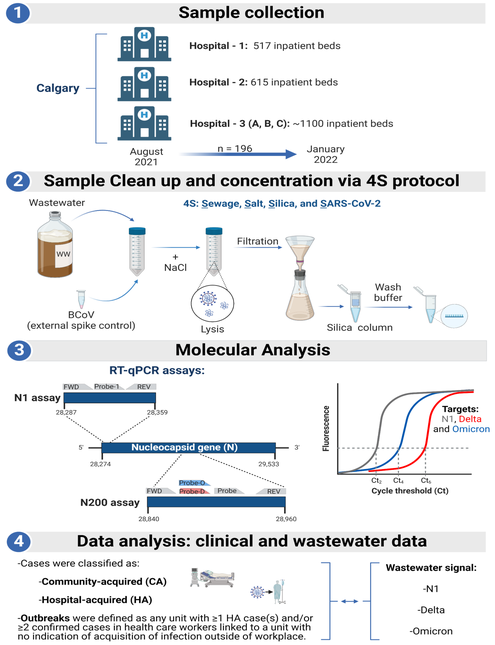
Surveillance of SARS-CoV-2 variants of concern in hospital wastewater samples and its correlation with hospitalized cases of COVID-19 and the occurrence of outbreaks in Calgary (Canada)

Nicole Acosta, Maria A. Bautista, Barbara J. Waddell, Janine McCalder, Kristine Du, Puja Pradhan, Navid Sedaghat, Chloe Papparis, Jianwei Chen, Jennifer Van Doorn, Kevin Xiang, Leslie Chan, Laura Vivas, Kashtin Low, Xuewen Lu, Thierry Chekouo, Xiaotian Dai, Jason Cabaj, Steve Hrudey, Srijak Bhatnagar, Norma Ruecker, Gopal Achari, M. Cathy Ryan, Rhonda G. Clark, Craig Pearce, Joe Harrison, Jon Meddings, Jenine Leal, Bayan Missaghi, Jamil Kanji, Oscar Larios, Elissa Rennert- May, Joseph Kim, Xiao-Li Pang, Bonita Lee, Kevin Frankowski, John Conly, Casey Hubert, Michael Parkins
University of Calgary, University of Alberta, Advancing Canadian Water Assets, City of Calgary, and Alberta Health Services
*paula.acostaamador@ucalgary.ca

Background

Wastewater surveillance is as a powerful tool that can assist in real time the monitoring of SARS-CoV-2 levels across different communities including high-risk facilities such as hospitals (1,2). This approach relies on detecting RNA genomic material in wastewater from fecal viral shedding of symptomatic and asymptomatic individuals. SARS-CoV-2 has been detected in community wastewater and its abundance correlated with community COVID-19 incidence, hospitalizations and deaths. Through the course of the COVID-19 pandemic, the world has witnessed a rapid emergence and spread of successive waves of SARS-CoV-2 infection – often driven by different variants of concern (VOC). We sought to correlate the differential abundance of Delta and Omicron SARS-CoV-2 VOC in wastewater from three hospitals in Calgary using the CDC "N1" and "N200" RT-qPCR multiplex assay (3) and compare this with hospital data on cases and outbreaks.

Methods



Hospital wastewater SARS-CoV-2 RNA and clinical data through the Delta and Omicron waves of COVID-19

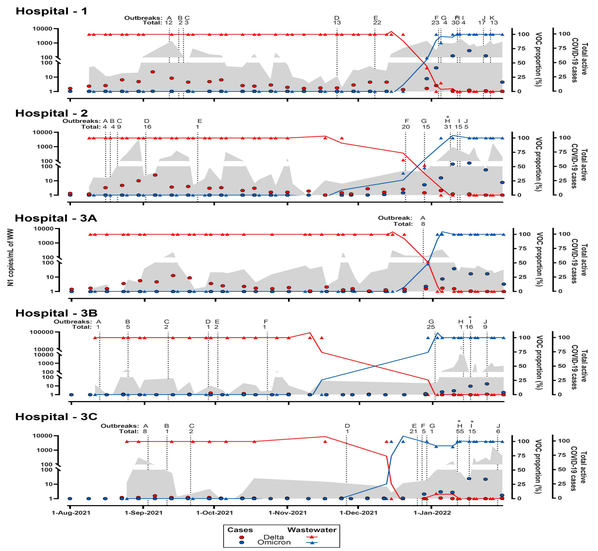


Figure 1. Daily census of COVID-19 hospitalized individuals and SARS-CoV-2 RNA in hospital wastewater as a function of each Variants of Concern (VOC). Concentration of SARS-CoV-2 RNA N1 signal (grey area), and the VOC proportion (%) of Delta (red triangles) or Omicron (blue triangles) in wastewater. Red and blue circles denote the weekly mean total number of prevalent cases for each VOC in the hospitals which is presented by the second right y-axis. Vertical dash lines correspond to days where outbreaks were declared, and the number effected .

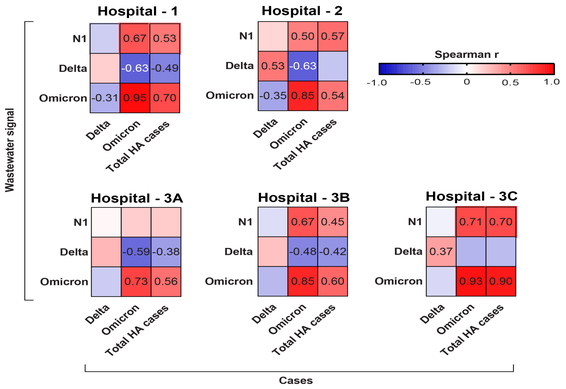


Figure 2. Occurrence of hospital-acquired (HA) infections strongly associate with peaks in SARS-CoV-2 RNA abundance in wastewater from hospitals. Heatmap for the Spearman analysis between HA cases of COVID-19 attributed to Delta, Omicron or total active cases and wastewater signal from five hospital locations. HA cases occurring +/- 2 days were compared to wastewater signals. Spearman r value is only shown for those analysis when P<0.05.

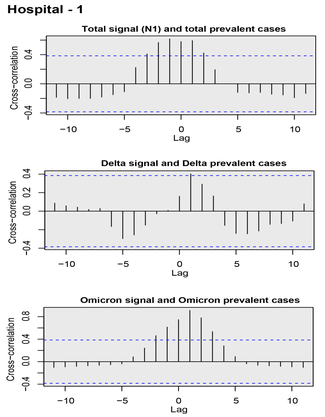


Figure 3. Cross-correlation function (CCF) demonstrates the association between wastewater and clinical data in Hospital-1. Figures show the CCF analysis between prevalent cases (Total or VOC-specific) and wastewater signal measured with either N1, Delta or Omicron signals. Blue dashed lines indicate confidence threshold for $\alpha = 0.05$.

Association between outbreaks and wastewater SARS-CoV-2 signal

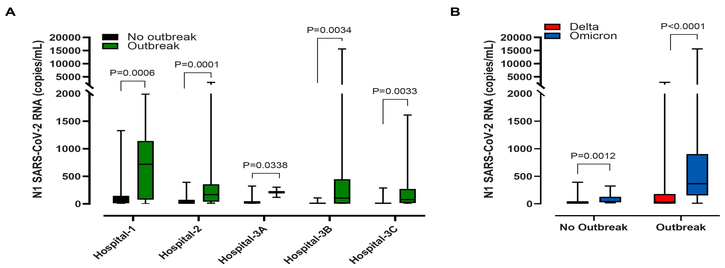


Figure 4. SARS-CoV-2 abundance in hospital wastewater is markedly elevated during outbreaks, and during the Omicron wave. N1 SARS-CoV-2 RNA values within 5 days of an outbreak being declared were compared with samples collected during outbreak-free periods. A) N1 SARS-CoV-2 RNA signal (copies/mL) per hospital. B) Combined N1 SARS-CoV-2 RNA data from the Delta-wave were compared with samples collected during Omicron-wave. Median and interquartile ranges are indicated as the middle, top, and bottom lines of each box. Ends of the whiskers mark the lowest and highest signal. Differences were determined using the Mann Whitney test.

Conclusions

- Wastewater surveillance is a powerful tool for early detection and monitoring of circulating lineages of SARS-CoV-2.
- Omicron in hospital wastewater rapidly supplanted Delta by mid-December and this correlated with lack of Delta-associated hospital-transmissions during a period of frequent hospital outbreaks.
- Monitoring demonstrated that as total prevalent cases increased (Delta plus Omicron), so did the wastewater N1 and N200 signals. Acutely occurring hospital acquired infections disproportionally increased SARS-CoV-2 RNA abundance.
- There were significant differences in median SARS-CoV-2 N1 copies/ml between outbreak-free periods vs outbreak periods and between delta and omicron waves.
- Hospital surveillance provides unique insight into wastewater SARS-CoV-2 dynamics and suggests that peak viral shedding occurs very early in the disease course.

References

1. Medema, G., et al. Presence of SARS-Coronavirus-2 RNA in Sewage and Correlation with Reported COVID-19 Prevalence in the Early Stage of the Epidemic in The Netherlands. Environ. Sci. Technol. Lett. 7, 511–516 (2020).
2. Acosta, N. et al. A multicenter study investigating SARS-CoV-2 in tertiary-care hospital wastewater. viral burden correlates with increasing hospitalized cases as well as hospital-associated transmissions and outbreaks. Water Res. 201, 117369 (2021).
3. Fuzzen, M. et al. Multiplex RT-qPCR assay (N200) to detect and estimate prevalence of multiple SARS-CoV-2 Variants of Concern in wastewater. doi:10.1101/2022.04.12.22273761 (2022).