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Cite this as: *BMJ* 2022;378:o1869
http://dx.doi.org/10.1136/bmj.o1869
Published: 29 July 2022

What poo tells us: wastewater surveillance comes of age amid covid, monkeypox, and polio

Sewage surveillance is going through a rebirth as covid, monkeypox, and now polio bring new urgency to virus detection. Bryn Nelson reports

Bryn Nelson *science journalist*

Amid widespread polio outbreaks in the summer of 1939, researchers from Yale University first detected poliovirus in sewage samples from Charleston, South Carolina, and Detroit, Michigan. Sweden's State Bacteriological Institute replicated that successful find during an outbreak in Stockholm later that year. Reflecting on their initial discoveries, the Yale scientists concluded: "This virus can be transported, for short distances at least, through the medium of flowing sewage."[1]

Earlier this year, routine wastewater surveillance identified repeated signs of poliovirus in samples from London's Beckton sewage treatment works, which serves roughly 4 million residents in north and east London.[2] It came as a surprise that a nearly eradicated virus could be circulating again in a country where the last case of polio had been documented in 1984. Then on 21 July, health officials in New York State's Rockland County reported the first clinical case of vaccine derived polio in the US since 2013. Retroactive testing prompted by the case, in which a young man was at least temporarily paralyzed, detected the virus in wastewater samples collected back in June for covid-19 monitoring.[3]

Wastewater epidemiology, it seems, has come full circle. The environmental surveillance tool that got its start with polio and soared in popularity with covid-19 has reasserted its potential to sound the alarm on both old foes and new threats like monkeypox, which has been declared a public health emergency of international concern by the World Health Organization. The revelations in our sewage, experts suggest, have offered evidence for why building and maintaining the infrastructure necessary for wastewater-based disease surveillance should be an urgent public health priority.

"With covid we had an expansion of our imagination about what is possible for these tools that our field has used for a long time," Marlene Wolfe, an assistant professor of environmental health at Emory University in Atlanta, told *The BMJ*. As the surveillance method began proving itself more widely, she saw a dramatic shift in how public health officials viewed the new data, from sceptical dismissals to enthusiastic endorsements. "They've said very clearly to us, 'We don't want this data to go away,'" she said.

The covid testing ground

In March 2020, Wolfe and Alexandria Boehm, a professor of civil and environmental engineering at Stanford University, led a team that began testing wastewater at a constellation of northern California and Bay Area treatment plants. The Sewer Coronavirus Alert Network (SCAN) has since expanded to include dozens of testing sites throughout the US.

From its investigative work, the team discovered early on that wastewater solids offered particularly high rates of SARS-CoV-2 viral detection. "We have been building this as a platform to be able to pivot to whatever the next thing is," Wolfe said. "We can take that sample, which is less than a gram of wastewater solids, from communities all across the country: that small sample can represent up to 4 million people in some cases."

In Italy, 167 wastewater treatment plants are now monitored once or twice a week to detect both SARS-CoV-2 trends and variants. Giuseppina La Rosa, an environmental virologist at the National Institute of Health in Rome, said participating agencies in the European Union are discussing how they might build on their existing infrastructure. "Now that we have created such a powerful network of environmental surveillance, the question is how to use it in the future—for example, for other emerging viruses or for antimicrobial resistance or drugs."

As testing wanes, sewage picks up the slack

In September 2020, Colleen Naughton, an assistant professor of civil and environmental engineering at the University of California, Merced, began tracking the growth of wastewater surveillance around the world. By 20 July 2022, her laboratory's COVIDPoops19 dashboard had tallied more than 3500 testing sites in 68 countries.

Her group's own monitoring work in California's Central Valley, in collaboration with SCAN, has shown how the relatively cost effective early warnings can help inform public health interventions. In the city of Merced, wastewater surveillance detected the original SARS-CoV-2 omicron variant weeks before the first confirmed clinical case there.[4] As omicron quickly overtook the delta variant in wastewater samples, Naughton said, local public health officials factored the shifting ratio into their decisions about when to stop recommending or authorising the purchase of monoclonal antibodies that were proving far less effective in treating omicron.

Based on a 295 day comparison between wastewater and clinical sequences at the University of California, San Diego, a large collaborative effort likewise detected emerging variants of concern in wastewater samples up to two weeks before their identification

in clinical samples, along with "multiple instances of virus spread not captured by clinical genomic surveillance."[5]

From a separate sewershed in San Francisco, SCAN has underscored what clinical case reporting can miss. Unlike the correspondingly sharp peaks in reported SARS-CoV-2 cases and wastewater viral levels during the delta and initial omicron waves, the current surge—attributed largely to the omicron BA.5 subvariant—appears much more modest if based on case data alone. But the spike in wastewater levels measured at the San Francisco site and many other locations suggests that the case based signal is hiding a much more dramatic surge. "If you look at the wastewater, we are at least as high as we were in January when everybody was so concerned," Wolfe said.

The decoupling between reported cases and wastewater data—perhaps in part because of a precipitous falloff in more expensive polymerase chain reaction tests, a switch to home antigen tests whose results are less often reported, and a growing lag in data submission by local and state officials—may be contributing to a false sense of lower risk despite high viral concentrations. That upswing, Wolfe said, is also reflected in a spiking case positivity rate that is approaching the heights seen during the first omicron surge. In other words, she said, the wastewater data are providing a clearer picture of the current pandemic than the case data.

Cryptic cases of monkeypox and polio

In the UK, meanwhile, officials facing funding shortfalls began dismantling the surveillance infrastructure they had expanded for covid-19, only hastily to reassemble some of the capacity when London's poliovirus discovery forced a U turn. The virus, in fact, was detected through a pre-existing surveillance programme led by the National Institute of Biological Standards and Control, which conducts regular tests in London and Glasgow and reports its results to the UK Health Security Agency (UKHSA). "It's thanks to them that we've had any form of environmental surveillance," Nicholas Grassly, a professor of infectious disease and vaccine epidemiology at Imperial College London, told *The BMJ*.

The detection of closely related polioviruses has since prompted upstream testing from smaller sewer catchments, in coordination with UKHSA, to find where the virus may be circulating. Other sewage treatment works have begun testing to determine whether the virus is circulating elsewhere in the country. Although the London discovery hasn't yet met formal WHO criteria for a circulating poliovirus, the pattern of detection and the related genetic sequences of the captured viral strains both point towards circulating vaccine derived poliovirus type 2, perhaps among "closely linked individuals," said UKHSA.

Polio can be hard to detect if relying on clinical symptoms—as few as one in 500 type 2 cases result in paralysis. "It highlights that environmental surveillance can be more sensitive than reporting of cases of paralysis," Grassly said—not only for countries trying to eradicate the virus but also for countries at risk of importing it.

In California, SCAN began testing for monkeypox on 19 June 2022 and detected the first signs of the virus the next day, at a testing site in San Francisco. Since then, six testing sites in northern California have found the virus, including in some communities that hadn't yet reported any confirmed cases. The outbreak has infected more than 18 000 people in 70 non-endemic countries, mainly among men who have sex with men. Stigma and discrimination may be limiting the awareness or willingness of at-risk people to have their symptoms evaluated. Even then, multiple cases have been misdiagnosed as herpes or syphilis while retrospective testing of archival samples at a large Belgian sexual health clinic revealed three asymptomatic cases dating back to May 2022.[6]

This is where wastewater surveillance can help. The anonymous pooled samples can capture the contributions of a community without divulging individual identities. Says Wolfe, "Not only do we capture people who may not be able to—or want to—access a test for whatever reason; we also capture people who don't even know that they might need to be tested." Increasing rates of detection and higher concentrations may point towards a growing burden of disease.

Expanding influence

With partners in Ghana, India, and Malawi, Grassly and colleagues have developed a similar technique for detecting the *Salmonella typhi* pathogen in wastewater. Such environmental surveillance works even in urban areas that lack formal sewer systems and have informal drainage channels instead, he said. "They still function as sensitive aggregators of poo from a lot of people," he noted. "If you do topological maps and drainage models and, ideally, if you have a map of the drainage network itself, you can put those things together and work out where you should sample and also estimate the catchment population for that sample."

Not every pathogen is reliably shed in faeces, and estimating case counts based on RNA or DNA concentrations in wastewater remains a work in progress. As another tool in the disease surveillance toolbox, though, wastewater epidemiology can provide an invaluable warning sign, said William Hanage, an associate professor of epidemiology at Harvard University. "It would be foolish to rely on it alone—but with other things as well it's phenomenally useful," he said.

An early warning's true use may depend on whether it prompts timely and effective interventions, like vaccination campaigns for covid-19, polio, monkeypox, or typhoid that prioritise the most vulnerable. In the London borough of Hackney, Grassly said, one in three 12 month old infants haven't yet had their full polio vaccination series.[2] A looming question is whether the current scare will help reduce that gap. "People think polio's been eradicated," he said. "We don't think about the diseases that we don't get because of routine vaccination, but it's certainly a wake-up call for us."

Competing interests: Bryn Nelson is author of the forthcoming book *Flush: The Remarkable Science of an Unlikely Treasure.*

Commissioned, not externally peer reviewed.

1 Paul JR, Trask JD, Gard S. Poliomyelitic virus in urban sewage. *J Exp Med* 1940;71:-77. doi: 10.1084/jem.71.6.765 pmid: 19870997

2 Grassly NC. Polio's detection in London is a wake-up call. *BMJ* 2022;377:. doi: 10.1136/bmj.o1589 pmid: 35760425

3 Cutler N, McKenna C. Polio in Rockland wastewater as early as June, samples show. 26 July 2022. https://news.yahoo.com/polio-rockland-wastewater-early-june-090159370.html

4 Kirby AE, Welsh RM, Marsh ZA, etalNew York City Department of Environmental Protection. Notes from the field: early evidence of the SARS-CoV-2 B.1.1.529 (Omicron) variant in community wastewater—United States, November–December 2021. *MMWR Morb Mortal Wkly Rep* 2022;71:-5. doi: 10.15585/mmwr.mm7103a5 pmid: 35051130

5 Karthikeyan S, Levy JI, De Hoff P, etal. Wastewater sequencing reveals early cryptic SARS-CoV-2 variant transmission. *Nature* 2022. doi: 10.1038/s41586-022-05049-6. pmid: 35798029

6 De Baetselier I, Van Dijck C, Kenyon C, etal. Asymptomatic monkeypox virus infections among male sexual health clinic attendees in Belgium.*Medrxiv* 2022:2022.07.04.22277226 [Preprint]. doi: 10.1101/2022.07.04.22277226.