

Status of environmental surveillance for SARS-CoV-2 virus

Scientific brief

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Background

Environmental surveillance by testing of wastewater for evidence of pathogens has a long history of use in public health, particularly for poliovirus¹ and more recently antimicrobial resistance (AMR).² In the context of the ongoing COVID-19 pandemic, it is being used for the detection of SARS-CoV-2 shed into wastewater from the upper gastrointestinal and upper respiratory system and via faeces.

Detection of non-infective RNA fragments of SARS-CoV-2 in untreated wastewater and/or sludge has been reported in a number of settings, such as Milan, Italy;³ Murcia, Spain;⁴ Brisbane, Australia;⁵ multiple locations in the Netherlands;⁶ New Haven, Connecticut⁷ and eastern Massachusetts,⁸ United States of America; Paris, France;⁹ and existing poliovirus surveillance sites across Pakistan.¹⁰ Researchers in the Netherlands,⁶ France⁹ and United States of America^{7,8} demonstrated a correlation between wastewater SARS-CoV-2 RNA concentrations and COVID-19 clinical case reports; the latter two further suggesting that the RNA concentrations could provide a 4- to 7-day advanced notice ahead of COVID-19 confirmed case data. Efforts are also ongoing to analyse historical wastewater samples for evidence of past SARS-CoV-2 circulation.

Most of these detections have been in the context of research studies. However, at least one country, the Netherlands, plans to incorporate daily sewage surveillance into its national COVID-19 monitoring.¹¹ A similar approach to using environmental surveillance as part of the routine COVID-19 surveillance package is being studied in Germany¹² and has been initiated in Australia and New Zealand.¹³

Most studies published to date on the use of environmental surveillance for SARS-CoV-2 have been from high-resource settings. However, approaches are needed that can be applied in lower-resource settings, where a greater proportion of the population is not connected to sewers and instead uses pit toilets or septic tanks. Possibilities include testing surface water contaminated by sewage.

To date, there have been no published studies demonstrating the use of environmental surveillance to identify SARS-CoV-2 in animal populations.

This brief explores potential use cases, considerations, and research needs for this emerging tool for SARS-CoV-2 detection that may be explored in close coordination with established public health surveillance for COVID-19. At present, there is not yet sufficient evidence to recommend environmental surveillance as a standard approach for COVID-19 surveillance. Recommended strategies for COVID-19 surveillance can be found in the WHO interim guidance "[Public Health Surveillance for COVID-19](#)".¹⁴

Major potential use cases for environmental surveillance for SARS-CoV-2

Early warning

Several studies have demonstrated that increases in SARS-CoV-2 RNA can be detected in environmental samples several days before detection of COVID-19 through clinical surveillance. Consequently, there is potential to use environmental surveillance for early warning, particularly of clusters or outbreaks in countries that have already contained transmission and are easing public health and social measures, or in the event of seasonality. Here, a cost-benefit assessment would need to be undertaken of the improvement in early warning. In addition, environmental surveillance would need to be closely linked to a plan for immediate action in the event of a positive signal or significant rise in cases from a non-zero baseline. Unanswered questions include what level of RNA rise is informative for action in the case of a significant rise.

Even in high-resource settings it is challenging to conduct widespread environmental surveillance for early warning because this approach requires frequent sampling to provide actionable data. Furthermore, a high sampling volume also is required because of low sensitivity. One potential approach could be to reserve environmental surveillance for pooled testing of particularly high-risk settings where response can be quickly implemented, such as closed residential settings (e.g. nursing homes, prisons, worker dormitories), large crowded workplaces or in the context of mass gatherings.

Detection of SARS-CoV-2 in locations with limited clinical surveillance

Environmental surveillance has the potential to be used to complement clinical surveillance or to trigger more comprehensive surveillance in areas with poor performance, for example in crowded, extremely low-resource settings such as informal settlements or more generally in marginalized populations. In these contexts, access to health facilities may be limited, health-seeking behaviour may be low, testing capacity may be low and clinical surveillance capacities may be stretched. Further, younger populations in such settings may exhibit less clinically apparent or ‘typical’ disease, further complicating clinical surveillance.¹⁵ However, such settings are also unlikely to have adequate sewerage, posing challenges for sampling and analysis from open drains (e.g. potential degradation of samples by ultraviolet light, difficulty in defining the catchment population).

Testing of environmental samples representing a large number of pooled individuals could optimize use of limited testing resources.¹⁶ For any site yielding positive samples, field investigation would then need to be undertaken in the catchment area, including active case finding, to try to identify any suspected cases and perform laboratory investigation. Detection in a well-defined catchment area could be linked to initial public health and social measures while further investigation is ongoing. Evidence of circulation of SARS-CoV-2 in a community will be important to reinforce public health measures to limit transmission (e.g. improved sanitation and hygiene, mask-wearing and physical distancing).

Monitoring circulation of SARS-CoV-2

While it has been demonstrated that environmental surveillance has the potential to be used for monitoring COVID-19 prevalence and temporal trends, it would be necessary to pilot this approach in low- and middle-income settings to demonstrate its added value to clinical surveillance.

Environmental surveillance could potentially be used to detect unrecognized transmission of SARS-CoV-2, as a way to determine whether COVID-19 has truly been contained in an area and/or as an additional source of information that can be used to support decision-making about whether to adjust public health and social measures. It is important to note, however, that it is currently not clear how useful environmental surveillance would be as evidence of non-circulation of SARS-CoV-2. Little is currently known about the time course of stool shedding of SARS-CoV-2 virus particles, particularly in relation to infectious clinical illness.^{17,18} Rates of false-positives and false-negatives of PCR testing of wastewater are not well-characterized; and little is known about the persistence of viral fragments in wastewater systems.¹⁷ Thus, currently, environmental surveillance for SARS-CoV-2 cannot provide the same value as for polio, which is transmitted through faecal discharge and is expected to be absent in virtually all settings.

Environmental surveillance could be used by countries to test historical samples to document early circulation of the virus in different settings.

Research

Environmental surveillance research should be seen as an important public health objective to advance knowledge about COVID-19.¹⁹ This approach could further elucidate virus shedding dynamics, as discussed by Wu, et al.⁸ Environmental surveillance also has the potential to detect SARS-CoV-2 shedding from animal sources, such as animal production facilities and wet markets; potentially supporting identification of any animal reservoirs.

Potential considerations for implementing environmental surveillance for SARS-CoV-2

Representativeness

For environmental surveillance to be of maximum utility, it would be important for it to be as representative as possible of the target population. Thus, systems would need to draw on geographically and demographically diverse populations and include areas and populations not connected to municipal sewerage. This approach presents logistical and methodologic challenges (e.g. pooling from on-site sanitation systems and the effect of sunlight on degradation of samples taken from open drains). Challenges to representativeness may thus be compounded in areas where clinical surveillance may have poor performance, such as informal settlements or humanitarian settings, which also usually lack centralized sewerage systems. However, environmental surveillance has the inherent advantage of providing objective sampling within a given catchment (i.e. free of any bias introduced by selective clinical testing criteria).

Coordination

Environmental sampling should involve close coordination among research laboratories, utilities, and public health authorities to ensure that sampling strategies are driven by public health need and that results are integrated with other sources of surveillance information and are linked to action.

Cost-effectiveness

In low-resource settings, establishing new environmental surveillance systems for SARS-CoV-2 could risk diverting scarce resources away from essential surveillance activities and crucial water, sanitation and hygiene (WASH) activities, such as scaling up hand hygiene in all settings and ensuring continuity and extension of water supply and sanitation services. Thus, the cost-benefit of environmental surveillance in relation to these other essential measures should be carefully evaluated. Environmental surveillance for SARS-CoV-2 might be more justified in locations where existing polio, antimicrobial resistance or other types of environmental surveillance have already been established. However, these locations have been selected to meet different objectives, and their suitability for COVID-19 surveillance purposes should consequently be evaluated.

Even in higher resource settings, the cost of investing in a new environmental surveillance system to identify SARS-CoV-2, versus strengthening essential surveillance and WASH activities, still needs to be carefully considered.¹⁶

Ethical and legal considerations

Environmental surveillance may serve to identify circulation of SARS-CoV-2 in a community without any consent having been given for testing; and may result in stigmatization of the community. However, given the inability to target specific individuals due to the pooled nature of environmental samples, stigmatization is likely to be much less than with individual clinical testing. It would be important not to use environmental surveillance to disproportionately target already-stigmatized communities with public health and social measures.

Quality assurance

There are currently no well-established quality assurance/ proficiency-testing mechanisms for SARS-CoV-2 environmental testing; these would need to be established.

Safety considerations

To date, no infectious SARS-CoV2 virus has been recovered from untreated or treated sewage.¹⁷ Given the myriad pathogens routinely expected to be found in untreated sewage and the commensurate precautions normally taken, sewage sampling in the context of COVID-19 is not expected to engender any additional infection risk to workers. Laboratory processing of wastewater samples should follow existing biosafety standards for handling SARS-CoV2, i.e., BSL-2.²⁰

Research needs

Environmental surveillance for SARS-CoV-2 is a rapidly evolving field, with several potential use cases identified above. However, before recommendations can be provided on the best use(s) of environmental surveillance, several important questions need to be addressed through well conducted research studies. These include:

Biologic

- Understanding of the association between faecal excretion (including quantitative information on viral shedding across all infection stages), period of infectiousness, and clinical spectrum of disease; and correlation with detection through environmental surveillance
- Quantification of a human gene marker in stool to enable estimation of the catchment population size represented in a sewage sample from an area without a sewerage system
- Persistence of SARS-CoV-2 RNA fragments in sewage
- Establishment of a cell culture model to evaluate virus viability from environmental samples
- Potential for survival of infectious live virus in untreated and treated sewage.

Epidemiologic

- Optimum site selection and sampling methodology (particularly for settings with low reticulated sewerage coverage), including potential matrix sampling methodologies to reduce areas requiring active public health investigation
- Modelling and interpretation of environmental surveillance data and identifying triggers for public health actions
- Feasibility of integration of SARS-CoV-2 sewage surveillance with other disease surveillance systems at different levels of operations – including site selection, collection, sample shipment, initial processing, diagnostic methodologies and data management.
- Role of wastewater surveillance for detection of SARS-CoV-2 from animal sources (e.g. animal production sites, wet markets).

Technical

- Standardization of protocols: collection timing, time integration, sample conservation, pre-treatment, identification of appropriate virus surrogates for process control, concentration and extraction methods, quality assurance
- Optimum molecular methods of detection (e.g. polymerase chain reaction, next-generation sequencing)
- Limits of detection and quantification, false-positive and false-negative rates
- Approaches to non-sewage (e.g. rivers, saltwater) testing
- Effect of sewage physical/chemical characteristics on SARS-CoV-2 testing.

Economic

- Further characterization of costs and benefits associated with environmental surveillance for SARS-CoV-2.

Other

- Community and sanitation worker perceptions of environmental surveillance and associated behaviour change for prevention and control of COVID-19.

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