THE Water Research FOUNDATION®

International Water Research Summit

Environmental Surveillance of COVID-19 Indicators in Sewersheds

CLOSING SESSION

April 30, 2020

3:00 PM – 5:00 PM EDT USA

International Water Research Summit

Welcome!

Christobel Ferguson, PhD

Chief Innovation Officer

The Water Research Foundation

ABOUT

MISSION

Advancing the science of water to improve the quality of life.

VISION

To create the definitive research organization to advance the science of all things water to better meet the evolving needs of subscribers and the water sector.

Agenda

RECOMMENDED BEST PRACTICES AND PRINCIPLES

Recommended Use Cases for Environmental Surveillance of COVID-19 Signal in Sewersheds
Chuck Haas, PhD, Drexel University

Communication of Environmental Surveillance Results with the Public Health Community, Elected Officials, Wastewater Workers, and the Public
Cathy Bailey, Greater Cincinnati Water Works

Sample Design, Collection, and Preservation of Wastewater Samples
Jim Pletl, PhD, Hampton Roads Sanitation District

Use of Molecular Genetics Tools to Quantify the COVID-19 Signal in Wastewater Samples
Kellogg Schwab, PhD, Johns Hopkins University

GREATEST NEAR-TERM RESEARCH OPPORTUNITIES

Research Opportunities to Strengthen Environmental Surveillance of COVID-19 Signal in Sewersheds
Vanessa Speight, PhD, University of Sheffield

Research Recommendations to Support Sampling of COVID-19 Signal in Sewersheds
Matt Burd, New York City Department of Environmental Protection

Research Opportunities for Analysis of COVID-19 Signal in Sewersheds
Joan Rose, PhD, Michigan State University

Research Opportunities to Enhance Communication of Monitoring Results of Indicators of COVID-19 in Sewersheds
Cathy Bailey, Greater Cincinnati Water Works

Q&A and NEXT STEPS

Peter Grevatt, PhD, CEO, The Water Research Foundation

Recommended Best Practices and Principles

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Recommended Use Cases for Environmental Surveillance of COVID-19 Signal in Sewersheds

Chuck Haas, PhD

LD Betz Professor of Environmental Engineering

Drexel University

WORKING GROUP 3

GOAL

To develop recommended approaches for use of indicator concentrations to inform trends and estimates of community prevalence

Working Group 3 - Interpret Results

Co-Chairs

Chuck Haas, Drexel University

Doug Yoder, Miami-Dade Water and Sewer

Gertjan Medema, KWR

Vanessa Speight, University of Sheffield

Participants

Mia Mattioli, Centers for Disease Control and Prevention (CDC)

Jay Garland, Environmental Protection Agency (EPA)

Jeff Soller, Soller Environmental, LLC

John Norton, Great Lakes Water Authority

Jeff Prevatt, Pima County Regional Wastewater Reclamation Dept.

Dimitri Katehis, New York City Dept. of Environment Protection

Steve Rhode, Massachusetts Water Resources Authority

Ken Williamson, Clean Water Services

Paul Kadota, Metro Vancouver

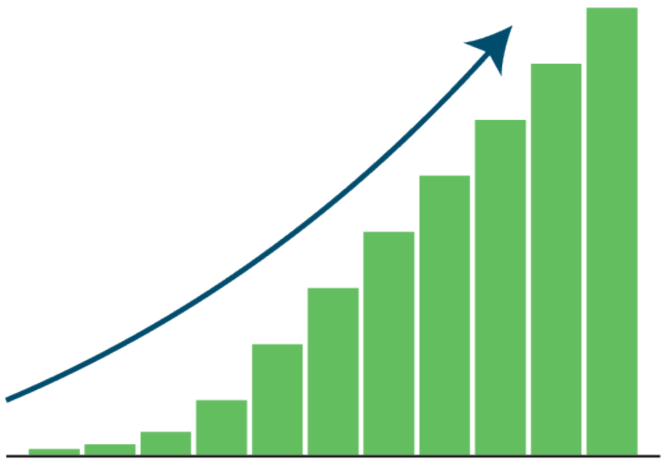
Reynald Bonnard, SUEZ Environmental Research Center

What Can You Use Sewershed Surveillance Data For Now?

General Use Cases	Can Inform	Current Feasibility
Trends/Changes in Occurrence	Early detection of Occurrence. Tracking the impact of medical and social interventions: A) curve increasing; B) curves decreasing	A) ++ B) +
Assessment of Community Infection	Tracking disease prevalence in the community. Identification of areas of concern	+/-
Risk Assessment	Risk to utility workers and those exposed to raw sewage	+/-
Viral Evolution	Source tracking of the virus	-

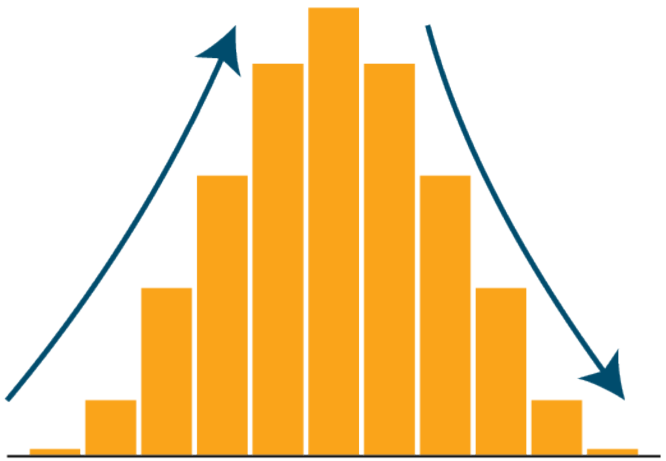
Use Cases

Trend Occurrence



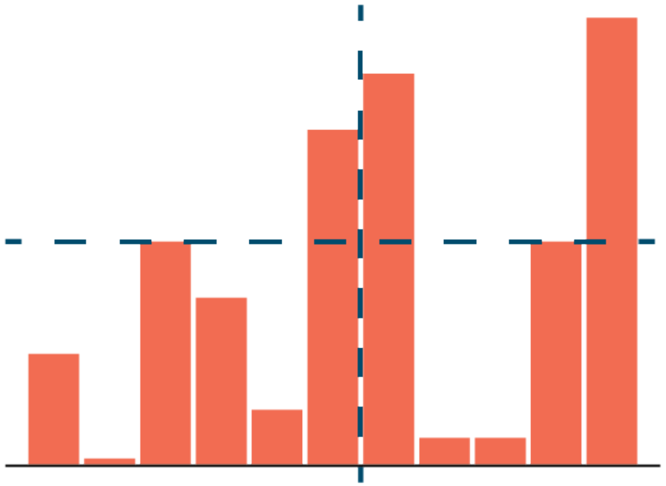
1 variable, 1 direction

Changes in Trends



1 variable, 2 directions

Community Prevalence



multiple variables, need to establish trigger levels

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Communication of Environmental Surveillance Results with the Public Health Community, Elected Officials, Wastewater Workers, and the Public

Cathy Bernardino Bailey

Executive Director

Greater Cincinnati Water Works

WORKING GROUP 4

GOAL

To develop strategies to communicate the implications of environmental surveillance results with the public health community, elected officials, wastewater professionals, and the public

Working Group 4 - Communication

Co-Chairs

Jim McQuarrie, Denver Metro Wastewater Reclamation Dist.

Cathy Bailey, Greater Cincinnati Water Works

Dan Deere, Water Futures

Participants

Jeff Oxenford, Rural Community Assistance Partnership

Vince Hill, Centers for Disease Control and Prevention (CDC)

Claire Waggoner, CA State Water Resources Control Board

Karen Mogus, CA State Water Resources Control Board

Chris Impellitteri, Environmental Protection Agency (EPA)

Diane Taniguchi-Dennis, Clean Water Services

Gabriella Rundblad, King's College London

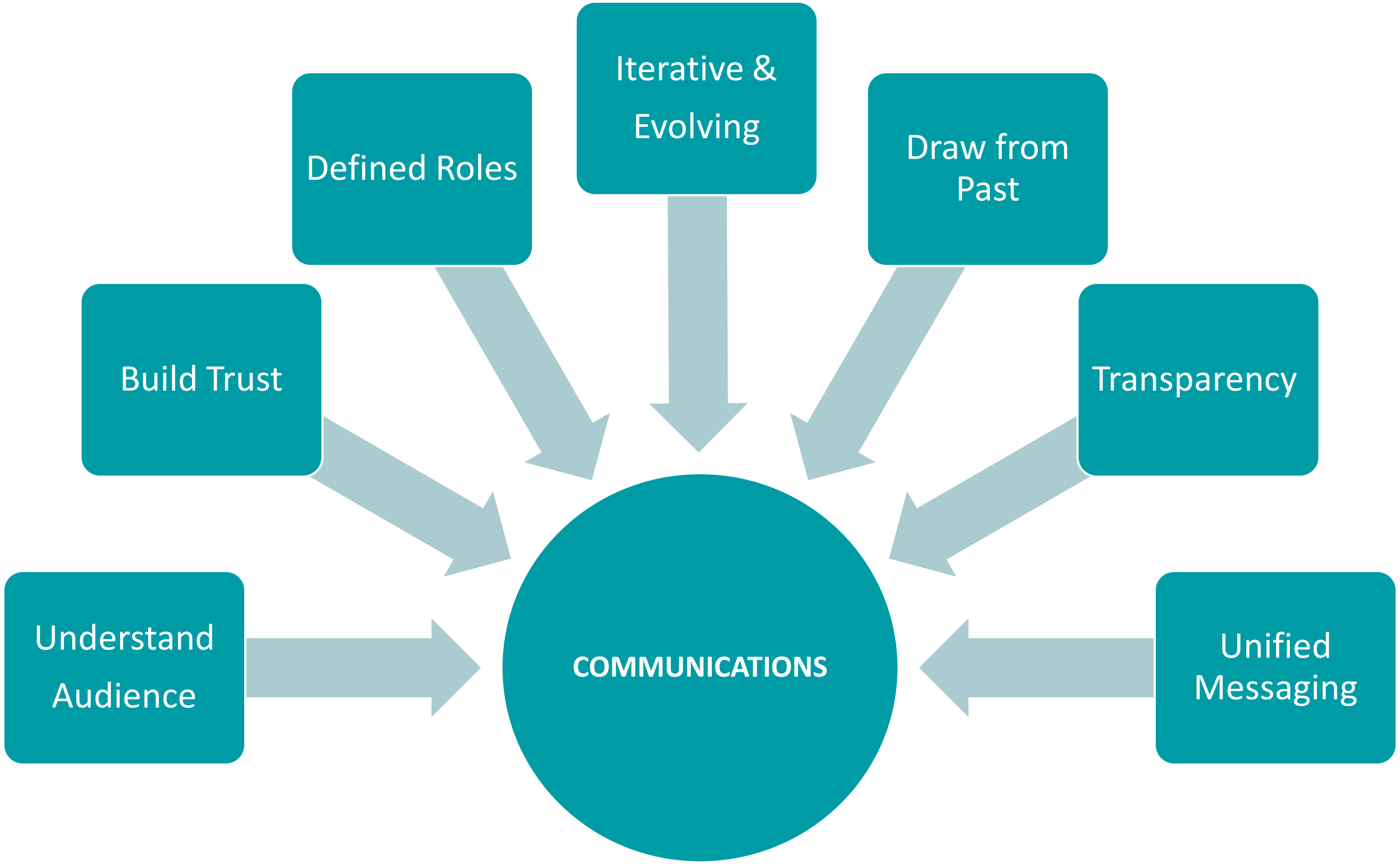
Josef Klinger, Technologiezentrum Wasser (TZW)

Bruno Tisserand, Veolia

Stephanie Rinck-Pfeiffer, Global Water Research Coalition

Yvonne Forrest, Houston Water

Communications Guiding Principles



Communications 101

What needs communicating?

Who are we communicating with?

How are we communicating?

When do we communicate?

Why do we communicate?

Communications Best Practice

GREATER CINCINNATI
WATER WORKS

Types of Audiences

General Public

Utilities

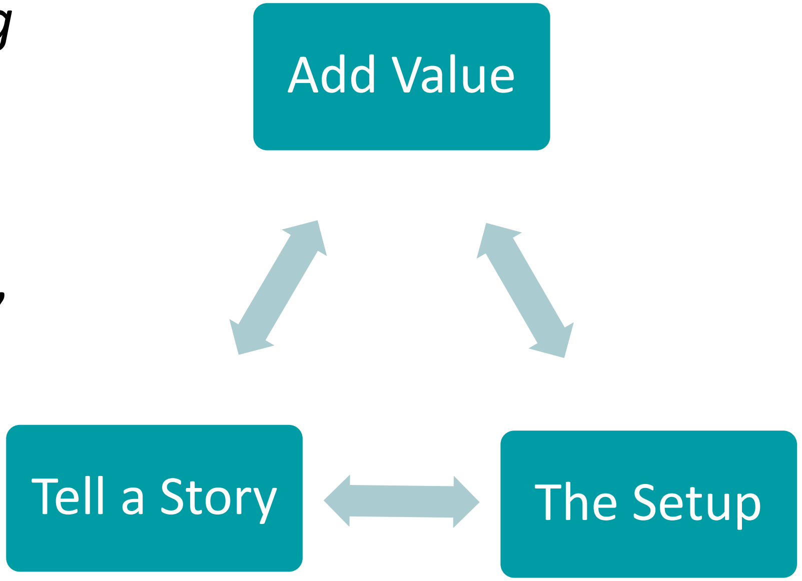
Public Health

Policy Makers

Media

Messaging

- **Add Value - We are contributing to the community**
  - *"We have the ES data, we know a lot, we are evaluating the best way to interpret and act from the data."*
- **The Setup - The relationship matters**
  - Establish the relationships you want with public, media, etc.)
- **Tell A Story - The Beginning, The Middle, and The End**
  - What are you doing now?
  - What are you going to do?
  - What is the outcome?



Example: Wastewater Utility

R – Responsible

Health department, utility, communications team, etc.

A – Accountable

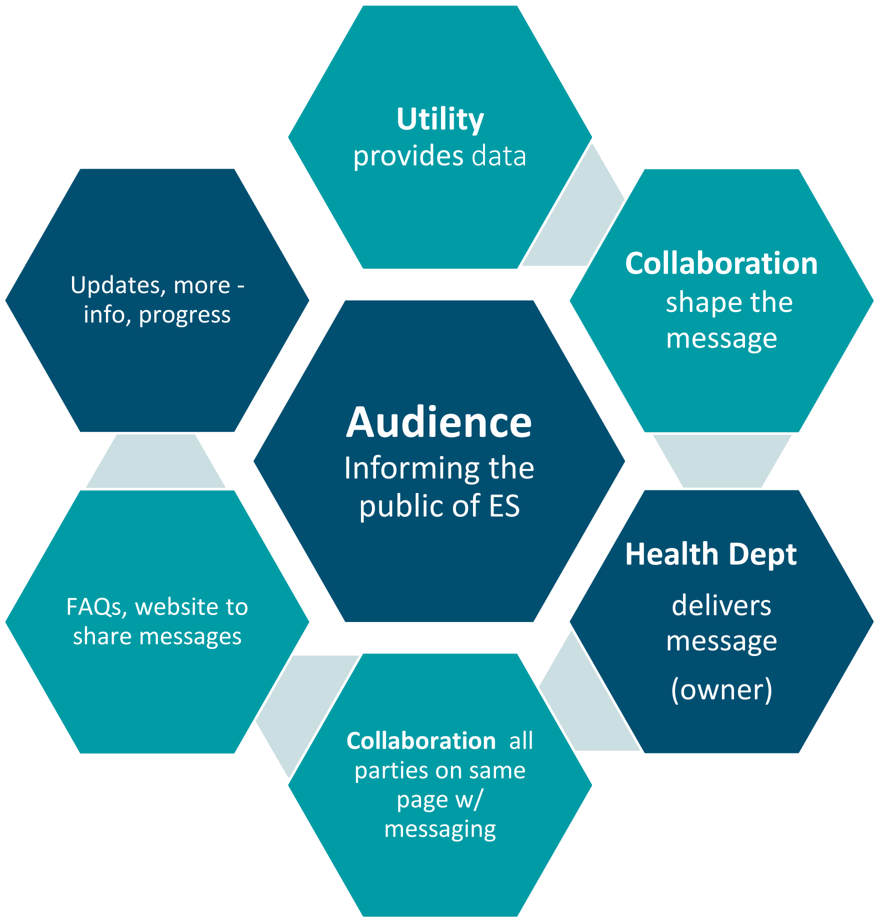
Health department for delivering the message

C – Consulted

Two-way communication, health department, scientists, communications team, utility, IT, other partners

I – Informed

One-way communication, perhaps a board, or council

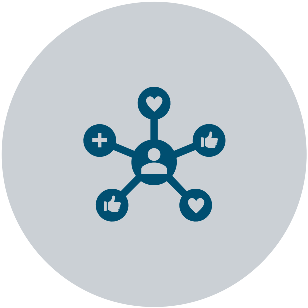


Communication Tools

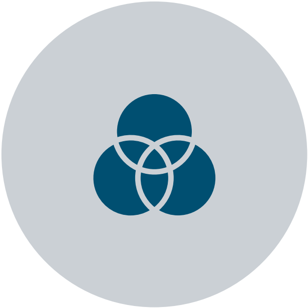
AUDIENCE (From General to Specialized) \ INFORMATION (From Basic to Complex)	Explanatory Graphics	FAQs/Glossary of Terms	Fact Sheets	Scientific/ Technical Research Reports
General Public	✓	✓		
Wastewater Workers	✓	✓		
Decision Makers/Elected Officials	✓	✓	✓	
Public Health Agencies	✓	✓	✓	✓

Graphic Needs

WHAT IS A SEWERSHED?



WHAT IS ENVIRONMENTAL SURVEILLANCE?



VENN DIAGRAM OF CLINICAL SURVEILLANCE AND ENVIRONMENTAL SURVEILLANCE

INTERSECTION OF PUBLIC HEALTH AGENCIES AND UTILITIES

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Sample Design, Collection, and Preservation of Wastewater Samples

Jim Pletl, PhD

Director of Water Quality

Hampton Roads Sanitation District

WORKING GROUP 1

GOAL

To develop best practices and considerations for sample design, collection and storage of wastewater

Working Group 1 - Sample Collection

Co-Chairs

Chuck Gerba, University of Arizona

Jim Pletl, Hampton Roads Sanitation District

Dan Gerrity, Southern Nevada Water Authority

Participants

Mark Sobsey, University of North Carolina at Chapel Hill

Amy Pickering, Tufts University

Mark Jones, UK Water Industry Research (UKWIR)

Katrina Charles, Oxford University

Kelly Hill, Water Research Australia

Christoph Ort, Eawag – Swiss Federal Institute of Aquatic Science and Technology

Matt Burd, New York City Dept. of Environmental Protection

Kaylyn Patterson, Metropolitan Water Reclamation Dist. of Greater Chicago

Amy Kirby, Centers for Disease Control and Prevention (CDC)

Sample Collection Guiding Principles

- Baseline assumption of centralized WWTP
- Data comparability requires some consistency in practices and documentation/metadata
- Recommendations are adaptable and modifiable to best meet needs
- Intention is NOT to inhibit utility operations during a pandemic
- Balance study goals with practical considerations: resources, operator ability, freezer storage space, budget
- Some best practices for sample collection apply to all use cases, whereas others are use-case specific
- Consider worker safety in sampling and sample prep guidance
- Proof of concept to support practice and research with potential for future meta-analysis, retrospective learning

ES Sample Plan Design: General Considerations

- Partnering with information customers
- Study goals
- Grab vs. Composites, study-specific
- Timing within an event
- Sensitivity vs. Quantitation in monitoring
- Complexity of wastewater infrastructure
- Frequency & Duration
- Representativeness
- Comparability

Critical Metadata

- Sample type: Grab vs. Composite
  - Composite type (flow vs. time)
  - Composite duration
  - # of aliquots
- Time of sample

Sample Collection & Storage: Best Practices

- Sample type – Grab vs. composite
- Frequency – 1/week/location
- Duration – requires data user input
- PPE
  - safety gloves and glasses, masks or face shields – recommendations may vary between handling wastewater and processing samples
- Sample solids – removal may reduce signal

Critical Metadata

- Sample type: Grab vs. Composite
  - Composite type (flow vs. time)
  - Composite duration
  - # of aliquots
- Time of sample
- Sample ID + container labeling
- Who collected the sample
- Location

Sample Collection & Storage: Best Practices

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- Documentation

Critical Metadata

- Sample type: Grab vs. Composite
  - Composite type (flow vs. time)
  - Composite duration
  - # of aliquots
- Time of sample
- Sample ID + container labeling
- Who collected the sample
- Location
- Weather: Rain events?
- Flow rate
- Separate or CSO
- Population served
- Public health data

Sample Collection & Storage: Best Practices

- Sample type – Grab vs. composite
- Frequency – 1/week/location
- Duration – requires data user input
- PPE
  - safety gloves and glasses, masks or face shields – recommendations may vary between handling wastewater and processing samples
- Sample solids – removal may reduce signal
- Documentation
- Metadata

Critical Metadata

- Sample type: Grab vs. Composite
  - Composite type (flow vs. time)
  - Composite duration
  - # of aliquots
- Time of sample
- Sample ID + container labeling
- Who collected the sample
- Location
- Weather: Rain events?
- Flow rate
- Separate or CSO
- Population served
- Public health data

Sample Collection & Storage: Best Practices

- Use new polycarbonate containers, leak-proof
- Field/trip blanks
- Equipment blanks
- Recovery spikes

1 Liter sample, split

For QC

Recovery spikes (necessary to universally use data)

For analysis

For archival

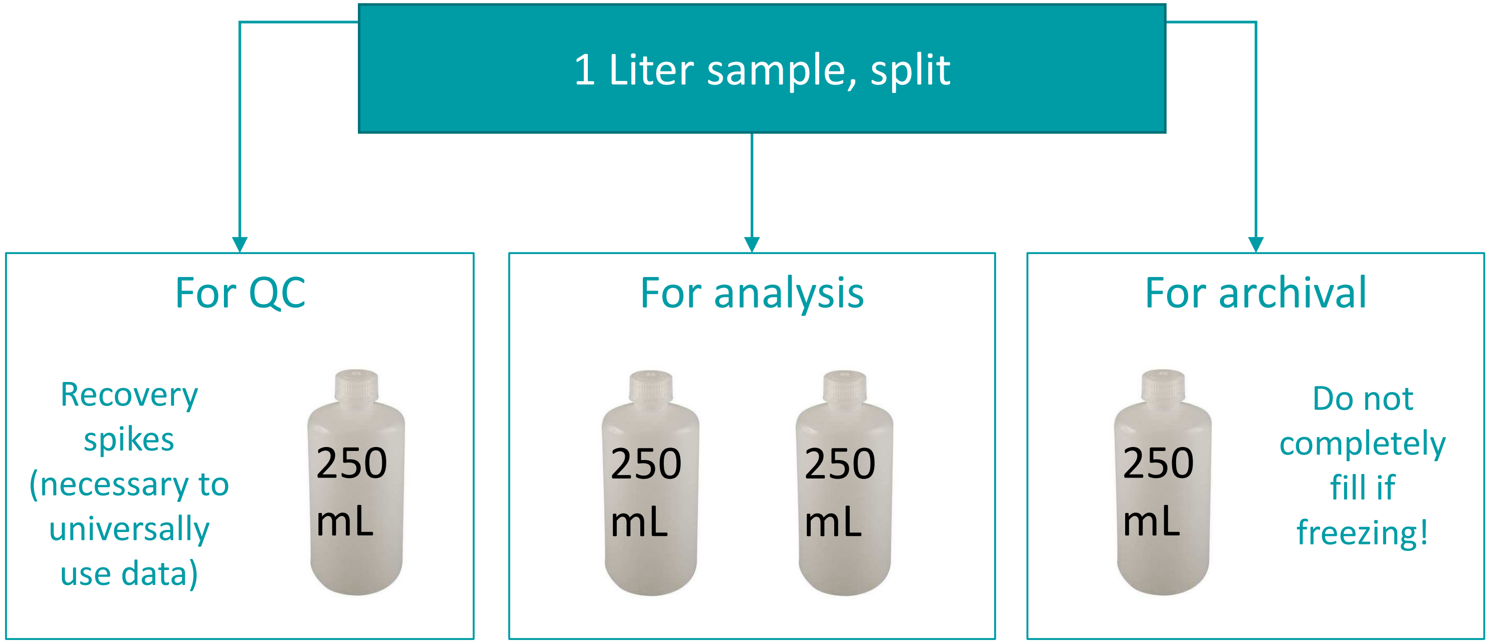
Do not completely fill if freezing!

Critical Metadata

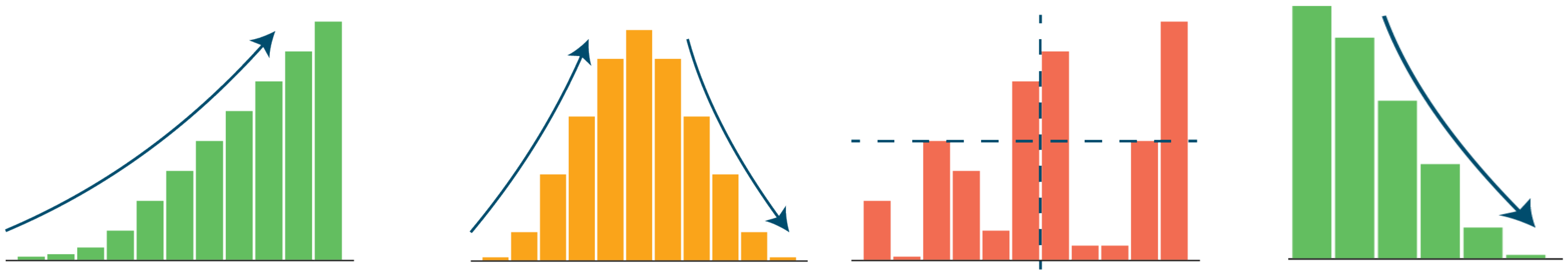
- Sample type: Grab vs. Composite
  - Composite type (flow vs. time)
  - Composite duration
  - # of aliquots
- Time of sample
- Sample ID + container labeling
- Who collected the sample
- Location
- Weather: Rain events?
- Flow rate
- Separate or CSO
- Population served
- Public health data
- Sample characteristics – TSS, pH, temperature, chlorine residual
- Storage temperature
  - qPCR: -20C min, -80C best
  - Avoid freezer defrost cycles
- Pasteurized? (not for infectivity study)
- Concentrated? (inhibition)

Sample Collection & Storage: Best Practices

- Use new polycarbonate containers, leak-proof
- Field/trip blanks
- Equipment blanks
- Recovery spikes



General Use Case: Trends/Changes in Occurrence



Pre- and early event

- Detection most important
- Grabs may be sufficient
- Sentinel sites

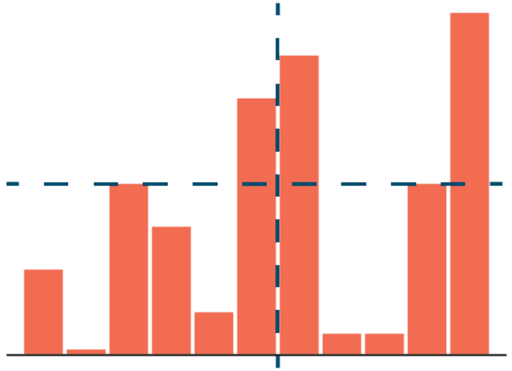
Mid-Event

- Quantitation important
- Flow-based samples likely needed
- Major conveyance junctures or plant influent desirable
- Less uncertainty in community calculations better supports studies of correlation with medical and social interventions

Late event

- Detection again becomes important
- Sentinel sites serve, again, as a metric of occurrence
- Monitor well past last incident of detection

General Use Case: Assessment of Community Prevalence



Sampling Considerations:

- Quantitation important
- Flow based composites could support calculating percentage of population shedding genetic material
- Sampling throughout a service area helpful – lower scale monitoring decreases uncertainty in calculations
- More spatial sampling requires balance between grabs and composites

General Use: Risk Assessment for Wastewater Exposure

Sampling Considerations:

- Quantitation of the ES signal is important
- Need to characterize distribution of concentrations
- Grabs might be best to characterize the distribution
- Consider aerosol exposure
- Infectivity data absent, qPCR could be used with assumptions in place
- Stored samples intended for future infectivity studies need to be collected, prepared and stored appropriately for this use, noting pathogen die-off

General Use Case: Viral Evolution

Quantitation important to assess variability in shedding across a community

Sampling sites with greater potential for outbreaks should be considered – schools, hospitals, nursing homes, rehab centers

Approach needs to be informed by health official case data

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Use of Molecular Genetics Tools to Quantify the COVID-19 Signal in Wastewater Samples

Kellogg Schwab, PhD

Professor

Johns Hopkins University

WORKING GROUP 2

GOAL

To develop best practices for the use of molecular genetics tools to identify the concentration of indicators of COVID-19 in wastewater samples

Working Group 2 - Analyze Results

Co-Chairs

Krista Wigginton, University of Michigan

Frederic Been, KWR

Joan Rose, Michigan State University

Participants

Raul Gonzalez, Hampton Roads Sanitation District

Kellogg Schwab, Johns Hopkins University

Scott Meschke, University of Washington

Rosina Girones, University of Barcelona

Kaye Power, Sydney Water

Sudhi Payyappat, Sydney Water

Zia Bukhari, American Water

Farida Bishay, Metro Vancouver

Tiong Gim Aw, Tulane University

Analysis Guiding Principles

- There is a need to provide credible information to decision makers
- Detection of target nucleic acids (RNA for SARS CoV-2) is a powerful tool
  - Fraught with challenges and potential misinterpretation
- Ultimately, molecular methods need to provide **reproducible, reliable and preferably quantitative information**
  - Evaluation and validation of methods are critical
  - Controls need to be included in each step during initial validation, so that the impact on subsequent steps are understood
    - For routine evaluation, overall recovery and detection controls can be used to streamline costs and efficiency

Analysis Guiding Principles

- **A Quality Assurance/Quality Control (QA/QC) checklist is essential**
- **Respect the matrix** – wastewater can be a complex mixture of municipal and industrial effluents (and is quite different from clinical samples)
  - The limit of detection/quantification needs to be established for your assay and the sample matrix
  - Biosafety considerations upstream of nucleic acid extraction
- Data must be collected for each sampling or analytical step to ensure that the appropriate context can be given to subsequent interpretation of results
- It is important to report on **all of the factors** in the study that could impact the result (i.e. detection results need to be related to water quality and other metadata)

Analysis Guiding Principles

Applying these principles will enable results to be compared and data analyzed with confidence to support rigorous decision-making

QA/QC Checklist

Minimally acceptable QA/QC standards for every assay include:

- ✓ Positive control
- ✓ Negative control
- ✓ Inhibition control

Validate recovery during method development:

- ✓ Initial Precision Recovery controls
- ✓ Matrix spike (periodic assessment)
- ✓ Estimate of the limit of detection and limit of quantification
- ✓ Reporting of the equivalent volume of sample analyzed

A primary source of error in qPCR occurs when the standard curve is generated. Each standard curve should be checked for validity

- ✓ Use appropriate standards for an RNA virus, specifically, the use of reverse transcriptase prior to PCR

Recommended Best Practices

- Environmental surveillance can provide unique and robust data to enhance information about various use cases with different levels of confidence:
  - Trends (increasing and decreasing) in occurrence
  - Community prevalence
  - Risk
- All molecular research must complete assays according to key principles and confirm QA/QC checks are working to enable confidence in sample results
- Examine sequential positive samples and/or positives from multiple sites to provide confidence that a trend is "real" (or negatives – for downward trends)
- Work closely with health officials to proactively engage with them regarding the analysis to be undertaken and how we are going to communicate results

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Research Opportunities to Strengthen Environmental Surveillance of COVID-19 Signal in Sewersheds

Vanessa Speight, PhD

Professor of Integrated Water Systems

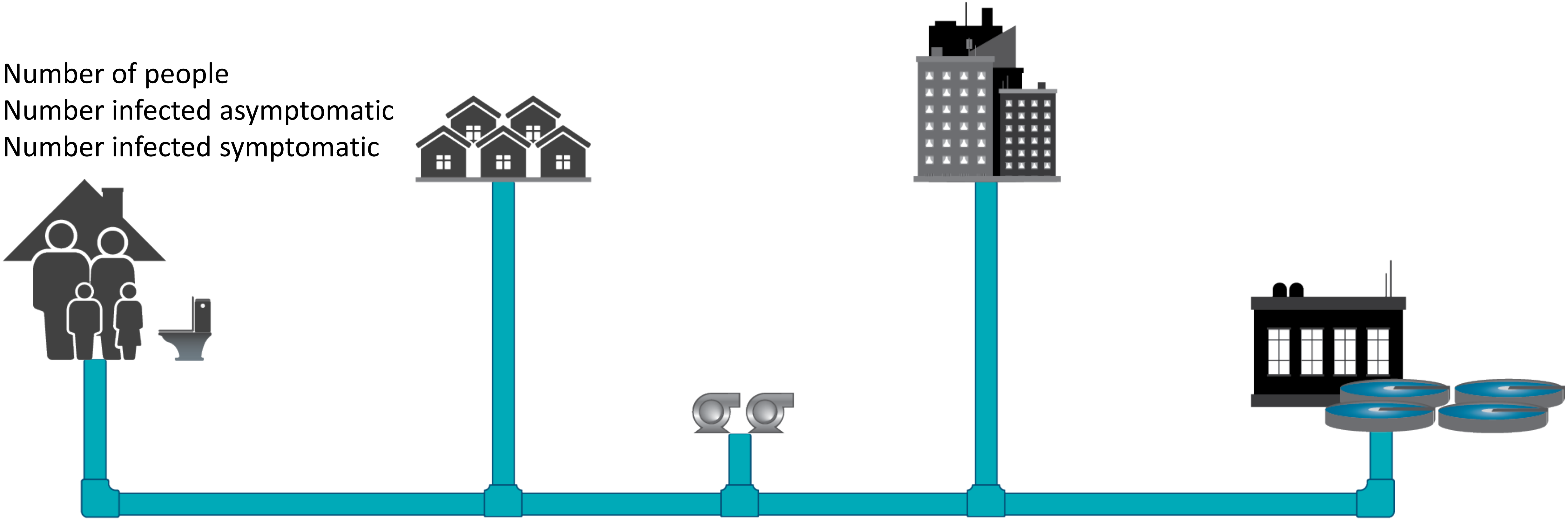
University of Sheffield

Data Assessments

START WITH THE PURPOSE OF THE STUDY (USE CASES)

WHAT CAN WE CURRENTLY DO WITH THE DATA?

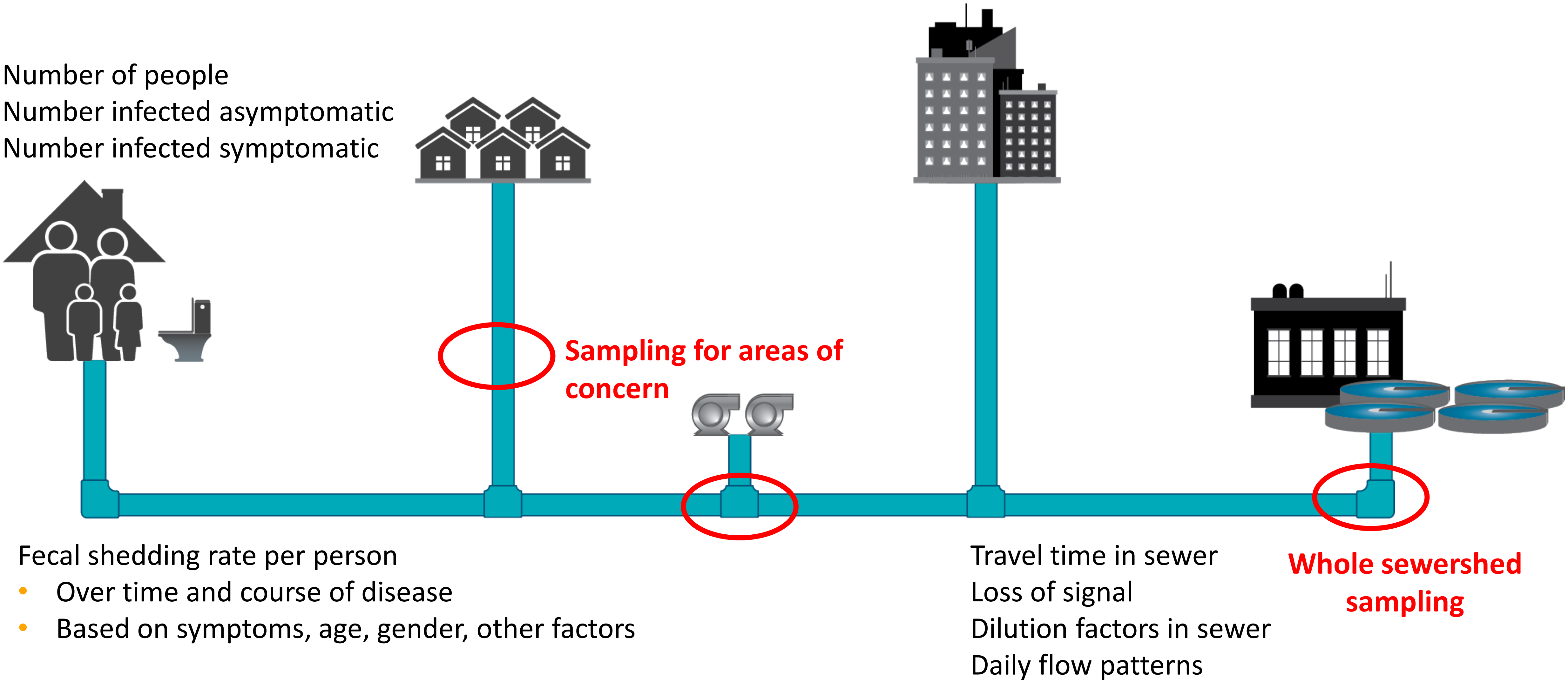
Number of people
Number infected asymptomatic
Number infected symptomatic



Fecal shedding rate per person

- Over time and course of disease
- Based on symptoms, age, gender, other factors

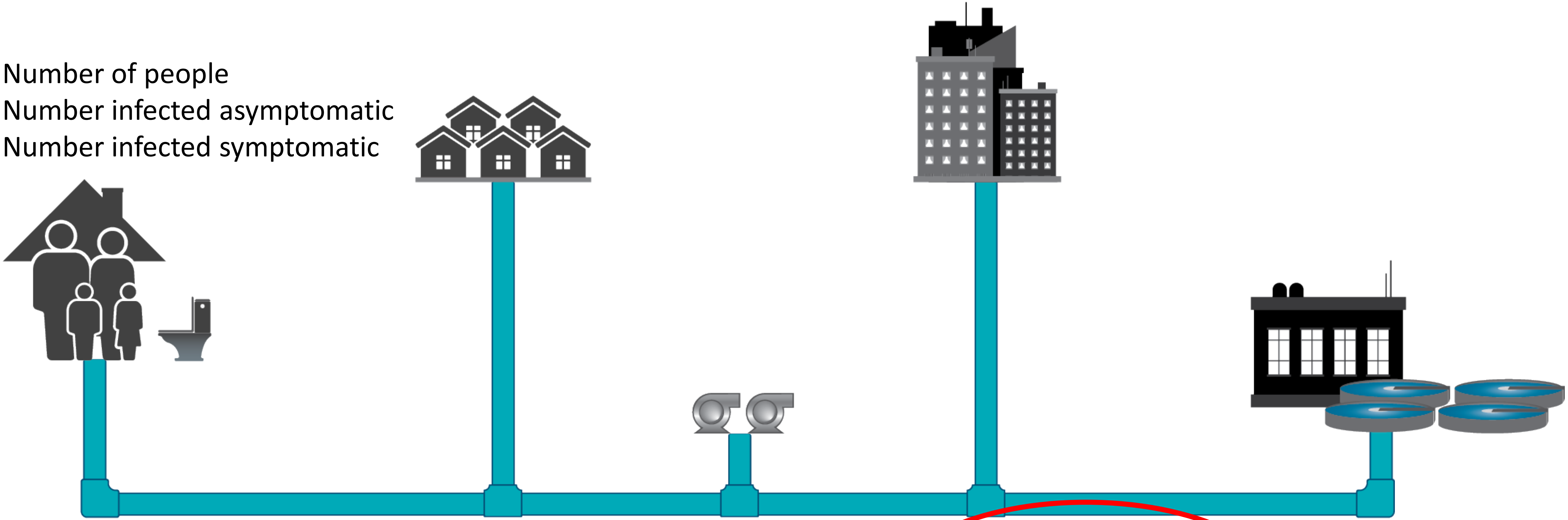
Travel time in sewer
Loss of signal
Dilution factors in sewer
Daily flow patterns


Number of people
Number infected asymptomatic
Number infected symptomatic
Sampling for areas of concern
Fecal shedding rate per person
• Over time and course of disease
• Based on symptoms, age, gender, other factors
Travel time in sewer
Loss of signal
Dilution factors in sewer
Daily flow patterns
Whole sewershed sampling

General Use Cases	Can Inform	Current Feasibility
Trends/Changes in Occurrence	Early detection of Occurrence. Tracking the impact of medical and social interventions: A) curve increasing; B) curves decreasing	A) ++ B) +

- Focus on genetic signal in wastewater at different spatial scales
- Key research needs related to reducing uncertainty in:
  - Analytical methods
    - Including recovery efficiency, inhibition, inter/intra-laboratory variability
  - Sampling
    - Including timing of sample collection, locations, rainfall
    - Correlations to other sewage parameters
  - Degradation of signal through travel in the sewer
  - Population characteristics for sewershed over time
  - Inherent variability

Number of people
Number infected asymptomatic
Number infected symptomatic



Fecal shedding rate per person
- Over time and course of disease
- Based on symptoms, age, gender, other factors

Travel time in sewer
Loss of signal
Dilution factors in sewer
Daily flow patterns

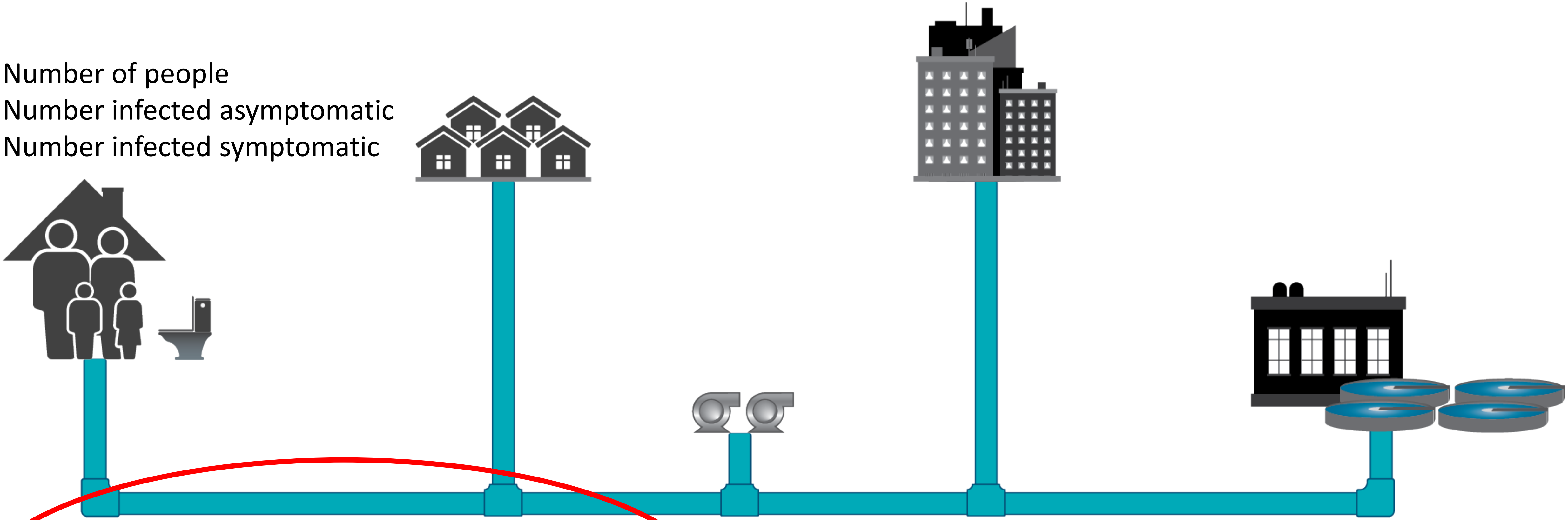
General Use Cases	Can Inform	Current Feasibility
Trends/Changes in Occurrence	Early detection of Occurrence. Tracking the impact of medical and social interventions: A) curve increasing; B) curves decreasing	A) ++ B) +

- Need measurements to meet minimum standards for analytical quality
- Comparing measurements to determine trends from the same sewershed using the same methods over time will reduce the impact of some of the analytical uncertainty. Comparing across sewersheds requires greater certainty about the data quality.
- Key research needs in interpretation of results
  - How large of an increase or decrease is significant?
    - And how might this change between initial onset, increasing part of the curve, and decreasing part of the curve?
  - How small of a signal can be detected?
  - If the background signal does not go to zero, can we see future increases?
    - Especially relevant given estimates of shedding over long time periods, possibly up to 6 weeks

General Use Cases	Can Inform	Current Feasibility
Assessment of Community Infection	Tracking disease prevalence in the community. Identification of areas of concern.	+/-

- Focus on link between genetic signal and infection prevalence
- Requires a high quality genetic signal
- Key research needs related to reducing uncertainty in
  - Fecal shedding rates of the virus
    - Over the course of the disease and after symptoms end
    - For different individuals (gender, age, symptoms)
- Ideally could be paired with high quality estimates of number of persons infected in a targeted, integrated study

Number of people
Number infected asymptomatic
Number infected symptomatic



Fecal shedding rate per person

- Over time and course of disease
- Based on symptoms, age, gender, other factors

Travel time in sewer
Loss of signal
Dilution factors in sewer
Daily flow patterns

General Use Cases	Can Inform	Current Feasibility
Risk Assessment	Risk to utility workers and those exposed to raw sewage	+/-

- Focus on infectivity of virus present in sewage
- Key research needs
  - Understanding infectivity of virus from fecal shedding along with good estimates of fecal shedding rates
    - Correlations between infective virus concentrations and genetic signal measurements
    - Loss of infectivity and genetic signal across different locations in a sewershed including sewers, treatment plant, labs, sewer overflow locations
  - Pathways of exposure for workers and others (droplets, contact, fomites)
  - Understanding of role of aerosols
  - Understanding of potential for fecal-oral transmission

General Use Cases	Can Inform	Current Feasibility
Viral Evolution	Source tracking of the virus	**–**

- Focus on understanding different strains of the virus and how they move across populations
- Key research needs
  - Sampling protocols
  - Analytical methods
  - Understanding of different strains, their sources and mutations

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Research Recommendations to Support Sampling of COVID-19 Signal in Sewersheds

Matt Burd

Wastewater Wizard

New York City Department of Environmental Protection

Research Needs

- Which spike organism to use for QA/QC purposes?
- Impacts of sample collection method (grab vs. composite, duration of composite, time of day) on results
  - May be able to extrapolate from data without discrete research project
- Distribution of virus (or RNA fragments) in liquid and solid phase
  - If substantial parts are bound to particulate matter, one also has to study efficiency of routine sampling devices for their suitability to collect solids
- What kind of aerosols are generated by various wastewater processes?
  - Review literature for other viruses and bacteria

Additional Needs for Implementation

- Communication and coordination among those who are archiving samples and those interested in analyzing or using those samples
- Communication and coordination with the public health community
- Coordination across environmental surveillance practitioners
  - Ongoing forum where there is exchange among practitioners during implementation phase of lessons learned
- Refinement of PPE guidance as data on infectivity become clear
  - sample collection
  - wastewater workers in general
  - sample processing/concentration

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Research Opportunities for Analysis of COVID-19 Signal in Sewersheds

Joan Rose, PhD

Homer Nowlin Chair in Water Research, Professor

Michigan State University

Recommended Research

- Method Evaluation needs to be accelerated
  - Recovery efficiency is likely to be different because it is an enveloped virus
  - Use wastewater samples to do split trials for comparative method recovery
- Persistence of the genetic signal should be understood
  - Shedding rate and duration influences the sewage signal
  - Through sewage transport and sample storage
  - Pre-treatments e.g. pasteurization impact
- Interlaboratory evaluation of methods supported
  - Labs use their own methods (that comply with the principles) and analyze "standard" samples
- Desktop literature review to address comparative methods for enveloped viruses – focusing on the concentration from wastewater matrix

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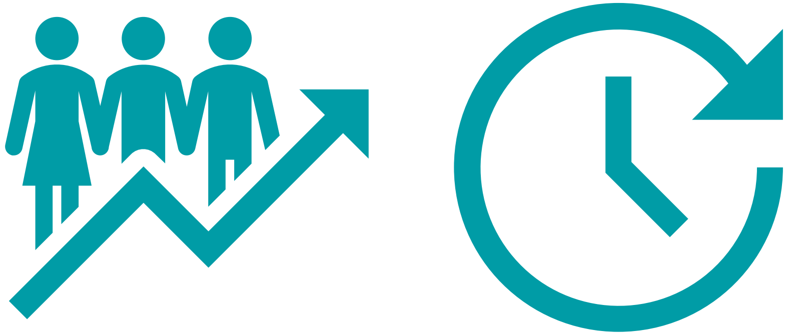
Research Opportunities to Enhance Communication of Monitoring Results of Indicators of COVID-19 in Sewersheds

Cathy Bernardino Bailey

Executive Director

Greater Cincinnati Water Works

Research Needs

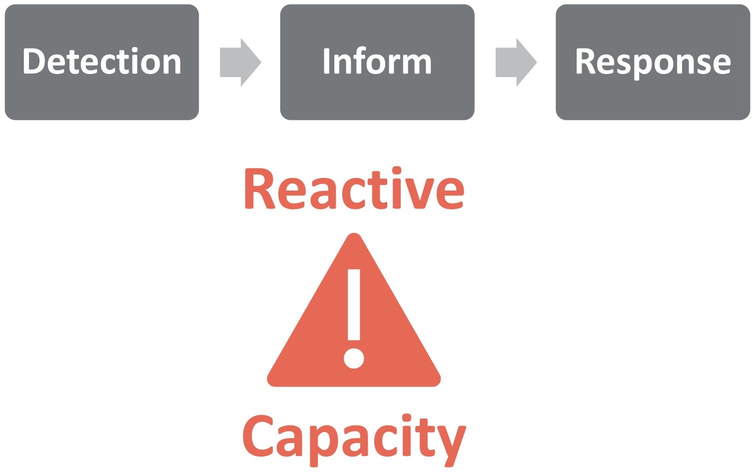


How can we leverage ES to provide useful data to the public health stakeholders

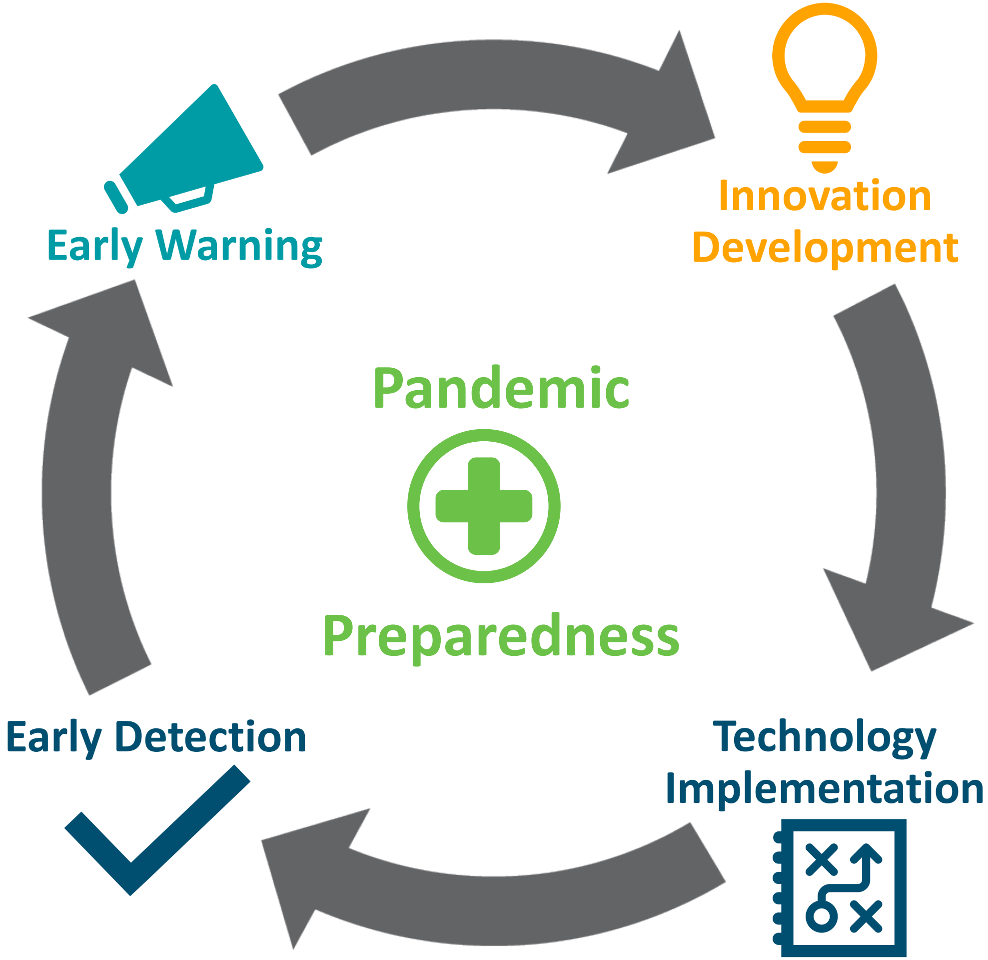
Define partnership opportunities

How to effectively translate COVID-19 research into pandemic preparedness and ES for future needs?

Present vs. Future Virus Detection



Current State



Future State

Key
Public Health Agencies
Utility
Private Sector

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Q&A and Next Steps

Peter Grevatt, PhD

Chief Executive Officer

The Water Research Foundation

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Environmental Surveillance of COVID-19 Indicators in Sewersheds

Thank You!