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POLICY BRIEF

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Strengthening Wastewater Monitoring and Surveillance for COVID-19 and Other Infectious Diseases

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Highlights

Public health surveillance is critical in combatting infectious diseases such as COVID-19. Environmental surveillance can complement monitoring of individual human infections and provide unique benefits. In particular, monitoring of wastewater is a valuable tool for obtaining information on disease outbreaks at the community scale, including asymptomatic and test-reluctant individuals, at a low cost. It should be included in national testing strategies and tracing programmes to gain a better understanding of the prevalence and evolution of diseases in communities and strengthen early detection of future outbreaks.

Recommendations:

- Implement wastewater-based tools and strengthen technical capabilities and cost-effective mechanisms to integrate existing clinical testing with wastewater surveillance systems.
- Improve governance frameworks to establish and strengthen wastewater surveillance systems.
- Strengthen public–private coordination to enhance data sharing and interpretation for efficient, supportable, and stable wastewater surveillance while maintaining ethical standards.

Wastewater Monitoring & Surveillance

Early detection of outbreaks is essential to prevent the spread of infectious diseases, such as COVID-19, in high-risk densely populated areas with high levels of human interaction. While public health surveillance is critical for monitoring infection rates, standard approaches depend on effective diagnostic tools, sufficient human and technical resources, health-seeking behaviour, access to clinical testing, and timely reporting. Furthermore, they are unable to capture the 18%–31% of COVID-19 infections that are asymptomatic (Mizumoto et al. 2020; Nishiura et al. 2020).

The SARS-CoV-2 virus that causes COVID-19 has been detected in the faeces of affected patients (Xiao et al. 2020). Faeces are generally collected in sewer systems and undergo treatment as wastewater, including disinfection. However, in developing countries they are often collected on-site and discharged into rivers or oceans without proper treatment due to lack of infrastructure and appropriate technology. Pathogenic microorganisms such as bacteria and viruses are present in high concentrations in sewage. Measuring them in wastewater can provide valuable information to analyse the spread of infectious diseases in communities.

Wastewater surveillance — the strategic sampling and testing of wastewater, and analysis and interpretation of the collected

data (such as presence or concentration of pathogens, physical-chemical measures) — enhances understanding of a disease within a community (CDC 2021). Wastewater analysis is equivalent to obtaining and analysing a pooled community urine and faecal sample that gives a snapshot of the status of public health (Xagoraraki & O'Brien 2020). It has been successfully used for early detection of other diseases, such as polio (Bhowmick et al. 2020; CDC 2021).

Wastewater monitoring has particular value in its ability to detect cases of infection among patients who are asymptomatic or reluctant to be tested. Tracking pathogenic microorganisms in sewage has the additional advantages of maintaining the privacy of infected people and streamlining testing by using government-controlled infrastructure. During the COVID-19 crisis this approach can support the launch of effective early warning systems and implementation of rapid intervention systems for on-site detection of infections at the wastewater source or collection points (Bhowmick et al. 2020). The approach is effective for water bodies within catchment areas, including surface and domestic water sources — particularly in low-income countries where contamination of water resources from untreated wastewater is common. It can also provide information on preventive measures to residents prior to outbreaks — including people living in vulnerable environmental and financial conditions. This can be highly effective in reducing spread, and strengthen resilience against infection, contributing to well-being and reducing the need for extreme countermeasures such as lockdowns, which have substantial negative socio-economic impacts.

For low-income countries in particular, it is infeasible to effectively monitor COVID-19 in the population using health surveillance systems alone, due to a lack of funding, human resources, and equipment, as well as the high cost of testing. Wastewater surveillance offers a cost-effective strategy to measure disease prevalence at the population level, especially for low- and middle-income countries facing resource constraints (Shrestha et al. 2021). Many high-income countries have already included wastewater surveillance systematically in national strategies to detect SARS-CoV-2 and identify variants rapidly to inform appropriate and timely responses (CDC 2021; European Commission 2021). The approach has rarely been included in national or regional disease surveillance frameworks in low- and middle-income countries. Clinical surveillance frameworks and setups in these countries — which can be limited, expensive, and involve sensitive data — can be supplemented by carefully designed wastewater surveillance to enable mass surveillance while maintaining privacy. But integrating wastewater monitoring requires improving the governance framework, coordinating public–private partnerships, and sharing data.

This policy brief identifies the key challenges and prospects for strengthening wastewater monitoring and surveillance systems for COVID-19 and other infectious diseases, with a particular focus on low- and middle-income countries, and provides recommendations for scaling up the approach.

Policy Recommendations

1. Integrate existing clinical testing with wastewater surveillance systems by implementing wastewater-based tools, strengthening technical capabilities, and developing cost-effective mechanisms

It is feasible to use existing testing methods for detecting and estimating the concentration of the SARS-CoV-2 RNA from wastewater in laboratories in developing countries (Kumar et al. 2021). However, COVID-19 testing protocols require costly kits and equipment, trained technicians, and laboratory facilities. Assessment is needed to determine the level of technical capability of low- and middle-income countries to conduct laboratory experiments for wastewater surveillance and their ability to purchase the required consumables. To address shortfalls in technical and financial resources, establishing and strengthening partnerships between environmental agencies and public health departments is essential. In addition to providing adequate funding, building institutional capacity, and improving technical expertise in testing areas, there is a need for quality control and harmonisation of reporting metrics to facilitate the implementation of surveillance activities.

Wastewater surveillance is straightforward when the entire population is connected to a formal sewer system. For cities that lack formal sewers or only have a fraction of the population connected to them, more experience is needed. Wastewater surveillance is difficult where there are only septic tanks and pit latrines. In such cases it can be informed by a shit-flow diagram for a city — a high level technical drawing used to display movement of wastewater from a location to its final disposal. Representative sample collections can be planned accordingly from open drainages, wastewater discharge points, septic tanks, and community-level decentralised wastewater treatment facilities, among others.

The cost of implementing a wastewater surveillance system should be considered necessary for an effective public health strategy — and it is far cheaper than monitoring individual infections. These systems can also be used for monitoring other infectious pathogens such as norovirus, *Vibrio cholerae* (cholera), *Giardia lamblia* (giardiasis), and *Cryptosporidium parvum* (cryptosporidiosis) and new pathogens in future.

There is an urgent need for additional investments and technical know-how in low- and medium-income countries to integrate wastewater surveillance. Overcoming these challenges will require international cooperation and financial aid. For instance, the World Bank has financed an integrated regional surveillance and laboratory network set up by the Africa Centres for Disease Control and Prevention (Africa CDC) to improve technical and testing capacity for surveillance (World Bank 2021). International collaboration should be extended to strengthen technological capabilities by establishing laboratories and building capacity — or by integrating existing health surveillance systems through the supranational, national, and regional integrated surveillance and laboratory networks that support low- and middle-income countries. In December 2021 the World Health Assembly agreed to develop a global accord on pandemic prevention, preparedness, and response. The scientific community should advocate for integration of wastewater surveillance in health surveillance system as a mandate. International organisations can play a key role by providing technical support and guidance, and sharing best practices for wastewater surveillance between governments, private institutions, and non-profit organisations.

2. Establish governance frameworks for scaling up wastewater surveillance systems

Wastewater surveillance should be institutionalised at the regional or municipal level as a strategy for pathogen detection, with government funding (Shrestha et al. 2021). Public or private academic and research institutions and profit-making clinical and environmental laboratories could become valuable partners for wastewater sample collection and pathogen testing. Environmental health experts can be mobilised to translate the virus data into public health estimates, while public health experts and authorities utilise the data. These strategies could be coordinated by entities such as health departments, home affairs departments, and bodies responsible for COVID-19 prevention and control.

An evaluation of governance frameworks is needed to determine the level of implementation and inform continual refinement and upgrading of the entire wastewater surveillance system (Takeda et al. 2021). As routine strategies these frameworks for wastewater sampling, testing, and reporting can reduce the need for system overhauls in case of future outbreaks (Keshaviah et al. 2021). However, governments must not consider wastewater surveillance tools as merely temporary measures; they should be prioritised as monitoring systems for SARS-CoV-2 and early warning systems for future epidemics. Adopting wastewater surveillance systems enables immediate policy interventions at the international, regional, national, state, and local levels to allocate resources and preventive measures for high-risk communities. Their funding mechanism stabilises under-pressure public health expenditures, incentivises sharing of data between academic and commercial labs, and bridges the gap between innovation and implementation.

In general, poor healthcare systems and a lack of funding for research in low- and middle-income countries leads to weak public health surveillance that produces inadequate, unreliable, and low-quality data. Efficient frameworks should be adopted for scaling up wastewater surveillance systems — including the planning, funding, and delivery of research to effectively combat COVID-19 through strong collaboration with global research funders and researchers in public and private health institutions (Norton et al. 2021).

3. Promote and strengthen public–private coordination to enhance data sharing and data quality for sustainable wastewater surveillance

When reporting wastewater data results, it is vital to secure active coordination and cooperation between stakeholders, including wastewater plant operators, public health officials, infectious disease control boards, testing labs, and researchers. National and local governments should build up teams involving public health and wastewater authorities, and other actors that can merge and link relevant datasets — for example, on wastewater surveillance and on COVID-19 infections. In processing and sharing data, ethical protocols are required to protect privacy and avoid discrimination and stigmatisation (Keshaviah et al. 2021). Wastewater surveillance can implement appropriate protections (Smith et al. 2021), and help to maintain trust and commitment for infection control measures among the community.

Data must also be interpreted appropriately and the results communicated effectively to inform public health policies and measures. Systems like the United States National Wastewater Surveillance System are important to build independent local implementation efforts for monitoring infectious diseases and provide early warning for future outbreaks and other public health risks linked to emerging pollutants, such as antimicrobial resistance.

Collaboration with information technology experts can produce highly accurate hotspot risk maps that can be made widely available and support geospatial analysis of the disease. Wastewater system maps provide detailed information on existing wastewater management systems and population sizes around catchment areas, allowing further screening of hotspots within a larger area. To support

rapid communication and assessment of emerging threats and preparedness for future outbreaks, a partnership is needed involving international organisations such as the WHO to mandate wastewater surveillance, as a public–private endeavour led by national governments, similar to the Global Polio Eradication Initiative. It is also essential to develop a framework to apply the One Health approach for early detection and surveillance of wastewater systems to identify outbreaks at the population level. The WHO should work closely with the Global Water Research Coalition and the UNEP Global Wastewater Initiative to promote multi-sectoral responses to public health threats and provide guidance to reduce infectious disease outbreaks.

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