Global Update on Wastewater Surveillance for SARS-CoV-2

Christobel Ferguson, PhD

advancing the science of water®

Overview

Rapid Development & Adoption

Wide Variety of Approaches

Use Cases

Trends, Variants, and Early Warning

Lessons Learned

Global Update

Knowledge gaps

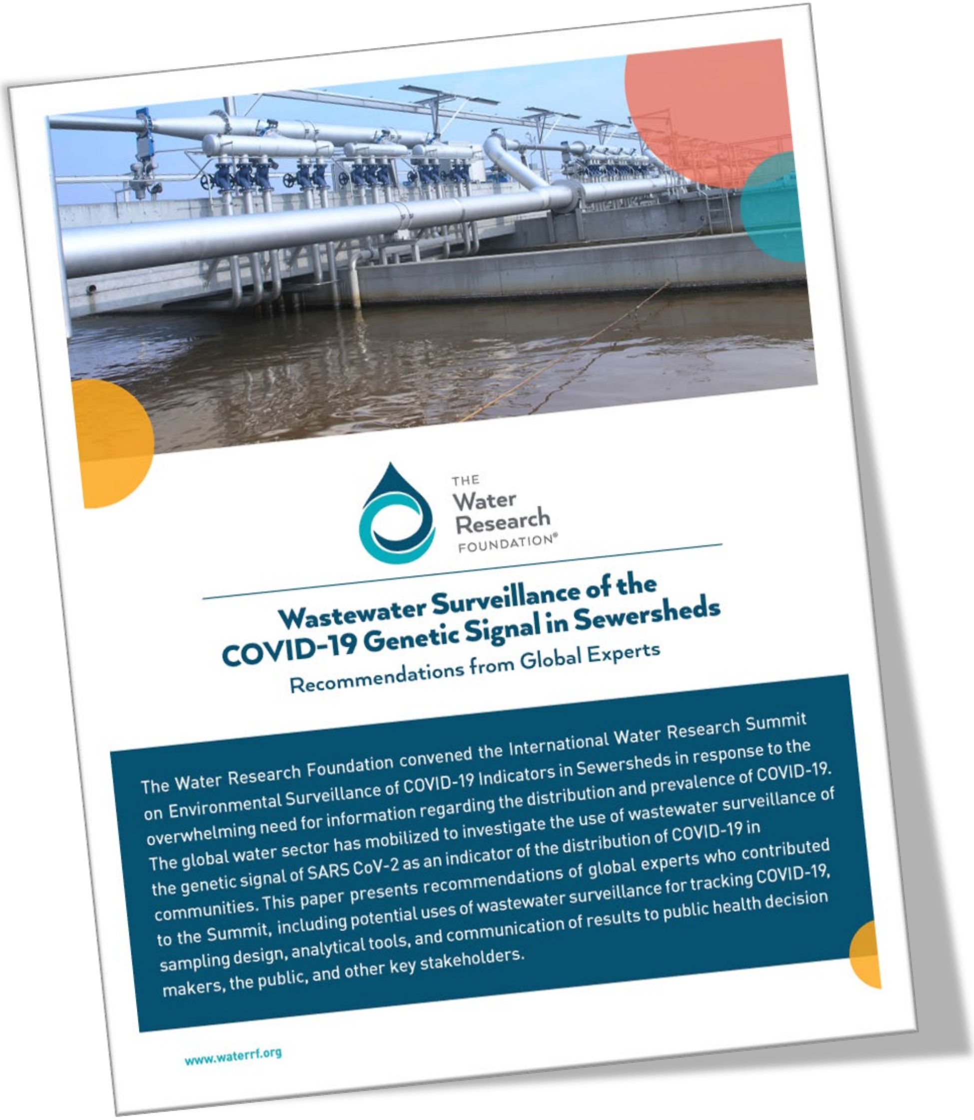
Next Steps

Rapid Development & Adoption

Wide Variety of Approaches

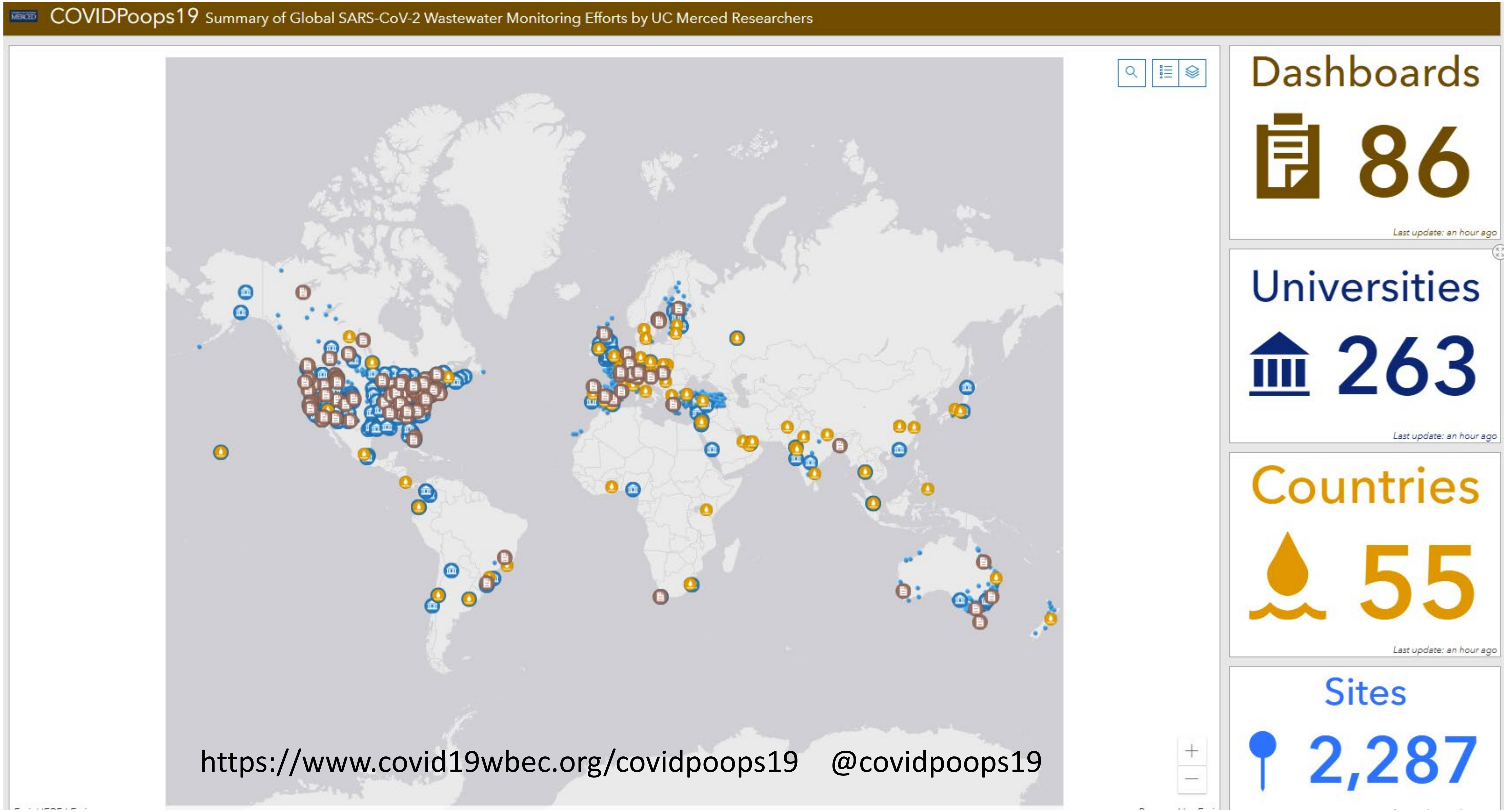
Methods to detect SARS-CoV-2 using wastewater surveillance.

Rapid Water Sector Response & Collaboration



- Interlaboratory and Methods Assessment of the SARS-CoV-2 Genetic Signal in Wastewater (#5089) DOI: 10.1039/d0ew00946f
- Method SOPs available on the WRF website https://www.waterrf.org/research/projects/interlaboratory-and-methods-assessment-sars-cov-2-genetic-signal-wastewater
- Understanding the Factors that Affect the Detection and Variability of SARS-CoV-2 in Wastewater (#5093) – due August 2021
- DHS and CDC Project with AquaVitas
- NSF Research Coordination Network on SARS-CoV-2 wastewater surveillance
- CDC National Wastewater Surveillance System
- Water Research Australia ColoSSuS project
- US EPA Research with Cincinnati Ohio
- WRC (South Africa) Pilot Projects on method development
- Canadian Water Network Method evaluation
- EU Umbrella study under European Health Emergency Preparedness and Response Authority (HERA)

Implementation across the globe



Use Cases

Trends, Variants and Early Warning

Selecting the approach that meets the community need.

RT-qPCR analytical method
Overview

		Concentration	Extraction	Genetic Ta
	Veolia Lazuka *et al.* (submitted)	Ultrafiltration	Silica spin column filter or Magnetic silica beads	N1[1], N2[1], E[2]
	KWR Medema et al. (2020)	Clarification using centrifugation + Ultrafiltration	Silica spin column	N1[1], N2[1], E[2]
French National Network Obépine	Eaux de Paris Wurtzer *et al.* (2020)	Ultracentrifugation	Silica spin column filter	
	CNRS-LCPME Bertrand *et al.* (2020)	Ultrafiltration	Magnetic silica beads	N1[1], N2[1], E[2], RdRp (IP2 & IP4)[3]
	CNRS-LCPME Bertrand *et al.* (2020)	Desorption + Precipitation PEG	Magnetic silica beads	

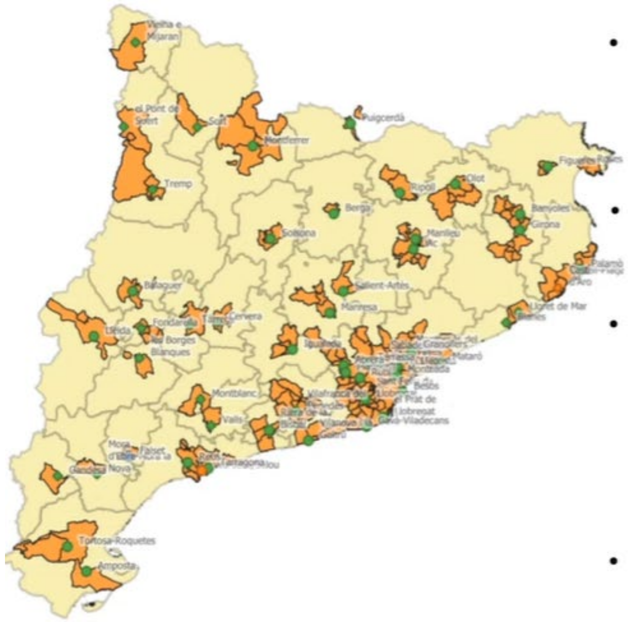
[1] US CDC; [2] Corman et al. 2020, [3] Centre National de Référence des virus des infections Respiratoires, Institut Pasteur, Paris

- Viral **recovery yield was 5.5 % +/- 0.5%** using heat-inactivated SARS-CoV-2.
- **N1** appeared to be the **most sensitive** biomarker.
- Protocol is **operational, quick and easy to implement**

Lazuka, Soyeux & Lacroix, Veolia, France, 2021

Trends

Activity



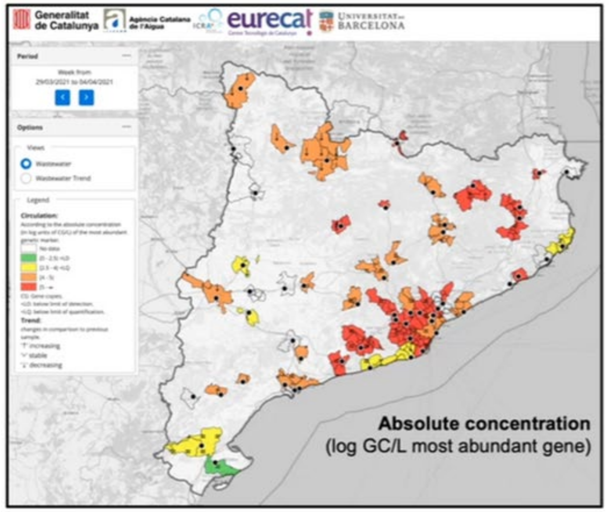
On-going since July 2020

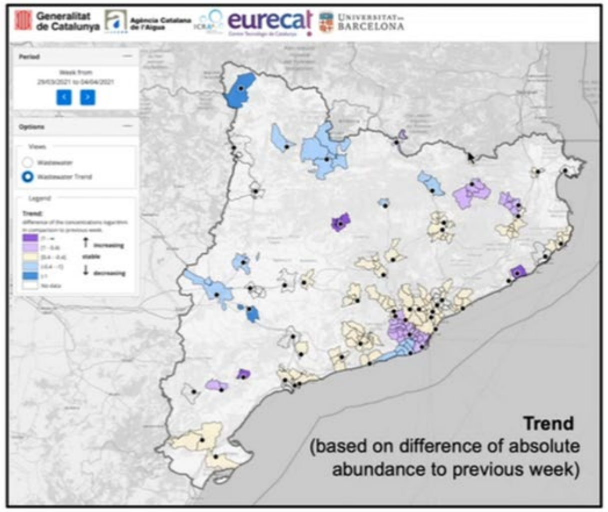
Sampling strategy, frequency and analysis

- A total of **56 WWTPs** selected based on two criteria:
  - *80% coverage of served population*
  - *Territorial evenness* (41 out of 42 regions)
- **Sampling frequency** 36 WWTPs weekly & 18 WWTPs fortnightly
- **Sample collection and analysis**
  - Collecting flow-proportional, 24h-composite (every 20min) INLET samples
  - Shipment and distribution to the labs
  - Results within 48 hours
- **Quantification of three gene targets**
  - N1 (*N* gene)
  - N2 (*N* gene)
  - IP4 (*RdRp* gene)

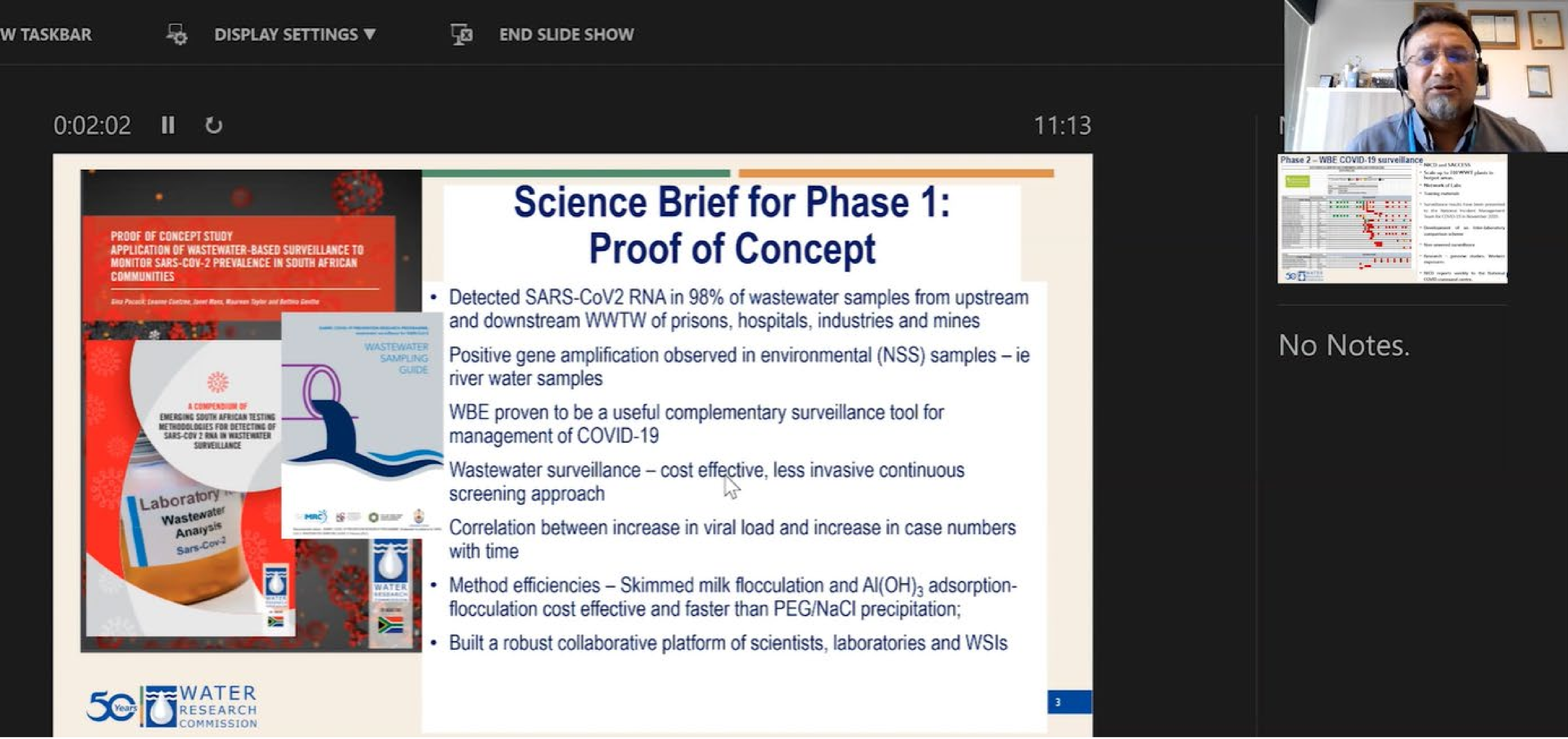
Visualization dashboard

https://sarsaigua.icra.cat



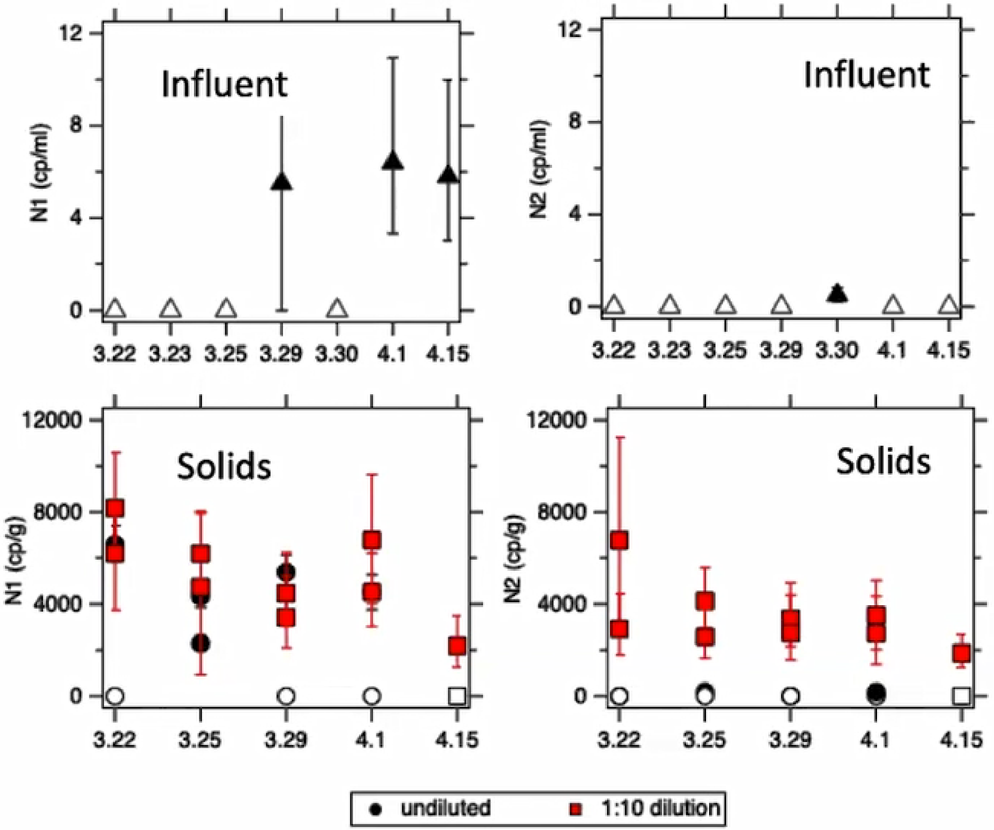


Borrego, Collado, Corominas, Guerrero & Pueyo
Catalan Surveillance Network, 2021



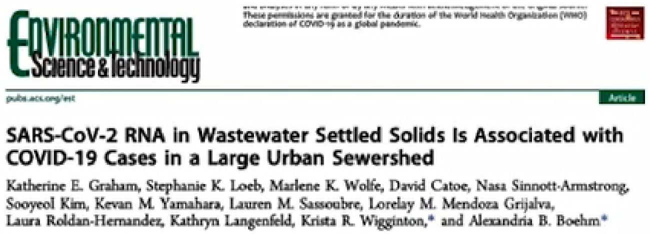
Jay Bhagwan, WRC, South Africa, 2021

We detected more positive signals by extracting directly from primary solids than with a PEG-based influent method.



Graham, et al. Environmental science & technology (2020) 55, 1, 488–498.

- Limited variation among replicates
- Inhibition an issue for some samples


Environmental Science & Technology

pubs.acs.org/est

Article

SARS-CoV-2 RNA in Wastewater Settled Solids Is Associated with COVID-19 Cases in a Large Urban Sewershed

Katherine E. Graham, Stephanie K. Loeb, Marlene K. Wolfe, David Catoe, Nasa Sinnott-Armstrong, Sooyeol Kim, Kevan M. Yamahara, Lauren M. Sassoubre, Lorelay M. Mendoza Grijalva, Laura Roldan-Hernandez, Kathryn Langenfeld, Krista R. Wigginton,* and Alexandria B. Boehm*

Krista Wigginton, University of Michigan, California, USA 2021

METHODS AND TARGETS

SAMPLE – PRIMARY INFLUENT, 24-HOUR FLOW WEIGHTED COMPOSITE SAMPLE

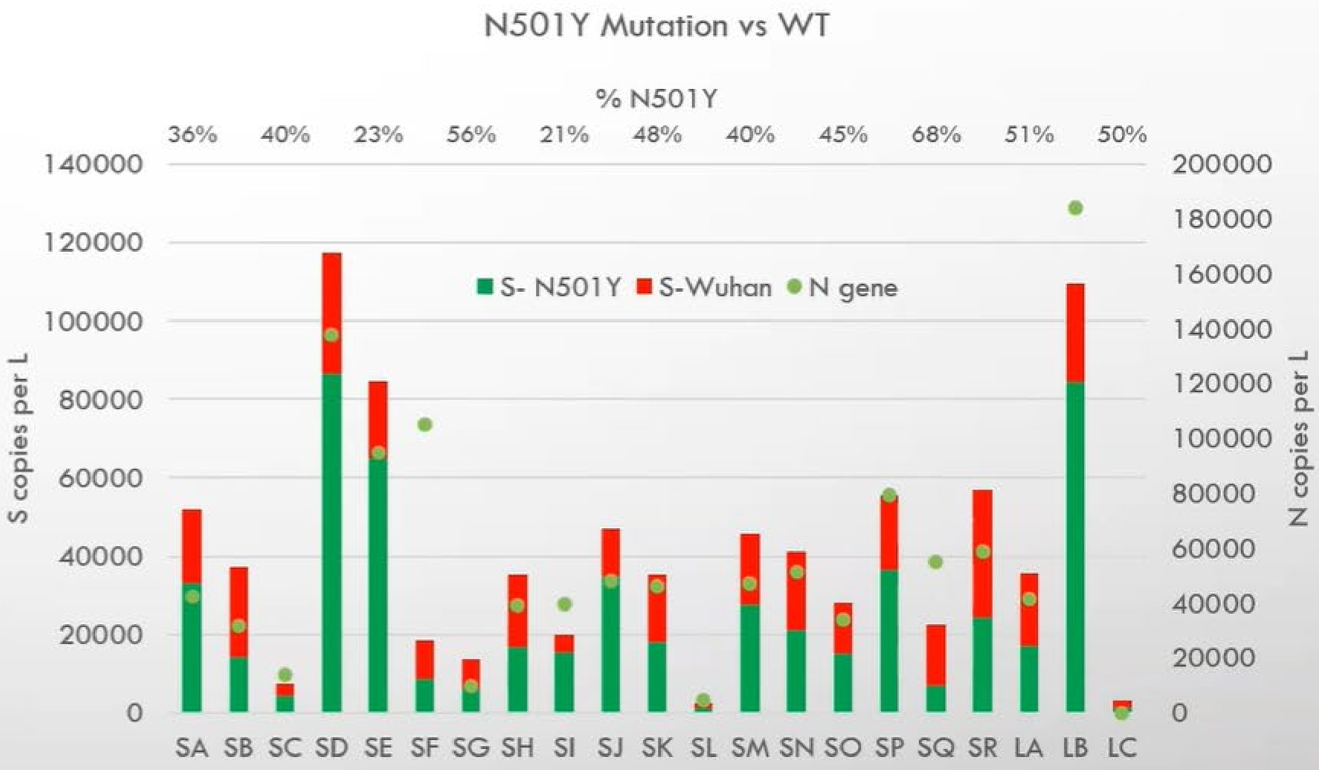
CONCENTRATION METHOD – INNOVAPREP CONCENTRATING PIPETTE

RNA EXTRACTION – QIAAMP VIRAL RNA KIT

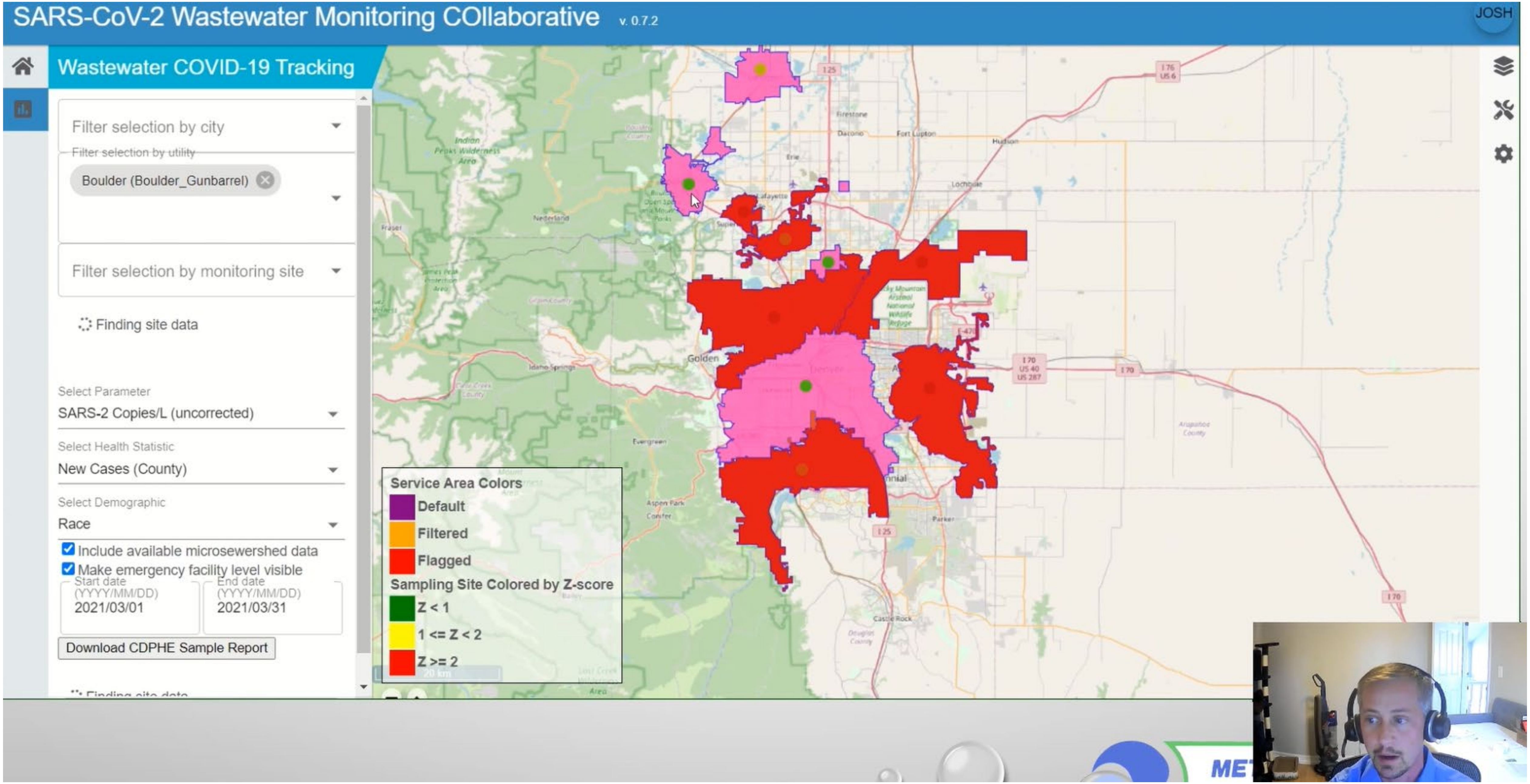
QUANTIFICATION – DDPCR

TARGETS

- SARS-COV-2 – N1
- RECOVERY – BCOV
- INDICATORS – PMMOV AND F^{+} BACTERIOPHAGE (GROUP II)
- VARIANT ASSAY – S GENE N501Y MUTATION AND WILD TYPE



Goldman-Torres, Werth & Fielder, Colorado, USA2021



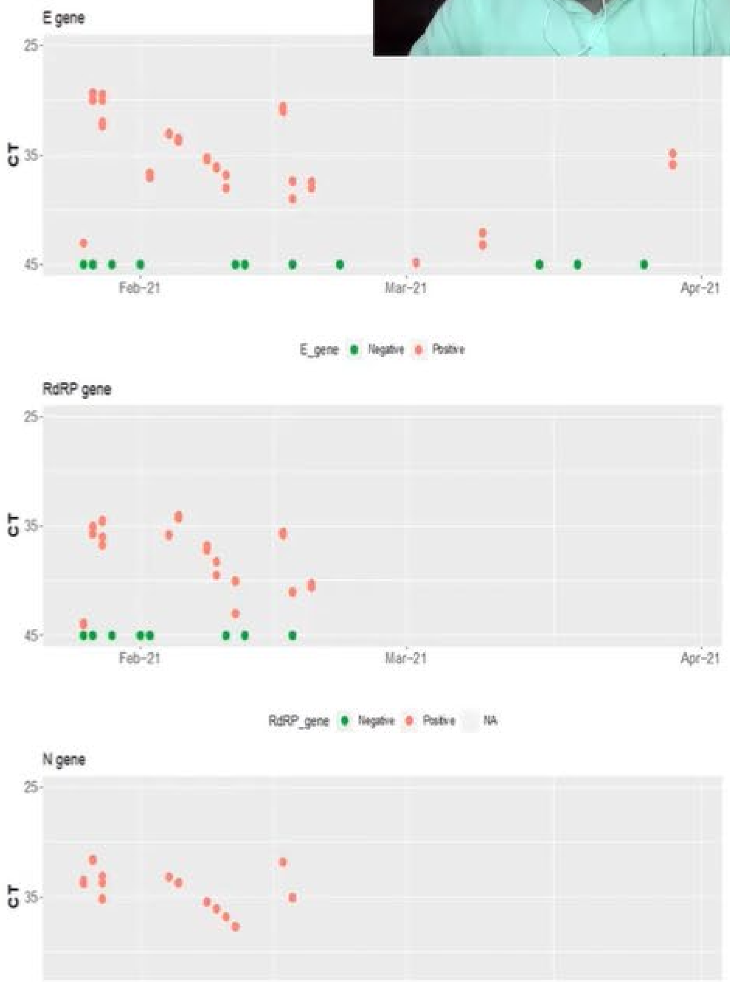
Goldman-Torres, Werth & Fielder, Colorado, USA2021

RESULTS

- SARS-CoV-2 RNA was detected from multiple onsite public toilet septic systems at Osu Alata within Korle Klottey

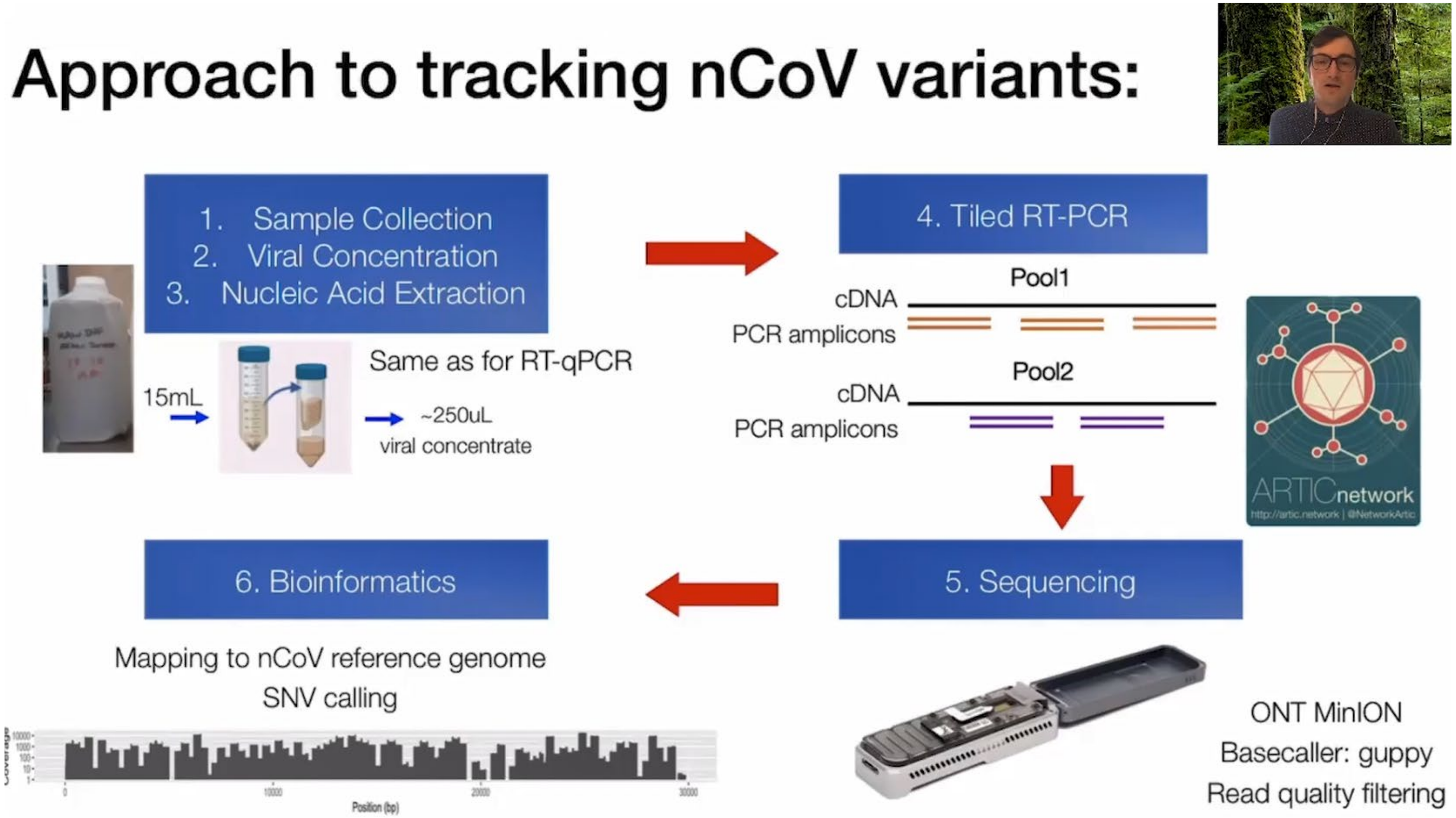
- SARS-CoV-2 RNA was detected in Community Two within the Tema sewer system

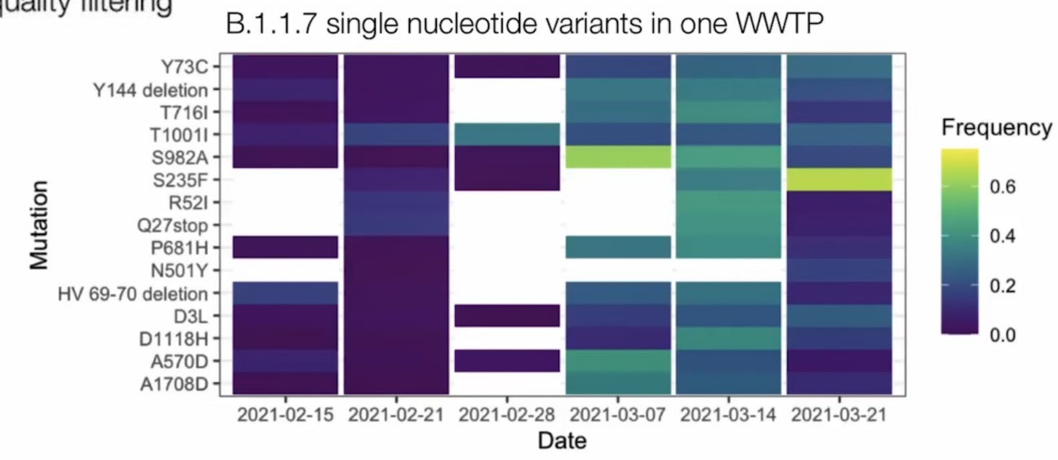
Tema Community 2



Habib Yakubu, Emory University, Ghana, 2021

Variants

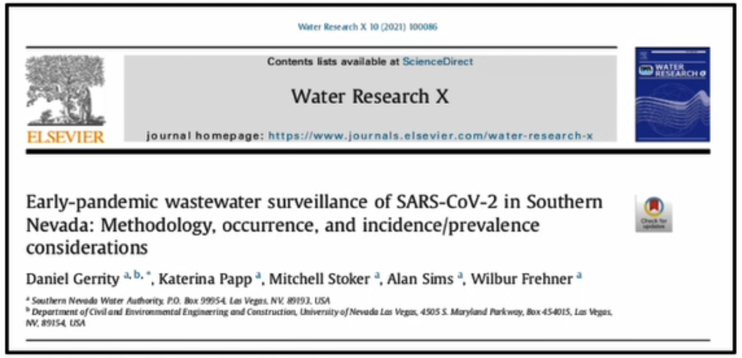




Ryan Ziels, University of British Colombia, British Colombia, Canada 2021

Southern Nevada Wastewater Surveillance

- **No hits in treated wastewater or local drinking water supply**
- **Wastewater influent samples collected weekly**
  - 1 site since March 2020 (100 mgd and 872k people)
  - 1 site since April 2020 (5 mgd and 86k people)
  - 4 sites since August 2020 (6-40 mgd and 115k-757k people)
  - 1 site since December 2020 (0.8 mgd and 16k people)
  - UK variant of concern (B.1.1.7) detected in wastewater prior to clinical confirmation
- **Short-term monitoring of a homeless shelter manhole**
  - 4 weekly samples from Late November – Early December (all positive)
  - Sampling coincidentally occurred during facility-wide outbreak
  - California variant of concern (B.1.427/429) detected in final sample
- **Participated in WRF round robin methods comparison**


Water Research X 10 (2021) 100086

Contents lists available at ScienceDirect

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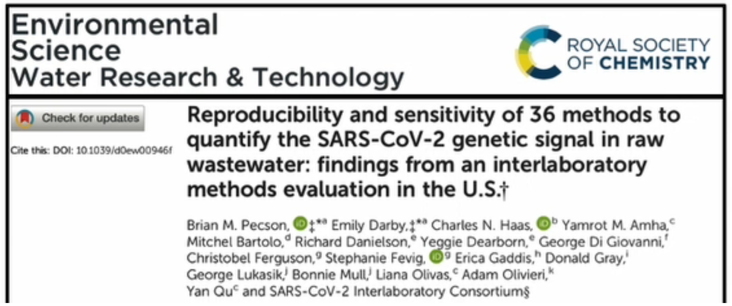
journal homepage: https://www.journals.elsevier.com/water-research-x

Early-pandemic wastewater surveillance of SARS-CoV-2 in Southern Nevada: Methodology, occurrence, and incidence/prevalence considerations

Daniel Gerrity [a, b, *], Katerina Papp [a], Mitchell Stoker [a], Alan Sims [a], Wilbur Frehner [a]

[a] Southern Nevada Water Authority, P.O. Box 99954, Las Vegas, NV, 89193, USA
[b] Department of Civil and Environmental Engineering and Construction, University of Nevada Las Vegas, 4505 S. Maryland Parkway, Box 454015, Las Vegas, NV, 89154, USA


Environmental Science
Water Research & Technology

Check for updates

Cite this: DOI: 10.1039/d0ew00946f

Reproducibility and sensitivity of 36 methods to quantify the SARS-CoV-2 genetic signal in raw wastewater: findings from an interlaboratory methods evaluation in the U.S.†

Brian M. Pecson, ‡*[a] Emily Darby, ‡*[a] Charles N. Haas, [b] Yamrot M. Amha, [c] Mitchel Bartolo, [d] Richard Danielson, [e] Yeggie Dearborn, [e] George Di Giovanni, [f] Christobel Ferguson, [g] Stephanie Fevig, [g] Erica Gaddis, [h] Donald Gray, [i] George Lukasik, [j] Bonnie Mull, [j] Liana Olivas, [c] Adam Olivieri, [k] Yan Qu[c] and SARS-CoV-2 Interlaboratory Consortium§

Daniel Gerrity, Southern Nevada Water Authority, Nevada, USA 2021

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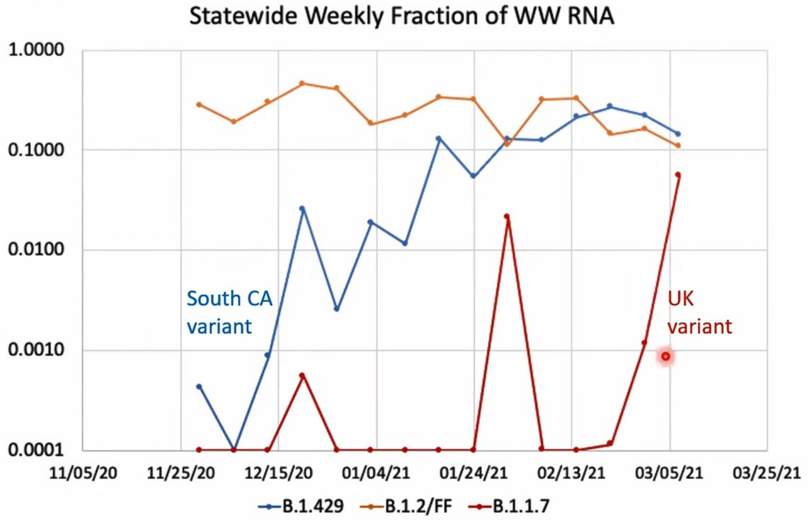
COVID-19 Wastewater Surveillance Symposium

A Global Update

Devrim Kaya, Ph.D.
School of Chemical, Biological & Environmental Engineering
Oregon State University

Covid-19 Wastewater Surveillance Efforts in Oregon

1) **NSF-RAPID:** Microsewershed surveillance in collaboration with Clean Water Services (CWS).
2) **TRACE-Oregon State University (OSU)** (Internally funded project): monitoring for SARS-CoV-2 at the building/dorm level & at the campus level for all 3 OSU campuses.
3) **TRACE-Community** (founded by David & Lucile Packard Foundation): combines WBE with random house-to-house nasal swab sampling to determine the "true" COVID-19 prevalence of a community
4) **OHA/U.S. CDC** : state-wide monitoring for SARS-CoV-2 and genotypes at 40+ WWTPs across the state of Oregon on a weekly basis.



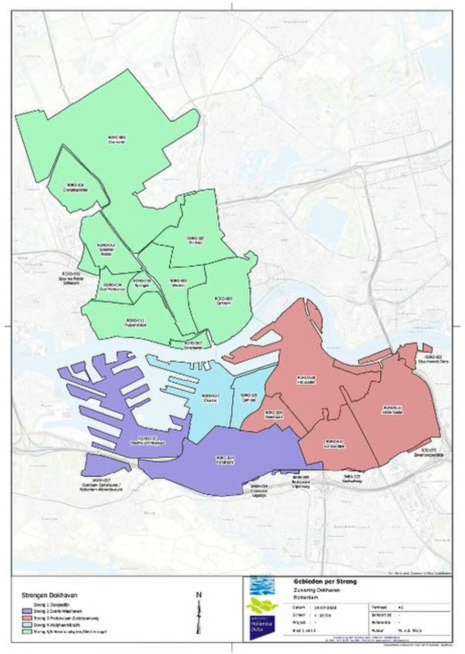
Devrim Kaya, Oregon State University, Oregon, USA 2021

City of Rotterdam

KWR

Below ground

- 2 WWTP
  - Including 4 individual influents
- 4 pumping stations (neighbourhoods)
- Sampling since August 2020



Above ground

- Patient testing in same catchments
- Metadata collection
- Faecal samples for viral shedding and sequencing

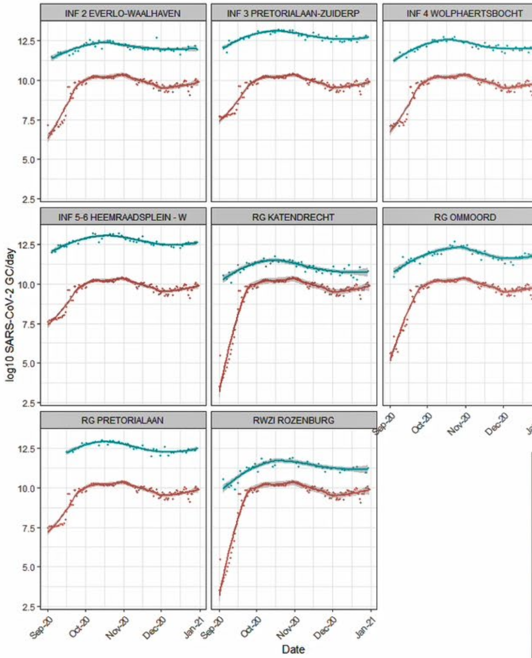
TOPSECTOR WATER & MARITIEM

2

Optimize shedding parameters to "fit" wastewater observations

KWR

- Use Monte Carlo simulations and kinetic models to derive (estimates) of realistic viral shedding

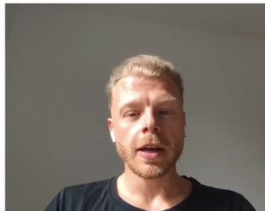


Goals:

- Observed trends
- Early warning
- Link with what happens above ground
- Incidence estimation

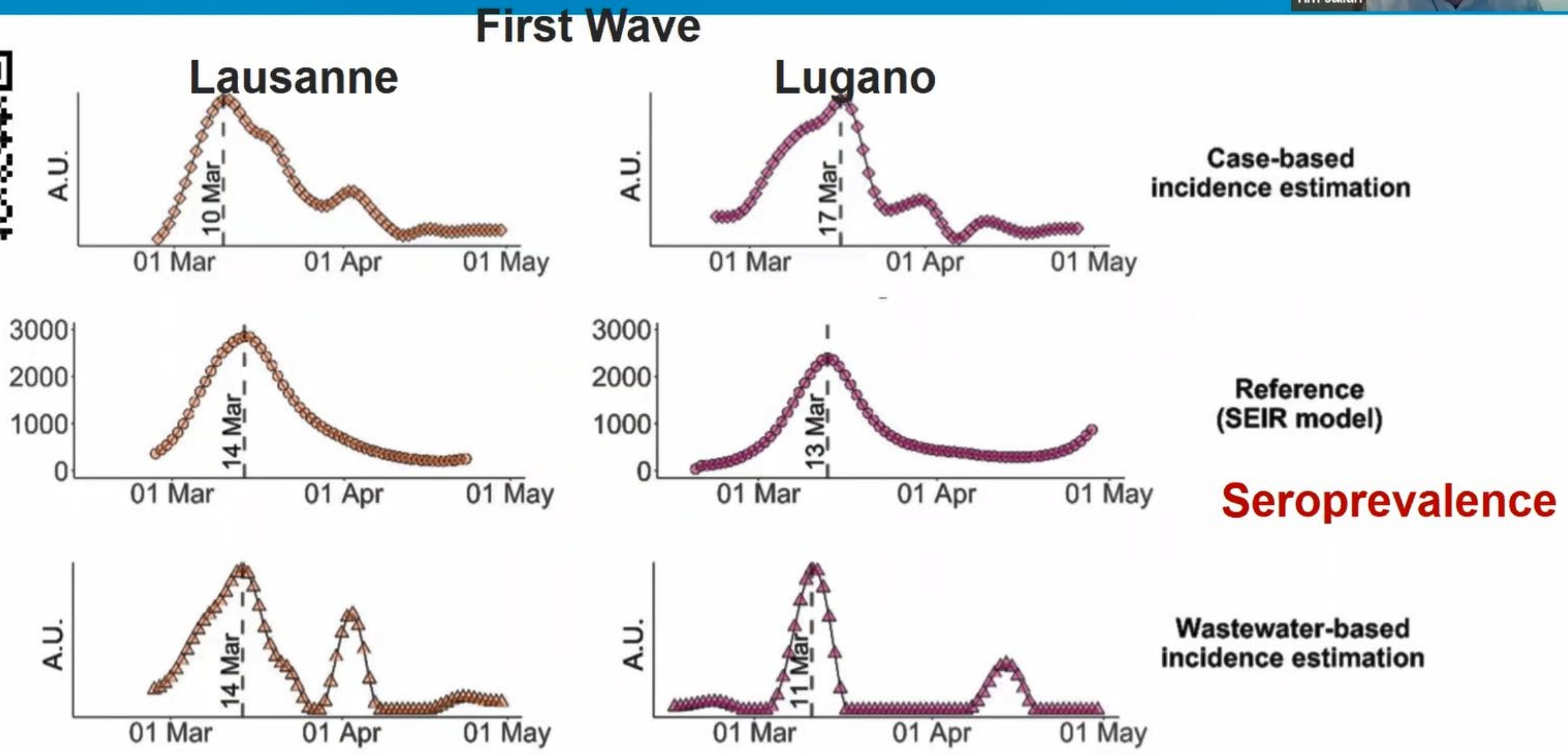
TOPSECTOR WATER & MARITIEM

8



Frederic Beén, KWR Water Research Institute, Netherlands 2021

Show Trends (better than cases?)

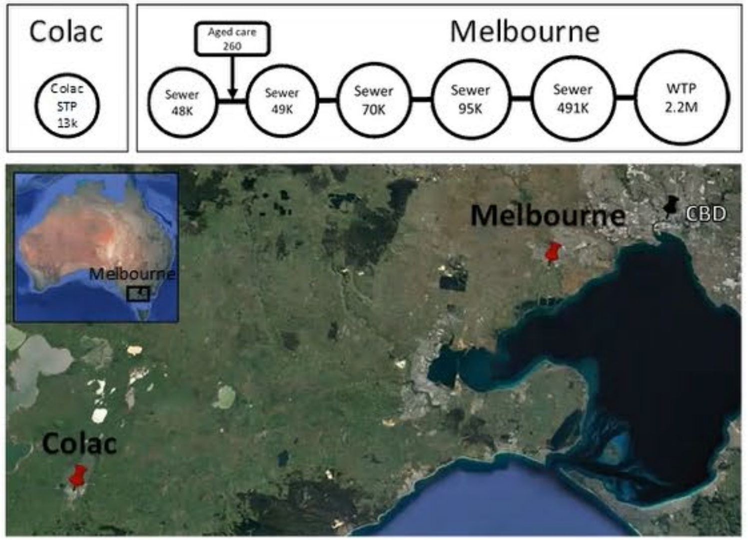


Fernandez-Cassi et al. (preprint)

Tim Julian, Eawag, Switzerland 2021

Early Warning

Passive sampling of SARS-CoV-2 in Wastewater: field

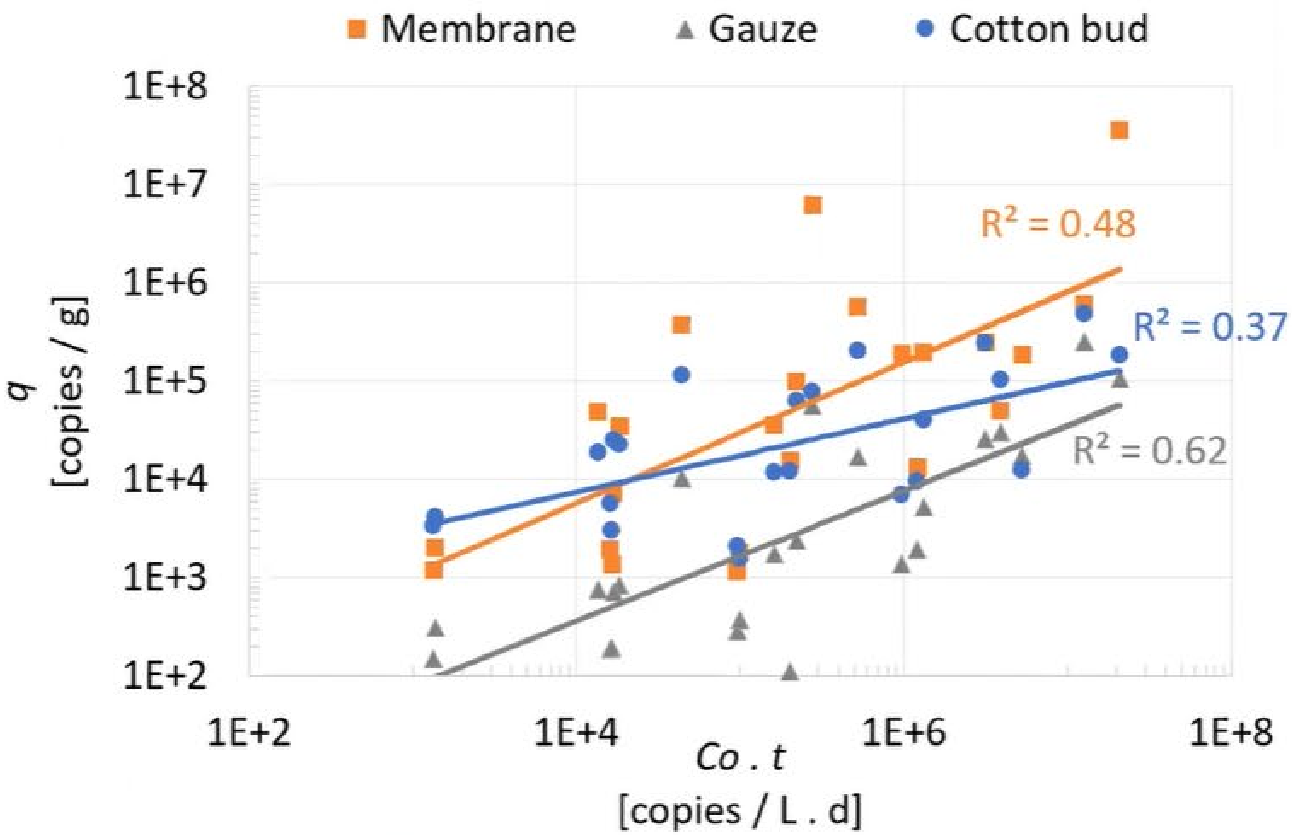


- Passive samplers had detection on 100% of days when wastewater concentrations were > DL

- Passive samplers detected SARS-CoV-2 on another 50% of occasions even though WW conc. < DL

McCarthy, Crosbie, Poon & Nolan, Monash Uni, Australia, 2021

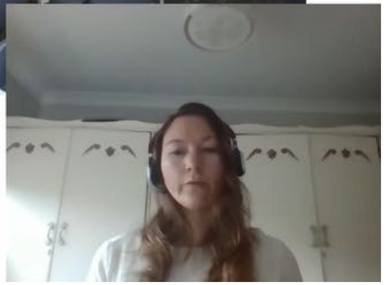
Passive sampling of SARS-CoV-2 in Wastewater: lab

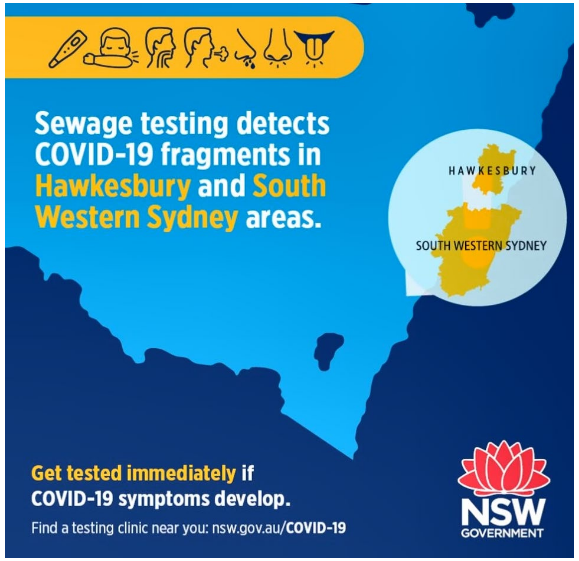


McCarthy, Crosbie, Poon & Nolan, Monash Uni, Australia, 2021

NSW program development

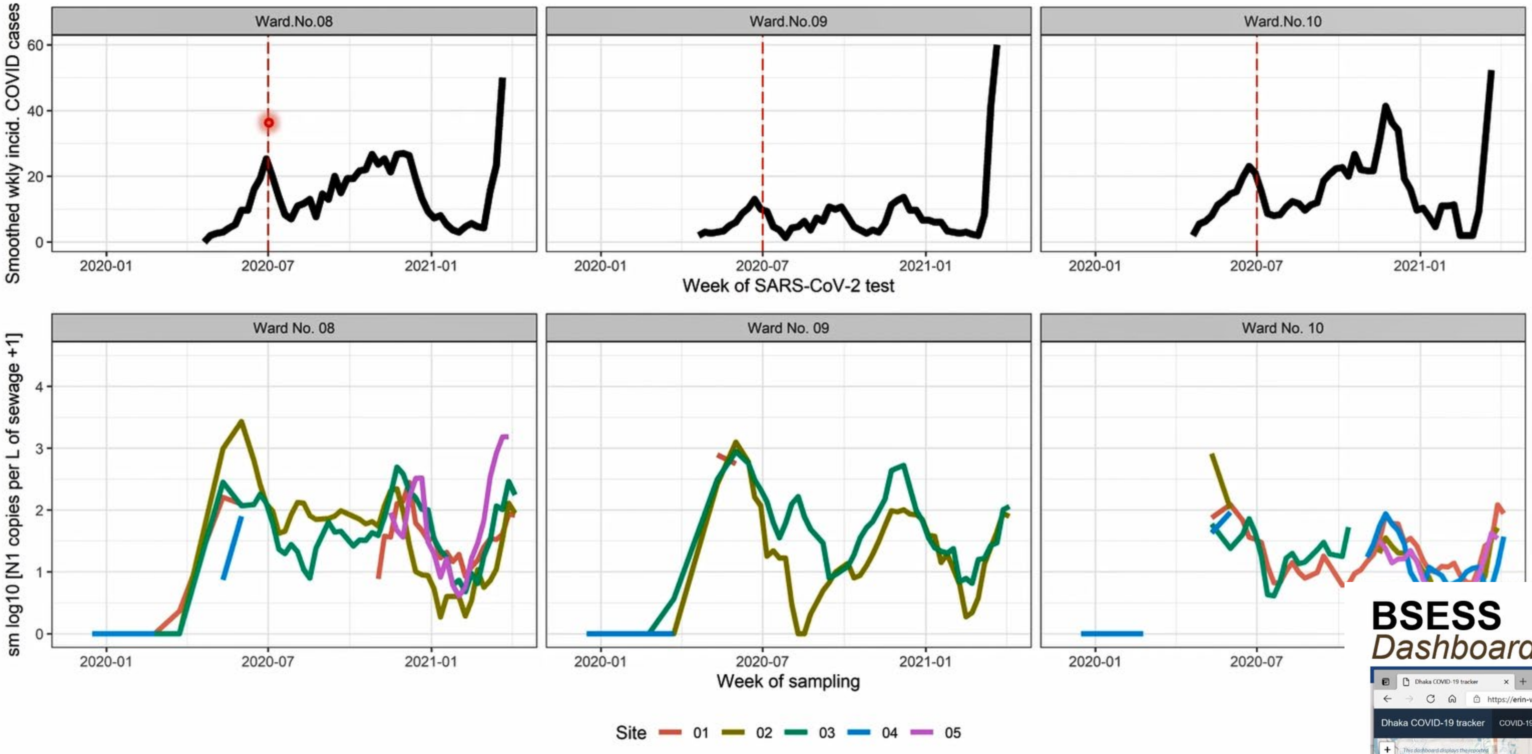
- February 2020 Sydney Water method development, collaboration with ColoSSoS partners
- March - July 2020 storing samples and analysis for method validation
- July 2020 started analysis of routine WWTP samples
- September 2020-February 2021 breaking down larger catchments in Sydney for routine network samples





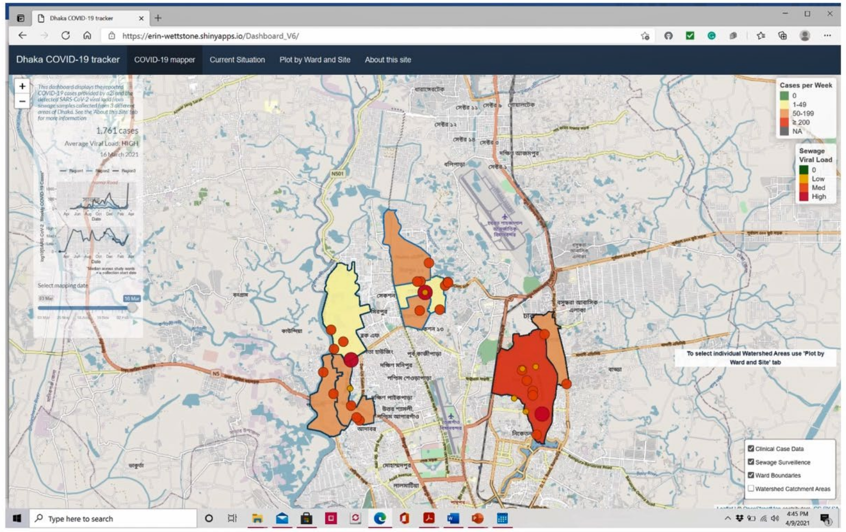
Zenah Bradford-Hartke, NSW Health, Australia 2021

SEWAGE AND COVID-19 CASE DATA



Started surveillance for SARS-CoV-2 in December 2019

BSESS
Dashboard



Developed by 4th year biomedical engineering undergrads at UVA

33 sites over 3 study area

Dashboard displays weekly sewage and case data to aid Bangladesh public health stakeholders on mitigation efforts

Current situation shows a marked increase in the amount of SARS-CoV-2 in sewag
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https://erin-wettstone.shinyapps.io/Dashboard_V6/

Mami Taniuchi, University of Virginia, Bangladesh 2021

Utah Surveillance Program (wastewatervirus.utah.edu)

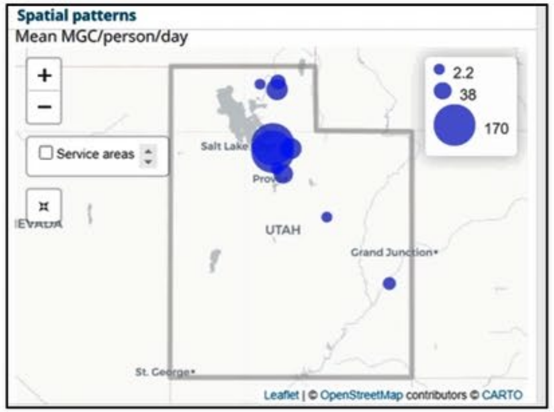
Phase I: Proof of concept

March 23 to April 6, 2020

- 2 facilities sampled daily for two weeks (17% population)
- U of U
- Urban center & ski location
- U of U seed funding

Phase II: Pilot

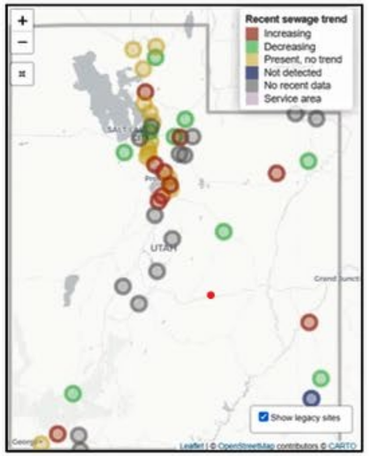
April 13 to May 24, 2020



- 10 facilities sampled weekly (39% population)
- U of U, BYU, USU
- Urban centers, tourist locations and rural areas
- Weidhaas, et al. 2021, Sci Total Env, 775: 145790
- DEQ seed funding

Phase III: Monitoring

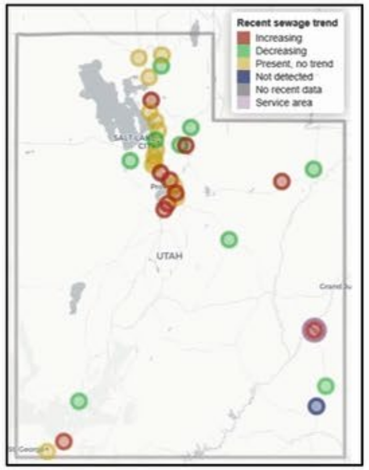
May 24 to Dec 31, 2020



- 43 facilities sampled weekly (87% population)
- U of U, BYU, USU, Soft Cell Bio
- CARES act funding

Phase IV: Optimization

Jan 1, 2021 to current



- 32 facilities sampled bi-weekly (86% population)
- UDOH/CDC funding

~2500 samples processed for Utah environmental surveillance to date

Roper and Weidhaas, Utah State University and University of Utalh, Utah, USA 2021

Results of Utah State University (USU) monitoring wastewater on campus

"Our actions have 'protected our community from wider spread infections'."

***Utah State Univ.* President Noelle Cockett quoting *Bear River Health Director* Lloyd Berentzen**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Informed USU – BRHD interventions

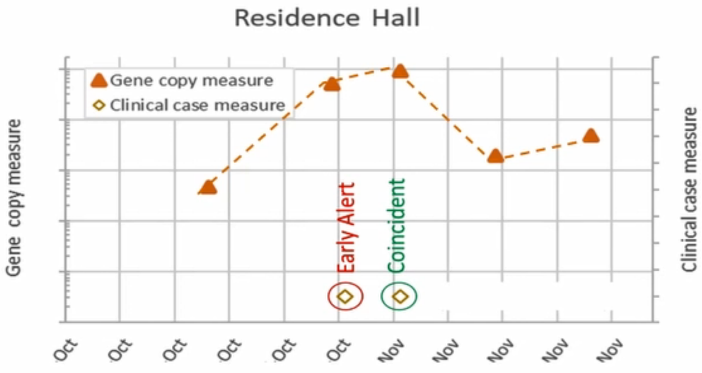
- ❑ Quarantine + required testing (4 dorms)
- ❑ E-mail advisories (specific housing areas)
- ❑ Targeted directives to test (hot spots)
- ❑ Deployment of mobile testing unit

Validated actions

- ❑ Reduced clinical cases in monitored dorms
- ❑ Identified clusters (specific housing areas)
- ❑ Monitored isolated cases & quarantines
- ❑ Feedback & guidance to contact tracing

Improved Fall 2020 to Spring 2021

	Fall 2020 *Oct 21-Nov 20*	Spring 2021 *Jan 14-Feb 12*
Living areas	11	11
Samples/wk	18	30
Early Alert (%)	44	78
Coincident (%)	5	5



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https://www.usu.edu/today/story/usu-biological-engineers-monitor-coronavirus-in-sewage

~2500 samples processed for Utah environmental surveillance to date

Roper and Weidhaas, Utah State University and University of Utalh, Utah, USA 2021

Lessons Learned

Global Update

Innovation through Collaboration

Lessons Learned

- Early warning (KWR & CDC ~ 6 days, WRC ~ 2 weeks)
- Objective population surveillance, independent of human test behavior
- Feasible for emergence of variants (signature mutations of)
- Fast (ddPCR within days, compared to 3-4 weeks for clinical surveillance)
- Efficient: on population sample, allowing high resolution surveillance
- Population size affects sewer signal dynamics

Medema, KWR, Netherlands, 2021

- Decentralized wastewater systems will not be captured
  - ~25% of US residences are not connected to sewer
  - Onsite treatment increasingly common at correctional facilities, universities
- Negative results do not indicate absence of cases
- Low incidence may be below the limit of detection
- Cannot be used to "clear" a community or facility
- May be impacted by pre-treatment of sewage for odor or worker safety

Amy Kirby, CDC, 2021

Method Changes over time

- By April 2021 approx 50% of survey respondents were using WBE with recovery controls to track trends and ~60% of those were using Bovine CoV, with human OC43 next most common
- Most results are not adjusted for recovery efficacy
- Most groups use at least one of the CDC N gene primers
- Groups needing high throughput and short TAT are using ddPCR
- Many WBE programs are using commercially available kits
- Passive samplers are being used to detect low levels and/or to capture infrequent events to "monitor" for hotspots

Knowledge gaps

Next steps

Priorities for further Research

Research Needs

- Define ways to account for factors that impact interpretation at different scales and across different methodologies
- Improve TAT for real-time management of early warning use case
- Increased sensitivity to detect decreases in levels as case loads decline and to pick up hot spots for early warning
- Standardization of internal controls and reporting – should results be adjusted for matrix recovery and/or fecal strength – or not?
- Development of standard reporting – Effective Reproductive number (Re) value?

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Thank You