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CADTH Horizon Scan

Wastewater Surveillance for Communicable Diseases

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Key Messages

- This Horizon Scan summarizes the available information regarding wastewater epidemiology, or wastewater surveillance, for the detection of pathogens that cause communicable diseases.
- Wastewater surveillance can detect the presence of pathogens or chemical substances within the wastewater system and allows for the monitoring of a broad population with a single sample.
- Wastewater surveillance has been used for decades but has become more common since it was implemented around the world for the detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19. In Canada, wastewater surveillance is currently used for the detection of SARS-CoV-2, influenza, and respiratory syncytial virus.
- Studies conducted in Canada and internationally indicate that wastewater surveillance can be used as a reliable method for detecting pathogens at the population level.
- Future uses of wastewater surveillance may include monitoring of antibiotic use and antibiotic resistance, detection of cancers in the population, or assessing the prevalence of other infections within communities.

Purpose

The purpose of this report is to present health care stakeholders in Canada with an overview of information related to the use of wastewater epidemiology, or wastewater surveillance, for the detection of viral and bacterial pathogens. This report describes what wastewater surveillance is and how it works, summarizes the evidence regarding its use in Canada and internationally, and presents ethical considerations.

This report is not a systematic review and does not involve critical appraisal or include a detailed summary of study findings. It is not intended to provide recommendations for or against the use of the technology.

Methods

Literature Search Strategy

A limited literature search was conducted by an information specialist on key resources including MEDLINE, Embase, the Cochrane Database of Systematic Reviews. Grey literature was identified by searching relevant sections of the Grey Matters checklist. The search strategy comprised both controlled vocabulary, such as the National Library of Medicine's MeSH (Medical Subject Headings), and keywords. The main search concepts were wastewater surveillance and infectious diseases. No filters were applied to limit the retrieval by study type. Conference abstracts were removed from the search results. The search was completed on November 10, 2022, and limited to English-language documents published since January 1, 2019.

Regular alerts updated the search until project completion; only citations retrieved before December 13, 2022, were incorporated into the analysis.

Study Selection

One author screened the literature search results and reviewed the full text of all potentially relevant studies. Studies were considered for inclusion if the intervention was wastewater surveillance. Grey literature was included when it provided additional information to that available in the published studies.

Background

Wastewater surveillance, also called sewer monitoring or wastewater-based epidemiology, is an aggregate and anonymous method of monitoring for population-level infection trends and the spread of viral variants by testing samples of communal wastewater. Viruses that are shed in feces or urine can be detected using wastewater testing.[1] Testing wastewater for the presence of specific pathogens allows for the monitoring of a large population at the same time that can include subclinical, asymptomatic, and symptomatic cases, thus providing a more complete picture of population-level infection than clinical testing alone. This is particularly important when clinical confirmation of infection is difficult or resource intensive.[1] Systematic and continuous monitoring of wastewater samples for communicable pathogens can be used for early warning alerts for the emergence of new variants during an ongoing outbreak or monitoring for future outbreaks.[1] Surveillance of wastewater can also be used for other purposes, such as estimating drug or alcohol use in a community or monitoring for antibiotic resistance.

Wastewater surveillance began in the 1940s when scientists in the US used cell culture techniques to detect poliovirus and other viral pathogens via wastewater samples.[2] Recently, wastewater surveillance has gained popularity as a tool to monitor and quantify the level of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, in the population at large.[3] People infected with SARS-CoV-2 shed the virus and viral genetic material in their feces which ends up in the wastewater system. Testing the wastewater for the presence of SARS-CoV-2 allows for tracking and monitoring of population-level viral levels without having to rely on clinical testing (either formal or by self-report of at-home rapid test results) and confirmation of individual infections.[3]

The Technology

Wastewater surveillance involves the collection of samples of wastewater that are representative of a population. These samples can be collected for a single building or an entire community depending on the location of the sampling site.[4] Sampling sites can range from a single waste pipe from a building to a wastewater holding pond at a water treatment facility. Wastewater samples are collected for analysis through a variety of sampling methods, including grab sampling, composite sampling, and passive sampling.[3] Grab sampling involves taking a single water sample from 1 location at a specific point in time. Composite sampling combines water samples from multiple time points or locations into a single sample for analysis. Passive sampling is done by leaving a sample collection device in 1 place within the wastewater system where it is in contact with the wastewater for an extended period of time. Comparisons have shown that passive sampling tends to provide better results for the detection of SARS-CoV-2 than grab sampling because of the extended time the sampling device spends in contact with the wastewater.[3]

A variety of factors influence the concentration of a virus in wastewater before sampling. These include the amount of virus shed in fecal matter or urine, population size, and in-sewer factors (e.g., the amount of solid particles, organic load, travel time, flow rate, wastewater pH, temperature).[5] Note that high-risk populations, such as some older adults or hospitalized patients, may not contribute to the viral RNA load in the wastewater if catheters or other incontinence aids that collect urine or feces are not emptied into the toilet.[5]

Wastewater samples must go through several steps before the target can be detected. For the detection of SARS-CoV-2 RNA, the sample must go through primary and secondary concentration via filtration before the sample is run through assays to extract, amplify, detect, and quantify the target gene sequences of the virus.[6] The assays used to detect SARS-CoV-2 include real-time (RT) quantitative polymerase chain reaction (qPCR) SYBR, RT-qPCR Taqman, other types of RT-qPCR, and digital droplet qPCR.[6] Because SARS-CoV-2 is still a relatively new virus, standardized methods of detection and analysis from wastewater have not yet been established.[7] Quantitative PCR assays are also used for the detection of other viruses (e.g., respiratory syncytial virus and influenza) in wastewater samples.

Cost

The costs involved in the wastewater surveillance process include costs related to the collection and analysis of the samples. There are labour costs for the sampling crew (e.g., travel to sampling locations and collection, packaging, and shipping of samples), laboratory staff, and project administration staff (e.g., data and project management).[8] At the sampling stage, there are costs associated with the purchase of sampling equipment and supplies, such as personal protective equipment for staff, sample bottles and packaging, and ice and shipping costs for sample transport. At the analysis stage, there are costs associated with the equipment and assays required for PCR quantification or measurement of specific targets of concern.[8] The total cost of surveillance will vary depending on how the samples are collected and analyzed and how many collection sites are included in the program.

Wastewater testing for infection surveillance of a population is considered to be a cost-effective method of estimating overall prevalence, particularly when compared with the costs of testing the individuals that make up the population.[9]

Who Might Benefit?

The use of wastewater surveillance to monitor infection at the population level could benefit most of the population. However, areas that rely on septic tanks for the removal of wastewater may not be included in surveillance due to the difficulty in collecting samples from singular sites and maintaining confidentiality of people's health information when sampling from a single dwelling. The sooner an outbreak can be identified and quantified, the sooner mitigation can be put into place to prevent or slow the spread of the pathogen. Population-level surveillance also helps provide public health professionals with a picture of overall infection, particularly when individual-level testing is inaccessible or not feasible.

Current Practice

Current Use of Wastewater Surveillance in Canada

Wastewater surveillance capabilities are present in every province and territory in Canada. As of December 2022, these sites provided information on approximately 62% of the Canadian population across all surveillance networks.[10] Coverage ranges from approximately 2% of the population in Yukon to 82% of the population in Alberta.[10] Federal wastewater surveillance includes 65 sites and covers approximately 25% of the Canadian population.[10]

At the beginning of the 2022–2023 respiratory virus season, monitoring for influenza and respiratory syncytial virus (RSV) was added to wastewater surveillance in some Canadian jurisdictions. In August 2022, the Public Health Agency of Canada announced that Canada would begin to monitor wastewater for the Mpox virus and poliovirus; however, no further information was identified regarding this plan.[11] Table 1 presents the state of wastewater surveillance in Canada as of December 2022.

Table 1: Wastewater Surveillance in Canadian Jurisdictions as of December 2022

Jurisdiction	Region	SARS-CoV-2	Influenza	RSV
PHAC[12]	Pan-Canadian	Yes	No	No
Alberta[13]	Province-wide data	Yes	Yes	Yes
British Columba[14]	Vancouver	Yes	No	No
Manitoba[12]	Brandon and Winnipeg	Yes	No	No
New Brunswick[12]	Moncton	Yes	No	No
Newfoundland and Labrador[15]	Province-wide data	Yes	No	No
Northwest Territories[16]	Province-wide data	Yes	Yes	Yes
Nova Scotia[12]	Halifax	Yes	No	No
Nunavut[10]	Territory-wide data	Yes	No	No
Ontario	Ottawa[17]	Yes	Yes	Yes
	Toronto[18]	Yes	No	No
	Province-wide data[19]	Yes	No	No
Prince Edward Island[20]	Province-wide data	Yes	No	No
Quebec[21]	Montreal and Quebec City	Yes	No	No

Jurisdiction	Region	SARS-CoV-2	Influenza	RSV
Saskatchewan[22]	North Battleford, Prince Albert, and Saskatoon	Yes	Yes	Yes
Yukon[12]	Haines Junction	Yes	No	No

PHAC = Public Health Agency of Canada; RSV = respiratory syncytial virus, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

Current Use of Wastewater Surveillance Internationally

Wastewater surveillance is used internationally for a variety of monitoring purposes. The main focus around the world continues to be the monitoring of SARS-CoV-2 and COVID-19. COVIDPoops19 is a dashboard that displays international wastewater surveillance sites and includes data from 70 countries, more than 150 dashboards, and close to 3,900 monitoring sites (as of January 3, 2023).[23] The dashboard was assembled using data from a literature review, direct submissions, and daily social media keyword searches.[24] A review of the dashboard showed that 65% of sites were located in high-income countries. [24] The data from these monitoring sites are not publicly available for analysis or to inform global public health action.[24]

Wastewater surveillance has been used for decades to identify poliovirus, which continues to be monitored internationally. In 2022, cases of polio were discovered in the UK. After a confirmed case of polio was detected in New York State in late 2022, wastewater surveillance revealed community transmission of poliovirus in the surrounding counties.[25] Wastewater surveillance has also been used to detect the presence of rotavirus,[26] norovirus,[27] and Mpox.[28]

Summary of the Evidence

Table 2 summarizes the results of studies conducted in Canada that examined the use of wastewater surveillance for SARS-CoV-2 during the COVID-19 pandemic.

The Public Health Agency of Canada monitors wastewater samples from 5 Canadian cities and uses those results as input for mathematical modelling to track and monitor SARS-CoV-2 in Canada.[7] Li et al. (2022)[29] conducted a study in Alberta to determine the minimum number of cases of COVID-19 required in a population to allow for the detection of SARS-CoV-2 RNA in the wastewater. To detect SARS-CoV-2 at a 99% probability required 38 cases per 100,000 people.[29] Masri et al. (2022)[30] also assessed the testing sensitivity and specificity of wastewater-based epidemiology for detecting SARS-CoV-2. For different genetic markers, the cut points were 19 cases per 100,000 per week for the *N1* gene and 16.3 cases per 100,000 per week for *N2*.[30]

Wastewater surveillance can be difficult in remote areas where samples need to be sent to labs outside of the community for analysis. The travel time and shipping conditions can result in degradation of the sample and add to the cost of the procedure. In an effort to enable sample analysis closer to the source, Daigle and colleagues assessed the clinical validation of GeneXpert, a rapid, portable detection system, to analyze wastewater samples for the presence of SARS-CoV-2 RNA in a remote community in the Northwest Territories.[31] Using samples from across Canada during a peak of infection, they determined that the GeneXpert testing showed high overall agreement with standard lab analysis (97.8%). When GeneXpert was used in Yellowknife, the test was able to detect SARS-CoV-2 in the wastewater samples, which coincided with a confirmed travel-related case of COVID-19 in the area. Contact tracing detected 6 more cases of COVID-19.[31]

Wastewater-based monitoring of SARS-CoV-2 RNA also correlated well with clinically diagnosed cases across the city of Calgary.[32] The authors of a study conducted in the city in 2022 concluded that monitoring at a smaller scale, such as at the neighbourhood level, could provide the most useful information for future disease monitoring; however, more work is required to make this level of monitoring specific enough to provide adequate information.[32] Another study conducted in Alberta tracked the spread of the Omicron variant of SARS-CoV-2 throughout the province between November 2021 and January 2022.[33] The authors found that the Omicron variant spread more quickly in urban centres than in rural areas. Small but busy areas, such as Banff and Fort McMurray, were the exception. The authors concluded that wastewater monitoring in Alberta offered early and reliable indicators of population-level results.[33]

In Saskatchewan, researchers compared the viral load present in wastewater between small and large cities and determined that wastewater surveillance data from larger cities can typically be used to indicate what is also happening in regions with smaller populations.[34]

Researchers in Ottawa observed an increase in SARS-CoV-2 viral RNA in wastewater 48 hours before clinical test numbers increased and 96 hours before an increase in hospitalizations.[35] Wastewater surveillance at a temporary housing shelter in Toronto was used to alert staff to the presence of active SARS-CoV-2 infection among the residents before confirmation with a clinical test.[36] Early detection of the infection allowed the staff at the shelter to introduce cleaning and testing protocols and symptom screening among residents before the virus was able to spread to a larger number of people.[36]

Table 2: Summary of SARS-CoV-2 Wastewater Studies Conducted in Canada

Author (year)	Type of study	Setting and sampling	Findings
Acosta et al. (2022)[32]	Prospective observational study June 2020 to May 2021	Calgary, Alberta • 3 wastewater treatment plants • 6 neighbourhood-specific sampling sites	• Wastewater-based monitoring of SARS-CoV-2 RNA correlated well with clinically diagnosed cases across the city • The authors concluded that more granular levels of monitoring (neighbourhood level) would be most useful for future disease monitoring, but more work is required to make this level of measurement more specific
Akingbola et al. (2022)[36]	Prospective observational study January 2021 to September 2021	Toronto, Ontario • 1 temporary housing shelter • 1-hour composite wastewater samples collected twice weekly from a terminal sanitary clean-out pipe during times of high sewage flow	• Wastewater surveillance alerted to the presence of SARS-CoV-2 in residents before positive tests for COVID-19 • Early detection allowed for timely introduction of cleaning and testing protocols and symptom screening

Author (year)	Type of study	Setting and sampling	Findings
Daigle et al. (2022)[31]	Clinical validation of a rapid, portable detection system (GeneXpert) for wastewater testing and a prospective evaluation of the system to detect SARS-CoV-2 in wastewater in a remote community March 2021 to April 2021	Yellowknife, Northwest Territories • 2 major lift stations including > 85% of the population	• Using samples from across Canada during a peak of infection, they determined that the GeneXpert testing showed high overall agreement with standard lab analysis (97.8%) • From the Yellowknife water samples, 2 weak positives were observed with the GeneXpert system, which coincided with a confirmed travel-related case of COVID-19 in the area of the lift station • 3 weeks after initiating the GeneXpert pilot project, there was a consistent SARS-CoV-2 signal in the wastewater • Following the consistent results, recommended testing and contact tracing for recent travellers to the Northwest Territories resulted in the identification of a cluster of 6 cases of COVID-19
Hubert et al. (2022)[33]	Prospective observational study tracking the emergence and spread of the Omicron variant by wastewater surveillance November 2021 to January 2022	Alberta • 30 municipalities across Alberta covering > 75% of the population	• Larger cities like Calgary and Edmonton had a more rapid emergence of Omicron than smaller and more remote areas • Banff and Fort McMurray — small but busy areas — were exceptions • The Omicron variant was first detected in Alberta in November 2021 • By late December 2021, Omicron made up almost 100% of SARS-CoV-2 detected. This was detected before the peak of diagnosed clinical cases in mid-January 2022 • The authors concluded that wastewater monitoring offers early and reliable indicators of population-level results
Joung et al. (2022)[7]	Review of the framework of the national wastewater-based surveillance conducted at PHAC to present methods used in Canada to track and monitor SARS-CoV-2 September 2020 to 2022	Canada • Vancouver, British Columbia • Edmonton, Alberta • Toronto, Ontario • Montreal, Quebec • Halifax, Nova Scotia	• Since wastewater-based surveillance is not yet an established practice, there is a lack of standardized procedures to address biases and uncertainty in sampling and results • Mathematical modelling developed by PHAC and NML was conducted based on samples from 15 wastewater plants in 5 cities to analyze Canadian trends of SARS-CoV-2 • Clinical surveillance data were obtained from publicly available sources
Li et al. (2022)[29]	Sensitivity assessment to determine the number of COVID-19 cases required in a population to detect SARS-CoV-2 RNA	Alberta • 12 WWTPs in 10 cities and towns across Alberta	• 1,842 wastewater samples were processed • Overall positivity for SARS-CoV-2 RNA was 49.84% (918 of 1,842 samples) ranging from 6.47% to 95% in different COVID-19 waves • The analyses determined that a RT-qPCR–based SARS-CoV-2 RNA detection threshold at 50%, 80% and 99% probability required a median of 8 (range, 4 to 19), 18 (range, 9 to 43), and 38 (range,

Author (year)	Type of study	Setting and sampling	Findings
	May 2020 to June 2021		17 to 97) new COVID-19 cases per 100,000, respectively.
Masri et al. (2022)[30]	Testing sensitivity and specificity of wastewater-based epidemiology for detecting SARS-CoV-2 January 2021 to July 2021	Vancouver Island, British Columbia	• 24-hour composite influent samples taken weekly at 4 WWTPs • A small proportion of samples had quantifiable levels of SARS-CoV-2 genetic markers • Overall case rates were weakly correlated with the concentration and flux of vial material • The authors found at a cut point of 19 cases per 100,000 per week for the *N1* gene and 16.3 cases per 100,000 per week for *N2*: ○ *N1* sensitivity = 78.3% ○ *N1* specificity = 74.2% ○ *N2* sensitivity = 75.6% ○ *N2* specificity = 63.1%
Oloye et al. (2022)[34]	Prospective observational study August 2021 to January 2022	Saskatchewan • Saskatoon • Prince Albert • North Battleford	• Weekly samples using 24-hour composite autosamplers at WWTPs • Whole genome sequencing was used to identify variants of concern • The dominant VOCs were the same in each city, but the proportions of sublineages differed • Saskatoon was the largest of the 3 cities and was always first to present with new VOCs • Viral load varied between cities but there was not a direct correlation with population size • The authors concluded that wastewater surveillance data from larger cities can typically be used to indicate what is also happening in smaller regions
D'Aoust et al. (2021)[35]	Prospective observational study	Ottawa, Ontario • Primary clarified wastewater sludge was tested every 2 days from a water resource recovery facility in Ottawa in the summer of 2020	• An increase in SARS-CoV-2 viral RNA was identified in wastewater 48 hours before an increase in positive clinical test and 96 hours before an increase in hospitalizations • The authors concluded the evidence supports the use of wastewater-based COVID-19 surveillance to augment the efficacy of diagnostic testing

NML = National Microbiology Laboratory; PHAC = Public Health Agency of Canada; qPCR = quantitative polymerase chain reaction; RT = real time; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2; VOC = variant of concern; WWTP = wastewater treatment plant.

The results of systematic reviews that examined the use of wastewater surveillance for SARS-CoV-2 are summarized in Table 3. The correlation between the SARS-CoV-2 RNA concentration in wastewater and new cases of COVID-19 was stronger than that of active cases and cumulative cases.[37] Qualitative synthesis indicated that environmental surveillance may serve as an early warning system of 1 to 2 weeks for SARS-CoV-2 infection.[38] The effectiveness of wastewater surveillance is influenced by the use of different sampling methods, data normalization, and estimation of viral load.[38] Wastewater sample positivity was often reported before the detection of cases in the community.[39] The authors suggested that wastewater surveillance cannot replace large-scale diagnostic testing but it can serve as a complement to clinical surveillance.[39] Standardized protocols are needed to ensure reproducibility and comparability of outcomes.[40]

Table 3: Summary of Systematic Reviews Examining Surveillance of SARS-CoV-2

Author (year)	Objective	Findings
Li et al. (2023)[37]	To examine the correlation between the concentration of SARS-CoV-2 RNA in wastewater and cases in the community	• The correlation between RNA concentration in wastewater and new cases was stronger than that of active cases and cumulative cases • Correlation coefficients were potentially affected by environmental and epidemiological conditions and sampling design • Larger variations in air temperature, clinical testing coverage, and the increase in catchment size showed strong negative impacts on correlation
Hyllestad et al. (2022)[38]	To identify and synthesize evidence on the environmental surveillance of SARS-CoV-2 as an early warning system to evaluate the added value for public health	• Qualitative synthesis indicated that environmental surveillance may serve as an early warning system of 1 to 2 weeks • Effectiveness is influenced by the use of different sampling methods, data normalization, and estimation of viral load • Environmental surveillance could compliment clinical surveillance for SARS-CoV-2 but the cost-benefit value for public health needs to be assessed based on the stage of the pandemic and resources available • It is possible that environmental surveillance could be upscaled or downscaled depending on shifting needs • More studies are required that focus on methodological knowledge gaps and guidance on how to use and interpret surveillance signals for public health action • Studies included in this review were published at the early stages of the COVID-19 pandemic and may not represent the most current state of the literature
Shah et al. (2022)[39]	To assess the performance of wastewater surveillance as an early warning system of COVID-19 community transmission	• There was moderate overall sample positivity of 29.2% • Wastewater signals increased up to 63 days before increase in confirmed cases • Wastewater sample positivity was often reported before the detection of cases in the community • Authors concluded that wastewater surveillance cannot replace large-scale diagnostic testing, but it can serve as a complement to clinical surveillance
Amereh et al. (2021)[40]	To summarize existing methods of sampling procedures, detecting, and quantifying SARS-CoV-2 in sewage samples and provide direction for future research to improve the current scientific knowledge	• Improved awareness of the usefulness of wastewater surveillance for infectious diseases is required • Standardized protocols are needed to ensure reproducibility and comparability of outcomes • Areas that require the most improvement include sampling procedures, concentration and enrichment, detection, and quantification of the virus in wastewater

Author (year)	Objective	Findings
		• Selecting the most accurate population estimation method is still a challenge • Wastewater surveillance can be used as an early warning tool, a management tool, and a way of investigating vaccination efficacy and spread of new variants

SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2.

Ethical Issues

In 2021, a Canadian group released a document outlining ethics guidance for environmental scientists about wastewater surveillance of SARS-CoV-2.[41] The authors pointed out that environmental scientists in particular may not be as familiar with the ethical requirements associated with collecting and sharing human health outcomes data as researchers who regularly work in health research fields.[41] Generally, the ethical concerns related to data collected through wastewater surveillance become greater when the population contributing to the collected samples is smaller.[41] This may occur when samples come from a single institution, such as a prison or a dormitory, or from a wastewater plant in a small community. The authors based their recommendations on a 2017 evidence-based guidance document from WHO regarding ethical issues in public health surveillance.[41]

The authors suggested that surveillance only be undertaken when there is a clear and legitimate public health purpose and there is a plan for data collection, analysis, and dissemination based on public health priorities. Countries undertaking wastewater surveillance have an ethical obligation to ensure the data collected are of sufficient quality to meet public health goals and values while taking into account the concerns of the communities involved.[41] Monitoring for harm related to the surveillance should be ongoing and include actions to mitigate any harm, if identified. Data collected through surveillance must be shared.[41]

Future and Related Developments

Wastewater surveillance can be used to monitor the presence of a range of pathogens and chemicals. The Canadian Wastewater Survey has been estimating levels of various licit and illicit drugs in the wastewater of 5 Canadian cities since 2019.[9] Wastewater surveillance is or has been used around the world to:

- measure the level of psychiatric drugs, alcohol, and stimulants used during the COVID-19 pandemic and associated lockdowns[42,43]
- measure the level of environmental contaminants, such as pesticides and plasticizers, present in wastewater[4]
- estimate community-level prevalence of cardiovascular disease or cancer by the detecting specific urinary protein biomarkers to monitor trends[44]
- test hospital sewage for antibiotic resistance and antibiotic use in the community[7]
- assess the prevalence of sexually transmitted infections in the community[7]

- monitor specific settings, such as cruise ships and airplanes,[45] university campuses, or hospitals, to provide a snapshot of viruses that may be present and spreading among the population.

Limitations and Additional Considerations

As mentioned previously, although wastewater surveillance capabilities exist in every Canadian province and territory, data from portions of the population are not included in these surveillance activities. Rural and remote areas often rely on septic tanks for the removal of wastewater and do not have municipal wastewater systems or wastewater treatment plants to serve as locations for sample collection for testing and surveillance.[7]

There are several known and suspected sources of uncertainty associated with wastewater surveillance, which are outlined in Table 4.

Table 4: Sources of Uncertainty in Wastewater Surveillance

Domain	Uncertainties
Population	• Proportion of population previously vaccinated or infected with the target pathogen • Shedding rate, duration, and viral profile • Population mobility
Wastewater network	• Leakage from the network • Temperature- and time-driven decay • Chemical status of the water • Contribution from industrial effluent • Rainfall inflow and groundwater • Variation between sites
Sampling	• Method, time, duration, and frequency of sample collection • Sampling location in the network • Sample volume, preservation, and storage
Analysis	• Limits of levels of quantification and detection • Number of technical and biological replicates • Sample transportation time

Final Remarks

As the spread of communicable diseases continues around the world, wastewater surveillance may become an even more important method to monitor the spread of existing pathogens and the emergence of new ones. Monitoring the spread of communicable disease is not a new idea but the emergence of the COVID-19 pandemic and subsequent outbreaks of polio, RSV, and influenza around the world have brought more awareness to the need for reliable ways to track infections and their spread in larger populations. The need for monitoring as an element of public health management must be balanced with the need for individual and group privacy. When done appropriately, wastewater surveillance can provide a cost-effective and reliable method for the surveillance of some communicable diseases. However, wastewater monitoring should not be the only surveillance method used; it is most effective when combined with clinical testing and diagnosis.

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