



Wastewater Surveillance Signals as Early Indicators of Community Respiratory Virus Circulation

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Abstract

Municipal sewage carries material shed by everyone connected to the network, including people who never seek care, and nucleic acid from respiratory viruses can be measured in it. Since 2020 this observation has grown from a laboratory curiosity into routine public health practice in many countries, first for severe acute respiratory syndrome coronavirus 2 and more recently for influenza A and B, respiratory syncytial virus and other agents. The attraction is timeliness: a wastewater signal does not depend on people presenting to clinicians or on laboratory testing capacity, so it can move before the clinical indicators that health departments have traditionally used. This short communication reviews what has been established about the lead time of wastewater signals for respiratory viruses, sets out the measurement problems that determine whether a rise can be trusted, and comments on how such data are best used alongside sentinel clinical surveillance. It argues that the value of wastewater monitoring lies less in a precise number of days of advance warning, which varies with catchment, assay and comparator, than in an independent indicator that is unaffected by changes in health-seeking behaviour. Practical requirements for programmes that wish to sustain the approach are described.

Keywords: Wastewater surveillance, Respiratory viruses, Influenza, Early warning, Environmental monitoring, Public health surveillance

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1. Introduction

Testing sewage to learn about infection in a population is not new. Environmental surveillance for poliovirus has been part of the eradication programme for decades, and in several countries it has detected circulating virus in the absence of any reported case of paralysis (Asghar et al., 2014). The method was extended to antimicrobial resistance genes in a global sampling of sewage from dozens of countries (Hendriksen et al., 2019). What changed in 2020 was the scale. Within months of the emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), groups in several countries reported viral RNA in untreated wastewater (Ahmed et al., 2020; Medema et al., 2020), and national programmes followed (Kirby et al., 2021).

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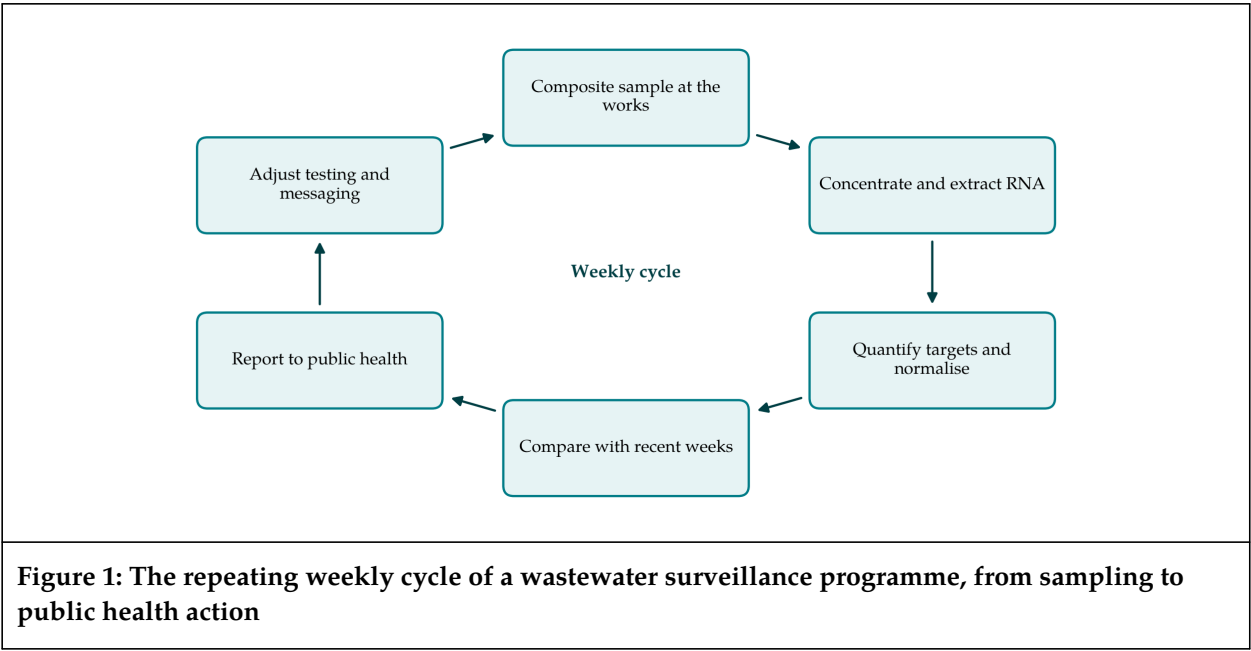
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The interest for infectious disease practice is the possibility of early warning. A clinical surveillance system observes people who feel ill enough to seek care and who are then tested. Each of those conditions introduces delay, and each can shift when behaviour or testing policy changes. Sewage samples everyone connected to the network at once, whatever their symptoms. This communication considers how far that promise has been borne out for respiratory viruses, what limits the interpretation of the signal, and how programmes should use it. It reports no new measurements.

2. What the Published Work Shows

Early studies established the basic correlation. Measurements of SARS-CoV-2 RNA in primary sewage sludge from a single treatment plant tracked the local epidemic curve and, in that setting, moved ahead of reported case counts and of hospital admissions (Peccia et al., 2020). Comparable findings from many catchments led to the now standard claim of a lead time measured in days rather than weeks. The size of that lead depends heavily on what it is compared with. Against a case count built from community testing with same-day results, the advantage is small; against hospital admissions, which lag infection by a week or more, it is substantial. Larsen and Wigginton (2020) set out the reasoning that connects shedding, catchment population and sampling frequency to the signal that can be expected.

Extension beyond SARS-CoV-2 came next, and matters more for ordinary respiratory disease surveillance. Influenza A has been detected in municipal wastewater and the concentration has risen in step with recognised outbreaks (Wolfe et al., 2022). A prospective study measuring several respiratory viruses in the same samples found that concentrations of influenza A, respiratory syncytial virus, human metapneumovirus, parainfluenza viruses, rhinovirus and the seasonal coronaviruses followed clinical indicators for those viruses in the same communities (Boehm et al., 2023). That result is important because it shows a single sample stream can be used for the whole respiratory panel, which changes the economics of the approach. Figure 1 shows the weekly cycle that a programme of this kind repeats.



3. What Determines Whether a Rise Can Be Trusted

A wastewater time series is a ratio of a biological quantity to a hydraulic one, and both vary. Rainfall and infiltration dilute the sample; industrial discharges alter its chemistry; the proportion of virus bound to solids differs between viruses and between sample types, so that concentration from the liquid fraction and measurement in settled solids do not give interchangeable answers. The usual correction is to normalise to a marker of human faecal input, commonly pepper mild mottle virus, or to flow. Reviews of the methods have shown that recovery efficiency differs substantially between concentration protocols, which is one reason absolute concentrations are hard to compare between laboratories (Polo et al., 2020).

Respiratory viruses raise a particular difficulty. Shedding into the sewer comes from swallowed respiratory secretions and from the gastrointestinal tract, and the quantity and duration vary between viruses and between people. The relationship between the measured concentration and the number of infected people in the catchment is therefore not a fixed one, and a wastewater figure should not be converted into a prevalence estimate without strong assumptions. The practical consequence is that the useful output is a trend, read against the recent history of the same site with the same method, and not a level. Table 1 lists the main sources of variation and the usual mitigation.

Table 1: Sources of variation in wastewater signals for respiratory viruses and usual mitigations		
Source of variation	Effect on the signal	Usual mitigation
Rainfall and infiltration	Dilution that mimics a fall	Flow normalisation and faecal marker
Partition between solids and liquid	Different results by sample type	Fix one matrix per site (Polo et al., 2020)
Recovery of the extraction method	Shifts absolute concentrations	Spiked process control in every run
Variable shedding into sewage	Weak link to case numbers	Report trends, not prevalence
Inhibitors in the sample	Underestimation or assay failure	Inhibition control and dilution series
Catchment population movement	Apparent change with no change in risk	Interpret with local context

4. Using the Signal Alongside Clinical Surveillance

Wastewater monitoring complements sentinel clinical surveillance and does not replace it. It cannot identify who is infected, cannot describe severity or age distribution, and on its own supports no clinical decision. What it adds is independence. When testing policy changes, or when people stop presenting to care, clinical indicators move for reasons that have nothing to do with transmission, while the wastewater signal does not. Agreement between the two therefore strengthens an inference, and divergence is informative in itself.

Sequencing the same samples adds a second function. Variant composition can be followed in wastewater, and where the resources exist the same extracts used for quantification can be sequenced to describe which lineages are circulating in a catchment. For influenza this offers a route to early detection of subtype change, although the depth of coverage obtainable from environmental samples is lower than from clinical isolates and the interpretation of mixtures is not straightforward. National programmes have shown the approach can be sustained at scale with standard operating procedures and common reporting ([Kirby et al., 2021](#)).

Three requirements separate a programme that produces usable intelligence from one that produces interesting figures. The first is methodological stability: a site should keep its matrix, concentration method, assay and normalisation constant, because a change in method is indistinguishable from a change in transmission. The second is a defined trigger agreed with the health department in advance, stating what magnitude and duration of rise will prompt what action. The third is the ethical frame. Catchments should be large enough that no individual or household can be identified, and reporting should avoid attaching an apparent prevalence to a named institution or neighbourhood, a concern that applies equally to the sequencing of environmental samples.

5. Conclusion

Wastewater surveillance for respiratory viruses has moved from demonstration to routine use in a few years, and the published work supports a modest and genuine advantage in timeliness over clinical indicators, with the size of the advantage depending on the comparator. Its more durable value is as an

indicator that does not depend on who seeks care or who is tested. Realising that value requires stable methods, trends read against a site's own history, agreed triggers for action and attention to privacy, rather than precision about how many days of warning the signal provides.

Conflict of interest

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