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Wastewater surveillance for public health: *Quo Vadis*?

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Wastewater surveillance of enteric pathogens began as early as the 1920s and saw consistent, albeit geographically limited, use as part of polio eradication programs in settings where polio remained endemic. With the onset of the COVID-19 pandemic, wastewater testing became quantitative and widely applied for the first time for the surveillance of a respiratory pathogen – SARS-CoV-2. The global uptake demonstrated the great potential of wastewater surveillance and established the institutional infrastructure necessary for its continued use. Many wastewater surveillance programs have now begun testing for other endemic pathogens, such as RSV and influenza A, and for emerging or re-emerging ones, such as Mpox and avian influenza A (H5).

Implementing wastewater surveillance systems during the SARS-CoV-2 pandemic involved a massive collaborative effort among researchers, public health practitioners, and wastewater utilities that could best be described as "building the plane while flying it". To ensure the sustainability of wastewater surveillance for public health, it is critical to move "beyond the ordinary" and innovate for the future. This themed issue highlights several innovations in wastewater surveillance that are critical to maximizing its utility and sustainability. These innovations cover topics such as: (1) expansion to new pathogen targets by Kazmer *et al.* (2025) (**https://doi.org/10.1039/D4EW00521J**), Zhou *et al.* (2025) (**https://doi.org/10.1039/D4EW00525B**), Roldan-Hernandez *et al.* (2025) (**https://doi.org/10.1039/D4EW00225C**); (2) on-site detection systems by Donia *et al.* (2025) (**https://doi.org/10.1039/D4EW00384E**), Wu *et al.* (2025) (**https://doi.org/10.1039/D4EW00526K**); (3) optimization of sampling sites for equity and representativeness by Muralidharan *et al.* (2025) (**https://doi.org/10.1039/D4EW00552J**); (4) advancing sampling and detection methods by Hayes *et al.* (2025) (**https://doi.org/10.1039/D4EW00350K**), Gouthro *et al.* (2025) (**https://doi.org/10.1039/D4EW00370E**); and (5) quantification of the economic value of community wastewater monitoring by Yoo *et al.* (2025) (**https://doi.org/10.1039/D4EW00332B**).

Wastewater contains a wealth of information on community health. To maximize the value of wastewater surveillance systems, many studies have focused on characterizing wastewater for the surveillance of other endemic pathogens. Extending its application to other disease targets typically involves developing sensitive and specific assays for detecting pathogen targets, optimizing methods for recovering the targets from wastewater samples, quantifying target concentrations across an outbreak or seasonal epidemic, and comparing wastewater measurements with other data sources such as clinical or syndromic surveillance data. For some pathogen targets, this is relatively straightforward, and new applications of wastewater surveillance demonstrate reliable associations between wastewater levels and clinical data. Other disease targets, such as antimicrobial-resistant pathogens, are more challenging. Feasibility assessments for diverse pathogen targets, which vary in type and structure, transmission mechanism, infectivity, geographic range, *etc.*, also serve to build capacity for early detection of emerging pathogens.

As COVID-era motivation and prioritization expires, the sustainability of wastewater surveillance also requires innovations in resource optimization. Resource optimization includes advances in low-cost sampling techniques, such as passive samplers, and multiplexed assays that quantify numerous targets in a single reaction. It also involves optimization of sampling site selection and balancing coverage to achieve greater equity. Eventually, biosensors and on-site detection systems may enable near real-time wastewater monitoring and,

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thus, a future where wastewater data could be seamlessly integrated into smart cities and buildings to influence human behavior and manipulate building control systems to protect public health. Finally, the longevity of wastewater surveillance would greatly benefit from quantification of its economic and social value (including ethical consideration). While quantifying a surveillance system's cost-effectiveness and return on investment is challenging, other metrics can be used to inform economic value, as highlighted in this issue.

Historically, investment in pandemic preparedness has boomed and busted in response to the waxing and waning of epidemics. Ensuring that wastewater surveillance is resilient to such cycles requires persistent innovation and consistent demonstration of the myriad benefits of such a surveillance system. Many advancements have been made in the last five years. It is our hope that this themed issue contributes to an increasingly overwhelming body of evidence that supports opportunities and further innovation in wastewater surveillance and ultimately contributes to the development of enhanced infectious disease mitigation systems. The guest editors of this themed issue would like to thank all the authors for their high-quality contributions and the editorial staff for their guidance and support in bringing this issue to life.