Site-specific wastewater-based surveillance in early detection of COVID-19 new cases and prediction of mass testing outcomes in long-term care facilities

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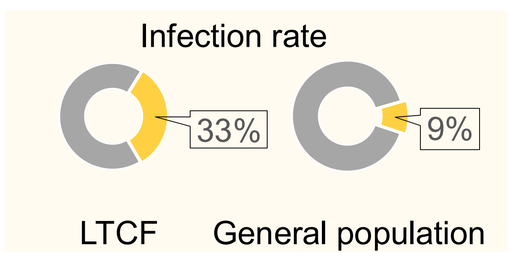
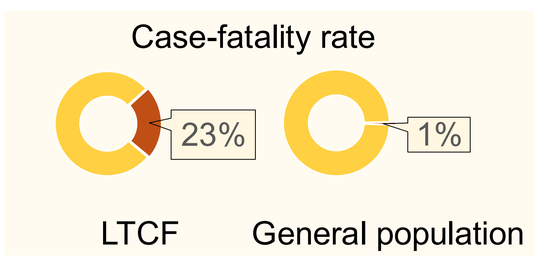
The challenge

Long-term care facilities (LTCFs) were disproportionately impacted during the COVID-19 pandemic.





Routine mass testing: necessary for early case identifications; significant resource and financial burden; practical challenges

Is there a potential cost-saving, non-invasive method improving outbreak management efficiency and individuals' quality of life?

An alternative: building-specific **wastewater-based surveillance (WBS)**

- Collect samples from a facility's sewer system to measure the collective viral load
- *Can WBS provide early warnings of clinical cases during outbreaks and accurately predict mass testing outcomes?*

The significance

WBS effectively signals emerging cases when no infections are present (wastewater turning from negative to positive)

In LTCFs, where cases remain on-site, **wastewater reflects both new and existing infections** → hard to interpret

This study will:

- Identify the **lead time** of WBS in LTCF setting
- Evaluate the **prediction accuracy** of mass testing outcomes
- Guide *outbreak investigators* and *public health officials* on effectively using the WBS information
- Inform the development of WBS for other infectious diseases

The data

Context: 9 LTCFs in Edmonton monitored from Jan 2021 to May 2023

Wastewater data: Collected 2–3 times per week, linear interpolated when daily values were required.

Clinical data: Daily new cases and testing numbers from Alberta Health Services.

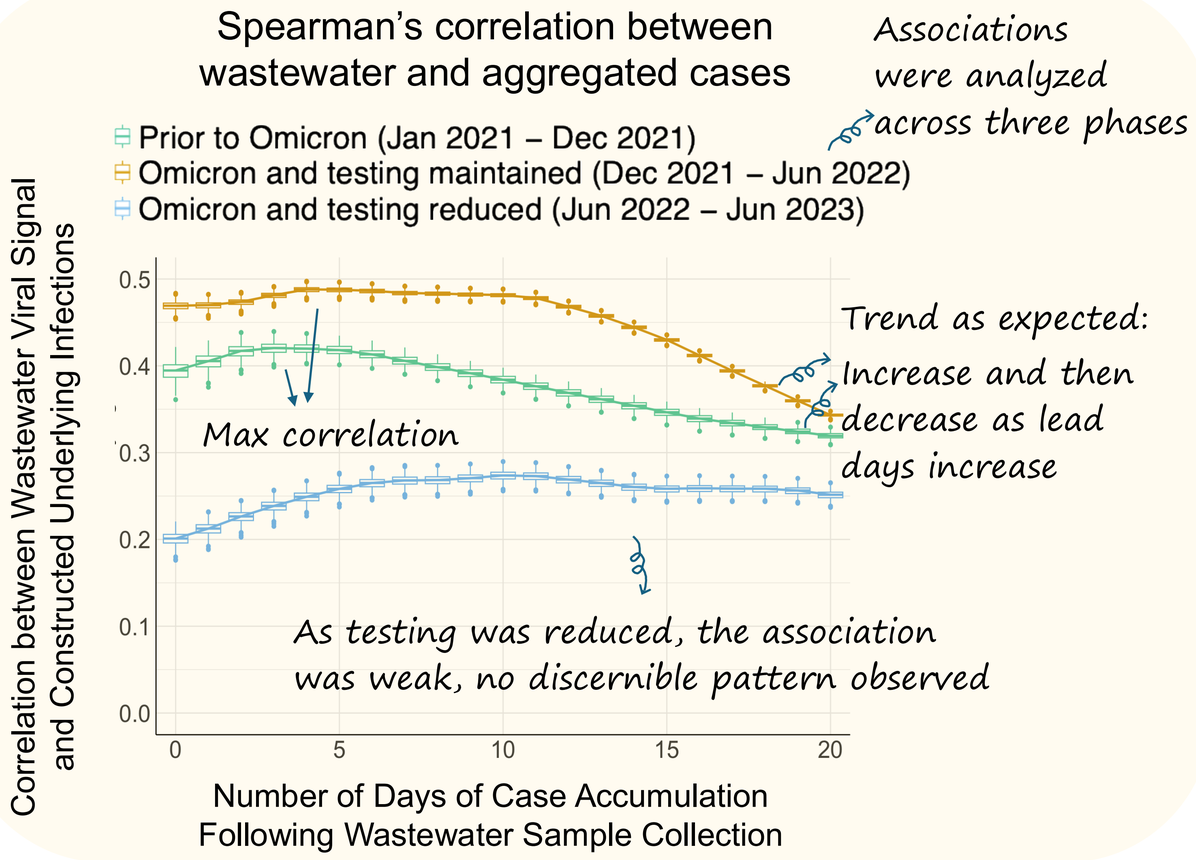
Wastewater provides a lead time up to 5 days for early COVID-19 case detection in long-term care facilities

Explorative analysis

Explore potential lead time by Spearman's correlation between aggregated cases (constructed underlying infections) and wastewater.

- Existing cases within the viral shedding window (21–32 days) were accounted for using Monte Carlo simulation.
- Associations were examined for daily new cases detected on the same day and up to 20 days later

Spearman's correlation between wastewater and aggregated cases



Associations were analyzed across three phases

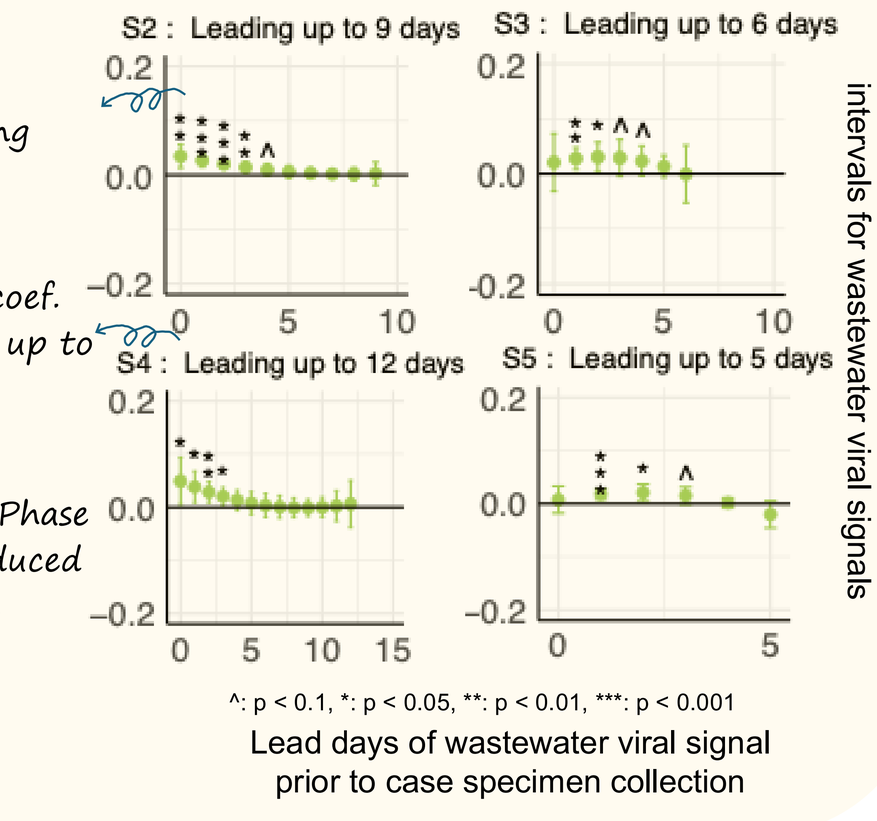
Trend as expected: Increase and then decrease as lead days increase

Distributed lag models

Identify significant lead time window during which wastewater signals predict new cases by distributed lag models

- A time series linear regression with quadratic constraints
- Covariates included testing numbers and one-day lagged case numbers.

Cases in long-term care facilities predicted by leading wastewater viral signals



Pre-Omicron + Omicron and testing maintained

Across sites: beta coef. indicate lead time up to five days

Fig not shown for Phase "Omicron with reduced testing": lead time results vary

Wastewater accurately predict mass testing outcomes, supporting optimal testing allocation

Mass testing: testing at least 20% of the unit (N = 110 instances)

Accurate prediction when no case identified (true negative)	85%
Accurate prediction when at least one case identified (true positive)	60%
Negative predictive value	77%
Positive predictive value	71%

Fisher's exact test compared WBS accuracy for predicting resident vs. staff cases and examined whether accuracy was influenced by sample frequency, outbreak duration, or sampling proximity to mass testing.

Accuracy in predicting resident case vs. staff case	74% vs. 33% (p = 0.02)

Sample frequency, outbreak duration, and timing relative to mass testing did not significantly impact accuracy.

The next

Integrate wastewater and individual-level data for improved precision.

Investigate the application of WBS in the ongoing infectious disease surveillance.

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