Preventing COVID-19 outbreaks using wastewater surveillance at long-term care facilities: A pilot modeling study

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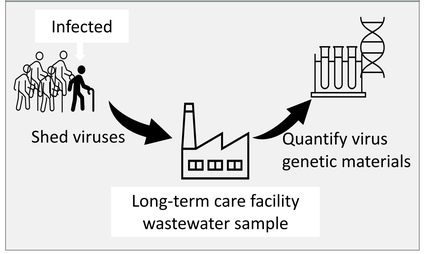
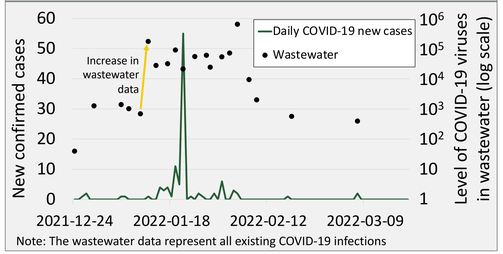
1. BACKGROUND

- Early detection of COVID-19 cases and rapid initiation of outbreak management are keys to control outbreak in long-term care facilities (LTCF). However, individual screening tests are invasive, and they can be resource-intensive when implemented on a large scale.
- Site-specific wastewater-based surveillance (WBS) can potentially control COVID-19 outbreaks more effectively at LTCF. WBS can identify pre-symptomatic and asymptomatic COVID-19 infections in the facility and therefore may allow more timely initiation of outbreak control measures.

How site-specific wastewater surveillance works?



One example of wastewater data provides early warning

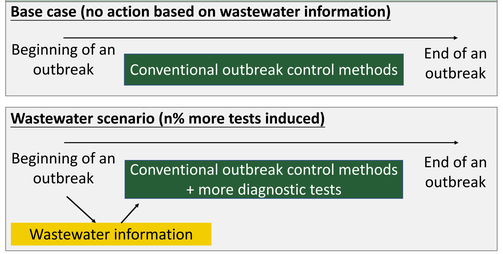


Note: The wastewater data represent all existing COVID-19 infections

2. AIM

- To evaluate the effectiveness of LTCF-site-specific WBS in preventing COVID-19 outbreaks, by comparing the ***base case*** of no action related to WBS and the ***wastewater scenario*** where more diagnostic tests were initiated due to positive wastewater test results.

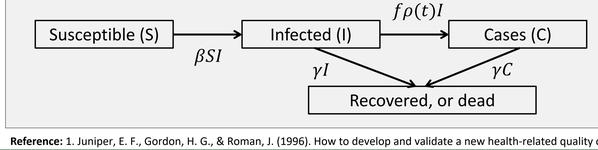
Study design



3. METHODS

- **Model (base case):** We built a susceptible-infected-cases-recovered (SICR) model to study COVID-19 transmission at LTCF in the base case. Compared to the SIR model, we had an additional "Cases" compartment. Infected individuals who get tested with a positive result will be identified as cases, for whom appropriate infection prevention control measures will be implemented. Therefore, infected individuals who are not identified as cases are the main source to transmit the virus to susceptible people.
- **Model (wastewater scenario):** All transitions and parameters are the same as the base-case model, but we hypothesized 10%-50% more diagnostic tests ($\alpha = 1.1, 1.2, 1.3, 1.4, 1.5$) induced by the positive wastewater result.
- **Assumption:** Aside from basic SIR model assumptions, we assumed the additional diagnostic tests due to WBS all had a positive result, i.e., transition from "Infected" to "Cases".
- **Data:** We used testing and cases data from an outbreak during the Omicron wave in one LTCF in Edmonton, Canada (December 2021 – March 2022), where wastewater data did not initiate actions.
- **Parameter fitting:** We fit base-case model parameters with daily cases and testing data using the nonlinear least-squares method.
- **Model validation:** We used daily wastewater data as an external data source to validate the model. We calculated the Spearman's association between the daily wastewater data and the predicted number of infected people. The strength of the correlation was interpreted as strong when $r \geq 0.5$ [1].
- **Outcome comparison:** We compared the outbreak size, i.e., predicted numbers of infections, to measure the effectiveness. We used the Wilcoxon signed-rank test to identify whether the outbreak size in the wastewater scenario was significantly smaller.

Susceptible-Infected-Cases-Recovered model structure (base case)



Model parameters

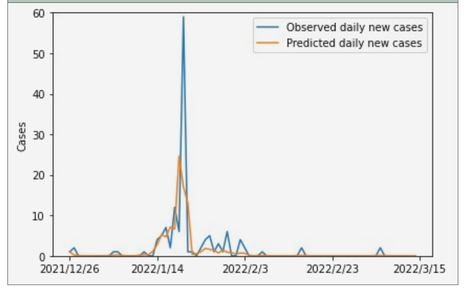
	Definition	Value
$\boldsymbol{\beta}$	Transmission coefficient	To fit
$\boldsymbol{f}$	Probability of infected individuals being investigated	To fit
$\boldsymbol{\rho(t)}$	Probability of individuals being investigated have positive test results	Estimated from data
$\boldsymbol{\gamma}$	Recovery rate	1/10
$\boldsymbol{\alpha}$	Percentage of tests induced by positive wastewater results	1.1-1.5

Reference: 1. Juniper, E. F., Gordon, H. G., & Roman, J. (1996). How to develop and validate a new health-related quality of life instrument. In B. Spiker (Ed.), *Quality of Life and Pharmacoeconomics in Clinical Trials. 2nd ed.* (Vol. 6). Philadelphia, PA: Lippincott-Raven Publishers.

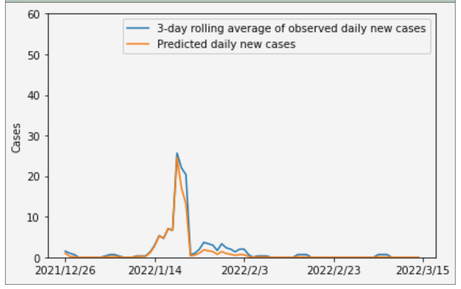
4. RESULTS

- In the base case, the total number of infections is 265 (51.7%), and the daily number of infections peaked on day 25, with 23.8% of individuals being infected.
- The model fitted well internally, as the observed and predicted new cases are comparable. It also has good external validity, as the wastewater data strongly correlated with the predicted number of infected individuals ($r = 0.77$, $p<0.001$).
- In the wastewater scenario, all hypothesized values resulted in a significantly smaller outbreak size ($p<0.001$); Adding 10%-50% more diagnostic tests could lead a total of 9-27.2 percentage point lower infection rate compared to the base case.

Base-case: daily new cases (observed vs. predicted)



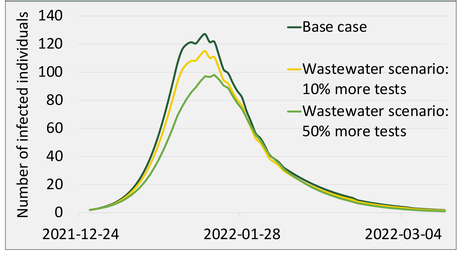
Base-case: 3-day rolling average of daily new cases



Number of infections (proportion in the total population)	
Base case	265 (51.7%)
Wastewater scenarios *	
10% more diagnostic tests	240 (42.7%)
20% more diagnostic tests	212 (37.7%)
30% more diagnostic tests	187 (33.3%)
40% more diagnostic tests	162 (28.8%)
50% more diagnostic tests	138 (24.5%)

Note: * All wastewater scenarios were significantly different from base case ($p<0.001$).

Predicted number of daily existing infections



5. Conclusions

- This pilot study demonstrates the potential effectiveness of using LTCF-site-specific wastewater surveillance data to help control the COVID-19 transmission.
- Future works include engaging policymakers in analyzing the use of wastewater data in decision-making to early identify COVID-19 outbreaks and specific wastewater-based actions. We will estimate the associated costs and outcomes to explore the cost-effectiveness of incorporating wastewater surveillance to monitor and control COVID-19 outbreaks.