Wastewater surveillance for COVID-19: It's complicated

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Credit: AI-generated image (disclaimer)

Lately, the phrase "wastewater surveillance" has been all over the news—but what is it, exactly? And why is it useful to researchers and public health experts trying to get a grasp on fluctuating levels of COVID-19 infection?

"Wastewater surveillance and testing come with a lot of challenges," says Elena Naumova, chair of the Division of Nutrition Data Sciences and professor at the Friedman School of Nutrition Science and Policy. "But it can be an incredibly valuable tool for getting a complete picture of the data about the prevalence of SARS-CoV-2 (the virus that causes COVID-19) in a given locale at a given time." That picture, she explains, can help shape public policy and keep communities informed about potential health-related dangers.

To better understand the science behind monitoring wastewater, Tufts Now spoke with Naumova about the methods and rationales underlying the process and the pros and cons of its use.

Tufts Now: How does wastewater surveillance work?

Elena Naumova: In the U.S., samples of liquid wastewater and sludge are collected from about 930 sites at wastewater treatment facilities nationwide. It's quite an accomplishment to get so many sites and so many coordinating agencies working together. The samples are gathered from sewersheds, which are community areas served by wastewater collection systems, into treatment plants.

The samples are then sent to environmental or public health laboratories to be tested for SARS-CoV-2. Each sample goes through laborious processing to measure the amount of SARS-CoV-2 ribonucleic acid (RNA) it contains. The amount of SARS-CoV-2 RNA in a given sample provides information about how much of the virus is present at a given moment in time.

After processing, the data are analyzed and reported to the Centers for Disease Control and Protection (CDC). In order for viral levels to be compared across sampling locations and over time, the data has to be converted so that it's normalized by population.

Here's one way to understand how that works: Imagine having a glass of water that represents a particular watershed population and calculating how many particles are in the glass of water. You could say, I have six—or 26—particles—but because every system serves a different number of people, neither figure means anything on its own.

But if you say this glass of water represents 200 people who are served by a particular watershed, that gives you information you can use to make meaningful comparisons with samples from other systems.

Finally, the results are made publicly available through CDC's COVID Data Tracker.

Why are public health efforts using this strategy now?

We have some tools for checking the vital signs of the nation; testing wastewater gives us an additional one. To monitor health conditions accurately and reliably, we need many instruments with various degrees of precision, convenience, and cost. Individual testing (using nasal swabs, for example) is the most accurate, but it's also invasive and expensive.

Noninvasive routine sampling, like wastewater monitoring, are essential to public health professionals to inform authorities and the public about potential harm and also to establish regulations and policies and track their enforcement, but many factors can mitigate the effectiveness of both policies and monitoring.

The United States has been tracking SARS-CoV-2 in wastewater since September 2020. Some researchers believe that wastewater surveillance might have the potential to identify changes in community infections sooner than clinical testing and allow for a more rapid public health response. Some think that if wastewater is simply confirming the trends already seen in clinical tests, it may not be the best investment.

By monitoring wastewater for pathogens, chemicals, and pharmaceuticals, we can learn more—and learn it faster—about what might happen in the population. We can watch for emerging trends. A combination of tools helps to calibrate their use. Think of using both an electrocardiogram and a watch to check a pulse—both tools are useful, yet one is preferable in severe conditions and another for routine, daily use.

Wastewater sampling in combination with traditional hospital-based surveillance and contact-tracing allows us to learn more about potential hotspots of infections or unstable health conditions and how well disease control measures work in a given community.

So it's effective—but it's not a golden ticket to identifying outbreaks, containing the virus, and stopping the pandemic?

It's complicated. The system is very useful when we understand its caveats.

One challenge is standardization. Wastewater is a complex and variable mixture, and often contains compounds that can interfere with RNA quantification methods, thereby impeding accurate measurement. For each wastewater treatment location and at each step of detecting a virus, all analytical methods must be well-tailored to the particular wastewater mixture. This is a chemically and biologically complex process and involves multiple steps that are difficult to standardize and that require systematic controls.

Another challenge: the number of people contributing to a given sewershed could change over time, whether seasonally (because of tourism and vacations) or weekly (because of work-related commutes or temporary workers). Or there may even be one day when nobody leaves their homes—because of a snowstorm, say. All these factors will affect the amount that people are contributing.

There's also the need for environmental calibration. Rainwater or industrial discharge can dilute wastewater samples and require adapting testing methodology. Wastewater also contains RNA from dogs, cats, and other animals—all potential hosts for the variant. Contaminants such as animal waste can compromise the interpretation of samples: the origin of detected pathogens may not always be clear.

Another factor is affordability: the potential cost-savings from wastewater surveillance are unclear. As the Government Accountability Office puts it, "wastewater surveillance can be particularly useful when clinical testing is resource-constrained, but it is difficult to quantify the value due to a lack of cost-benefit analyses." Combined testing for both pathogens and chemicals, such as opioids, requires different processes and more complex logistics.

Finally, there are privacy and ethical concerns: Wastewater data could be linked with identifiable data, especially in small communities, and that's a potential privacy problem. What if the genetic data is misused? What if communities face consequences because surveillance suggests pathogen spread or illicit drug use?

In lower-income communities, individual testing can be prohibitively expensive or difficult to obtain. Does wastewater surveillance help resolve any issues related to equity?

Not really, unfortunately. A lot depends on available resources and political will. And the public health utility of wastewater surveillance for SARS-CoV-2 has not yet been thoroughly demonstrated in low-resource waste systems—for example, systems with substantially decaying infrastructure—or wastewater-impacted environmental waters.

As the CDC has said, "these systems have unknown fecal inputs and losses and are open to environmental processes that unpredictably impact the persistence of SARS-CoV-2 RNA throughout the system, including sunlight, predation from other microorganisms, and variable pH and temperature."

Also, many such communities might be served by septic systems. According to the Environmental Protection Agency, more than 60 million people in the United States—about 20% of households—are. Such systems do not connect to wastewater treatment plants, where sampling often occurs. Communities and households that rely primarily on septic systems are not represented in the wastewater surveillance data.

Given all that, is wastewater surveillance still a worthwhile undertaking?

In my opinion, it's a powerful approach, and it should be further developed and expanded to cover testing for well-known agents like influenza, rotavirus, norovirus, antibiotic-resistant bacteria. It should also be used as a tool for detecting novel pathogens.

The entire infrastructure is set up to do disease tracking for existing or emergent diseases, so it allows you to be constantly vigilant. And there's so much evidence right now that we need to be vigilant for anything that might come up—like monkeypox or new variants of coronavirus.

Its biggest value is that it allows for triangulation of data coming from multiple sources. That lets us be more certain about our information. Ultimately, it could be a really reliable monitoring system. I compare it to weather monitoring.

We no longer question why we need to have thousands of monitoring stations for meteorological data, because we know that these stations provide critical information for early warnings about, say, a tornado 15 minutes earlier than we'd otherwise have those warnings. These stations are life-saving devices.

The same is potentially true of wastewater surveillance systems. Wastewater monitoring could be the next valuable tool for detecting emerging pathogens in an effort to reduce risk of infection, amplification, and spread—the goals of the ongoing STOP Spillover project led by Tufts.

Provided by Tufts University

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