International public health
Open Data
Researchers
Students
Media
General public
Health care
Policy actors
Businesses

Web use and data access at 613covid.ca/wastewater





470 000 sessions since October

500 data access per week

Users by Country

Country	Users
Canada	125,117
United States	2,870
United Kingdom	221
France	172
(not set)	74
Germany	72
Netherlands	53
Switzerland	47
United Arab Emirates	45
Australia	44

Users by City

City	Users
Ottawa	85,832
Toronto	11,331
Montreal	7,875
(not set)	2,828
Brampton	1,857
Gatineau	1,727
Mississauga	1,482
Hamilton	1,266
Waterloo	1,260
Guelph	1,018

Drivers of the pandemic

THE SEVERITY of COVID-19 varies from completely asymptomatic to extremely ill and death

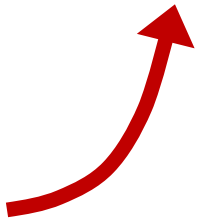
*Difficult to **detect***

DIAGNOSTICS are resource intensive and requires people to have capacity, opportunity, and motivation

*Difficult to **diagnose***

INEQUALITY in case detection and health burden

*Difficult to equitably and completely **measure***



THE SPREAD of COVID-19 occurs early during infection and by people who are asymptomatic

*Difficult to **control***

Adapted from: Campbell J, Evans T, Mohpal A, & Veillard J **Population-Level, National Testing Strategies for COVID-19: Latin America & The Caribbean. World Bank, 2021.** Report Number: AUS0001928

Wastewater testing fills surveillance gaps

ALL STAGES of disease are detected

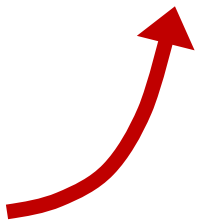
*Supports **broad detection***

AFFORDABLE compared to clinical testing and requires **NO EFFORT** from people to be tested

*Supports **sustainable** surveillance*

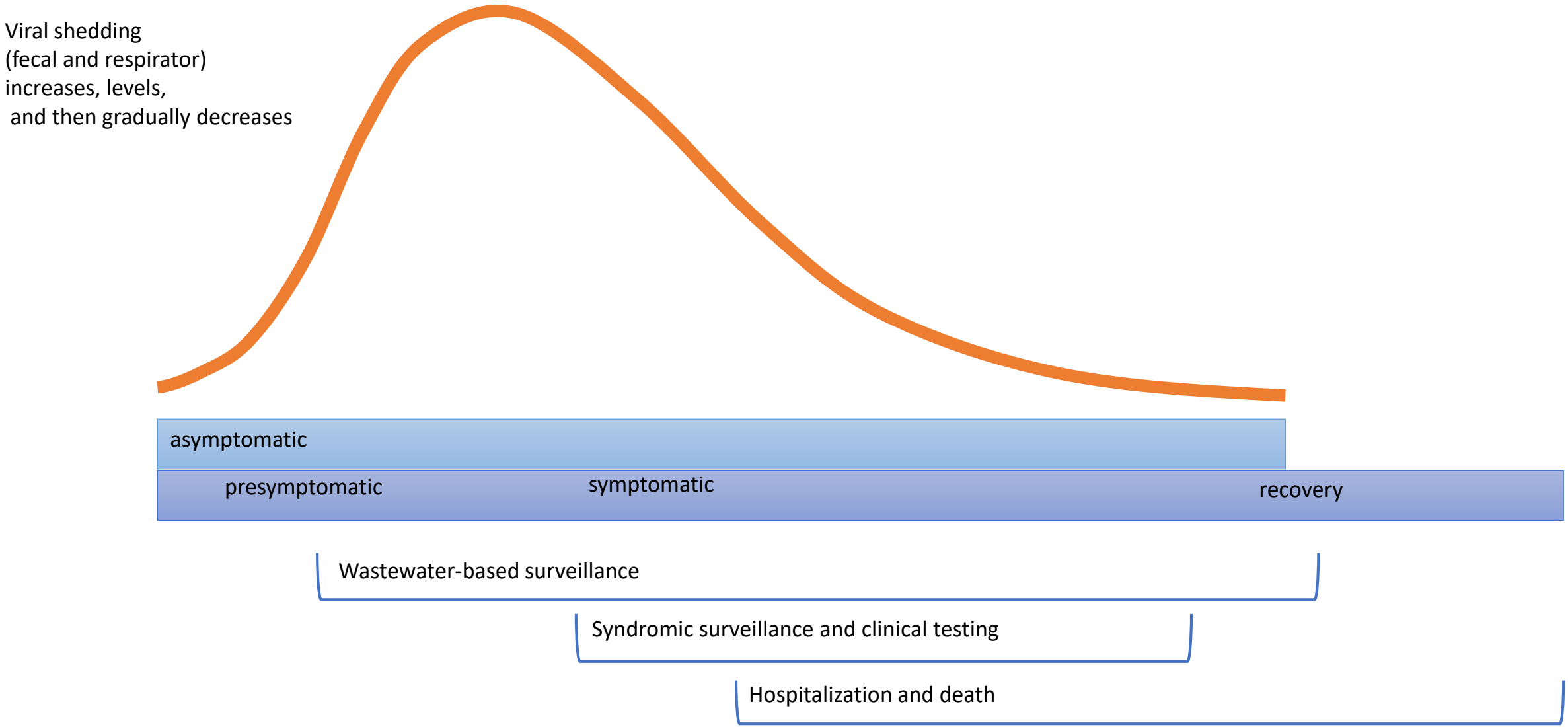
EVERYONE is included in wastewater testing with ability to focus on **VULNERABLE** populations

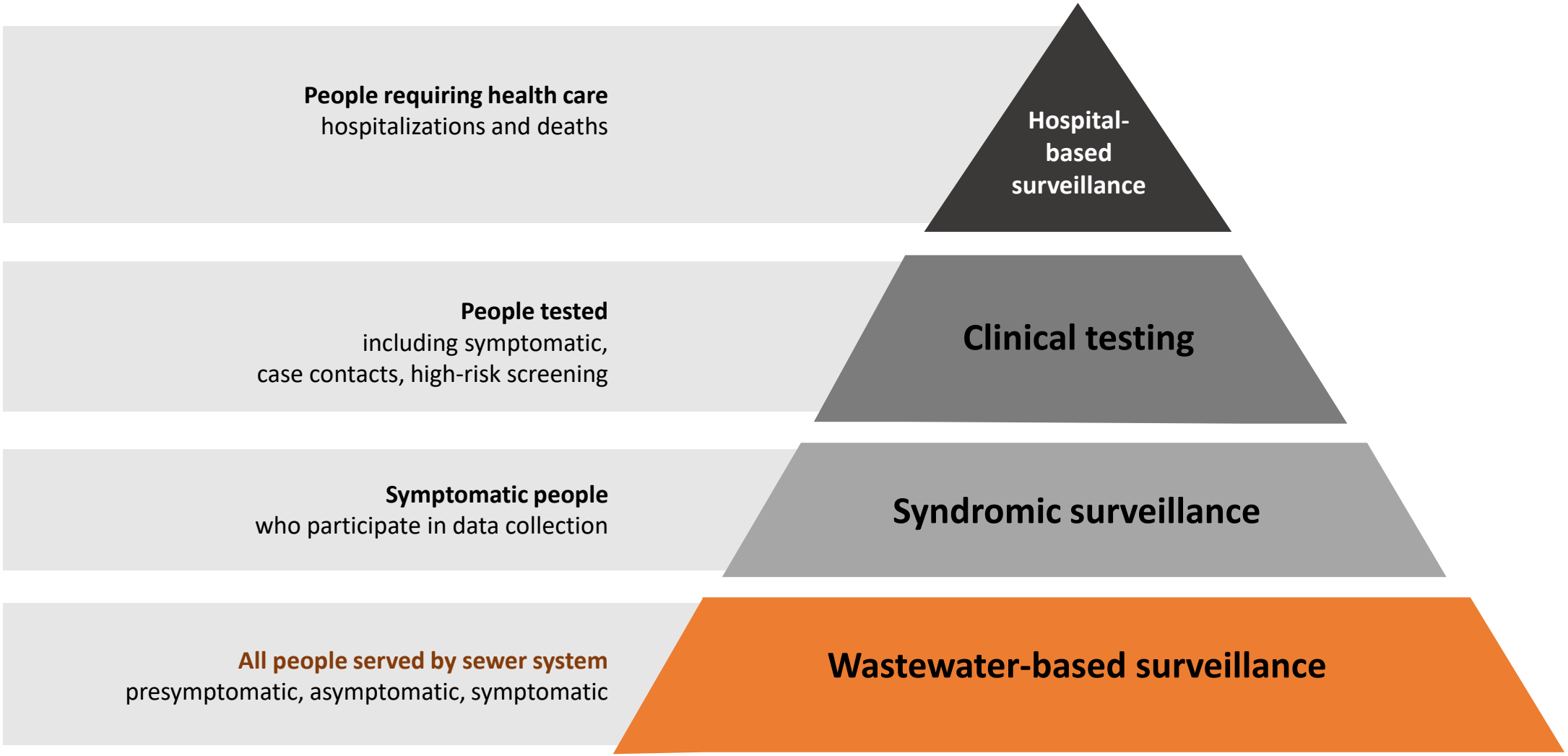
*Supports **equity** and **population-based** surveillance*



EARLY detection enables control by quickly identifying outbreaks and waves

*Supports **control***


Viral shedding
(fecal and respirator)
increases, levels,
and then gradually decreases
asymptomatic
presymptomatic
symptomatic
recovery
Wastewater-based surveillance
Syndromic surveillance and clinical testing
Hospitalization and death


People requiring health care
hospitalizations and deaths
Hospital-based surveillance
People tested
including symptomatic, case contacts, high-risk screening
Clinical testing
Symptomatic people
who participate in data collection
Syndromic surveillance
All people served by sewer system
presymptomatic, asymptomatic, symptomatic
Wastewater-based surveillance

Four uses

- **Early detection of outbreaks and surges**
- **Population-wide surveillance**
- **Specific population surveillance**
- **Variants and mutations of concern and interest (VOC/VOI)**

Additional potential uses

- **Later-stage surveillance**
- **Monitoring of other pathogens and health risks**

Future uses and considerations

- **Later-stage surveillance**
- **Monitoring of other pathogens and health risks**

Considerations

- **Equity**
- **Resource implications**
- **Public health measure compliance**

Three challenges

- **Analytic methods** - Improved quality assurances between various analytical methods to measure SARS-CoV-2 in wastewater.
- **Reporting and interpreting wastewater tests** – Collaboration with public health, testing laboratories, and wastewater utilities.
- **Sustained programs** – Transition from academic pilot programs to expanded organized and sustainable surveillance systems.

Wastewater viral recovery and reporting is influence by

- Variations between people.
- Variations in wastewater infrastructure and the environment.
- Variations in sample collection and method of measuring SARS-CoV-2 viral load.

Wastewater Surveillance Initiative

PHO Rounds

Bahar Aminvaziri, M.Eng., P.Eng.

July 13, 2021

Wastewater Surveillance Context & Benefits

- Ontario has just overcome the third wave of COVID-19.
- Wastewater based epidemiology for COVID-19 is underway in several jurisdictions globally.
  - It tests for the presence of the gene fragments (SARS-CoV-2 RNA) that are shed by the COVID-19 virus from both asymptomatic and symptomatic individuals in wastewater effluent.
  - It offers the ability to test the whole population to identify trends in COVID-19 spread at a relatively low cost.
  - It allows public health to quickly identify and respond to COVID-19 surges and waves of the virus to protect the health and safety of population, especially those living in congregate settings.
  - It can identify and monitor the proportion of Variants of Concern in populations monitored
- Wastewater surveillance provides an additional detection tool that can be used in tandem with clinical testing and other public health data help inform complex decisions for ongoing management of COVID-19.

- The Ministry of the Environment, Conservation and Parks in collaboration with academic/research institutions and municipalities, has developed a surveillance tool that tracks COVID-19 infection trends in wastewater.
- $12.2 million has been committed by the province over two years for wastewater surveillance.
- Wastewater sampling strategy developed includes a network of wastewater treatment plants across the province providing coverage for >80% of population.
- Application of sewage indicator results could:
  - Confirm detection of increases of COVID-19 in subpopulations.
  - Target areas with defined, higher-risk populations within the sewershed where early action may be most beneficial.
  - Identify transmission trends and inform predictive modelling.
  - Help evaluate response effectiveness.
  - Inform decisions on future surveillance expansion or relocation.

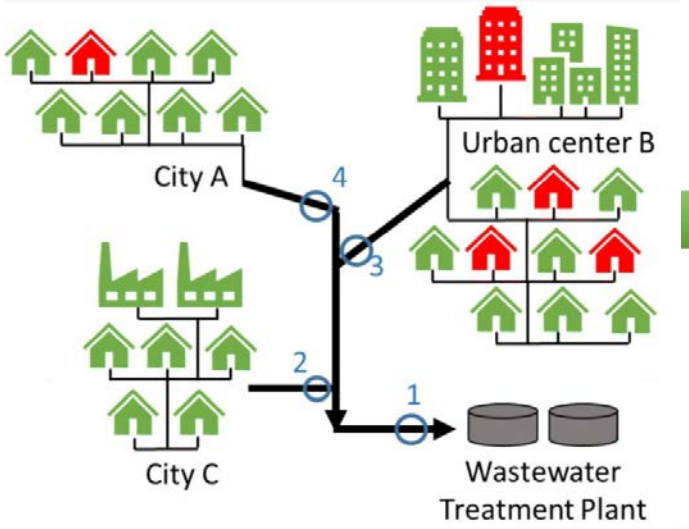
Ontario

Program Objectives

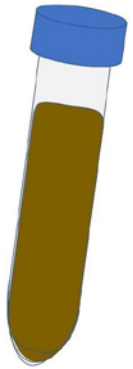
- Establish a coordinated Ontario initiative that tracks COVID-19 infection trends in wastewater.
- Develop a wastewater surveillance tool that provides Public Health Units with wastewater data that can be used along with clinical data to inform public health decisions.
- Build a wastewater sampling strategy and a network of wastewater treatment plants across the province providing >70% population coverage.
- Engage wastewater surveillance partners and experts to establish reliable wastewater surveillance sampling and analytical methods.
- Collaborate with other program areas, ministries, governments, academic institutions, and public health partners to reflect Ontario's interests in how wastewater surveillance trends can be interpreted and used to make informed public health decisions.
- Evaluate the feasibility for the expansion of wastewater surveillance.

How Wastewater Testing Actually Works

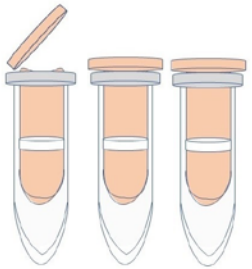
Sewershed Sampling



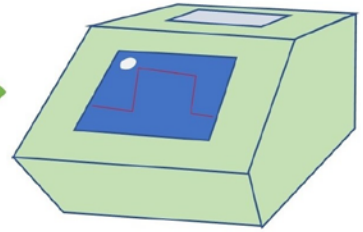
Concentration

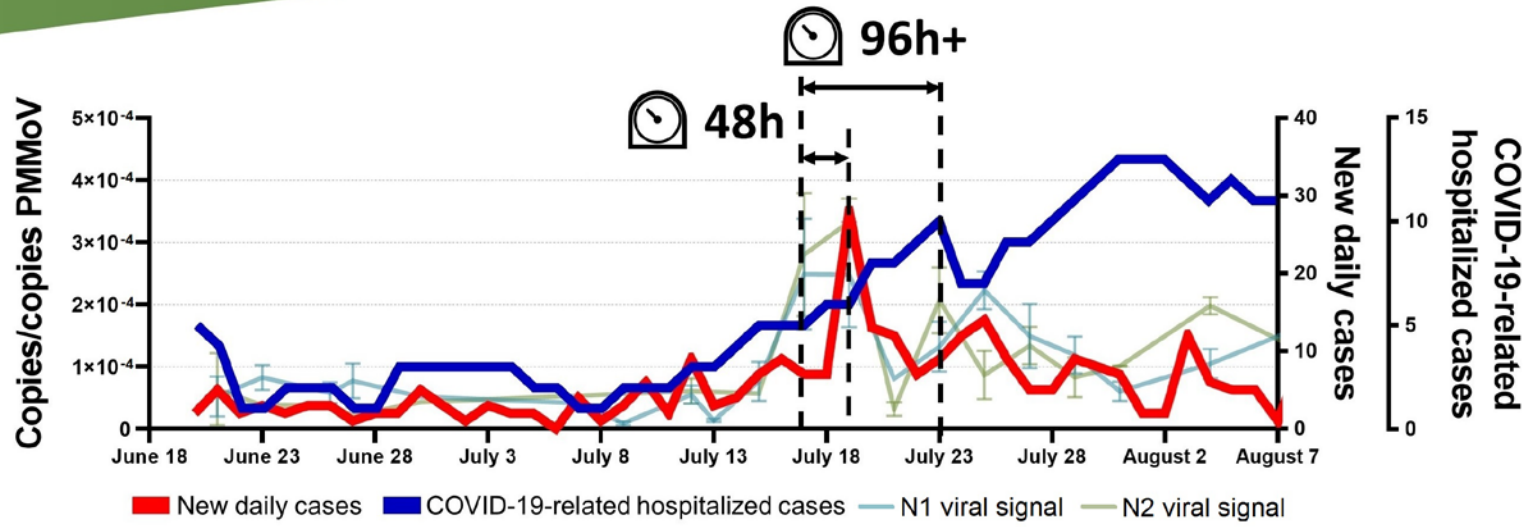


Nucleic acid extraction



RT-qPCR

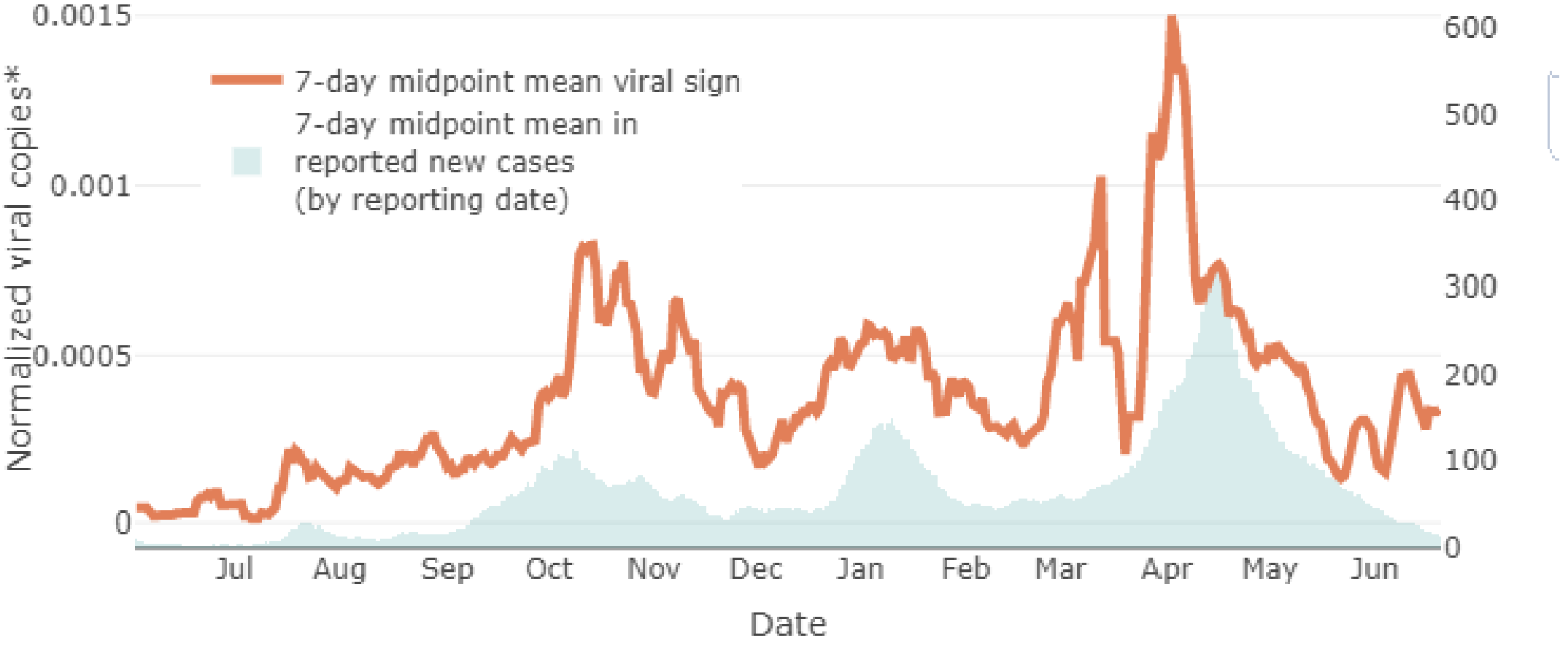




Adapted from P. D'Aoust, 2020

Ontario

How It Looks



- **University of Ottawa** is having success showing trends using primary sludge in the Ottawa and Hamilton WWTPs.
- The Ottawa Public Health Unit is sharing wastewater surveillance data with the public daily on their website: https://613covid.ca/wastewater/

Ontario

Sampling Strategy & Locations

Wastewater Treatment Plants
(88 locations)

- Wastewater treatment plant locations were identified by the Wastewater Surveillance Science Table.
- Four criteria were evaluated, and a scoring system was applied to prioritize sampling locations:
    - **Population Coverage** – cover over 70% of the population (over 10 million Ontarians)
    - **Risk Mitigation and Actionability**
    - **Northern and Sentinel Locations**
    - **Previous Partnerships Established**
- Wastewater surveillance results from 4 universities are showing a good trend with clinical data sets for wastewater treatment plant and sewershed results and for upstream sampling results.

Upstream Sampling
(71 Locations)

- Select upstream locations are being evaluated to determine the feasibility of sampling and actionability. These include:
    - **Facilities:** Long-term care homes, retirement residences, homeless shelters, correctional facilities and university residences
    - **Communities:** First Nation communities and municipal upstream sewershed locations.
- Three criteria were evaluated to identify representative upstream sampling locations:
    - **Risk Mitigation and Actionability**
    - **Feasibility**
    - **Partnerships Established**

Ontario

Wastewater Surveillance Initiative - Key Achievements

PHUs Onboarding

- **33** PHUs have been onboarded
- **26 of** PHUs onboarded are receiving regular sample results
- **7** information sessions completed for PHUs

Wastewater Data Use

- **6** municipalities making results available on their websites
- **2** municipalities have internal data wastewater dashboards
- **3** municipalities include the data in regular public briefings

Data and Visualization Hub

- **9** PHUs and their municipalities have access to their own dashboards provided through WSI's Data and Visualization Hub
- **45** municipalities have provided their sewershed boundaries

Municipalities/First Nations Onboarding

- **54** municipalities are receiving regular sample results
- **1** out of **4** First Nations onboarded receiving reliable results that are shared with the PHU

Sampling locations

- **159 locations** are part of the Initiative **(71** upstream locations and **88 WWTPs**
- **68 WWTPs** are currently being sampled and analyzed
- **55 upstream locations** are currently being sampled and analyzed
- Analysis results from **67 WWTPs** and **45 upstream locations** being shared with municipalities / PHUs

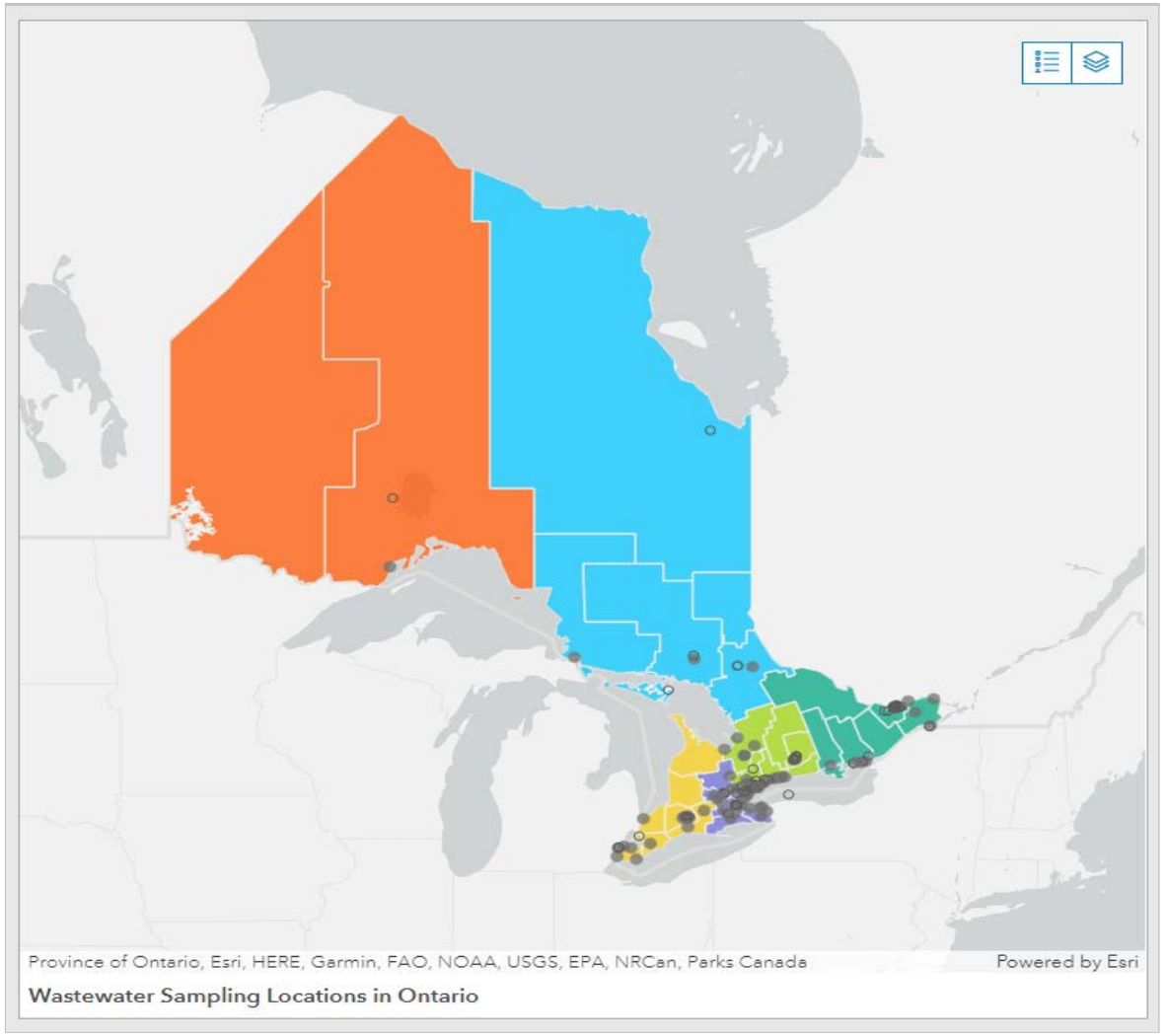
Sampling in high-risk communities

- **23** Sewershed level locations
- **19** University Campuses locations
- **5** Retirement Homes
- **4** Long-Term Care Homes
- **3** Correctional Facilities
- **3** Shelters
- **1** Hospital

Ontario

Data and Visualization Hub

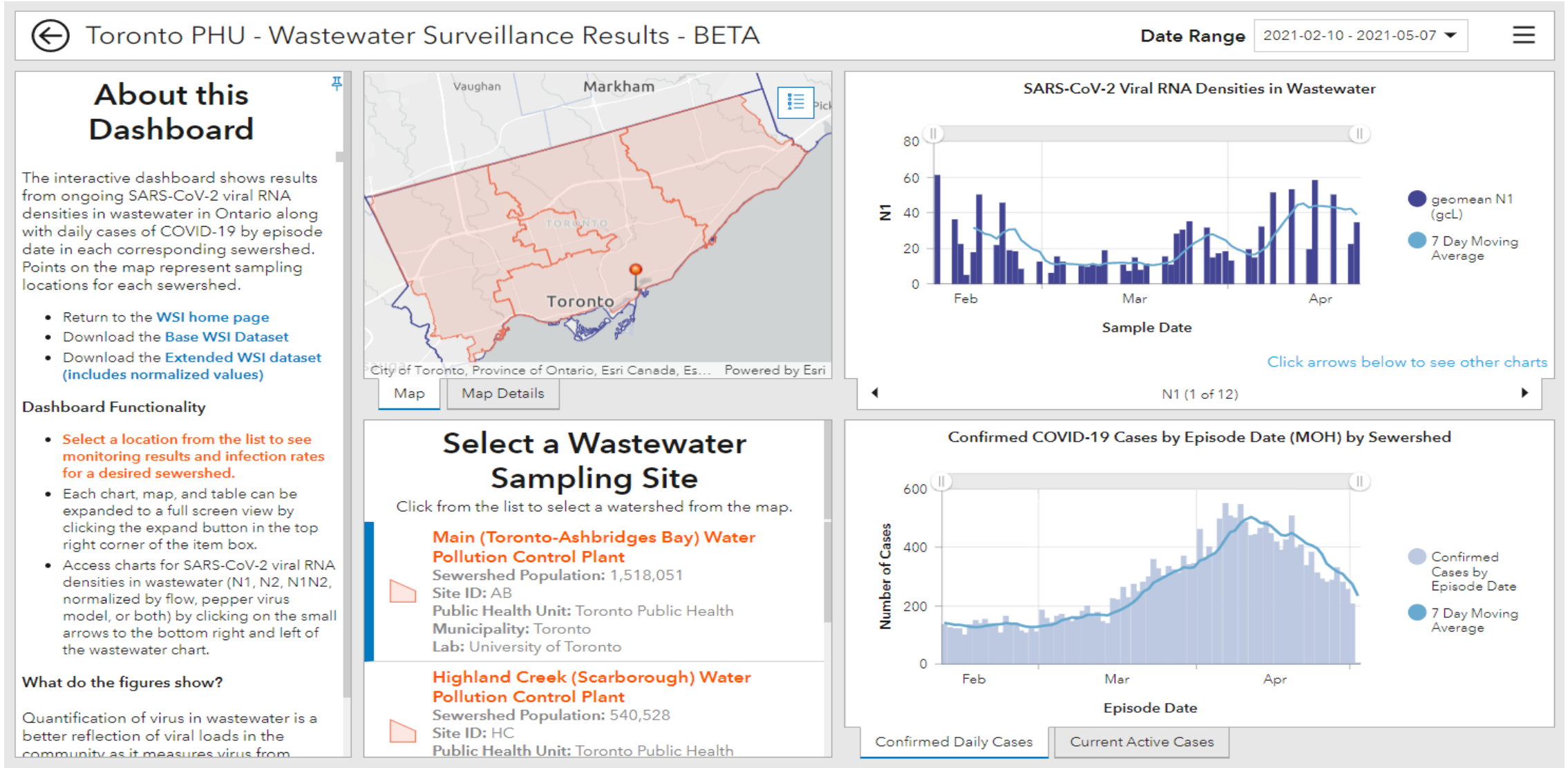
- Public Health Units, universities, and their associated municipalities can log into the Data and Visualization Hub to:
  - See the monitoring locations in their area only
  - Choose the most up-to-date data set to view or download
  - See the daily clinical case data grouped for the sewershed associated with a monitoring location
  - Use the statistical and visual presentation of the data for trend analysis and decision making.
- The Ministry of the Environment, Conservation and Parks, Ministry of Health, Public Health Ontario (PHO) as well as Public Health Agency of Canada (PHAC) will have access to all data sets for internal analysis and decision-making purposes.
- A Public Health Unit working group being established to support their ability to interpret the data and take appropriate action.
  - Guidance document on interpretation and response framework will also be developed, with examples from a use-case survey.



Ontario's Data and Visualization Hub, ARC GIS Online website, ESRI Canada

Ontario

Data and Visualization Hub – Dashboard

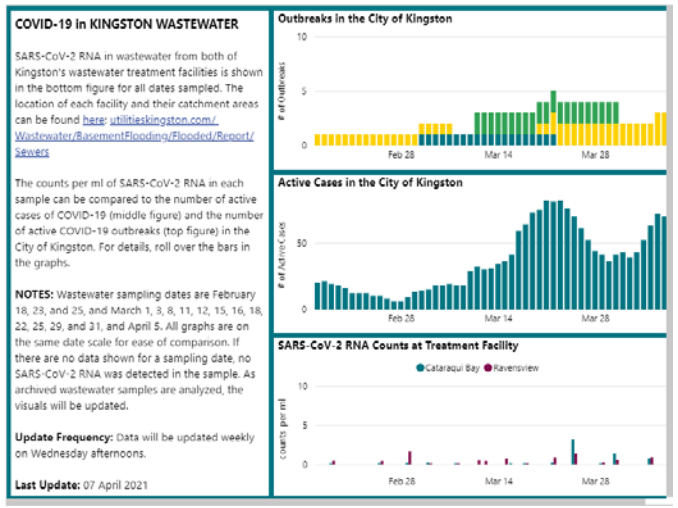


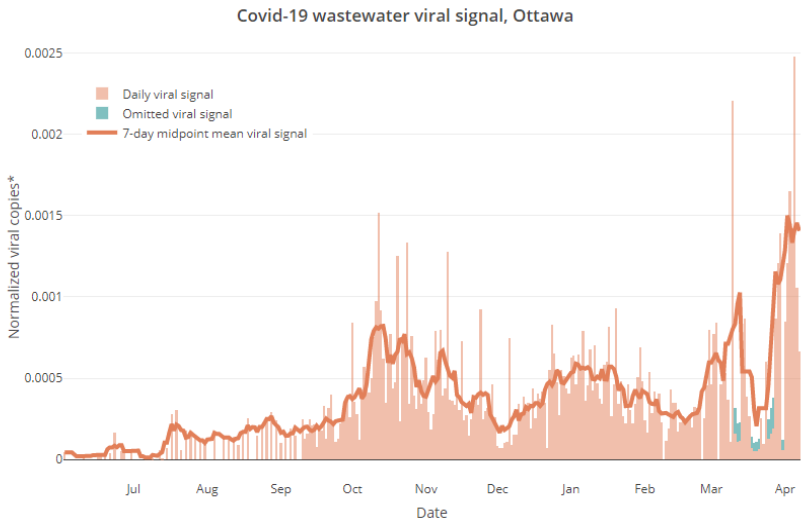
Ontario's Data and Visualization Hub, ARC GIS Online website, ESRI Canada

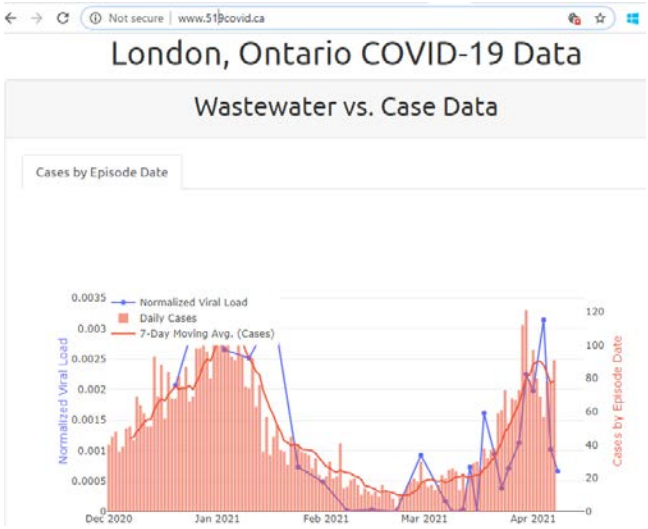
Ontario

Engaging Local Public Health Units

- 54 Municipalities – 26 Public Health Units (PHU) are receiving regular sample results from 11 universities.
- Regular meetings are being held to assist in virus signal trends interpretation.
- PHUs are at differing stages/abilities to interpret and act on results: Kingston, Ottawa, London, York, Peel, and Waterloo are publishing results publicly. Windsor includes wastewater data in regular public briefings. Peel, York, Toronto have created internal dashboards.
- MECP has set up a working group with PHU epidemiologists to facilitate interpretation.



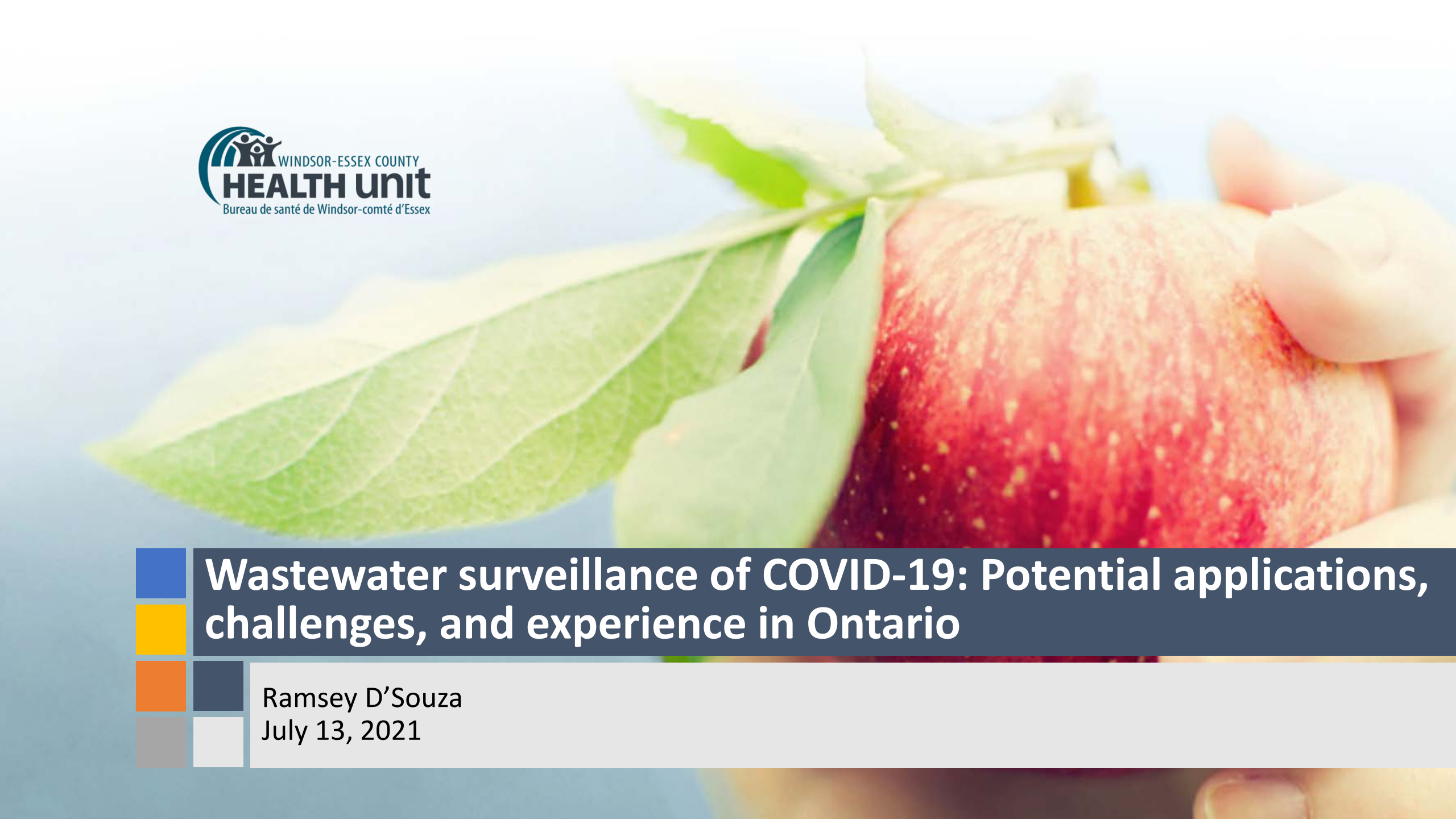




Ontario

Next Steps: July – August 2021

- **Inter-Laboratory Study Conclusions**
  - Implementation of recommendations
  - Assessment of needs for future studies involving municipal, public health and commercial labs
  - Release of guidance documents on QA/QC best practices
- **Sampling Strategy & Locations Expansion**
  - Expand sampling locations to more Public Health Units, northern municipalities & First Nation communities
  - Refine analytical methods including Variants of Concern assays
  - Finalize strategy to detect and monitor Variants of Concerns
- **Data and Visualization Hub**
  - Expand the dashboard access to all municipalities PHUs
  - Finetune the dashboard to display information and analytics needed by PHU/PHO/MOH/PHAC
- **Data Sharing Agreements**
  - Amend the Data and Visualization Hub's Terms of Use as needed from time to time
  - MECP & IAO to develop data sharing agreements with First Nation communities being sampled.
- **Public Health Engagement**
  - Engage public health units through frequent discussion of results
  - Lead the development of guidelines for public health interpretation and response planning
- **Program Evaluation**
  - Future program structure



Wastewater surveillance of COVID-19: Potential applications, challenges, and experience in Ontario

Ramsey D'Souza
July 13, 2021

About Windsor-Essex County

- Located in southwest region of Ontario
- Borders Detroit, Michigan
- Region consists of nine municipalities
- 2021 population = ~438,001
- Approximately 23,300 post-secondary students enrolled at local college & university

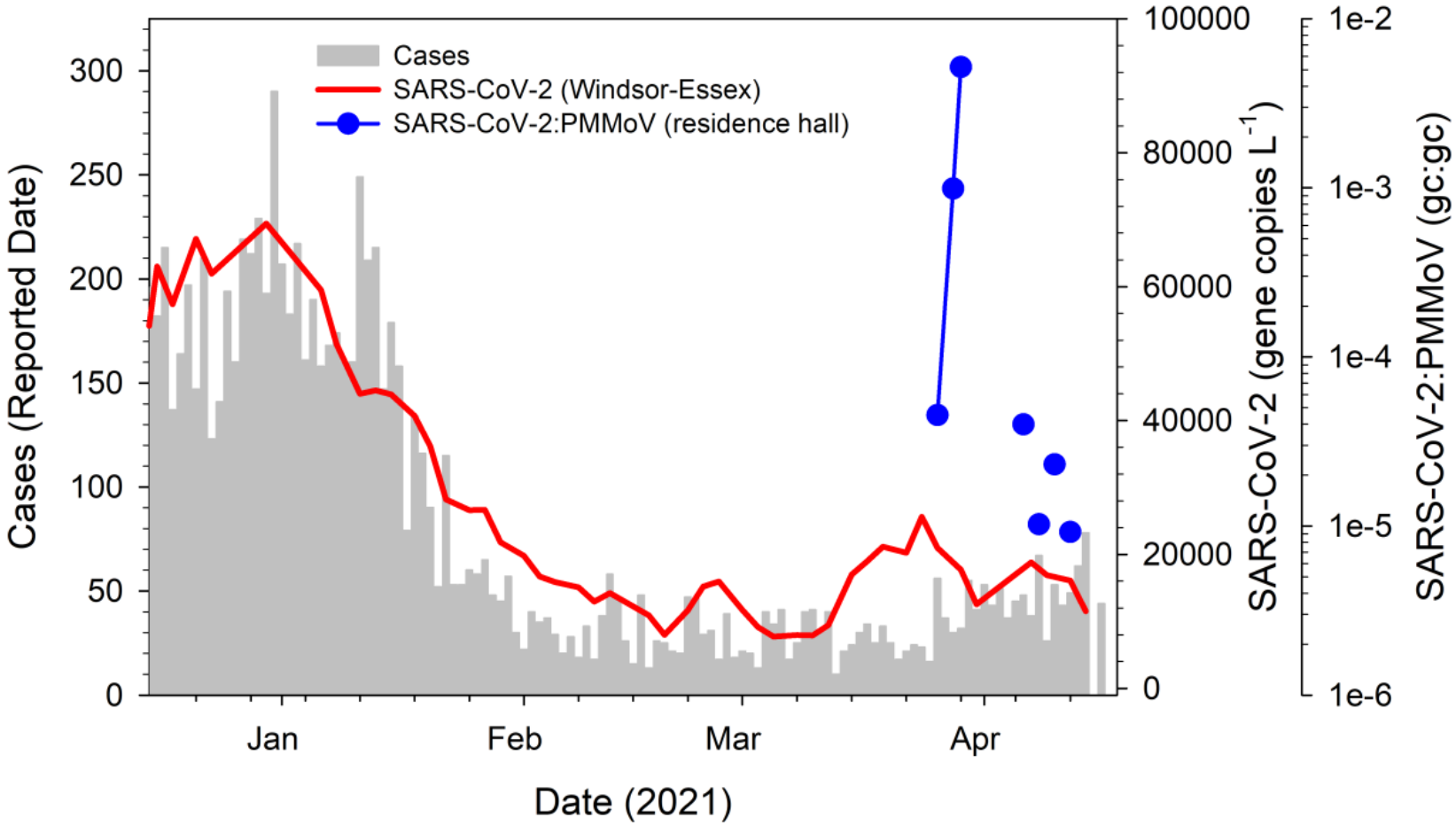
University Campus Sampling Strategy

- Location: On-site campus residence
- # of students living in residence: 186
- Sampling Start Date: February 2021
- Frequency of Sampling:
  - February 8 to March 22 = 3 times per week
  - March 23 to Present = Passive sampling using Moore Swab approach
- Samples collected, processed & analyzed by Dr. Mike McKay and his team at the Great Lakes Institute for Environmental Research (GLIER) at the University of Windsor

Averting A Potential Outbreak on Campus Residence

- Passive samples collected on March 26th, 2021 detected SARS-CoV-2
- Results available on March 27th AM
- Public Health Unit informed on March 27th PM
- Onsite testing available on morning of March 28th
- Two cases identified
  - Index case
  - Secondary case following contact tracing

Wastewater Data and Laboratory Confirmed Cases in Windsor-Essex



Conclusions

- Benefits of targeted wastewater sampling in high risk settings
- Increased collaboration between public health and facility/institution
- Possibility to scale up once college and university opens for in-person classes
- Can be replicated in other high risk facilities such as long-term care/retirement homes, schools, etc.

Toronto's experience: Implementation of COVID-19 wastewater surveillance

Shinthuja Wijayasri

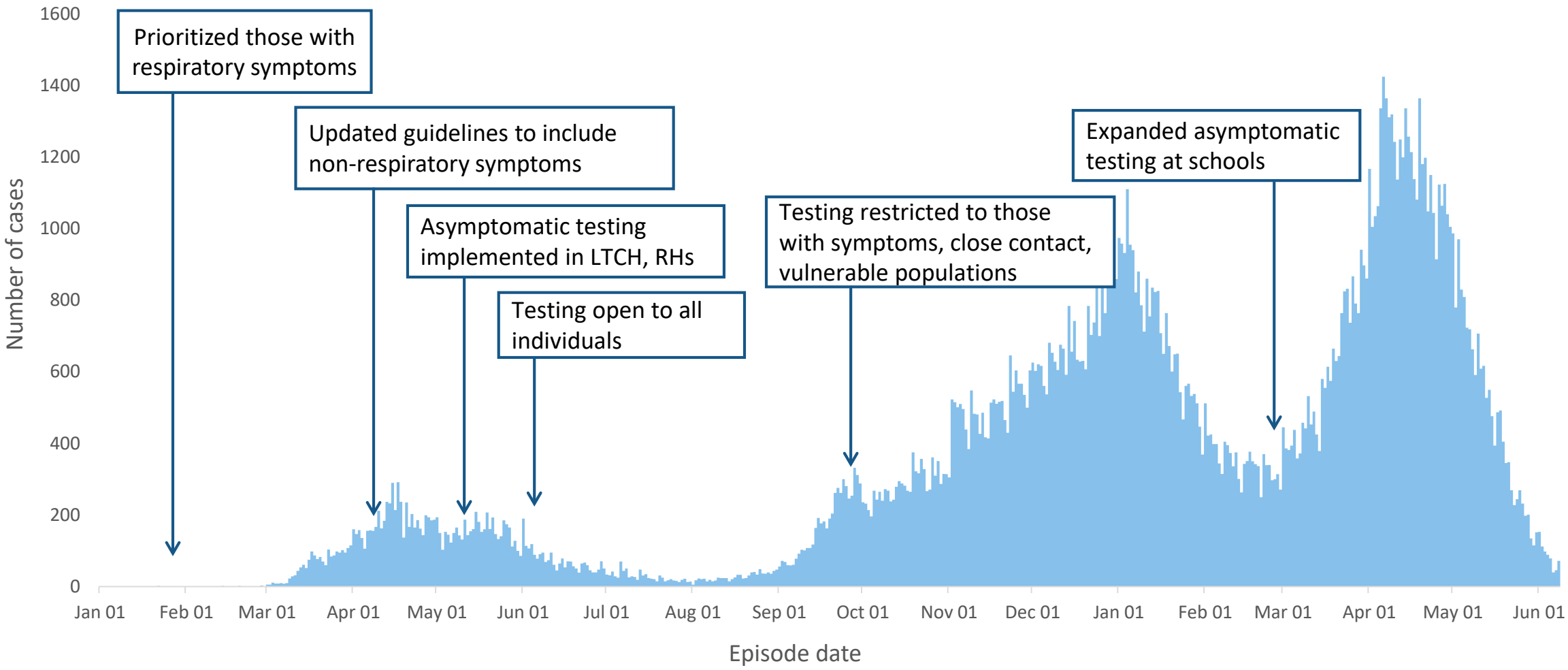
Communicable Disease Control, Toronto Public Health

Canadian Field Epidemiology Program, Public Health Agency of Canada

Disclosures

- None of the presenters at this session have received financial support or in-kind support from a commercial sponsor.
- None of the presenters have potential conflicts of interest to declare.

COVID-19 case detection is dependent on testing strategy



Source: Ontario Ministry of Health, Public Health Case and Contact Management (CCM), extracted by Toronto Public Health on June 9, 2021.
Abbreviations: LTCH, long-term care homes, RH, Retirement homes.

Why are we interested in COVID-19 wastewater surveillance?

We needed a tool that:

1. Is **independent** of clinical testing strategy and access.

2. Provides **situational awareness** to public health by capturing the burden of COVID-19 in a community that may not be captured by routine surveillance.

3. Can **monitor** COVID-19 trends in communities to support mobilization of resources related to the COVID-19 response.

4. Is an **early warning system** for changing trends that will inform escalation or de-escalation of public health measures and messaging.

Objectives of the presentation

1. Describe the pilot implementation of COVID-19 wastewater surveillance in Toronto during Toronto's third COVID wave.

2. Assess the value-add of wastewater surveillance in Toronto as the COVID-19 pandemic evolves.

3. Describe lessons learned and next steps.

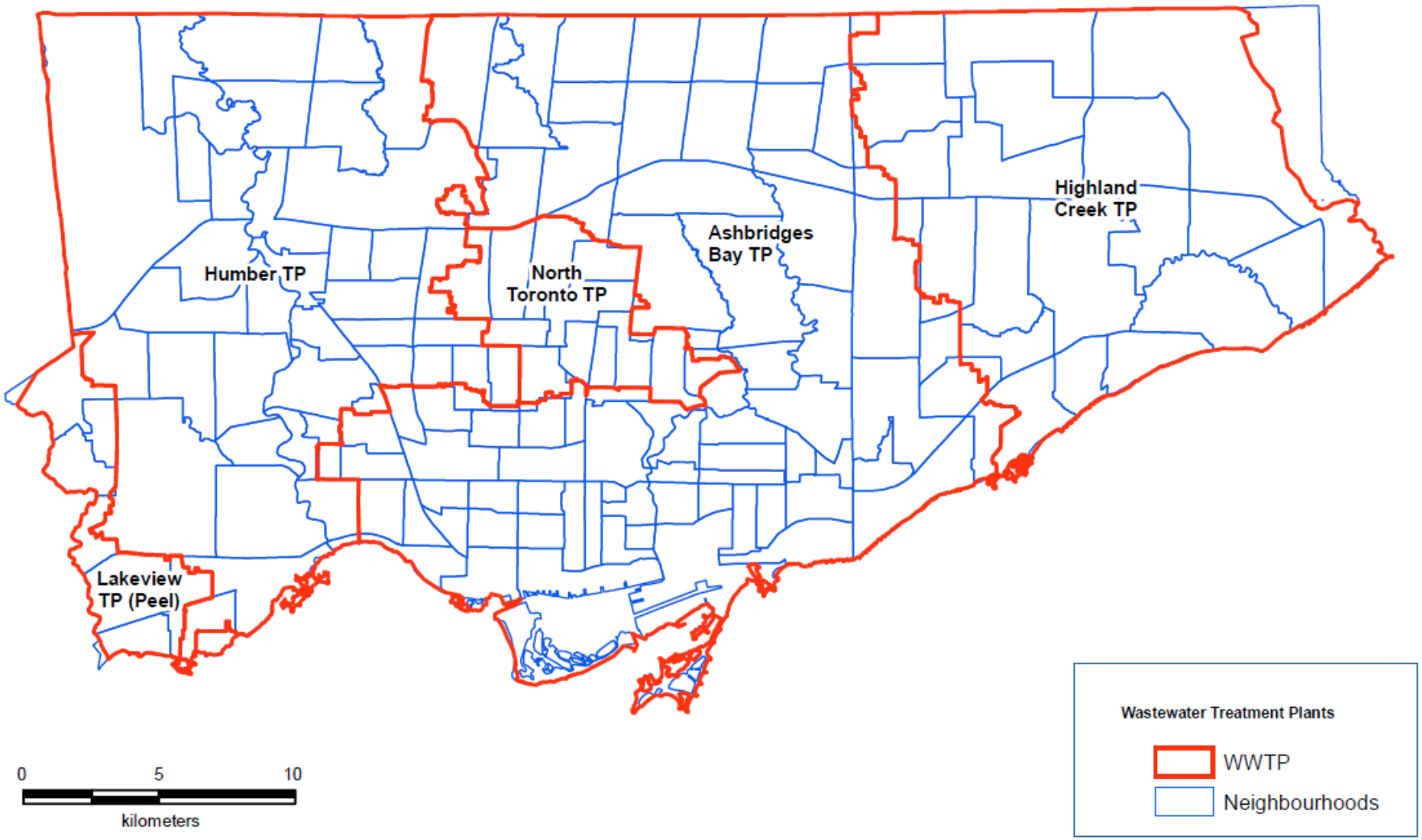
In Toronto, sampling locations include:

Four **wastewater treatment plants** (WWTPs) covering 97.4% of the city's population.

Six **upstream community sites** covering six smaller hotspot areas/neighbourhoods in the west region of Toronto.

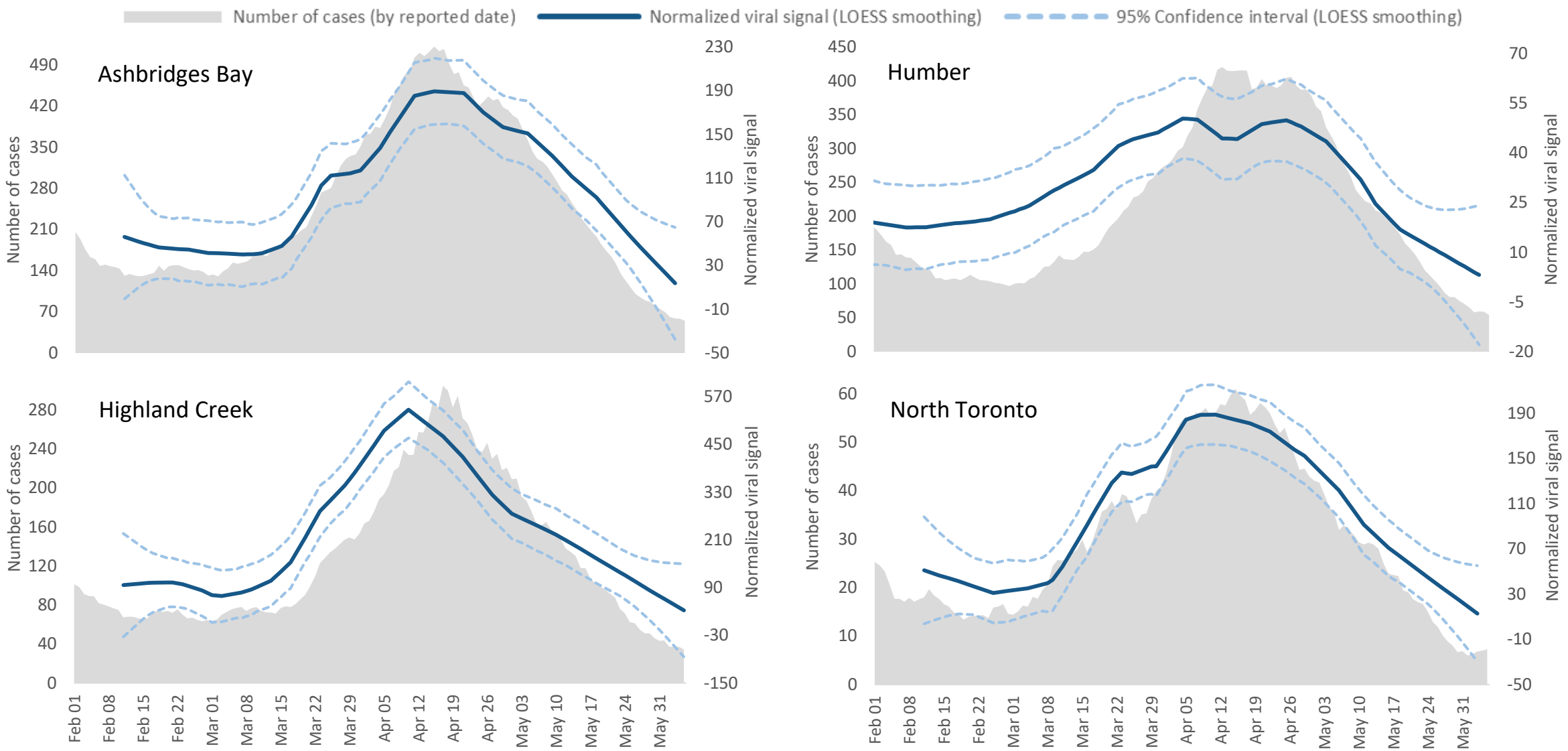
Five **facilities** (homeless shelters, hospitals and long-term care facilities).

Wastewater treatment plants



Source: 2006 Census Region Boundary Files, Enterprise Geospatial Repository. Data as of April 29, 2021.
Note: The northeast region of Toronto that is not covered by an identified treatment plant does not have a sewer network digitized, and mainly includes the Toronto Zoo and other open area. Sampling data are not available for Lakeview Treatment Plant, located in Peel Region, which covers approximately 2.6% of Toronto's population.
Abbreviations: WWTP, wastewater treatment plant.

Wastewater surveillance confirms city-wide trends observed in clinical surveillance, despite clinical testing strategy



Sources: Case data: Ontario Ministry of Health, Public Health Case and Contact Management (CCM), extracted by Toronto Public Health on June 9, 2021.
Wastewater sampling data: Ryerson University and the University of Toronto, received June 9, 2021.

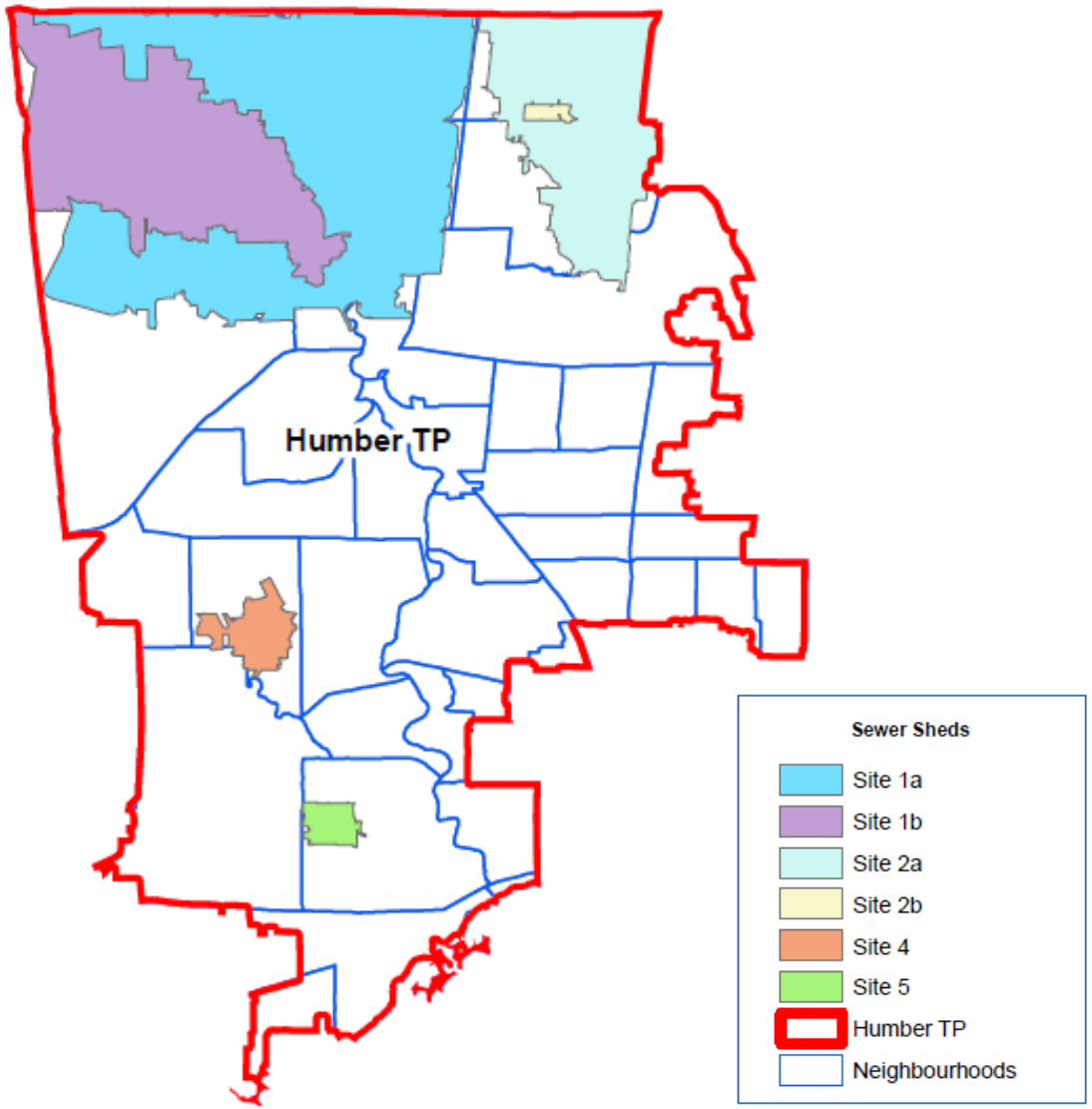
In Toronto, sampling locations include:

Four **wastewater treatment plants** (WWTPs) covering 97.4% of the city's population.

Six **upstream community sites** covering six smaller hotspot areas/neighbourhoods in the west region of Toronto.

Five **facilities** (homeless shelters, hospitals and long-term care facilities).

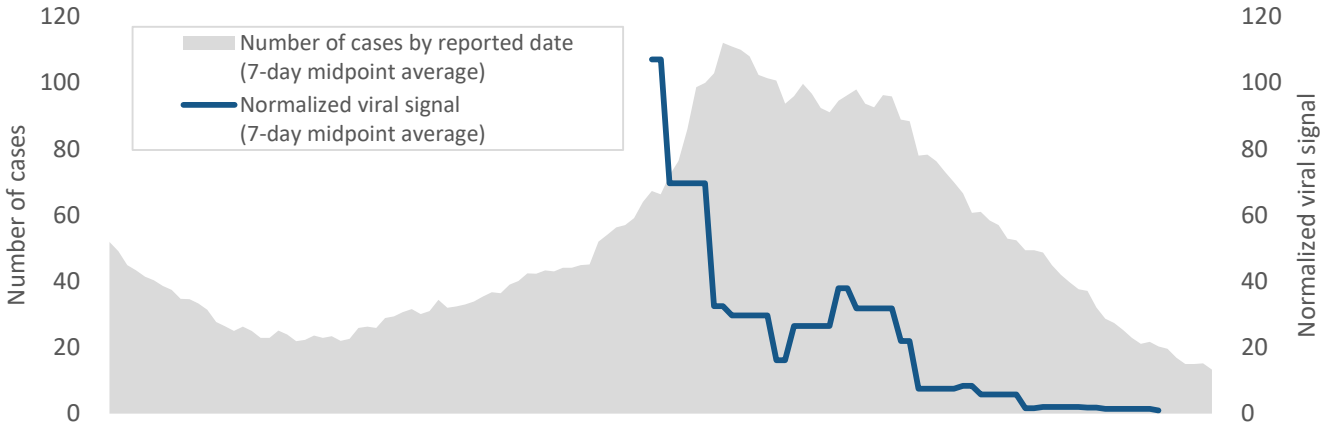
Upstream community sites



Source: 2006 Census Region Boundary Files, Enterprise Geospatial Repository. Data as of May 10, 2021
Abbreviations: TP, Treatment plant.

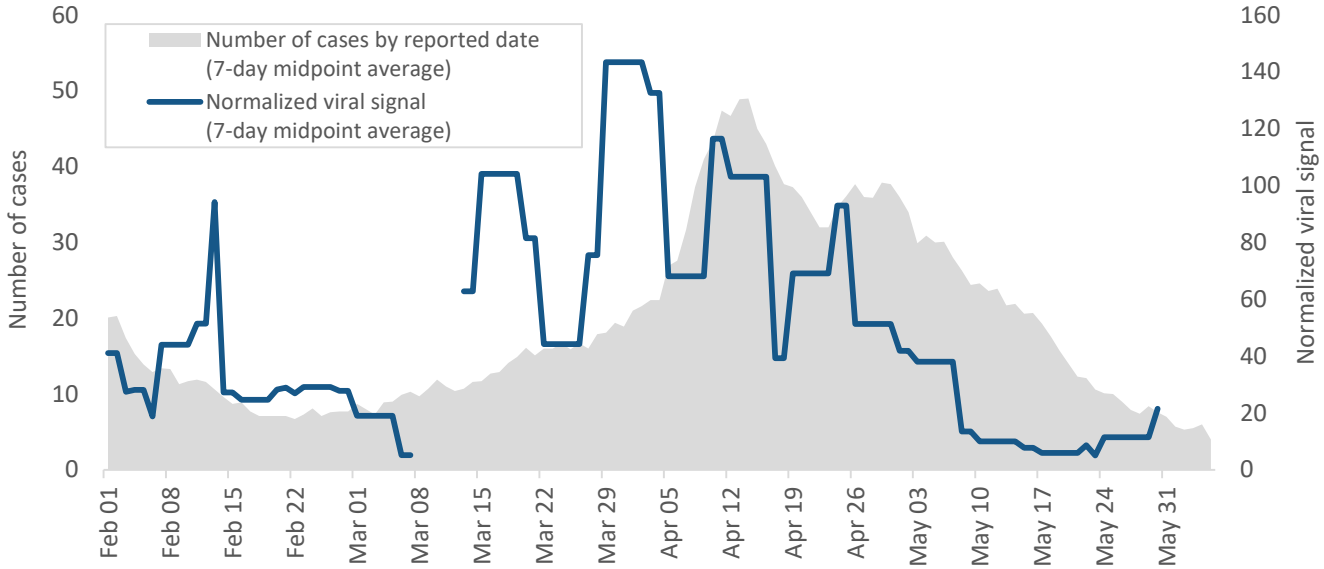
Upstream site data shows potential as an early indicator

Community Site 1A



- Covers ~ 130,810 people and several hotspot neighbourhoods.
- Declining signal ~ 6 days ahead of cases by reported date.

Community Site 1B



- Covers ~ 44,755 people (one neighbourhood)
- Declining signal ~10 days ahead of cases by reported date.

Source: Ryerson University, received June 11, 2021.

In Toronto, sampling locations include:

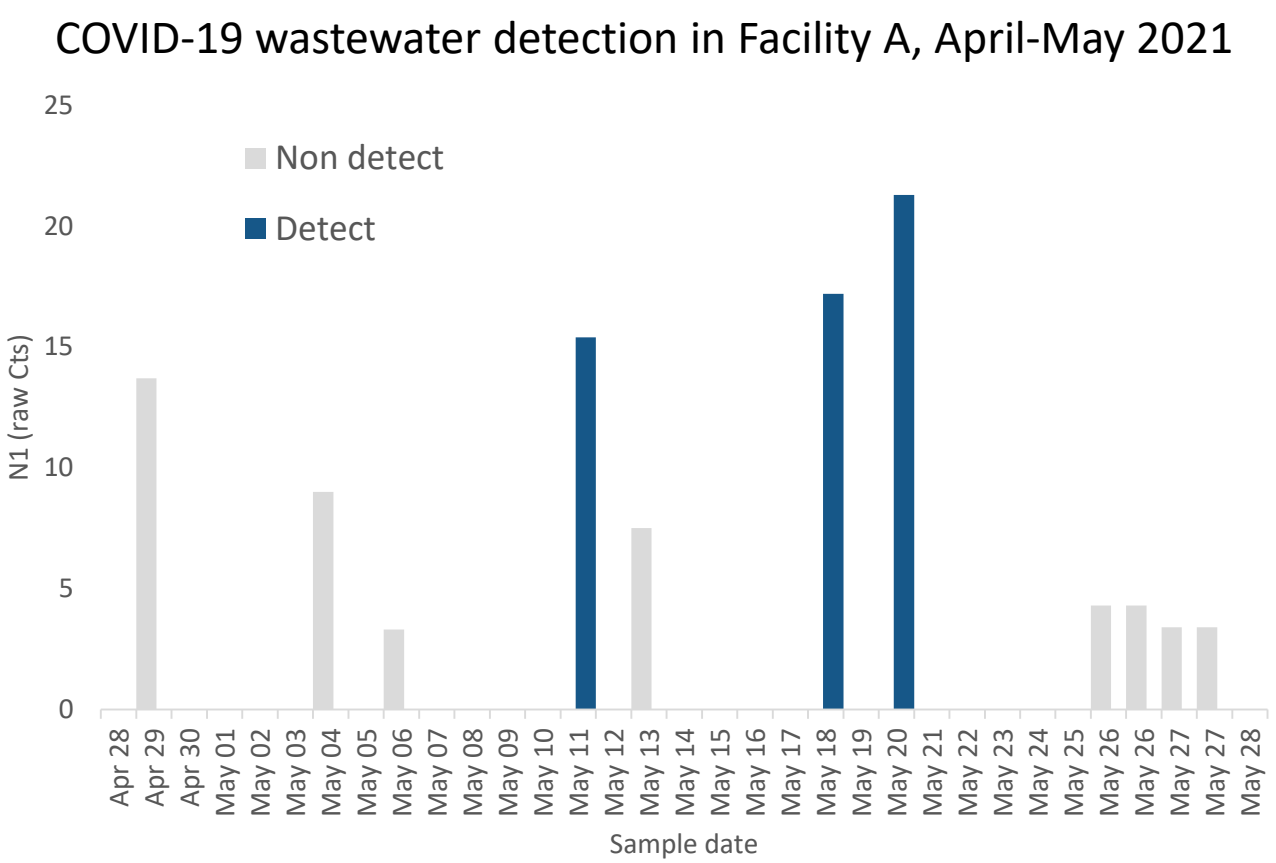
Four **wastewater treatment plants** (WWTPs) covering 97.4% of the city's population.

Six **upstream community sites** covering six smaller hotspot areas/neighbourhoods in the west region of Toronto.

Five **facilities** (homeless shelters, hospitals and long-term care facilities).

Example: Facility A

Healthcare institution (two long-term care wings + one hospital wing)

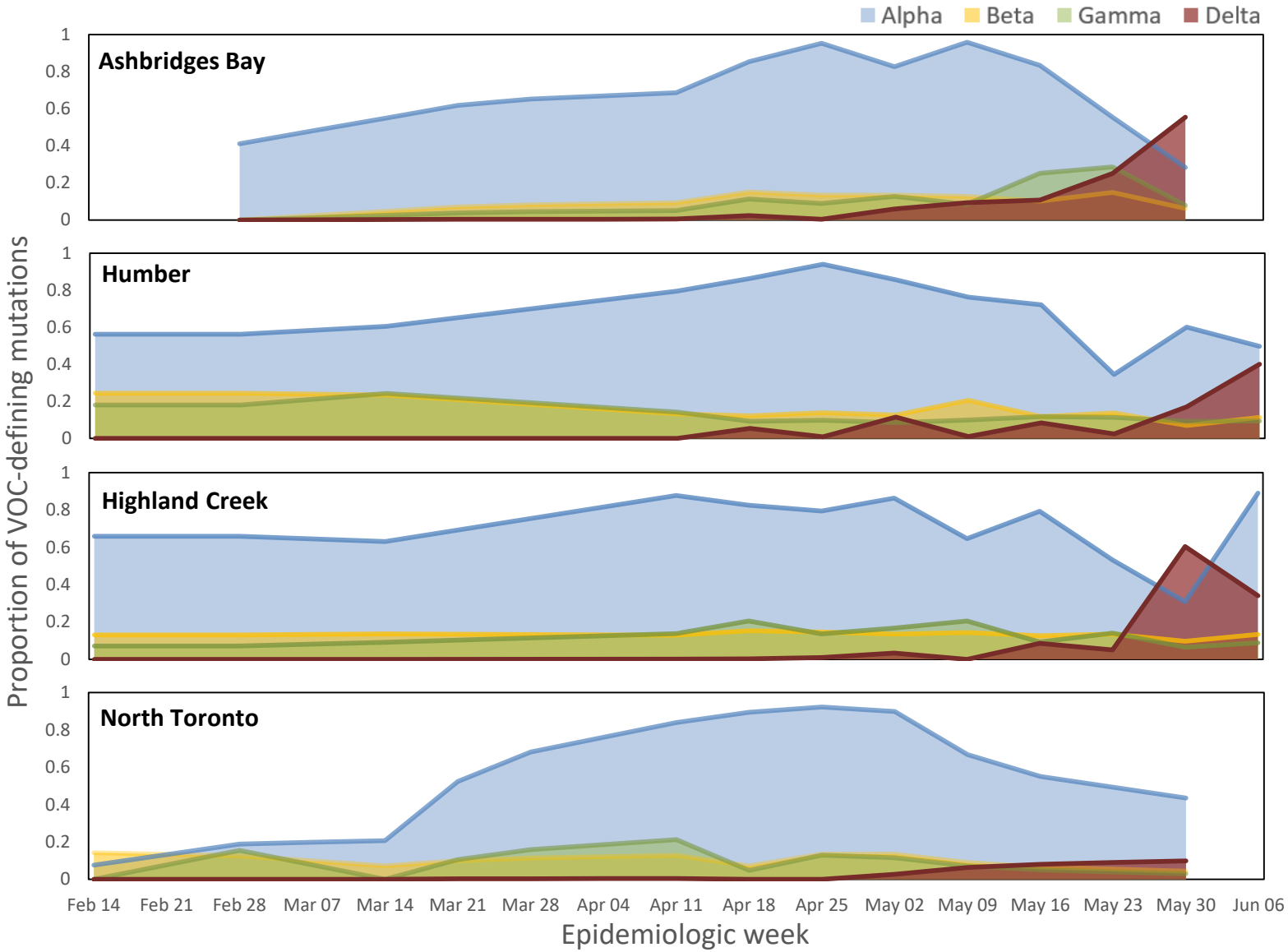


Source: Ryerson University, received June 11, 2021.

Action by Toronto Public Health

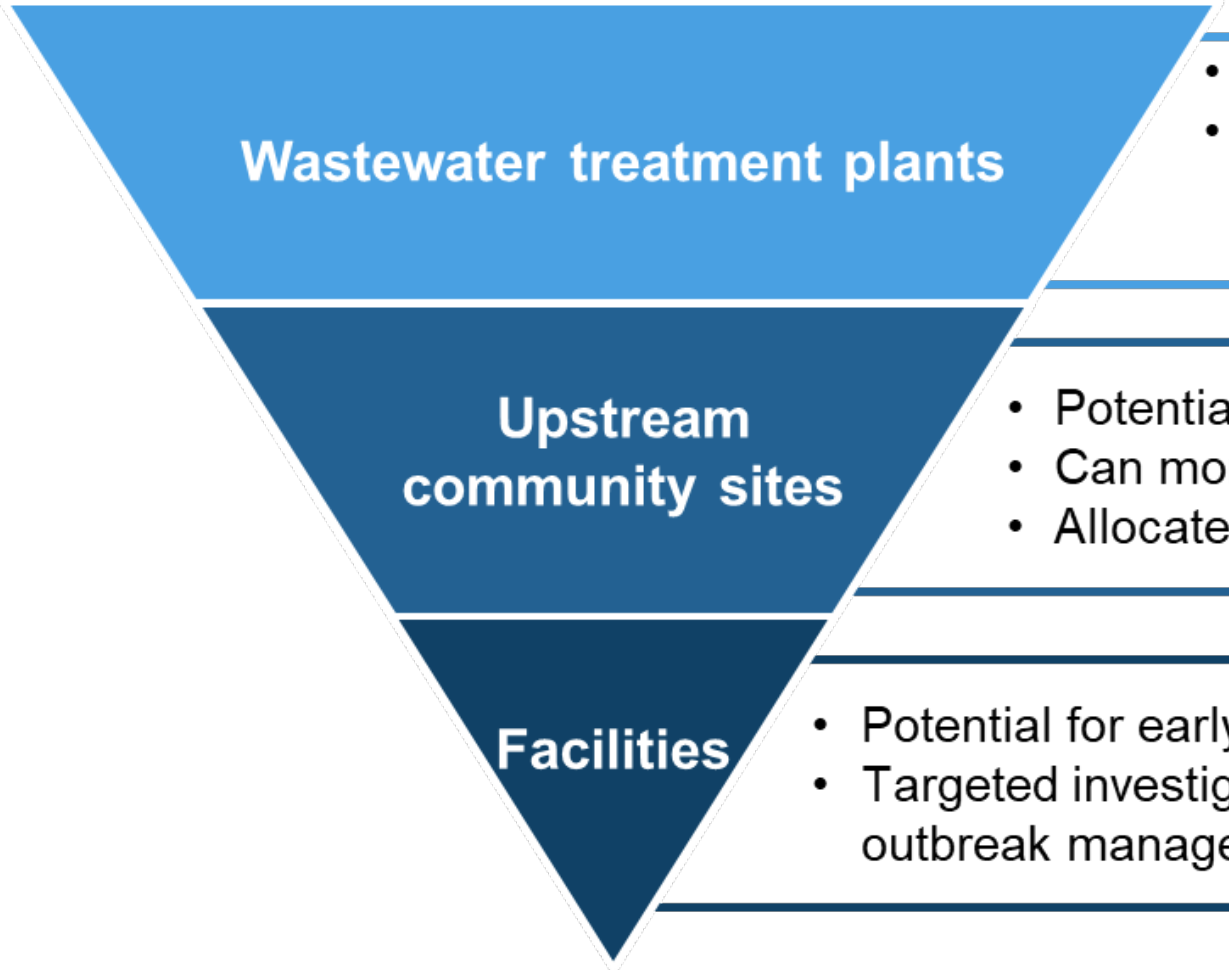
- Investigated available clinical information:
  - Several recent VOC outbreaks + High risk setting was concerning.
- TPH program area and facility IPAC were informed of signal.
  - Facility receives active COVID-19 cases from acute care.
- Heightened vigilance for cases.
- Continued wastewater monitoring.
  - Sampling was moved to another part of the facility.

VOC trends in wastewater surveillance are similar to clinical surveillance



Source: National Microbiology Laboratory, Public Health Agency of Canada, received June 25, 2021.

Wastewater surveillance in smaller targeted sites may provide more opportunities for public health action



- Corroborates clinical data regardless of testing rates.
- Promote vigilance, individual responsibility (adherence to public health measures, seek testing, immunization campaigns, etc.).

- Potential for early warning, particularly when testing wanes.
- Can monitor hotspot neighbourhoods when testing is limited.
- Allocate and mobilize resources (pop-up testing, vaccines).

- Potential for early warning when testing in these facilities is limited.
- Targeted investigation and action (enhanced/rapid antigen testing, outbreak management and control).

Limitations

- **Wastewater data are highly variable due to a variety of environmental and laboratory factors, particularly in larger WWTP catchment areas.**
  - Difficulty interpreting short-term trends and comparing to clinical indicators.
  - There is often variability in wastewater signal with no other evidence of changes to true incidence of COVID-19 cases.
  - The integration of wastewater surveillance and clinical surveillance requires additional local expertise to interpret results that appear to be unclear or contradictory.
- **Uncertainty about representativeness, sensitivity and specificity**
  - Wastewater surveillance may not be able to determine the overall prevalence or determine zero transmission of COVID-19 in a population.
- **Early warning system requires frequent sampling and timely reporting of results.**
  - The lag time in processing samples, reporting to public health and interpreting results limits our ability to identify and action real time changes.

Conclusions & next steps

Conclusions

- Wastewater surveillance correlates well with clinical data, confirming it can be a useful supplement when clinical testing wanes.
- It shows most promise as an early indicator in smaller communities (upstream sites, facilities), particularly during limited testing/low prevalence.

Next Steps

- Determine triggers for action and how local public health should respond to various signals.
- Need to evaluate the utility of wastewater surveillance as vaccine coverage increases, re-openings begin and the population becomes more mobile.
- With timelier data, wastewater surveillance can also be used to monitor trends for existing and emerging Variants of Concern.

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Thank you

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