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Invited Perspective: The Promise of Wastewater Monitoring for Infectious Disease Surveillance

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Wastewater provides a naturally composited biological sample that includes pathogens shed in feces, urine, blood, sputum, and vomit and that can be used to infer information about disease occurrence in the community. Early in the COVID-19 pandemic, it was noted that SARS-CoV-2 RNA is regularly shed in the feces of infected people, and monitoring of wastewater to estimate disease occurrence became an attractive option.[1,2] Wastewater monitoring has been used previously, mostly for enteric diseases such as polio[3] and salmonellosis,[4] but a significant investment in research and implementation has elevated the approach as part of the COVID-19 response and measurements of SARS-CoV-2 RNA in wastewater have been consistently highly associated with reported COVID-19 cases.[2,5] The U.S. Centers for Disease Control and Prevention began the National Wastewater Surveillance System (NWSS) to support and aggregate data from wastewater nationwide, the first such program in the United States. There is a growing acceptance of wastewater monitoring. A depth of research indicates the strength of its performance as a surveillance tool that public health officials and media have begun to include in their reports on the pandemic, but there are challenges around the coordination of its protocol and policies. Now, there is a further need to document the impact of specific public health actions that have been taken based on this data, as in Deng et al.,[6] and to examine the ethical considerations and sustainability concerns around these programs.

Deng et al. describe not only a large-scale program monitoring wastewater for SARS-CoV-2 in Hong Kong but also a close relationship with public health intervention.[6] Wastewater was sampled from within the sewer network, capturing populations ranging from tens of thousands of people down to groups as small as 17 individuals. Based on positive wastewater test results, compulsory testing was triggered, and during the study period, 62 cases were identified during individual testing following a positive wastewater sample. Some of these cases were asymptomatic or presymptomatic; these cases may not have been identified, especially in a timely manner, without wastewater guiding the investigation. The study by Deng et al.[6] is a compelling example of wastewater monitoring working together with public health interventions at a large scale, but it also raises questions about both sustainable use cases for wastewater and the importance of ensuring that these emerging tools are used appropriately.

Use cases for wastewater monitoring for public health action are largely dependent on the scale (and frequency) at which samples are taken, and sustainability may depend on the geographic scale and frequency of sampling. Monitoring can be done using samples from treatment plants that represent large segments of towns and cities, or from within a sewer network or building outflow to monitor smaller, targeted communities (as in Deng et al.[6]). Treatment plant samples provide information about a larger community with a single sample and can usually be collected by existing treatment plant staff and in many cases with existing equipment, making costs lower and coordination simpler than collecting samples from within a sewer network that may provide more detailed information. It is important to match testing to the level of possible intervention—for example, citywide monitoring provides information at an appropriate level to inform policies and forecast needs that are managed at this level, such as hospital staffing. City-level monitoring can also be used to detect the introduction of rare new targets, such as emerging SARS-CoV-2 variants,[7] and provide an overall picture of the outbreak in a region.[8] For smaller segments of communities, and as shown in Deng et al.,[6] the focus is often on determining where to target additional testing, and this can also be done for other services, such as vaccination. In the United States, wastewater monitoring has been widely used on college campuses, sometimes alongside additional testing for those associated with positive wastewater tests.[9–11]

Wastewater monitoring programs should also address important ethical considerations. An advantage of wastewater monitoring is that samples are naturally collected and aggregated such that individuals are not directly identifiable. However, monitoring small populations raises privacy concerns, and even if individuals cannot be identified they may be impacted by responsive interventions. Others have noted that wastewater monitoring should be used only in populations that are large enough to ensure the anonymity of those monitored.[12–14] People who are represented in a wastewater sample are, for the most part, not able to opt out of their participation.

In Deng et al. populations as small as 17 people were monitored.[6] It is notable that although Deng et al.[6] monitored small populations with the explicit purpose of implementing compulsory testing based on the results, it does not appear that any ethical review board was consulted. Smaller-scale testing can inform planning for testing and vaccination clinics or guide policies in schools or other institutions, but it is also more resource intensive and has unique ethical considerations. Programs should carefully consider the size and vulnerability of the populations monitored when evaluating the ethics of monitoring, and public health officials should avoid responses that are unduly burdensome or punitive.[14] All actions based on monitoring should operate based on principles of protection for individuals, including their privacy, and should acknowledge limitations in interpreting results. Deng et al. note, for example, that there is still uncertainty about the timing and magnitude of fecal shedding of SARS-CoV-2, and that in some cases positive signals were likely a result of convalescing cases.[6] This is a particularly important limitation of the method when data is used to request or require individuals to take action based on the results.

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Wastewater monitoring will continue to guide responses to the COVID-19 pandemic and other disease outbreaks. Sampling at the treatment plant level is a sustainable approach to monitoring communities for infectious diseases because the cost and labor for the few samples needed is relatively low. Although monitoring at the community level as described by Deng et al.[6] is much more resource intensive, there are many cases in which monitoring at the small community, institution, or building level is desirable and worth an investment to support the targeted protection of public health. Existing and developing ethical guidelines should be considered when these programs are implemented, especially for smaller community sites. Schools, correctional facilities, and many businesses are all places where relatively consistent groups of people intermingle and where early identification of an outbreak could allow for responsive action to prevent further illness. Sustainable and ethical implementation of wastewater monitoring at both treatment plant and smaller community levels will enable further use of wastewater data for the protection of public health using a tool that is less biased by health care access than traditional surveillance. Programs that balance these considerations and work with the community can produce data that can not only guide public health interventions but can also be used by communities to advocate for their needs and help shape interventions to appropriately and effectively limit the spread of disease.

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