Wastewater Surveillance for Infectious Diseases

Use Cases
Practices &
Challenges

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Wastewater Surveillance for Infectious Diseases: Use Cases, Practices, and Challenges

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Executive Summary

Wastewater surveillance is an increasingly important public health tool, particularly for monitoring infectious diseases. Historically used primarily for poliovirus surveillance, the COVID-19 pandemic demonstrated the broader value of wastewater surveillance as a complement to traditional surveillance systems. During the pandemic, wastewater data enabled earlier detection of shifts in SARS-CoV-2 transmission trends and captured populations typically missed by clinical testing. This provided public health authorities with more timely and inclusive information to support targeted public health actions. Since its widespread use during the pandemic, health authorities have used wastewater to monitor other infections, such as influenza, measles, and mpox.

Despite its growing use, more work is needed to optimize the impact of this surveillance tool and its influence on public health decision making. The goal of this report is to define the most promising use cases for wastewater surveillance of infectious diseases, provide a high-level overview of the current state of implementation, and identify key challenges that must be addressed and opportunities to optimize its role in public health monitoring.

Although wastewater surveillance approaches vary by geographic context, we identified common lessons in implementation and use that can inform programs across diverse settings. To identify these lessons, we examined wastewater surveillance use cases from low-, middle-, and high-income countries, drawing on a sample of publicly available information and key informant interviews. This report highlights examples from 11 countries representing a variety of geographic and socioeconomic contexts: Bangladesh, Denmark, England, Ghana, India, Nepal, the Netherlands, the Philippines, Senegal, South Africa, and the United States of America.

Central to the continuation and expansion of wastewater surveillance is the funding landscape. This report describes key aspects of wastewater surveillance funding, including major funders, evolving funding paradigms, and evidence on cost effectiveness from both public health and national security perspectives. To date, wastewater surveillance has been supported largely through time-limited funding streams, including philanthropic investments and temporary government allocations, many of which originated during the COVID-19 pandemic. This report reviews the current funding landscape and highlights the need for more stable and sustained investment.

While evidence on the cost-effectiveness of wastewater surveillance is limited, the available findings summarized in this report suggest that it can reduce costs relative to surveillance systems that rely solely on clinical surveillance. It can also contribute to reductions in morbidity and mortality. Additional cost-benefit analyses are needed to strengthen the economic case for wastewater surveillance, particularly as funding declines and many programs are forced to scale back operations.

Introduction

Wastewater surveillance represents a promising yet evolving approach to monitoring infectious diseases and informing public health responses. Although it has long been used to track poliovirus and other enteric pathogens, its application for other epidemic- and pandemic-prone diseases has expanded considerably since the COVID-19 pandemic. Today, many wastewater surveillance programs are being used to track a wide range of pathogens, including but not limited to measles, mpox, dengue virus, respiratory syncytial virus, and antimicrobial resistance genes. This flexible tool has proven valuable for supplementing traditional surveillance for a number of diseases and conditions of importance to public health–from global pandemics and local outbreaks to seasonal fluctuations of endemic infections.

Wastewater surveillance programs utilize a range of analytical approaches to detect and characterize pathogens. Some rely on traditional methods such as microbiological culture and real time polymerase chain reaction (PCR), while others incorporate newer technologies like droplet digital PCR (ddPCR) and high throughput sequencing methods such as metagenomic or target-based genomics. In some systems, these tools are used in combination to balance speed, sensitivity, and breadth of detection. However, the choice of methods often depends on available resources, infrastructure, and surveillance goals, which varies across different settings.

Although wastewater surveillance is increasingly routine in public health, key knowledge gaps and operational challenges limit its ability to improve public health surveillance and support timely decision-making. For example, unresolved scientific questions, such as how wastewater data relates to the number of human infections, can limit confidence in the data and hinder its use in public health decision making. Few studies have rigorously analyzed or validated the cost effectiveness of wastewater surveillance. Additionally, many wastewater surveillance programs have been subject to the "boom-bust" cycle that is common in public health, with funding and investment surging during crises, such as the COVID-19 pandemic, but waning when immediate threats subside. Further, some decision makers remain skeptical about the practical value of wastewater surveillance, as there is limited documented evidence showing how wastewater data has directly informed public health action. Finally, fragmented engagement across implementing partners, inconsistent data policies, and weak cross-sector coordination further complicates the translation of wastewater data into public health action.

For wastewater surveillance to reach its full potential, these questions must be addressed. This white paper consolidates current knowledge to provide a high-level overview of the major use cases for wastewater surveillance, identify key knowledge gaps– such as return on investment and implementation challenges– and outline priorities for strengthening wastewater surveillance programs globally.

Wastewater Surveillance Context

- Traditional tool originally used for polio surveillance in the 1930s, useful for asymptomatic infections as it does not depend on a sick person seeking clinical testing
- Historically recognized as a potential method of early identification of circulating pathogens
- Refined and expanded recently, with method and array of detectable pathogens advancing since the 1990s
- Wastewater surveillance infrastructure took off globally during the COVID-19 pandemic, strongly mirroring trends in clinical surveillance data
- Polymerase chain reaction (PCR), culture, and genomic sequencing, among other methods, are now employed in over 3,000 monitoring sites across 58 countries

Methodology

For this analysis, we employed a mixed methods approach. We reviewed peer-reviewed scientific literature, focusing on publications from 2020 and later. We also reviewed the gray literature to identify reports from government agencies, philanthropic organizations, multilateral organizations, conference proceedings, and surveillance dashboards.

To complement the literature, we conducted unstructured interviews with experts involved in wastewater surveillance programming. Much of the information about these programs is not publicly available or documented online, making direct engagement essential to capture on-the-ground realities. Interview participants included public health officials, academics, research scientists, and program implementers with direct experience establishing or operating wastewater surveillance programs. These interviews provided insight into operational challenges, decision-making processes, and ongoing wastewater surveillance activities often absent from published sources.

Brief case studies were developed by synthesizing findings from the literature review and expert interviews. This mixed-methods approach enabled us to capture both the technical evidence base and the practical implementation realities of wastewater surveillance across low-, middle-, and high-income settings. These case studies are not meant to be an exhaustive representation of all nations that conduct wastewater surveillance. Comprehensively, they form a representative mix of low-, middle-, and high-income nations in which wastewater surveillance use cases have been well-documented through expert interviews or publicly accessible literature.

Wastewater Surveillance Methods

Wastewater surveillance programs employ a range of analytical methods, with the choice of tools shaped by the program's objectives and operational context. Multiple complementary approaches exist for pathogen detection, characterization, and quantification in wastewater samples, each offering distinct advantages and limitations that must be carefully considered when designing surveillance systems.

While molecular methods like quantitative PCR provide rapid, sensitive detection of pathogens, culture-based approaches are often more feasible in low-resource laboratory settings. Additionally, genomic sequencing can provide more detailed information about the pathogen of interest, such as phylogeny, but require greater technical expertise and infrastructure investments. Understanding the operational characteristics and performance trade-offs of available tools is essential for developing sustainable wastewater surveillance programs that align with local laboratory capacity and public health priorities. The following table outlines key characteristics of commonly used wastewater surveillance methods. While additional approaches exist, the table focuses on those most widely applied.

Wastewater surveillance methods

Method	Method Description	Advantages	Disadvantages
Amplicon-based sequencing	Sequences specific genes or genomic regions of interest	Can detect variants and mutations; provides phylogenetic information; more comprehensive information on target pathogen	Requires knowledge of target pathogen beforehand; library preparation is typically time and labor intensive
Culture	Grows viable bacteria and other microorganisms using selective media	Detects only living infectious organisms; feasible in most microbiological labs globally	Results not available for days to weeks; cannot detect non-culturable organisms; largely limited to bacteria
Droplet Digital PCR (ddPCR)	Absolute quantification of gene targets by partitioning samples in thousands of droplets for PCR amplification	Provides absolute quantification; highly precise; less affected by PCR inhibitors; good for low abundance targets	Lower throughput than qPCR; more expensive than qPCR; requires specialized equipment
Hybridization capture targeted sequencing	Probes hybridize to region of interest and enrich for targeted sequencing	Allows you to sequence genes from multiple pathogen targets simultaneously; can detect mutations in specific genes	Only sequences pieces of DNA, not full genome; requires knowledge of target gene beforehand
Loop-mediated isothermal amplification (LAMP)	Amplifies nucleic acids	Simpler alternative to PCR; Short turnaround time; tolerant to some PCR inhibitors; potential for low-cost and field-deployable applications	Limited multiplexing capability; primarily qualitative or semi-quantitative; less standardized for wastewater surveillance than other methods
Metagenomic sequencing	Sequences all genetic material in a sample	Captures known and unknown pathogens; no prior knowledge of target needed; provides comprehensive community profiling	Expensive; low abundance targets (such as emerging variants) may be missed; requires significant computational resources and expertise
Quantitative PCR (qPCR)	Amplifies and quantifies specific DNA/RNA sequences in real-time using fluorescent probes	Fast results (hours); highly sensitive and specific; high throughput when using TaqMan array cards	Susceptible to inhibitors found in wastewater; does not provide absolute quantification, only relative quantification

Table 1. Wastewater surveillance methods.

Infectious Disease Use Cases for Wastewater Surveillance

Wastewater surveillance supports diverse applications, from outbreak detection to routine disease monitoring. The following table summarizes examples of pathogen targets and use cases that are currently implemented or piloted in various countries, rather than an exhaustive list of all possible applications. It highlights common targets and well-documented use cases, along with information on their primary public health applications, validation status, geographic implementation, demonstrated impact, protocol availability, and key implementation considerations. "Validation Status" indicates evidence supporting pathogen detectability in wastewater and correlation with clinical data.

- **Extensively validated**: There is strong and consistent evidence, across multiple studies and settings, that the pathogen can be reliably detected in wastewater and that trends closely correlate with clinical case data. These use cases have been widely adopted and integrated into public health decision-making.
- **Well established**: Multiple studies support the pathogen's detectability in wastewater and its potential for public health use, and some public health programs have adopted it. However, broader validation across diverse settings or full integration into routine surveillance may still be in progress.
- **Proof of concept**: Initial research shows that the pathogen is detectable in wastewater and may correlate with clinical trends, but evidence is still limited. These use cases have not yet been adopted widely, and further studies are needed to confirm reliability and public health utility.

Table 2. Common use cases for wastewater surveillance of pathogens

Common use cases for wastewater surveillance of pathogens

Target	Application	Validation Status	Region of Use	Impact of Use	Established Protocols	Notes
Antimicrobial resistance genes	Endemic monitoring	Proof of concept National Library of Medicine Science of The Total Environment Nature Reviews Microbiology	Multiple countries	Understanding AMR burden in communities	Several protocols available for various genes	Increasing attention; methods developing, lacks standard interpretation
Candida auris	Outbreak response	Proof of concept National Library of Medicine	United States	Monitoring antifungal resistant pathogens	Yes	Detected in wastewater solids, tracked by WastewaterSCAN in the US
Chikungunya virus	Emerging pathogen surveillance	Proof of concept The Lancet Microbe	Americas, Asia	Detection of community-level circulation during outbreaks	Developing	—

Target	Application	Validation Status	Region of Use	Impact of Use	Established Protocols	Notes
Chlamydia trachomatis	Endemic monitoring	Proof of concept ACS ES&T Water MDPI	North America, Europe	Monitoring STI prevalence trends at the community level	No	—
Crypto-sporidium spp.	Endemic monitoring	Proof of concept Springer	North America, Europe	Early indication of protozoal contamination and outbreak risk	Developing	—
Dengue	Emerging pathogen surveillance	Proof of concept The Lancet Microbe National Library of Medicine Environmental Challenges	North America, Europe, Asia	Detection of arboviral circulating	Developing	Dengue has low shedding rates, so may require increased sampling frequency
Disease "X"	Epidemic/ Pandemic preparedness or biological attack detection	Proof of concept National Library of Medicine Environmental Science & Technology Letters	—	Early warning for unknown pathogens	No	Metagenomic approaches for unknown pathogen detection; WHO priority
Enterovirus 68	Respiratory surveillance	Well established National Library of Medicine American Soiciety For Microbiology Science of The Total Environment	Multiple countries	Monitoring severe respiratory illness outbreaks	Yes	Like polio, enterovirus 68 can cause acute flaccid myelitis, leading to sudden paralysis
Giardia dudenalis	Endemic monitoring	Proof of concept Springer	Multiple countries	Monitoring community-level exposure to waterborne parasites	Developing	High environmental persistence; interpretation can be influenced by background contamination

Target	Application	Validation Status	Region of Use	Impact of Use	Established Protocols	Notes
Hepatitis A	Outbreak response	Well established National Library of Medicine Water Research	Multiple countries	Early warning for HAV outbreaks	Yes	Successful outbreak detection; correlation with clinical cases
Human Immunodeficiency Virus (HIV)	Endemic monitoring and drug resistance surveillance	Proof of concept Science of The Total Environment MDPI	Africa, Europe	Monitoring transmission trends and antiretroviral resistance markers	No	Ethical and data governance considerations are critical
Human metapneumovirus	Respiratory surveillance	Well established National Library of Medicine	Multiple countries	Complementary respiratory pathogen monitoring	Yes	—
Influenza A viruses	Pandemic/ outbreak response	Well established Science of The Total Environment National Library of Medicine Water Research	Multiple countries	Population level monitoring; subtype verification (H1, H3, H5)	Yes	Validated for seasonal surveillance and pandemic preparedness
Influenza B viruses	Pandemic/ outbreak response	Well established National Library of Medicine National Library of Medicine	Multiple countries	Seasonal outbreak tracing	Yes	Complementary to influenza A surveillance
Measles virus	Pandemic/ outbreak response	Well established Science of The Total Environment American Journal of Public Health National Library of Medicine	United States	Early warning for outbreaks and guidance for resource allocation	Yes	The US is tracking the virus in wastewater via WastewaterSCAN and NWSS; Texas and Utah State Health Departments have also been conducting surveillance; As of 2025, wastewater surveillance serves as the primary method for tracking measles in the US.

Target	Application	Validation Status	Region of Use	Impact of Use	Established Protocols	Notes
Mpox (clades Ib & II)	Pandemic/ outbreak response	Well established The New England Journal of Medicine Journal of Travel Medicine Journal of Travel Medicine	Multiple countries	Early detection of community transmission	Yes	Successful detection in wastewater during outbreaks
Neisseria gonorrhoeae	Endemic monitoring	Proof of concept ACS ES&T Water MDPI	North America, Europe	Population-level estimation of STI burden and trends	No	—
Norovirus	Outbreak response	Well established Emerging Infectious Diseases Water Research	Multiple countries	Gastroenteritis outbreak tracing	Yes	—
Poliovirus	Vaccination coverage assessment	Extensively validated National Library of Medicine National Library of Medicine National Library of Medicine	Multiple countries	Established wastewater surveillance as a reputable tool for surveillance (early warning and monitoring of vaccine strains after immunization campaigns)	Yes	Long history of environmental surveillance; WHO endorsed
Respiratory Syncytial Virus (RSV)	Pandemic/ outbreak response	Well established ACS ES&T Water National Library of Medicine Science of The Total Environment	Multiple countries	Early detection of community transmission	Yes	Strong correlation with clinical cases; seasonal monitoring
Rotavirus	Gastroenteritis surveillance	Well established National Library of Medicine PMC - Cureus	Multiple countries	Childhood illness monitoring	Yes	—

Target	Application	Validation Status	Region of Use	Impact of Use	Established Protocols	Notes
Salmonella Typhi	Endemic monitoring	Proof of concept National Library of Medicine Public Library of Science National Library of Medicine	Africa	Foodborne pathogen tracking	Developing	—
SARS-CoV-2	Pandemic/ outbreak response	Extensively validated	Multiple countries	Accelerated the development and implementation of wastewater surveillance to track high-consequence pathogens	Yes	Widely used globally; strong correlation with case data
Vibrio cholerae	Endemic monitoring and outbreak response	Proof of concept Water & Health	Africa, South Asia, Southeast Asia	Early detection of cholera circulation and outbreak risk; informs targeted vaccination and WASH interventions	Yes	—
West Nile virus	Emerging pathogen surveillance	Proof of concept National Library of Medicine	North America, Europe	Monitoring regional circulation of mosquito-borne pathogens	Developing	Detection may reflect both human and animal sources
Zika virus	Emerging pathogen surveillance	Proof of concept Water Research eBio Medicine	Americas	Early detection of community transmission during outbreaks	Developing	Low shedding rate, may require frequent sampling

Global Approaches to Wastewater Surveillance: Systems, Capacity, and Context

Since the COVID-19 pandemic, many countries have established national wastewater surveillance programs that integrate data from multiple cities and regions. These surveillance programs are often implemented by a mix of government, academia, nonprofit organizations, and the private sector whereas the funding can range from government allocation, grants, multilaterals, and the private sector. Given the diversity of implementing organizations, it is difficult to determine exactly how many countries currently conduct wastewater surveillance. Nonetheless, the global landscape demonstrates that a range of institutional arrangements can sustain effective systems.

Several factors can accelerate the development and implementation of wastewater surveillance systems. Adequate laboratory capacity, access to molecular and genomic equipment and materials for pathogen detection and characterization, and capacity building for implementers, end-users, and public health officials are major enablers. Additionally, stable and sustained funding also plays a key role in maintaining surveillance activities.

The structure of local sanitation infrastructure plays an important role in determining how wastewater surveillance systems can be implemented. Centralized wastewater infrastructure facilitates sampling from well-defined catchment areas and enables routine use of composite samples, which are often more representative of the communities sampled. In many low- and middle-income countries (LMICs), however, decentralized wastewater systems are the norm. Although these systems introduce additional complexity, they do not prevent effective wastewater surveillance. When few households are connected to centralized sewer networks, surveillance can provide valuable insight by focusing on sewage-impacted water bodies areas rather than aiming for full population coverage. Because waste streams in decentralized systems may come from smaller or less mixed populations, sample representativeness can vary. Even so, grab samples have proven effective for detecting pathogens like SARS-CoV-2 and poliovirus in low-, middle-, and high-income settings. Passive samplers and other tools can enhance signal capture when available but are not always necessary. Rather than serving as a barrier, decentralized systems simply require sampling strategies tailored to the local sanitation context, which can still yield meaningful public health insight

As wastewater surveillance continues to expand, important operational and strategic challenges remain. The value of wastewater surveillance increases substantially when linked to specific mitigating actions that can be taken by decision-makers. However, relatively little work has focused on practical use cases for wastewater surveillance. There remains a need for literature that clearly articulates how wastewater surveillance can be operationalized. Moreover, while wastewater surveillance is widely regarded as cost-effective, there is a lack of comprehensive studies evaluating its return on investment.

Translating Wastewater Data into Public Health Action

Countries are increasingly using wastewater data to guide targeted responses to emerging health threats, though the evidence base for its impact remains underdeveloped. Research is ongoing to better understand how wastewater data informs public health decision making, but the examples below illustrate how countries are already using wastewater surveillance to guide timely and targeted responses to emerging health threats. However much of this information remains unpublished or inaccessible, highlighting a critical need for more documented evidence linking wastewater surveillance to specific public health actions.

Monitoring trends of high burden illness to inform community-wide interactions

Many countries adopted wastewater surveillance to augment traditional public health surveillance during the pandemic. In areas where there were surveillance gaps or widespread at-home testing, wastewater became an important way to track trends in community infections.

Across several U.S. states, wastewater data has been used to inform local decision making and public health action. In Ohio, for example, a tenfold increase in SARS-CoV-2 concentrations in wastewater automatically triggered alerts to local and state public health departments, utilities, and community leaders. Within affected areas, the state offered local health departments additional testing, vaccination, and contract tracing support. In Utah, wastewater data were used to rank local municipalities, helping decision makers prioritize where to send resources. Similarly, in Oklahoma, zip codes with elevated SARS-CoV-2 levels in wastewater were identified Local school districts used this information to conduct targeted outreach to parents in affected areas, encouraging testing and vaccination for both children and families. Hospitals and health departments complemented these efforts with localized testing and vaccination campaigns.

Similar uses of wastewater data emerged in LMICs. In Bangladesh, Dhaka's COVID-19 task force reviewed a COVID-19 wastewater dashboard weekly to inform decision making during the pandemic. Wastewater data guided actions such as relocating testing sites and, in instances where clinical testing data were limited, to support decisions regarding potential shutdowns.

These are just a few examples that demonstrate the versatility and value of wastewater surveillance as an actionable public health tool. However, more documented cases are needed to demonstrate its impact and build confidence in its use.

Early detection of rare pathogens

Countries are also using wastewater surveillance for early detection of more rare pathogens. In Ghana, wastewater monitoring of poliovirus triggered targeted vaccination campaigns to prevent community transmission. Israel's wastewater surveillance program detected a polio outbreak months before any clinical cases were detected. This early warning enabled public health officials to rapidly execute a vaccine campaign before any cases of acute paralysis. In the United States, wastewater surveillance has become a critical tool for tracking measles. Public health response efforts to the 2025 measles outbreak have been hampered by individuals' unwillingness to undergo testing and some communities' reluctance to disclose infections, resulting in widespread underreporting of cases. Consequently, wastewater surveillance now serves as the primary source of reliable data on measles activity. When measles is detected in wastewater, the CDC collaborates with state and local health departments to determine whether any individuals have developed symptoms or have been diagnosed with the virus. Together, they decide on next steps, such as alerting local healthcare providers to potential cases, increasing public outreach and education, and conducting vaccination clinics.

Spatiotemporal monitoring of pathogens to prompt investigation and trigger industry

Translating wastewater data into public health action also presents challenges. Wastewater signals can be difficult to interpret, as seen during the recent H5N1 outbreak in the United States. Many wastewater detections of the virus were linked to animal waste, not human infections, limiting the ability of public health officials to act on observed trends. Although early warning in such a context could theoretically enable local farmers to intensify investigations on their farms and prompt local health departments to increase human case investigations, such action pathways have not yet been clearly defined.

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It is important to emphasize that wastewater surveillance not only supports specific public health actions but also generates broader situational insight. Like any other surveillance system, it functions as one data source among many, offering a critical piece of information that becomes most valuable when integrated with other indicators. In practice, public health decisions are typically driven by the synthesis of multiple data streams rather than one surveillance source alone.

Examples of Public Health Responses Informed by Wastewater Data

- Targeted vaccination campaigns guided by spatiotemporal trends in wastewater
- Intensified diagnostic testing in areas with elevated signals
- Preparing medical facilities for a potential influx of patients
- Promoting non-pharmaceutical interventions including but not limited to improved sanitation and hygiene, mask use, and social distancing
- For zoonotic pathogens, early engagement with relevant partners to strengthen biosecurity measures

For detailed country-level case studies detailing how wastewater surveillance has been implemented across a range of geographic and socioeconomic settings, see the appendix.

Current & Future Funding Landscape

Various philanthropic organizations have invested in advancing wastewater surveillance initiatives globally. The Bill and Melinda Gates Foundation, for example, has funded research and implementation efforts in countries such as South Africa, Ghana, and India. Other major funders, including Global Fund, World Bank, Rockefeller Foundation, Wellcome Trust, and Asian Development Bank, have supported wastewater surveillance in several countries throughout the world. The United States' Agency for International Development was also previously invested in wastewater surveillance projects in countries such as Jordan and Ivory Coast. In the United States, WastewaterSCAN, the second largest public wastewater monitoring program in the country, is supported by the Sergey Brin Family Foundation and Bloomberg Philanthropies. Together, these examples illustrate a funding landscape that is diverse but largely project-based, with limited long-term sustainability.

Beyond philanthropic support, wastewater surveillance programs in some countries are funded by local or national health agencies. However, many of these programs rely on temporary funding mechanisms established during the COVID-19 pandemic. For instance, the United States' National Wastewater Surveillance System is funded primarily through supplemental COVID-era funding.

As a result, wastewater surveillance programs have been affected by the “boom-bust” cycle that often characterizes global health investments. As the urgency of the COVID-19 pandemic has waned, many government and philanthropic organizations have scaled back their wastewater surveillance activities and funding. In Switzerland, for instance, the national wastewater surveillance program was reduced from monitoring 117 WWTPs at its peak to just 10 as of January 2026. Additionally, Ontario, Canada ended its wastewater surveillance initiative in 2024. Patterns like these have been reflected in several other countries.

This funding instability persists despite growing recognition of the value of wastewater surveillance. There remains limited evidence evaluating its cost-effectiveness and return on investment, constraining efforts to justify long-term funding. Further economic assessments are needed to inform sustained funding and support its long term integration into public health systems.

In addition to being a means of protecting public health, wastewater surveillance is also a means of bolstering and protecting national security. This is important to note as funding paradigms are increasingly shifting toward a prioritization of national security. By acting as an early warning system, wastewater surveillance at airports and other common national entry points can provide real-time warnings to countries about pathogen spread, illicit drug use, antimicrobial resistance, and potential instances of bioterrorism. Having robust wastewater surveillance infrastructure allows countries to detect and respond to biological security threats more swiftly and efficiently.

Return on Investment

The return on investment for implementing a wastewater surveillance program is not well-documented, though evidence from the COVID-19 pandemic offers promising initial insights. Researchers have shown that wastewater surveillance is more cost-effective than clinical testing at the population scale. One study found that wastewater surveillance was $10.5-$18.5 million USD less expensive annually in direct costs than clinical swab testing surveillance. Other studies have shown that wastewater surveillance provides positive return on investment through decreased hospitalization and morbidity rates.

A compelling example comes from a wastewater surveillance study conducted in Nepal and Malawi, which demonstrated wastewater surveillance annual costs of only $0.07 to $0.13 per person in a catchment area per year. The study also highlighted that for wastewater surveillance to be a worthwhile investment, systems must monitor multiple pathogens simultaneously. One of the most compelling features of wastewater surveillance is its capacity to detect a wide range of threats, such as viruses, antimicrobial resistant bacteria, sexually transmitted infections, and even chemical exposures like opioids, all from a single sample. This versatility creates opportunities for cross-sectoral funding models that can enhance long-term sustainability.

Economic modeling by de Lima et al demonstrated the value of wastewater surveillance for pandemic preparedness. The study modeled the economic benefits of wastewater surveillance during the first year of a new pandemic, and showed that under baseline assumptions, wastewater surveillance provides a 5-day early warning relative to syndromic surveillance. This early detection capability translates to significant health and economic benefits: the model showed that wastewater surveillance can reduce deaths from 149 to 134 per 100,000 population in the first year. These mortality reductions combined with reduced intervention costs and economic disruption, result in a net monetary benefit of approximately $1,450 per person. The analysis also suggests that wastewater surveillance provides net-positive benefits for long-term surveillance.

However, many existing programs rely on philanthropic donations, short-term government funding, and/or other grants, making them vulnerable as global health financing experiences significant cuts across the board. Wastewater surveillance presents a promising approach to help fill the surveillance gaps that are likely to emerge as public health faces resource reductions. However, this promise must be backed by evidence. To ensure long-term sustainability and attract investment, health ministries, donors, and international finance institutions need a clearer understanding of the economic case for wastewater surveillance.

Wastewater Surveillance for Detecting Disease X

The risk of disease outbreaks caused by novel pathogens is increasing. As globalization accelerates and climate change alters ecosystems, causing more frequent human-animal interactions, the risk of infectious disease spillover and global pandemics continue to increase. The global expansion of biological research raises concerns about the potential for accidental release of novel pathogens if adequate biosafety and security measures are not in place. Further, the rapid development of artificial intelligence, synthetic biology tools, and the availability of benchtop sequencers has increased the feasibility of a nefarious actor designing and releasing a novel pathogen. There is a critical need for tools that can detect novel, high-consequence threats – often termed “Disease X” – early.

While wastewater surveillance has proven effective for monitoring known pathogens, its potential for detecting Disease X remains largely untapped. Wastewater represents a pooled community sample, making it well suited to detect new diseases spreading within a population, especially when paired with pathogen agnostic technologies such as metagenomic sequencing. However, wastewater often contains heavily fragmented nucleic acids, which makes recovering the whole genome of a novel pathogen unlikely. Instead, routine surveillance of wastewater using metagenomic sequencing could help establish baselines of biological markers, representing typical community conditions. Significant deviations from these baselines may serve as early indication of the emergence of a novel target. Maintaining routine surveillance also preserves critical capacity– including workforce expertise, laboratory infrastructure, and supply chains– enabling faster scale-up of operations during outbreaks.

Wastewater surveillance also has potential applications in biosecurity, particularly for investigating deliberate biological threats. By identifying geographic entry points and tracking transmission dynamics, wastewater data can support outbreak investigations and help distinguish between natural emergence and intentional release.

An additional advantage of metagenomic sequencing is the ability for retrospective analysis: once a new pathogen is identified and its genome sequence is known, researchers can search through archived wastewater data to determine when it first appeared in a community. Together these capabilities highlight the potential of wastewater surveillance as a tool for early detection of Disease X. However, realizing this potential requires overcoming significant technical and operational challenges.

Wastewater is a highly complex matrix, and as a result, most metagenomic sequencing reads are unclassifiable. Ongoing research efforts, including those exploring the use of artificial intelligence to better categorize known and unknown reads, show promise, but the field has not yet reached that level of capability.

Additionally, discovering an unusual or novel sequence in wastewater raises complex questions about the verification process and decision-making thresholds. Detecting an unusual signal that may indicate a novel pathogen in wastewater is only the first step. The next challenge is verification: confirming that the signal truly represents a new, high-risk pathogen. This process would likely depend on integrating wastewater data with other surveillance sources, such as syndromic surveillance, in the respective communities. A convergence of signals across surveillance systems could strengthen confidence that a new pathogen is circulating. Establishing clear frameworks and quality assurance protocols to guide interpretation and validation will be essential for translating wastewater data into reliable public health intelligence.

Once wastewater indicates the presence of a potential novel pathogen, the next challenge lies in determining how to respond. What threshold of evidence should trigger public health action, and who is responsible for making that decision? Clear frameworks are needed to guide this type of high-consequence decision making. Developing surveillance tools is only part of the solution – equal attention must be given to translating wastewater findings into actionable data that can inform timely and proportionate responses.

It is also critical to consider how pathogen agnostic surveillance via wastewater can be adapted for use in LMICs. Large-scale implementation of next generation sequencing in LMICs remains limited for various reasons, including high costs, supply and logistics challenges, a shortage of trained personnel, and limited access to the bioinformatic tools necessary for data analysis. Investing in these capabilities in LMICs is essential to strengthening global health security and ensuring that surveillance efforts are effective.

It is important to recognize that wastewater surveillance does not function equally well as an early warning system for all pathogens. Sensitivity is strongly influenced by pathogen-specific factors, such as fecal shedding rates. Pathogens with high fecal shedding rates can often be detected in wastewater at low community prevalence, whereas pathogens with lower or more variable shedding may be difficult to detect until transmission is more widespread. These differences have important implications for early detection of emerging threats, as wastewater signals from some pathogens may only become detectable once a substantial proportion of the population is infected.

Key Limitations & Opportunities

While wastewater surveillance is a powerful tool with significant potential for infectious disease monitoring, there are limitations that must be addressed.

Lessons from Biowatch:
The Importance of Operational Readiness

The U.S. BioWatch Program, implemented in 2003, offers an important cautionary example for biosurveillance system design. Although BioWatch deployed advanced environmental detection technology across multiple cities, the program faced persistent operational challenges that were viewed as limits to its success. These included questions about costs, delayed time-to-results, equipment challenges, and limited integration with public health decision making.

Several of these challenges had significant consequences. Jurisdictional ambiguity was a major issue: when a positive detection occurred, it was unclear whether local or federal authorities held decision-making responsibility. Terrorism is a federal concern, but local governments operated equipment, managed the laboratories, and faced the immediate public health consequences of any alert. Another problem arose from the technology itself. Because local laboratories were not consulted in the design process, BioWatch was poorly aligned with their infrastructure and needs. This created resistance from local labs and meant that operational procedures varied from site to site, undermining the consistency that the program desired.

Unresolved implementation questions led to multiple external reviews and governmental oversight hearings. For example, In 2011, the National Academy of Science/Institute of Medicine published a review of the system that concluded that Biowatch “needs better technical and operational testing to establish its effectiveness. It also needs better collaboration with public health systems to improve its usefulness.”

Challenges in the implementation of Biowatch underscore the importance of addressing operational considerations and engaging with end-users before large scale system deployment.

Quantifying Infection Numbers

Converting wastewater surveillance data into accurate estimates of the number of infected individuals is a complex challenge. The conversion requires information that is difficult to ascertain and may vary by individual, such as pathogen density in feces and fecal production rate. The process also requires data that varies based on the wastewater system, like decay rates during transit in sewer lines. This gap between wastewater surveillance data and number of infections can make it challenging for public health officials to interpret and act on wastewater surveillance data.

Although wastewater surveillance data cannot be translated into the number of infected individuals at scale, it offers valuable insight that complements and guides traditional disease surveillance methods. Scientists can track temporal trends in infections, monitor the circulation of variants, and identify emerging outbreaks. This information provides decision makers with critical situational awareness that can inform targeted interventions.

Source Attribution

A key technical challenge in wastewater surveillance is source attribution. Many WWTPs receive input from animals, such as wild birds, or byproducts from nearby farms. Additionally, decentralized systems are often open and receive input from a variety of sources. This can make it difficult to ascertain whether a wastewater surveillance detection is connected to a human infection or an animal infection.

Despite this limitation, wastewater surveillance remains a powerful tool that can alert public health officials to the presence of a pathogen in a region. Additionally, animal health and human health are closely intertwined, particularly in LMICs where communities often have increased contact with animals. A monitoring system that detects pathogen presence, regardless of source, can be the key between containing an outbreak and facing a pandemic.

Detection Sensitivity

Detection sensitivity is another significant technical challenge. Several factors impact the ability to detect circulating pathogens in wastewater, such as sample collection methods, shedding rate, fecal production rate, analytic tools, and bioinformatics analysis approaches. These factors are particularly consequential during the early stages of an outbreak, when pathogen concentrations in wastewater may be low. For some pathogens, low prevalence and limited shedding can prevent wastewater detection, even when transmission is occurring within a community.

As a result, selecting the appropriate sampling and analytical methods is critical for effective wastewater surveillance implementation.

Recommendations

Establish Action Thresholds

The translation of wastewater surveillance data into effective public health action remains constrained by the lack of consistent benchmarks. Without established thresholds that define when pathogen concentrations or trends warrant specific responses, such as increased diagnostic testing or targeted shutdowns, decision makers will continue to face challenges converting wastewater surveillance data into practical interventions. This gap between data collection and actionable intelligence represents a critical bottleneck in realizing the full potential of wastewater surveillance as a public health tool.

Addressing this challenge requires developing evidence-based action thresholds that can be adapted to local contexts. Criteria for establishing such thresholds may include viral concentration, temporal trends such as duration and magnitude of spikes, and detection frequency. The thresholds can be validated through retrospective analyses that correlate wastewater signals with available clinical case data.

Develop Validated Protocols

In parallel, there is a pressing need for standardized operating procedures (SOPs) across a variety of pathogens. Core processes, such as sample collection or nucleic acid extraction, often vary based on the pathogen of interest, highlighting the importance of validated, adaptable protocols that reduce barriers to implementation. SOPs can also support decision making around the scope of surveillance efforts, including how many and which pathogens to monitor, what analytical tools should be used, how to balance cost with public health impact, and how to define catchment areas, particularly in decentralized wastewater systems. Establishing these guidelines will be essential for expanding and sustaining effective wastewater surveillance programs. The WHO has begun this work, with pilot guidelines currently available for six pathogens. Building on this foundation to develop comprehensive, widely adopted SOPs will accelerate implementation globally.

Develop Response Playbooks

A major barrier to fully integrating wastewater surveillance into public health systems is the gap between wastewater surveillance data and public health response. To address this, public health agencies, researchers, and other relevant partners should collaborate to develop response playbooks that provide clear yet adaptable guidance on how to interpret and act on wastewater data.

These playbooks would serve as practical roadmaps, outlining how wastewater findings can trigger specific action in different scenarios, whether signaling emergence of a novel pathogen, identifying an unusual rise in an endemic disease, or tracking seasonal infection trends. Establishing such protocols would help to shorten the time between detection and response, which is critical for containing outbreaks early.

Response playbooks can also specify actions for different actors based on wastewater detections. For example, if avian influenza is detected in a community, public health authorities could alert local farmers and implement targeted testing or vaccination campaigns. At the community level, public messaging could provide guidance on risk reduction, such as avoiding unpasteurized milk or taking other preventive measures.

Multiple versions of these playbooks should be designed to fit different operational contexts. For example, high-income countries with centralized wastewater systems may require distinct strategies from those in LMICs, where decentralized systems are more common. Developing context-specific playbooks will help to ensure that wastewater surveillance data are not only collected but effectively translated into timely, evidence-based public health action.

The WHO has begun this work by incorporating operational guidance into their interim wastewater surveillance guidelines for surveillance programs. Complementary playbooks that translate these detections into actionable responses for other key actors will help in closing the gap between surveillance and action.

Consistent Programming & Research

Routine wastewater surveillance is important not only for monitoring endemic diseases but also for maintaining an operational baseline, ensuring that the systems, staff, and processes are ready to scale up quickly in response to emerging pathogens. A sustained program creates a “warm base” that enhances public health preparedness.

In parallel, additional research is critical to address key scientific questions. These include understanding how wastewater signals correspond to community-level incidence, determining which pathogens are reliably detectable, and identifying optimal sampling and analytical strategies for diverse pathogens of concern. Addressing these knowledge gaps will improve the interpretability and utility of wastewater surveillance.

Integrate Metagenomics into Wastewater Surveillance Programs

Preparing for a future pandemic caused by an unknown pathogen is a growing global priority. Countries should invest in and integrate metagenomic sequencing into wastewater surveillance to enhance early detection of emerging threats. Metagenomics enables detection of all genomic material present in a sample, allowing both known and novel pathogens to be identified. When applied routinely with wastewater, metagenomics can serve as an early warning system for both reemerging and novel threats.

Recent technological advances have made metagenomic sequencing increasingly affordable and accessible, creating a timely opportunity to strengthen public health surveillance systems, though it still remains a challenge in LMICs. Strategic investment is needed to scale this capability within national and regional wastewater surveillance programs.

To maximize the value of metagenomic data, investment should also extend to AI powered tools that can process large datasets and rapidly detect anomalies. Building this capacity will enable wastewater surveillance programs to transition from a reactive to a proactive model, positioning public health authorities to detect and respond to emerging threats with greater speed and precision.

Bioinformatics Capacity & Infrastructure

Investment in both bioinformatics expertise and computational infrastructure is essential for sustainable wastewater surveillance programs. Genomic sequencing generates large, complex datasets that require specialized analysis to convert raw signals into actionable public health insights. This challenge is two-fold: the analysis process demands bioinformatics training while the computational requirements, particularly when monitoring multiple pathogens simultaneously, necessitates extensive cloud computing resources and data storage. Addressing these interconnected needs requires capacity-building initiatives, including hands-on training programs. Establishing long-term regional training hubs with ongoing mentorship and technical support is essential to build and retain local bioinformatics expertise.

Simultaneously, investment in scalable computational infrastructure and cloud-based platforms is crucial to ensure rapid turnaround times between wastewater collection and interpretable insights. Outsourcing data analysis often causes significant delays and raises data sovereignty concerns.

Enhance Geographic Information Systems for Decentralized Wastewater Systems

Given the prevalence of decentralized wastewater systems in LMICs, investment in advanced Geographic Information Systems (GIS) tools is critical for efficient characterization of catchment areas. While researchers have demonstrated the feasibility of surveillance in these systems, current catchment mapping processes remain labor and time-intensive. Additionally, the cost of acquiring various software licenses and developing decision support systems is often prohibitive in LMICs.

Development of new mapping tools, remote sensing integration, and artificial intelligence-assisted catchment characterization will be essential for scaling surveillance in these regions. Open-source GIS solutions and cloud-based platforms can reduce licensing costs while providing scalable alternatives to proprietary software.

Develop costing tools

Expanding the development and sharing of wastewater surveillance costing tools can support more informed program planning and implementation. Costing tools can support planning and feasibility assessments by helping programs estimate the resources required to implement and sustain wastewater surveillance. These tools allow decision makers to align surveillance goals with available budgets by comparing the costs of methods such as culture, PCR, targeted sequencing, and metagenomic sequencing across different settings. A costing tool is currently being developed by a team at the Indian School of Business for this purpose. By accounting for key inputs including equipment, consumables, personnel, sample throughput, and maintenance, costing tools can inform method selection and program design.

Appendix:
Case Studies of Wastewater Surveillance

Wastewater surveillance is being used to enhance surveillance and inform public health decision-making in a variety of ways in diverse settings. Below represents a cross section of the case studies encountered throughout the preliminary research phase. Work is on-going to document the ways in which countries and sub-national actors are using wastewater surveillance to enhance surveillance and public health decision-making.

Bangladesh

Wastewater surveillance in Bangladesh dates back to 2019, when the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) began developing a multi-pathogen surveillance platform. The initiative aimed to integrate polio environmental surveillance with other relevant targets such as antimicrobial resistance genes and enteric pathogens. Initial efforts focused on poliovirus eradication monitoring in Dhaka, where 12 wastewater sites were monitored for poliovirus before and after a vaccination campaign.

In March 2020, icddr,b shifted its focus to SARS-CoV-2 surveillance, collaborating with Imperial College London and the Institute of Epidemiology Disease Control and Research, a Bangladesh government research institution, to monitor the virus in wastewater. This partnership resulted in an interactive dashboard that tracked SARS-CoV-2 clinical cases and wastewater data. This initiative demonstrated a significant impact on public health decision-making. Wastewater surveillance data was reported weekly to the national COVID-19 task force through the interactive dashboard, providing critical situational awareness that directly informed government response efforts. For instance, when authorities considered shutdowns in areas with limited clinical surveillance, wastewater data served as a key decision making tool.

The program's success was particularly notable given Dhaka's wastewater infrastructure. With only 20% of the city's sewage systems being formal, most wastewater samples were collected from converging informal sewage networks like canals, manholes, and wastewater outlets. This approach demonstrates the feasibility of wastewater surveillance in regions with predominantly decentralized wastewater systems. Catchment areas for each site were characterized using mapping tools such as blue line tracing, or the process of using Geographic Information Systems (GIS) tools to trace the flow of wastewater through sewage lines.

Building on this foundation, icddr,b has expanded its surveillance program to monitor additional pathogens including cholera, measles, RSV, influenza, and diarrheal diseases including *Vibrio cholerae*, *Escherichia coli*, *Shigella* spp., and *Salmonella* spp from multiple sites across Dhaka. The organization is also currently incorporating artificial intelligence to make the process of mapping sewage lines to characterize catchment areas less manually intensive.

Denmark

In Denmark, a SARS-CoV-2 wastewater surveillance system was implemented in July 2021 and fully rolled out in October 2021 for a study that went from September 27, 2021 to June 26, 2022. This system included 201 wastewater treatment plants, which were sampled three times per week during this period, covering 85% of the population. Samples were purified and analyzed using RT-PCR and linked to incidence data from clinical testing.

Using this infrastructure, wastewater surveillance was also used in Denmark to track the consumption of drug abuse among Danes. Currently, there remains a SARS-CoV-2 wastewater surveillance structure in Denmark, covering 49% of the population and consisting of 29 wastewater treatment plants throughout the country. SARS-CoV-2 wastewater concentration is assessed weekly on the Statens Serum Institut website.

England

During the COVID-19 pandemic, England established the Environmental Monitoring for Health Protection programme (EMHP), a national wastewater surveillance initiative designed to track SARS-CoV-2 variants. At its peak, the program tested wastewater from 308 treatment plants and 197 sewer network sites three to four times per week, covering approximately 74% of the English population.

The program was funded by the UK Health Security Agency (UKHSA), the national body responsible for health security in England in collaboration with other government entities – including the Department for Environment, Food, and Rural Affairs, the Environmental Agency, and the Centre for Environment, Fisheries, and Aquaculture Science – as well as academic institutions and water companies. Findings were reported weekly to national public health authorities and local partners. The EMHP strengthened collaboration between national and local public health teams and established consistent channels for communicating surveillance data. However, the program was scaled down and paused in March 2022.

In August 2025, the UKHSA launched a new program to evaluate how wastewater surveillance can be used to detect a wide range of pathogens. The goal is to evaluate how new technologies can be used to improve the UK's wastewater surveillance capacity. This renewed investment reflects a growing recognition of wastewater surveillance as a vital component of national biosecurity.

Ghana

The Ghana Health Services (GHS) has conducted environmental surveillance using wastewater approaches since 2016, initially focusing on poliovirus as part of the country's polio eradication efforts. In the Northern Region, Disease Control Officers collected sewage samples and tested them for the virus. In June 2019, when a sewage sample tested positive for vaccine-derived poliovirus, the Regional Health Administration immediately alerted local public health officers to increase clinical surveillance. This enhanced surveillance led district health teams to identify a confirmed case of polio. In response, the GHS organized three rounds of targeted polio vaccination campaigns to curb the spread. The environmental surveillance program has since expanded to 14 sites in seven regions and is a key tool in Ghana's polio eradication efforts.

In 2020, Ghana expanded its wastewater environmental surveillance to track SARS-CoV-2. GHS worked with the Bill and Melinda Gates Foundation to develop a wastewater surveillance strategy that accounted for both sewered and non-sewered systems, such as pit latrines, in two cities. This was important as only 10% of the country is connected to the national sewer network, while 75% of the country uses improved sanitation like shared latrines. Relying solely on sewered systems would have provided data from only a small fraction of the population. By incorporating non-sewered systems, GHS significantly expanded its reach.

The wastewater surveillance data collected during the COVID-19 pandemic directly informed public health interventions. In some communities, infections were detected in wastewater despite no reported clinical cases. This prompted targeted response efforts, including community education on hygiene practices and the use of personal protective equipment to curb the spread of COVID-19. Additionally, factors such as cost and limited availability of testing facilities, along with the stigma surrounding COVID-19, led to underreporting of cases across communities. Wastewater surveillance helped bridge this gap, offering a more accurate overview of transmission dynamics.

Wastewater surveillance is now being expanded in Ghana, as GHS explores its use to monitor pathogens such as *Vibrio cholerae*, *Salmonella Typhi*, and Group A rotavirus. More recently, GHS launched the Waste-Water Surveillance for Pandemic Prevention (WaSPP) initiative to expand the country's wastewater surveillance targets.

India

The Alliance for Pathogen Surveillance Innovations (APSI)-India is a multi-city consortium established in 2021 that conducts wastewater surveillance across India. Initially created to monitor SARS-CoV-2, APSI-India has since expanded its focus to monitor a wide range of pathogens in wastewater such as dengue, influenza, respiratory syncytial virus, antimicrobial resistant bacteria, and more. The organization collects samples from both sewered- and non-sewered systems, including open drains and water bodies, to ensure comprehensive public health monitoring.

During the COVID-19 pandemic, APSI-India played a crucial role in early detection and outbreak response. Some of its surveillance sites covered up to 92% of a city's population, allowing for near real-time tracking of viral transmission. The consortium demonstrated the early warning potential of wastewater surveillance by detecting infection trends 8-14 days before they became apparent in clinical case data. Additionally, APSI-India successfully detected silent waves of COVID-19, driven by emerging variants that were otherwise missed due to declining diagnostic testing rates. Anecdotally, wastewater data collected through this initiative was actively used by city governments and major public health leaders to inform decision making during the pandemic.

Beyond its surveillance efforts, APSI-India has developed several standardized protocols for detecting various pathogens in wastewater. The consortium has also designed a low-cost pathogen detection kit to expand access to wastewater surveillance and has conducted metagenomic sequencing to enhance pathogen detection and characterization.

Most recently, in August of 2025, the Indian Council of Medical Research (ICMR) announced plans to initiate wastewater surveillance for 10 viruses across 50 cities in India, representing a major scale-up in coverage from the five cities that had been covered prior to this.

The Netherlands

In the Netherlands, the National Institute of Public Health and the Environment (RIVM), has been actively engaged in wastewater surveillance research since 1992. In 2020, RIVM established a national SARS-CoV-2 wastewater surveillance program that analyzed wastewater from every WWTP in the country. This program was funded by the Ministry of Health, Welfare, and Sport and is still active.

Nongovernmental research organizations have also played a significant role in advancing wastewater surveillance in the Netherlands. The KWR Water Research Institute operated one of the country's leading wastewater surveillance initiatives early in the COVID-19 pandemic, prior to the development of the national program. Following the launch of RIVM's national program, KWR redirected its efforts toward research aimed at improving wastewater-based epidemiology and improving understanding of how viral concentrations in wastewater correlate with clinical data.

Nepal

As part of the Asian Development Bank's Accelerating Sanitation for All in Asia and the Pacific initiative, Nepal piloted wastewater surveillance beginning in 2022. The initiative, implemented through a collaboration between the Kathmandu Valley Water Supply Management Board, Tribhuvan University, and Emory University, established a new molecular biology laboratory in Kathmandu Valley in August 2022.

The program focused on SARS-CoV-2 and the locally endemic *Vibrio cholerae*. Following capacity-building training on laboratory setup, sample collection, and data visualization, the laboratory became operational in August 2024. The pilot program strategically sampled sites around the Bagmati River and the Guhewswori Wastewater Treatment Plant, successfully detecting both target pathogens. This pilot demonstrated the feasibility of establishing wastewater surveillance capacity in settings without pre-existing infrastructure.

Philippines

The Philippines also participated in the Asian Development Bank's Accelerating Sanitation for All in Asia and the Pacific initiative, focusing on building wastewater surveillance capacity in Metro Manila. By partnering with the Manila Water Company, Inc. (MWCI), the program leveraged existing infrastructure, including an established molecular biology laboratory, to develop a testing protocol for SARS-CoV-2.

Using detailed sewerage system maps, the team assessed catchment areas, population density, poverty rates, and COVID-19 case rates to inform sampling site selection. The final selection included eight wastewater treatment plants and two fecal sludge treatment facilities. Between May and September 2023, 165 wastewater and fecal samples were analyzed for SARS-CoV-2, with results displayed through a dashboard for public health officials. The initiative successfully demonstrated integration of wastewater surveillance into existing water utility operations.

Senegal

The Institut Pasteur de Dakar (IPD) has conducted environmental surveillance using wastewater approaches since 2012, initially focusing on poliovirus and enteric viruses in two regions as part of research programs. In 2020, the IPD team expanded the wastewater surveillance for polio to 8 WWTPs all in the Dakar region. In December 2020, when a sewage sample tested positive for vaccine-derived poliovirus, ten years after the last clinical case, the IPD team alerted local public health officers to increase clinical surveillance. This enhanced surveillance led district health teams to identify a confirmed case of polio in February 2021. In response, the Ministry of Health and Public Hygiene (MHPH) organized three rounds of targeted polio vaccination campaigns to curb the spread. The environmental surveillance program has since expanded to 15 sites in seven regions, covering up to 45% of the population, and is a key tool in Senegal's polio eradication efforts. In late 2023, wastewater surveillance in Senegal allowed early detection of a new emergence group of vaccine-derived poliovirus, months before the identification of the first clinical case.

In 2022, Senegal leveraged its wastewater environmental surveillance for polio to track SARS-CoV-2. Wastewater surveillance data collected during the COVID-19 pandemic contributed to the early identification of variants of concern such as the Omicron variants BA4/BA5 circulating before the 4th wave of clinical cases, offering an accurate overview of transmission dynamics. This directly informed public health interventions such as targeted hotspots for vaccination, community education on hygiene practices, and the use of personal protective equipment to curb the spread of COVID-19.

Wastewater surveillance is now being expanded in Senegal with the support of the WHO, as the MHPH in Senegal explores its use to monitor pathogens such as *Vibrio cholerae* through a multipathogen surveillance approach.

South Africa

In 2018, South Africa's National Institute for Communicable Diseases (NICD) established an environmental monitoring program for polio, which continues to operate successfully today. Building on this infrastructure, the NICD expanded its efforts in 2020 by launching the South African Collaborative COVID-19 Environmental Surveillance System (SACCESS) to monitor SARS-CoV-2 in wastewater.

At its peak, SACCESS included 87 wastewater treatment plants spread across all nine provinces. The program remains operational today and boasts relatively quick turnaround times, with results shared with public health leaders within 48 hours of sample collection and made publicly available through an online dashboard.

The South African Medical Research Council (SAMRC) has also led a nationwide wastewater surveillance initiative since 2020, publishing weekly summary reports that track SARS-CoV-2 trends. This collaborative effort, spanning multiple universities, think tanks, communities, and funders, covers at least eight districts and 23 cities across the country. Beyond SARS-CoV-2, SAMRC also has launched the HIV Wastewater Epidemiology in South Africa Initiative to explore wastewater surveillance as a tool to detect HIV transmission and drug resistance.

United States of America

There are currently two major national wastewater monitoring programs in the United States of America. The first is the CDC's National Wastewater Surveillance Program (NWSS). This program was developed in 2020 to help monitor SARS-CoV-2 and has since expanded to track measles, influenza A, influenza A (H5), mpox, and RSV. Through collaboration with state, local, tribal, and territorial health authorities, the system consolidates independent wastewater monitoring programs into a coordinated national framework that now covers 44% of the U.S. population.

The second national wastewater monitoring program is WastewaterSCAN, a collaboration between Stanford and Emory Universities supported by philanthropic funding and a private partnership with Verily for sample testing. WastewaterSCAN reflects a centralized program model, wherein the organization conducts all sample processing and analysis, allowing for uniform methods and pathogen targets across participating WWTPs. The program currently covers nearly 12% of the US population.

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