Multi-scale outbreak tracking using clinical and environmental genomic surveillance

SANBI May 9th, 2023

SARS-CoV-2 continues to evolve



Nextstrain

Clinical sampling blind spots



Brito, Semenova, Dudas et al., 2021



Overall percentage of sequenced cases (log scale)

Rader, Astley et al., 2020

Wastewater as a promising alternative



SEARCH Dashboard

Today's talk

- 1. Wastewater sampling and virus quantification
- 2. Computational methods for analyzing mixed samples (Freyja)
- 3. Wastewater surveillance for early, cryptic detection
- 4. Integrated clinical and environmental surveillance for real-time public health guidance

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UCSD Campus

Point Loma



Sampler Types Residential: 72 Isolation dorms: 4 Non-residential: 58

~18,000 residents in campus housing



Primary wastewater treatment plant serving the greater SD area

Serves ~2.3 million residents



Image credit: Erik Jepsen, Caroline Sheikhzadeh, UCSD

High-throughput wastewater SARS-CoV-2 viral detection pipeline



Image courtesy: The Scientist

Karthikeyan et al. mSystems 2021

Detection of 85% of cases on campus via wastewater





Self-administered test via vending machines

Pilot stage: All on-campus residents mandated to test weekly

City-wide catchment area closely tracks clinical cases



SEARCH Dashboard

Higher viral diversity observed in wastewater



Uncertainty associated with randomly sampling an allele

Number of single nucleotide variant (SNV) sites

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Lineage Barcoding



>3000 SARS-CoV-2 lineages





Lineage Barcoding





Does this work on wastewater?





qPCR VOC Detection ଜ୍

Variant Prevalence



Mutation	Variants	Mutation	Variants
L452R	Delta, Epsilon, Kappa	K417T	Gamma
P681R	Delta, Kappa	K417N	Beta
E484Q	Карра	DelHV69/70	Alpha
DelY144	Alpha	N501Y	Alpha, Beta, Gamma

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San Diego County Surveillance

Wastewater samples show earlier appearance of VOCs

Data from 31,149 nasal swab sequences from SD county and 734 wastewater sequences

UCSD Campus Surveillance



UCSD Campus data

Extended cryptic virus spread during early Alpha and Delta waves



San Diego County wastewater surveillance

Wastewater captured virus diversity during the Delta wave





Point Loma

The BA.1 Omicron wave in San Diego







The BA.1 Omicron wave in San Diego



The BA.1 Omicron wave in San Diego



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Omicron

ATTIME

Time





Omicron

MUU



Campus transmission networks with consensus genomes

High resolution sampling on UCSD capture individual infections, clusters of SARS-CoV-2 spread

Freyja indicates sample is composed of a single lineage

Can use standard consensus sequence calling methods (iVar etc.)

UCSD Wastewater UCSD Clinical United States

Data de-identified in accordance with IRB (approval #210699, #200477)



Real-time building-level sampling on campus





Instruction Jan. 31

I am happy to report that UC San Diego is on schedule to return to in-person instruction beginning Monday, Jan. 31. As of today, viral levels in wastewater reported from the Point Loma treatment facility are dropping, student positivity rates on and off campus are falling, and our proactive use of rapid antigen tests has greatly reduced the need for isolation housing for returning students.

signal before

{last date}

8/16

8/16

8/14

8/16

8/16

8/16

8/12

7/11

6/12

N/A

N/A

N/A

Community-level wastewater genomic surveillance

Rapid turnaround: 26h sample-sequence data



Relative growth rate estimation from wastewater



Lineage	Growth Advantage	Bootstrap 95% Cl
XBB.1.9.X	17.4%	[9.14% , 28.68%]
XBB.1.16.X	8.8%	[4.23% , 22.44%]
XBB.X	3.7%	[-4.46% , 10.90%]
XBB.1.5.X	1.8%	[-2.20% , 6.85%]
Other recombinants	-7.0%	[-26.22% , 9.37%]
BQ.1.1.X	-13.6%	[-52.30% , -4.81%]
BA.2.X	-17.3%	[-53.07% , -7.30%]
BQ.1.X	-21.1%	[-39.91% , -15.11%]
BA.5.X	-29.2%	[-242.89% , -8.65%]

Wastewater surveillance across the world



Rising tide

Number of known wastewater sites* monitoring for SARS-CoV-2 RNA, '000



Wastewater surveillance across the world



Wastewater surveillance in Blantyre, Malawi





Surface water-based surveillance in Blantyre





Multi-scale surveillance in Bangalore, India



Lamba et al., 2023

Wastewater surveillance in South Africa with NICD





NATIONAL INSTITUTE FOR COMMUNICABLE DISEASES Division of the National Health Laboratory Service

SARS-CoV-2 waves in South Africa (via wastewater)



Wastewater surveillance going forward

International surveillance networks and public dissemination of analyses





covSPECTRUM

Expansion to multi-pathogen surveillance





Explore staphb/freyja



staphb/freyja 🕸

By staphb • Updated 14 days ago

Freyja: recover relative lineage abundances from mixed SARS-CoV-2 samples from a sequencing dataset

Container

NATIONAL INSTITUTE FOR COMMUNICABLE DISEASES Division of the National Health Laboratory Service



>80k downloads

Overview Tags

Acknowledgements







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