Wastewater-based Disease Surveillance for Public Health Action

Emergency response to the global COVID-19 pandemic catalyzed innovation in many areas, including the rapid development of testing and the deployment of diagnostic assays, vaccines, and medications. The pandemic also spurred innovation in wastewater surveillance as municipalities and universities developed systems to explore the feasibility and potential public health value of detecting SARS-CoV-2 RNA in wastewater.

To help coordinate and centralize those efforts, the U.S. Centers for Disease Control and Prevention (CDC) launched the National Wastewater Surveillance System (NWSS) in September 2020, with pilot sites in eight states. As of October 2022, the NWSS comprises more than 1,250 sampling sites in 42 states, covering a population of 133 million individuals.

Produced at CDC's request, this report reviews the usefulness of community-level wastewater surveillance based on the experience with COVID-19 and assesses its potential value for control and prevention of infectious diseases beyond the pandemic. The report concludes that wastewater surveillance is and will continue to be a valuable component of the nation's management of infectious diseases and lays out a vision for national wastewater surveillance beyond COVID-19.

WHAT IS WASTEWATER SURVEILLANCE?

Wastewater-based infectious disease surveillance systems detect and quantify the presence of pathogen biomarkers, most commonly microbial DNA or RNA, that are shed by infected persons into a municipal sewer system. Whereas clinical laboratory testing tracks individual cases of infection, sampling and analysis at the wastewater treatment plant level provides aggregate data from the homes, businesses, and other institutions that share a common sewer system (see Figure 1).

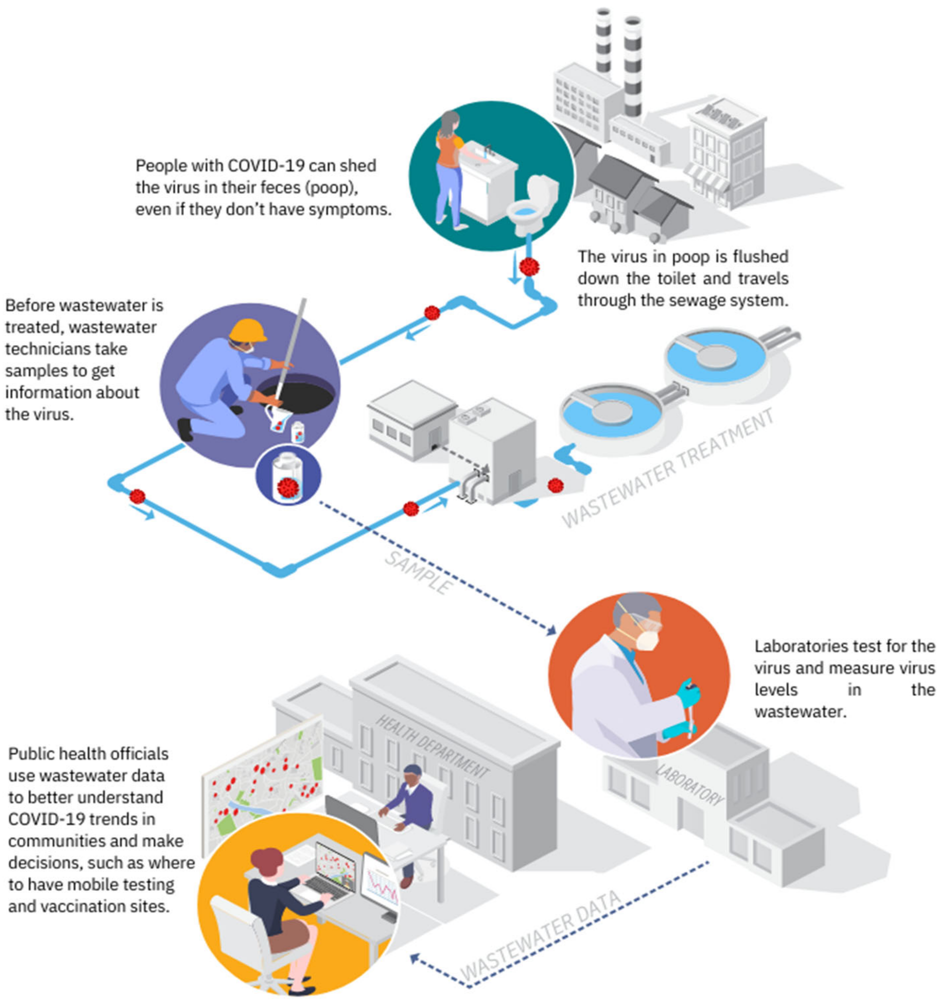

FIGURE 1 Components of a community-level wastewater surveillance system.
SOURCE: Adapted from https://www.cdc.gov/healthywater/surveillance/pdf/Wastewater-COVID-infographic-h.pdf.

Sampling is carried out at wastewater treatment plants that serve communities across a wide range of scales from as few as 100 to as many as 4 million people. The concept of wastewater surveillance was originally developed to understand polio transmission in a population.

VALUE OF WASTEWATER SURVEILLANCE FOR COVID-19

The experience with wastewater surveillance during COVID-19 demonstrates that the data are useful for informing public health action and that wastewater surveillance is worthy of further development and continued investment. As COVID-19 clinical testing and reported case data became less reliable in recent months due to many factors, including increased at-home testing, wastewater surveillance provided continued information on where the virus was circulating and the degree of exposure risk. Wastewater surveillance also provides comprehensive information on the relative proportions of known variants, and genome sequencing of wastewater samples is an effective strategy to screen for emerging variants among a large contributing population.

Public health agencies found the data useful for informing policy decisions (e.g., masking and social distancing rules), and for allocating public health resources (e.g., testing and vaccination sites, public notification efforts) and clinical resources (e.g., staffing, hospital beds). These data rarely stood alone but rather were frequently used in conjunction with other disease surveillance data sets (e.g., case and hospitalization counts), each with their own limitations and advantages. Information on changing levels of SARS-CoV-2 RNA in wastewater were shared with the public, often on dashboards, to help inform personal decision making.

Building on the successful uses of wastewater surveillance systems during COVID-19, the challenge now is to unify sampling design, analytical methods, and data interpretation to create a truly representative national system while maintaining continued innovation.

VISION FOR A NATIONAL WASTEWATER SURVEILLANCE SYSTEM

Wastewater surveillance is and will continue to be a valuable component of the nation's strategy to manage infectious disease outbreaks, including continued surveillance of SARS-CoV-2 variants, resurgences of known pathogens, and newly emergent pathogens. The high likelihood that SARS-CoV-2 variants will continue to emerge and circulate is alone a strong rationale to maintain and strengthen a national wastewater surveillance system. The recent use of wastewater surveillance for poliovirus and monkeypox in mid-2022 illustrates the advantages of maintaining a national system.

To achieve its goals, a national wastewater surveillance system should be flexible, equitable, integrated, actionable, and sustainable. Flexibility includes the ability to track multiple pathogens simultaneously and pivot quickly to new threats. The system should be as equitable as possible across population demographics, with efforts to engage underrepresented communities and extrapolate findings, where feasible, to unsewered communities. Integration includes coordination and collaboration across multiple partners (e.g., utilities, laboratories, and public health agencies) and triangulation of data from different disease surveillance systems. For the information to be actionable, it must also be timely, available, reliable, representative, and interpretable. Finally, the system needs to be fiscally and operationally sustainable.

When evaluating potential targets for future wastewater surveillance, CDC should consider three criteria: (1) public health significance of the threat, (2) analytical feasibility for wastewater surveillance, and (3) usefulness of community-level wastewater surveillance data to inform public health action. Assessment of the public health significance of a microbial threat is important to develop and maintain a system that is responsive to current public health needs. Assessment of the feasibility to detect a specific pathogen in wastewater for disease surveillance is necessary to determine technical readiness and can also drive research or technology development for microbial threats that meet the other criteria. Finally, it is critical that the value of wastewater surveillance information be considered in the context of the broader universe of surveillance approaches so as to maximize the use of resources to inform public health action.

Temporal and spatial resolution of the NWSS sampling program should be subject to intentional design, informed by rigorous and iterative analysis of data for prioritized pathogens. Temporal and spatial resolution should be regularly re-evaluated to ensure the system is capable of detecting meaningful change with sufficient lead time needed to inform public health action. CDC should also give careful attention to the need for more representative sampling for prioritized use cases. Because 16 percent of the U.S. population resides in unsewered communities, wastewater surveillance in and of itself cannot be fully representative of the population but should be viewed as one key component of a national infectious disease surveillance system.

CDC should take additional steps to bring the benefits of wastewater surveillance to critical areas not addressed by the NWSS. Steps CDC could take to ensure that resources expended on wastewater surveillance systems are not distributed inequitably include (1) creating a comprehensive outreach program about the potential benefits of joining the national system; (2) reducing financial and staff capacity barriers to joining the system; and (3) assessing whether tools can be used to extrapolate data from monitored regions to estimate disease burden in areas without wastewater surveillance.

As part of a national wastewater surveillance system, strategic incorporation of sentinel sites is recommended as a mechanism for early detection. Sites that can directly inform community wastewater-based surveillance, especially as related to emerging pathogens, will provide important and distinct benefits in the context of a national surveillance network. Such sentinel sites could include wastewater surveillance at major international airports or zoos to monitor for specific emerging pathogens at their points of entry.

STRATEGIES FOR ACHIEVING THE VISION

To achieve the committee's vision for a national wastewater surveillance system beyond COVID-19, CDC should develop an open and transparent process for prioritizing targets for wastewater surveillance. CDC would benefit from an independent external advisory panel, with representation from industry, academia, and public health, to provide periodic guidance and input to this process and also create processes for public input. Although the committee judges that the benefits of responsibly managed wastewater surveillance outweigh the associated ethical concerns, CDC should address privacy concerns through clear public communication and by convening an ethics advisory committee.

Importantly, the effectiveness of the NWSS will depend on predictable and sustained federal investments. The COVID-19 pandemic emergency spurred many researchers and utilities to volunteer their labor and donate resources in support of the effort, but the vision of a sustained national wastewater surveillance system necessitates a shift from volunteerism to a strategic national plan with well-defined roles supported by federal investments. Federal funding is needed to continue to advance sampling and analysis methods and tools and maintain workforce capacity. Federal funding also helps support coordination among public health agencies, analytical laboratories, and wastewater utilities that is essential to generating reliable data and support its interpretation and use. Additional CDC engagement with the scientific community would drive innovation and ensure that a trained workforce can meet current and future needs of the broad national system.

COMMITTEE ON COMMUNITY WASTEWATER-BASED INFECTIOUS DISEASE SURVEILLANCE **GUY H. PALMER (NAM),** *Chair*, Washington State University; **AMI S. BHATT,** Stanford University; **MARISA C. EISENBERG,** University of Michigan; **RAUL A. GONZALEZ,** Hampton Roads Sanitation District; **CHARLES N. HAAS (NAE),** Drexel University; **LOREN P. HOPKINS,** Houston Health Department and Rice University; **NA'TAKI OSBORNE JELKS,** Spelman College; **CHRISTINE K. JOHNSON (NAM),** University of California, Davis; **ROB KNIGHT,** University of California, San Diego; **SANDRA L. McLELLAN,** University of Wisconsin–Milwaukee; **MICHELLE M. MELLO (NAM),** Stanford University; **JOHN SCOTT MESCHKE,** University of Washington; **REKHA SINGH,** Virginia Department of Health; **EERAJ SOOD,** University of Southern California; **KRISTA WIGGINTON,** University of Michigan

STUDY STAFF **STEPHANIE E. JOHNSON,** Study Director; **KATALYN VOSS** (until June 2022); **ALEXIS WOJTOWICZ** (starting July 2022); **CALLA ROSENFELD** (until May 2022); **PADRAIGH HARDIN** (starting May 2022)

FOR MORE INFORMATION

This Consensus Study Report Highlights was prepared by the National Academies based on the Consensus Study Report *Wastewater-based Disease Surveillance for Public Health Action* (2023).

The study was sponsored by the U.S. Centers for Disease Control and Prevention. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

This Consensus Study Report is available from the National Academies Press (800) 624-6242 | http://www.nap.edu | http://www.national academies.org

To read the full report, please visit http://www.nationalacademies.org/dels.

Division on Earth and Life Studies
Health and Medicine Division

NATIONAL ACADEMIES *Sciences Engineering Medicine*