Introduction to wastewater-based epidemiology

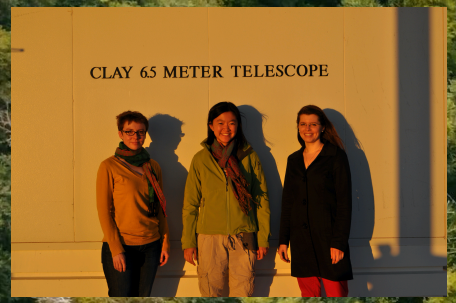
QinQin Yu

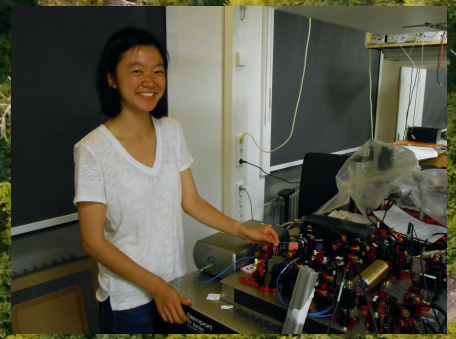
12th Annual Workshop to Increase Diversity in Mathematical Modeling and Public Health

March 4, 2024

My path

Undergraduate major in physics

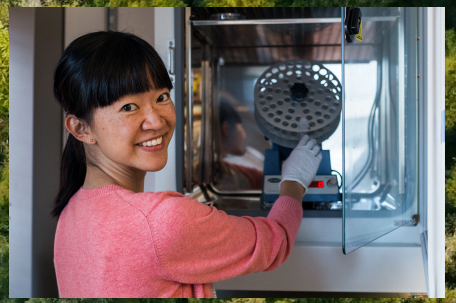




Interest in different cultures

Science education gap year in Rwanda

Grad school in biophysics and microbial evolution



Postdoc in infectious diseases and pathogen evolution

What is wastewater?

Anything that goes down the sink drain, shower drain, toilet

Wastewater-based epidemiology

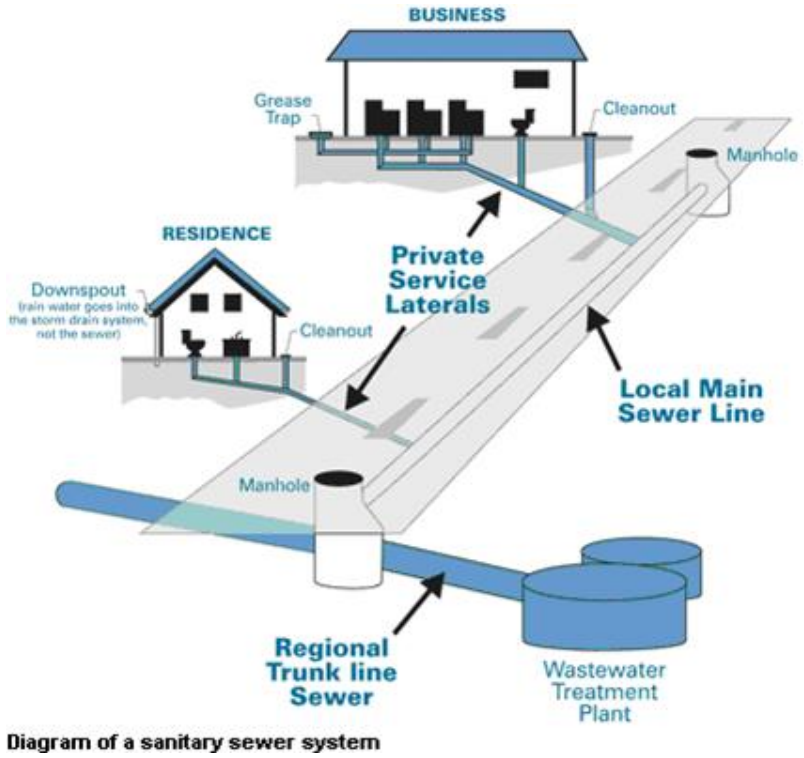
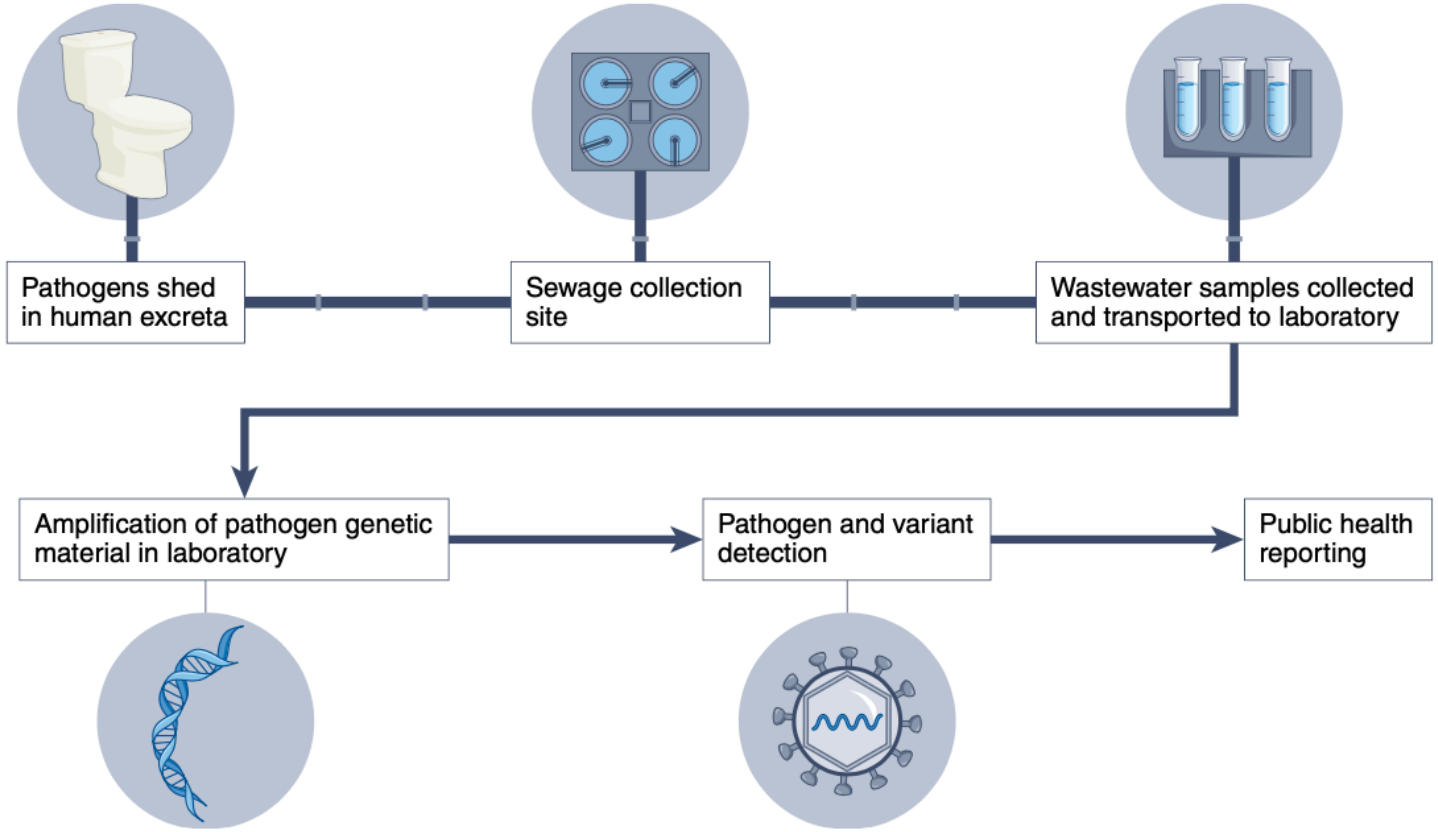


Diagram of a sanitary sewer system



LA County Department of Public Works

Diamond et al., Nature Medicine Comment, 2022

Wastewater sampling has been used in public health for decades

Detecting polio

TABLE I

Tests for the Virus of Poliomyelitis in Sewage in Relation to Cases Reported in New York, N. Y., and in New Haven, Conn.,—April, 1940 to June, 1941

Month	New York, N. Y.			New Haven, Conn.			
	Cases of poliomyelitis reported		Tests for virus at grit chamber	Cases of poliomyelitis reported	Tests for virus in sewage		
	In city	On sewer line		In city	In hospital	City Point disposal plant	Hospital
1940							
Apr.	1	None	−	None	None	0	−
May	None	"	0	"	"	−	−*
June	"	"	0	"	"	−	0
July	7	4	−	"	"	−	−
Aug.	16	3	−	"	3	−	−
Sept.	25	4	+	"	2	0	0
Oct.	14	None	−	"	2	−	−
Nov.	3	"	−	"	1	−	0
Dec.	1	"	−	"	1	−	−
194							
Jan.	None	"	−*	"	None	0	−
Feb.	2	"	−	"	"	−	−
Mar.	None	"	−	"	"	−	−
Apr.	"	"	−	"	"	−*	−
May	1	"	−	"	"	−	0
June	None	"	−	1	1	−	−

+, positive for poliomyelitis virus; −, negative; 0, not completed.
* Mononuclear meningitis without lesions in cord or brain stem.

Trask and Paul, J Exp Med, 1942

Detecting drug usage

Research

Estimating Community Drug Abuse by Wastewater Analysis

Ettore Zuccato, Chiara Chiabrando, Sara Castiglioni, Renzo Bagnati, and Roberto Fanelli

Department of Environmental Health Sciences, Istituto di Ricerche Farmacologiche Mario Negri, Milano, Italy

BACKGROUND: The social and medical problems of drug abuse are a matter of increasing global concern. To tackle drug abuse in changing scenarios, international drug agencies need fresh methods to monitor trends and patterns of illicit drug consumption.

OBJECTIVE: We tested a sewage epidemiology approach, using levels of excreted drug residues in wastewater, to monitor collective use of the major drugs of abuse in near real time.

METHODS: Selected drug target residues derived from use of cocaine, opiates, cannabis, and amphetamines were measured by mass spectrometry in wastewater collected at major sewage treatment plants in Milan (Italy), Lugano (Switzerland), and London (United Kingdom). The amounts of drug residues conveyed to the treatment plants, reflecting the amounts collectively excreted with urine, were used to estimate consumption of the active parent drugs.

RESULTS: Reproducible and characteristic profiles of illicit drug use were obtained in the three cities, thus for the first time quickly revealing changes in local consumption (e.g., cocaine consumption rose significantly on weekends in Milan). Profiles of local drug consumption based on wastewater measurements are in line with national annual prevalence estimates.

CONCLUSIONS: Patterns and trends of drug abuse in local communities can be promptly monitored by this tool, a convenient new complement to more complex, lengthy survey methods. In principle, searching the sewage for excreted compounds relevant to public health issues appears to have the potential to become a convenient source of real-time epidemiologic information.

KEY WORDS: amphetamines, cannabis, cocaine, drug residues, illicit drugs, mass spectrometry, opiates, sewage epidemiology, urinary metabolites. *Environ Health Perspect* 116:1027–1032 (2008). doi:10.1289/ehp.11022 available via *http://dx.doi.org/* [Online 1 May 2008]

Official figures for the prevalence and occurrence of drug abuse in different countries are currently obtained from population surveys

our group using cocaine as a model drug in 2005 (Zuccato et al. 2005). Sophisticated analytical methods for measuring several drugs of

Materials and Methods

Drugs of abuse. Community-wide consumption of common drugs of abuse, that is, cocaine, heroin, cannabis, and amphetamine-type drugs [amphetamine, methamphetamine, ecstasy (3,4 methylenedioxymethamphetamine)] was estimated by analysis of selected drug excretion residues in wastewater.

Selection of drug target residues. The drug residues targeted for wastewater measurement and back-calculation of drug consumption are referred to as drug target residues (DTR). An ideal DTR is a major and exclusive excretion product (metabolite or unchanged parent drug) of the drug under study that is stable in wastewater. The DTRs used for this study (Table 1) were chosen by determining the metabolic fate of each active drug in light of current knowledge and then experimentally determining the stability of candidate residues in wastewater (Castiglioni et al. 2006). We thus selected as DTRs the main urinary metabolites for cocaine, heroin, and cannabis, and the unchanged parent drug for the amphetamines (Baselt 2004; Huestis et al. 1996; Maurer et al. 2006). Glucuronic

Zuccato et al., Environmental Health Perspectives, 2008

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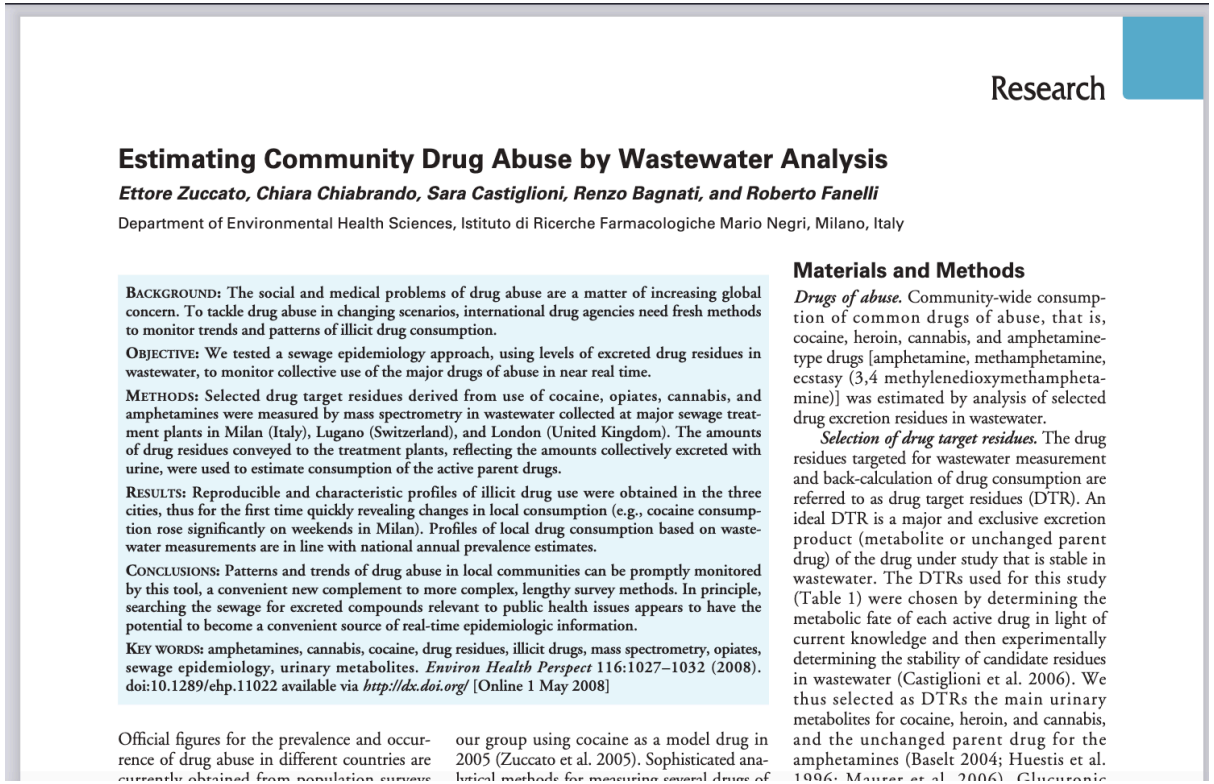

Research

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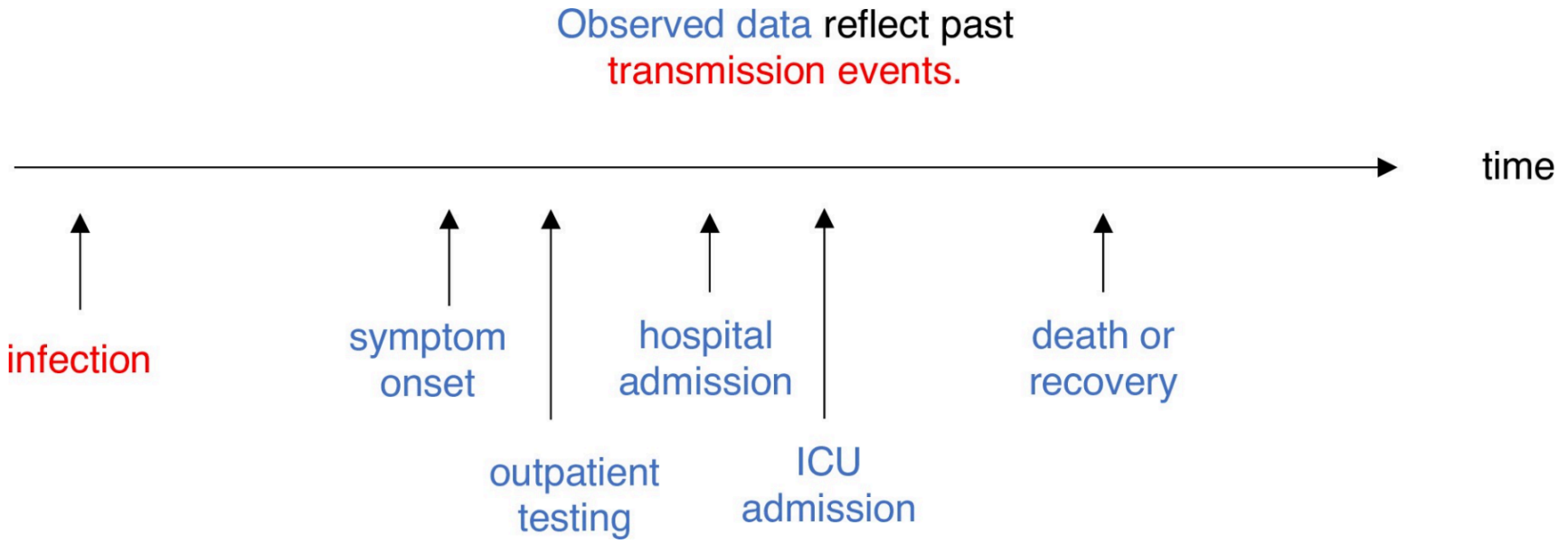
Zuccato et al., Environmental Health Perspectives, 2008

Challenges of conventional case detection

Overrepresents healthcare- or test-seeking individuals

Time delays



Gostic et al., PLOS Computational Biology, 2020

Potential benefits of wastewater

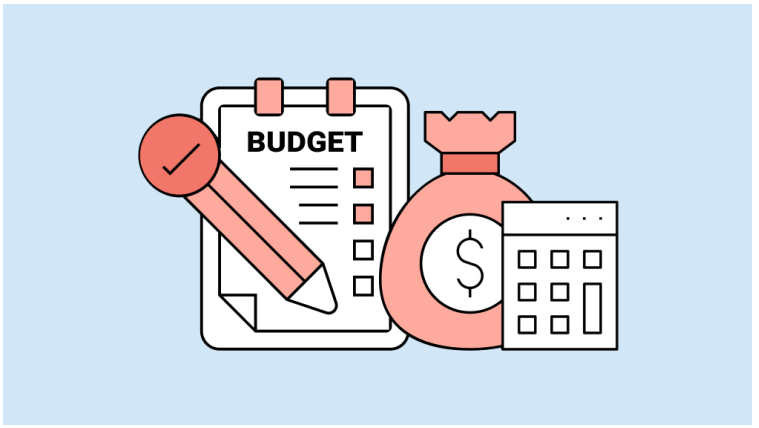
Non-invasive testing

Paul Chinn, San Francisco Chronicle, Getty Images

Independent of health-seeking behavior

The Management Trust

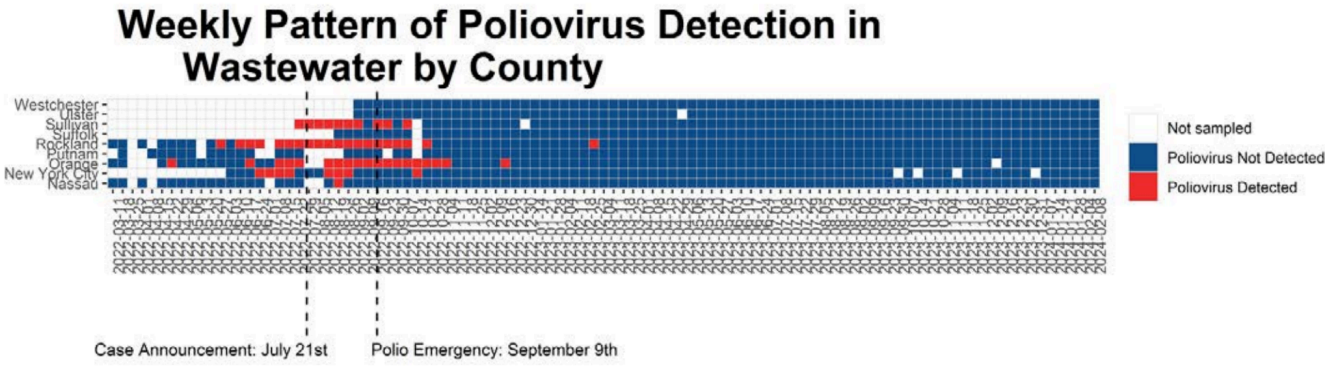
Possibly cheaper



Dania Accounting

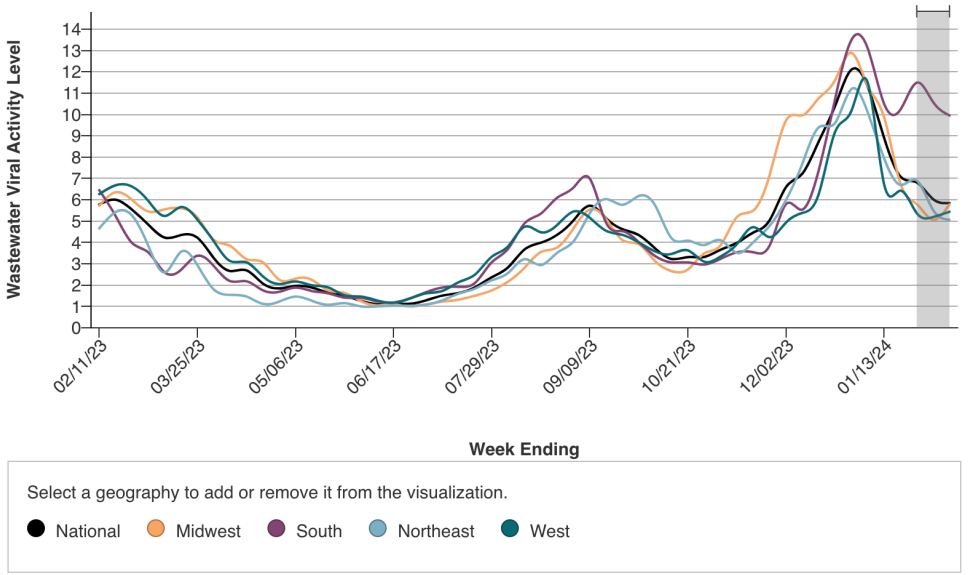
How do we use wastewater data?

Discovery: emerging and imported disease agents



NY Dept of Health, Polio Wastewater Surveillance Report, February 19, 2024

Surveillance “weather report”



CDC National Wastewater Surveillance System, February 15, 2024

What makes a pathogen a good wastewater target?

Shed in the feces when causing disease

Genetic material is stable in wastewater

Wastewater monitoring has been demonstrated for:

SARS-CoV-2
Seasonal human coronaviruses
Respiratory Syncytial Virus
Influenza A
Human metapneumovirus
Human parainfluenza
Human rhinovirus
And more…

Who is involved in wastewater detection?

Wastewater facilities

Local, state, and federal public health agencies

Local, state, and federal environmental and water agencies

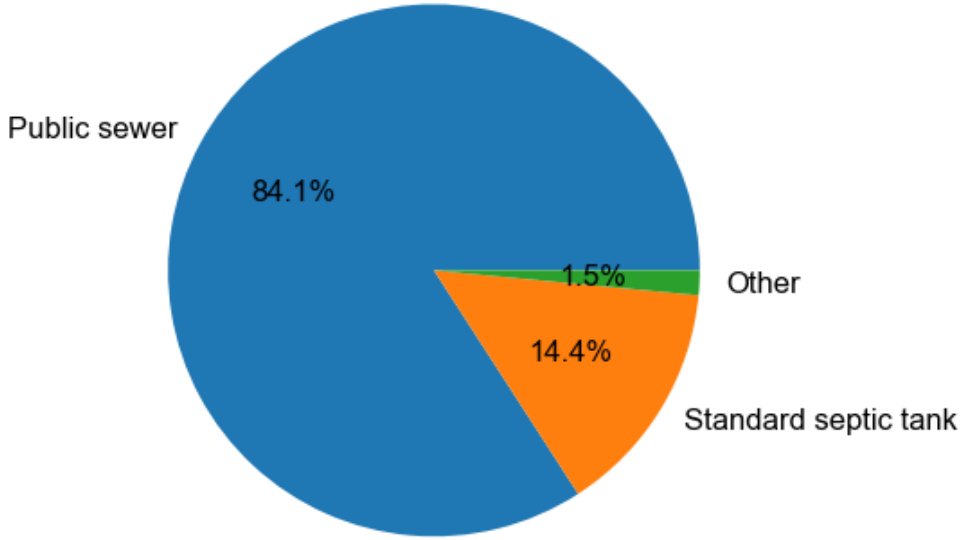
Academics

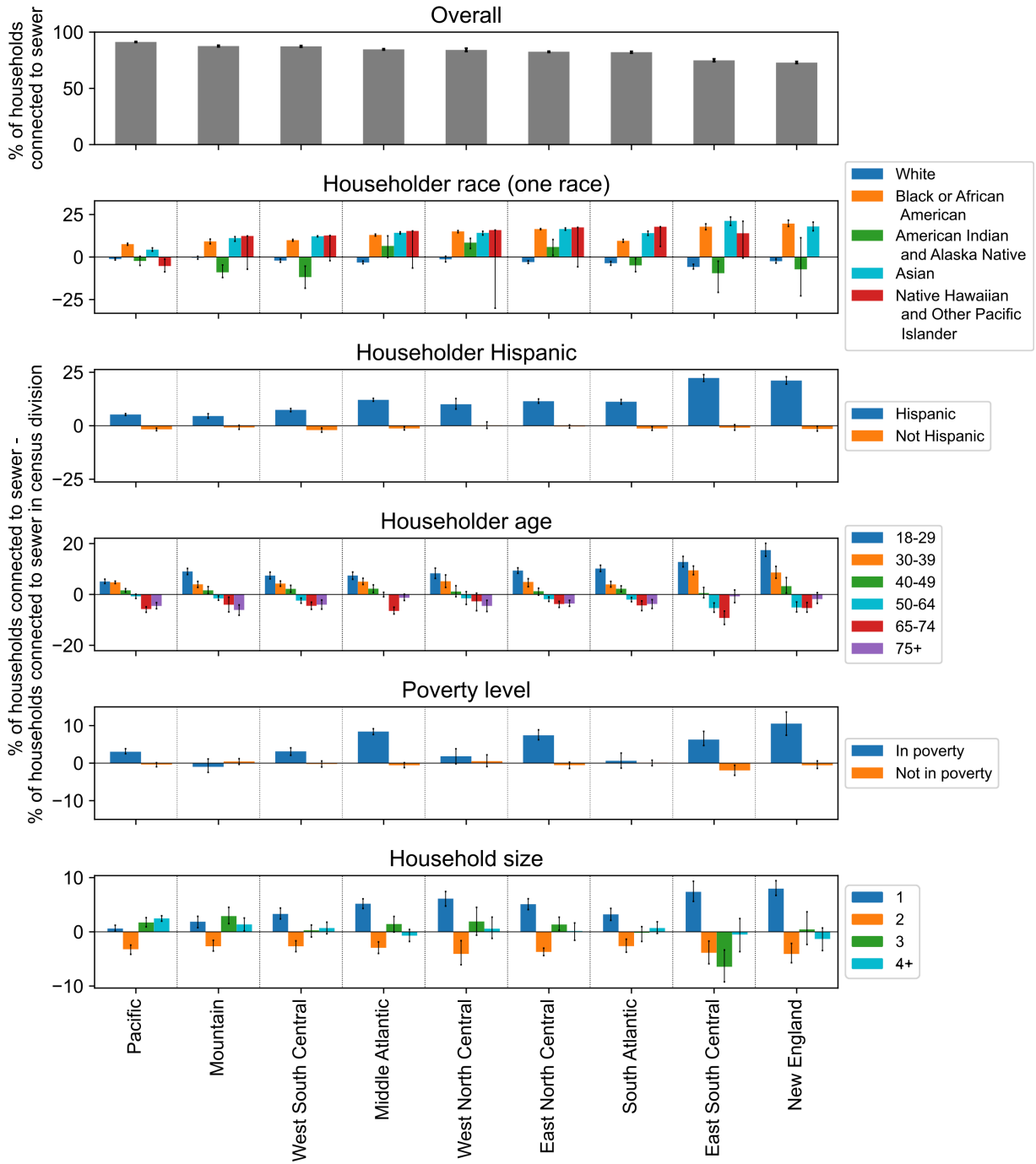
Companies

Community

Challenges: access equity

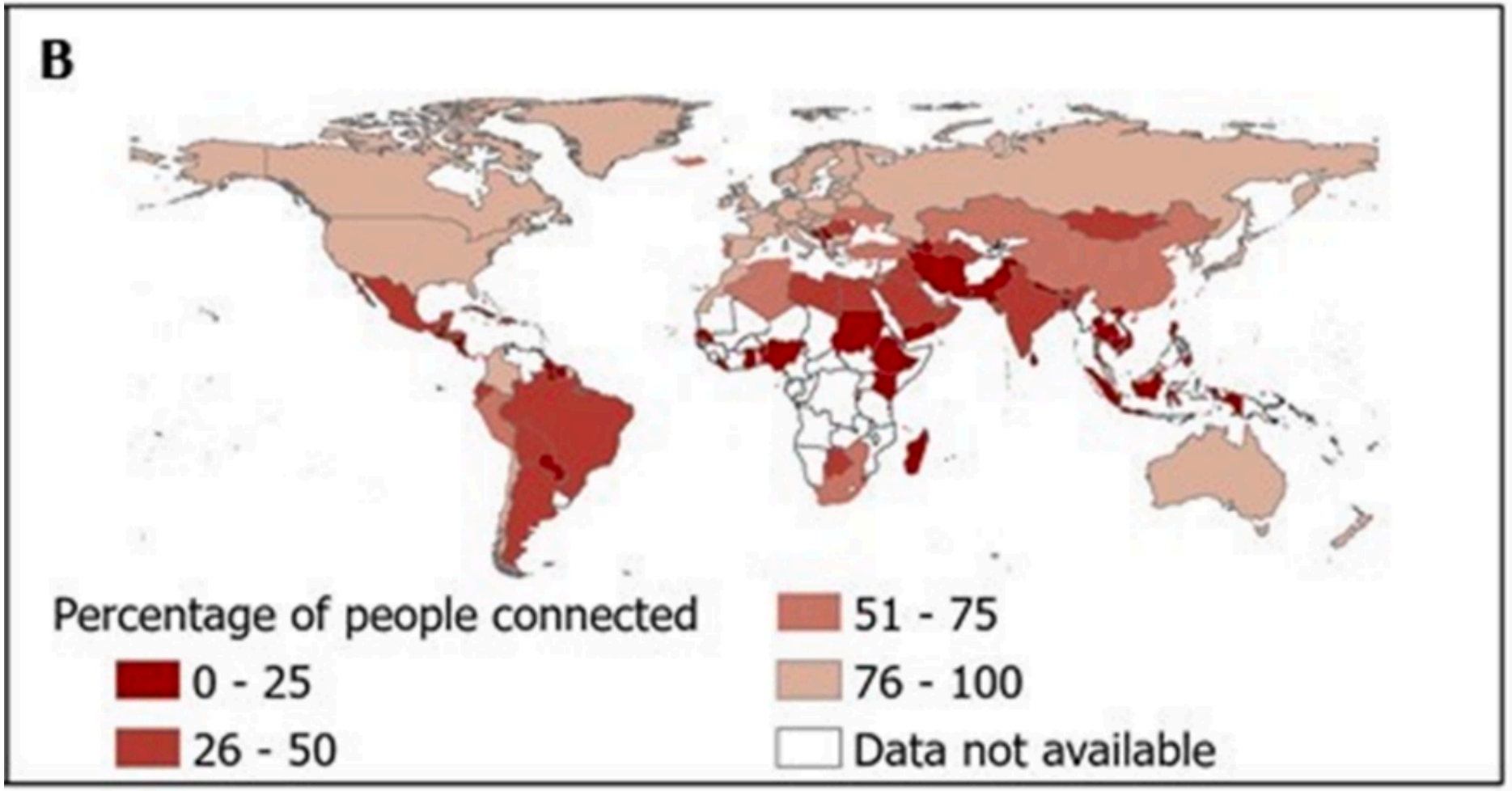
2021 American Housing Survey
(US Census)





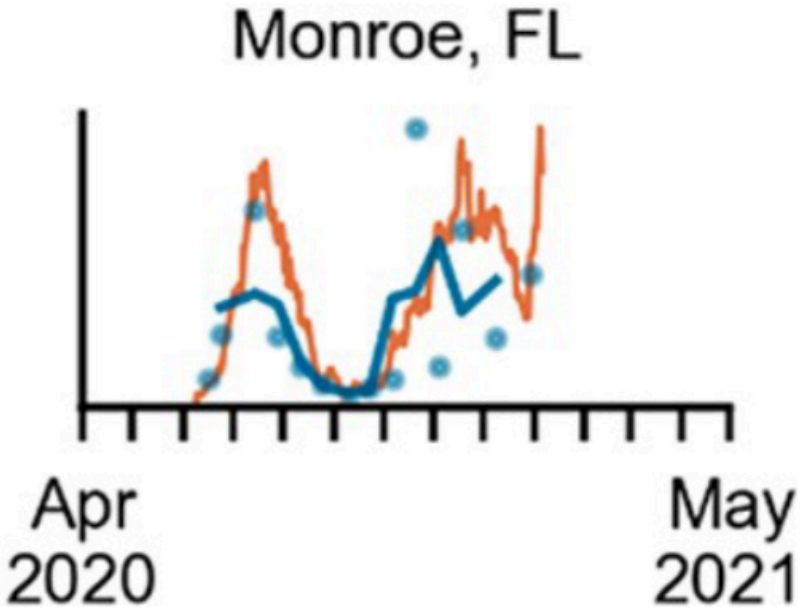
Yu et al., medRxiv, 2024

Challenges: access equity



Adhikari and Halden, Environment International, 2022

Challenges: noisiness & calibration



Duvallet et al., ACS ES&T, 2022

Pepper mild mottle virus (PMMoV)

UF/IFAS Pest Alert Web site/Pamela Roberts

Challenges: interpretations for policy

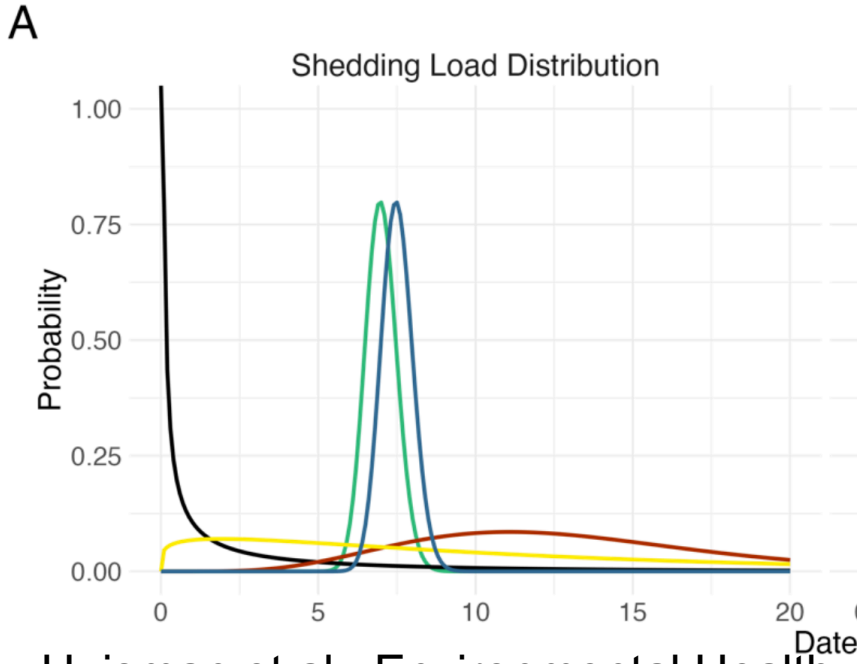
How to get the number of cases from the viral concentration?

Catchment properties may differ

The population may vary over time

How to interpret timing?

May depend on shedding load distribution



Huisman et al., Environmental Health Perspectives, 2022

Challenge: buy-in from stakeholders

Need buy-in from community and wastewater facilities

Especially challenging when the use case is changing

Hinge Marketing

Challenge: ethics and privacy

MARKETPLACE
Search For & Place Classifieds

The Columbus Dispatch

[News] Sports Entertainment Business Opinion Advertise Obituaries eNewspaper Legals

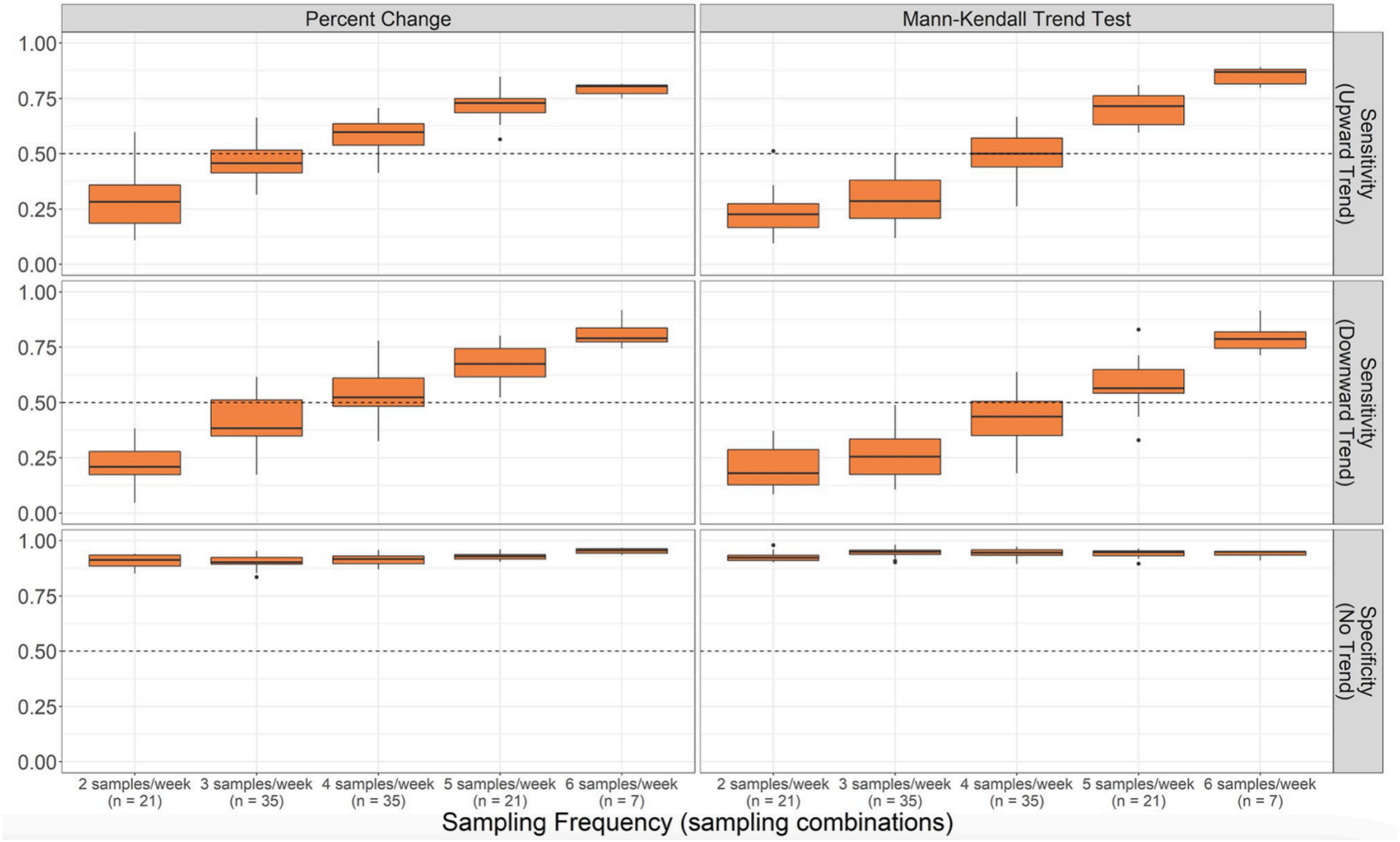
HEALTHCARE

A virologist's search for answers: Curious case of 'cryptic COVID' leads to Columbus area

Nathaniel Shuda
The Columbus Dispatch

Published 6:02 a.m. ET June 8, 2023 | **Updated 11:07 a.m. ET June 9, 2023**

Open question: how often to sample?



Chan et al., PLOS Water, 2022

Open question: where to sample?

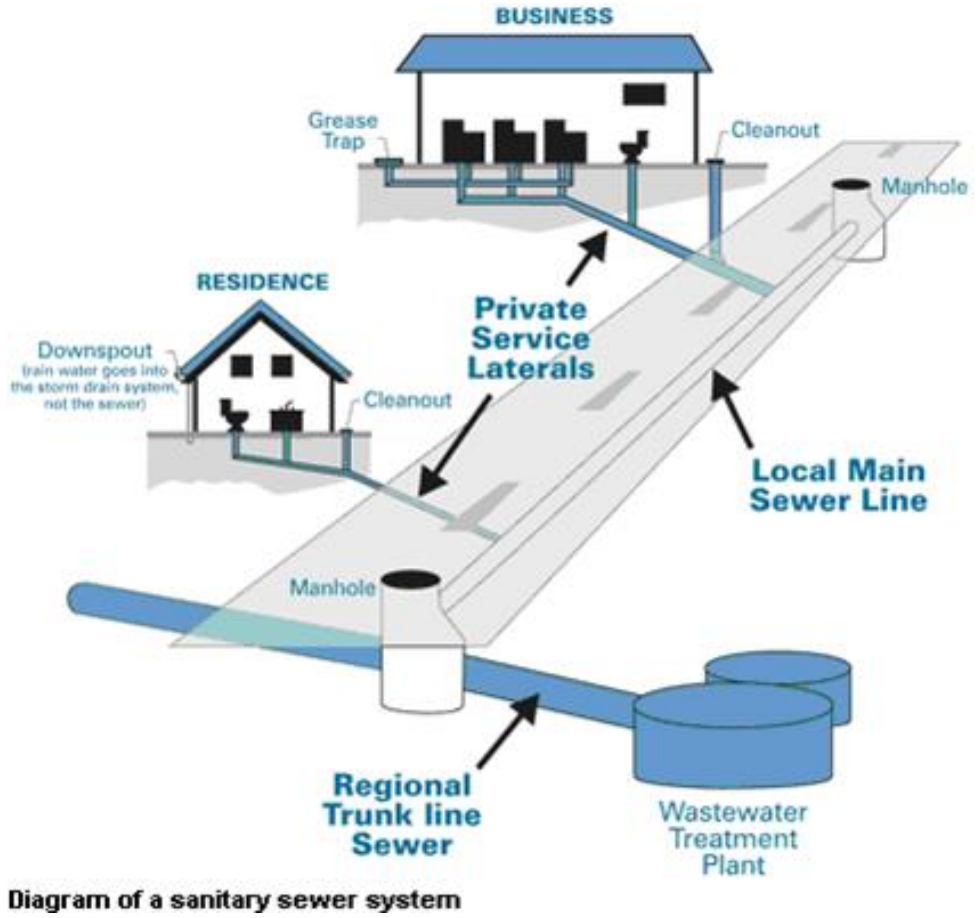


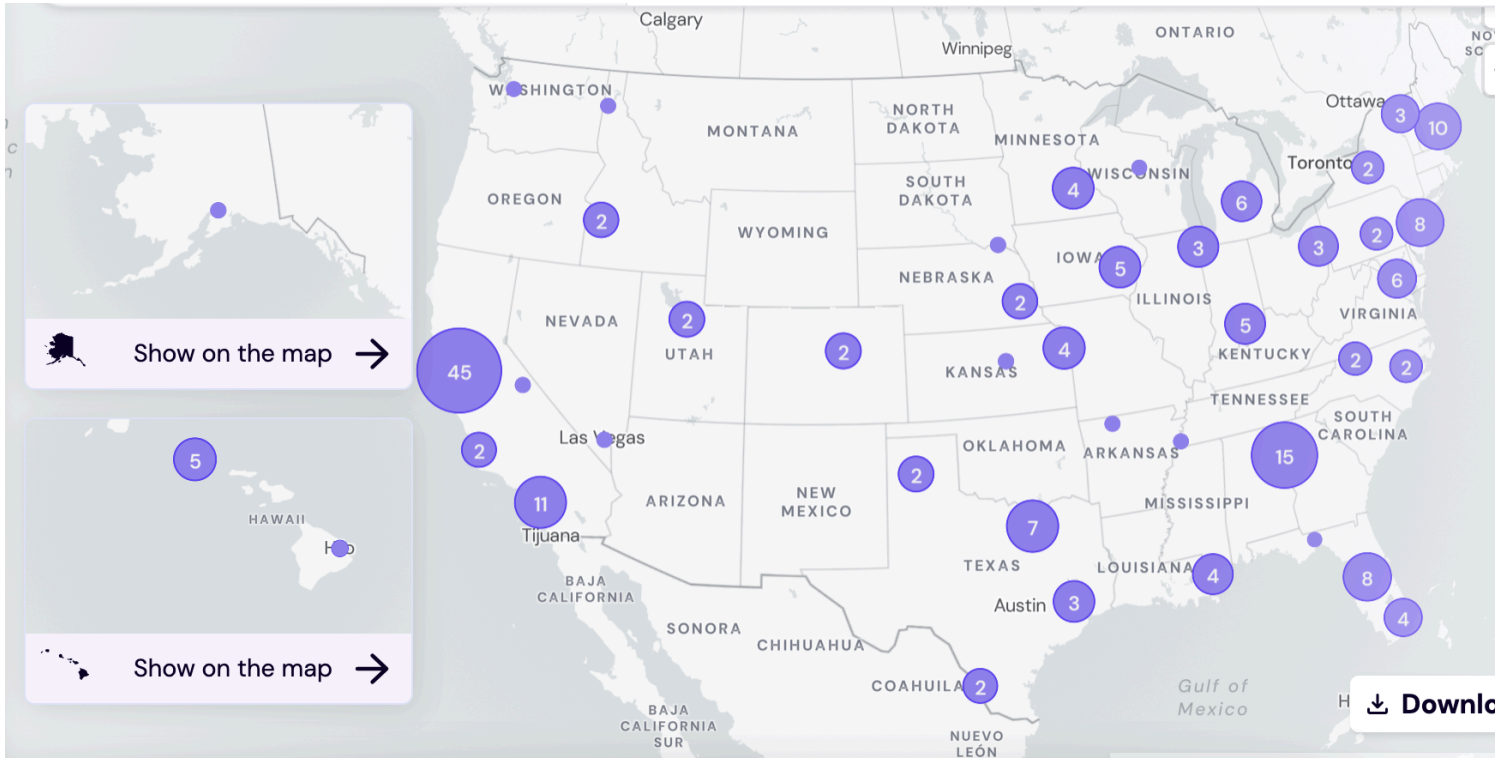
Diagram of a sanitary sewer system

LA County Department of Public Works

Spatial resolution depends on policy question and pathogen

Open question: where to sample?

WastewaterSCAN sentinel sites



https://data.wastewaterscan.org/

Nov 6, 2023 - News

Logan Airport testing wastewater from arriving planes for viruses

Mike Deehan

Axios.com

Open question: can wastewater monitoring be applied in unsewered settings?

How often and where should samples be collected?
How should data be normalized?
What policy questions can be addressed?

nature communications

Article

https://doi.org/10.1038/s41467-023-43047-y

Utilizing river and wastewater as a SARS-CoV-2 surveillance tool in settings with limited formal sewage systems

Received: 11 April 2023

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Published online: 30 November 2023

Kayla G. Barnes[1,2,3,4], Joshua I. Levy[4], Jillian Gauld[5], Jonathan Rigby[1,6], Oscar Kanjerwa[1], Christopher B. Uzzell[7], Chisomo Chilupsya[1], Catherine Anscombe[1,6], Christopher Tomkins-Tinch[2,8], Omar Mbeti[9], Edward Cairns[10], Herbert Thole[1], Shannon McSweeney[1,6], Marah G. Chibwana[1],

Future Medicine Ltd
Future Microbiology
Volume 13, Issue 1, January 2018, Pages 81-95
https://doi.org/10.2217/fmb-2017-0093

RESEARCH ARTICLE

Extended-spectrum β-lactamase-producing *Escherichia coli* in wastewaters and refugee camp in Lebanon

Sima Tokajian[,1], Rima Moghnieh[,2], Tamara Salloum[,1], Harout Arabaghian[,1], Sahar Alousi[,1], Jennifer Moussa[,1], Edmond Abboud[3], Souad Youssef[3] & Rola Husni[,4]
[,1] [1]Department of Natural Sciences, School of Arts & Sciences, Lebanese American University, Byblos, PO Box

Summary

- Wastewater-based epidemiology is a promising tool for public health that can supplement conventional data streams
- Many challenges and open questions exist in the technical, equity, and policy aspects

Acknowledgements

I am grateful to Alexandria Boehm and Jana Huisman, whose presentations I adapted to create this presentation.

Questions?