Wastewater surveillance for infectious disease preparedness

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The University of Oklahoma Wastewater Based Epidemiology (OU WBE) team highlights successes from their three years of wastewater surveillance in Oklahoma & how this surveillance approach can be used as next-level monitoring for infectious disease preparedness

The OU WBE team, founded by Bradley Stevenson, Jason Vogel, and Katrin Gaardbo Kuhn in response to the COVID-19 pandemic in Summer 2020, has expanded to one of the most extensive wastewater monitoring networks in the world with a team that has included over 50 faculty, students and staff.

In a paper published in 1942, Drs. James Trask and John Paul described a study to detect poliovirus in wastewater samples collected in New York and New Haven. They concluded, “It is likely that the periodic sampling of sewage for pathogenic viruses or bacteria may be a method of epidemiological value”. [(1)] Since then, wastewater surveillance has been used to detect sporadic outbreaks or clusters of various infectious pathogens, reaching new levels of routine utilization during the COVID-19 pandemic. [(2)]

Compared to the classic infectious disease surveillance approach, which relies on a chain of events from people developing symptoms through testing, diagnostics, and finally, the infection becoming reported to health authorities (if notifiable), wastewater surveillance offers important advantages concerning timeliness and representativeness.

By examining wastewater samples, we can first detect an increase in infections almost immediately when they happen (i.e., when an infected person excretes viral or bacterial particles). On the contrary, reported cases through classic surveillance are usually available two to three weeks after a person experiences their first symptoms.

Furthermore, wastewater monitoring is entirely independent of individual testing. It captures infections from everyone who contributes to the sewage, regardless of their symptom status, and therefore represents the entire cohort of infected people.

Lessons learned from wastewater surveillance: COVID-19 & beyond

The significant benefits of wastewater surveillance became particularly apparent during the COVID-19 pandemic, which prompted the implementation of routine SARS-CoV-2 wastewater monitoring in many different locations worldwide. [(3)] Thanks to these

approaches, we now have evidence that wastewater provides several weeks' early warning of increases or outbreaks of infections [4-6], is a simple but representative monitoring tool in resource-limited settings [7,8], and can be used to infer knowledge about intricate disease transmission dynamics which has traditionally relied on notified case reports. [9]

Following the success of wastewater surveillance for SARS-CoV-2, several countries, states, and cities rapidly expanded the coverage to include other respiratory pathogens such as influenza and respiratory syncytial virus, emerging diseases and diseases of low current transmission, which are considered a serious threat to public health if they re-emerge at a larger scale.

Overall, these programs have further cemented the usefulness of wastewater surveillance for rapid detection of seasonal or regional increases in respiratory infections but also highlighted a strong potential for identifying silent reservoirs of poliovirus and setting up wastewater-based early warning systems for new diseases being introduced in a community, as highlighted from the experience with Mpox. [10-13]

Tales from the sewer in Oklahoma

The OU WBE program was initiated during Summer 2020 in response to the COVID-19 pandemic. Initially focusing on the University of Oklahoma residence halls, the program rapidly expanded to include monitoring in Oklahoma's largest cities of Oklahoma City and Tulsa and Midwest City, Norman, and Anadarko. In Summer 2022, the Wastewater team signed a contract with the Oklahoma State Department of Health to set up a complete state-wide wastewater surveillance program covering various populations, including many vulnerable and underserved communities.

Using our long-term SARS-CoV-2 surveillance data, we have built models to show that wastewater concentrations accurately predict reported COVID-19 cases with an average of one week's early warning and that the early warning time significantly varies with demographic characteristics such as ethnic composition and household income in each community. [6] These results have helped city and public health leaders guide COVID-19 control and prevention approaches, including vaccine roll-out, regarding different population structures.

In addition to SARS-CoV-2, the state-wide wastewater program in Oklahoma currently also includes routine monitoring for other respiratory infections (seasonal influenza and respiratory syncytial virus) and gastrointestinal pathogens (norovirus, Salmonella, Campylobacter, and Shiga-toxin- producing *Escherichia coli*).

This expanded surveillance is one of the first in the world to cover routine monitoring of such a wide pathogen spectrum in wastewater. It has allowed us to confirm the causative agent of several gastrointestinal and respiratory disease outbreaks in the State and to generate new

knowledge of how these pathogens exhibit seasonal patterns in wastewater comparable to those observed for reported human infections.

How does wastewater & environmental surveillance apply to One Health?

The connection between human and animal health and the environment's overall health is known as One Health. [14] Because almost 80% of all emerging infectious diseases in humans are zoonoses (i.e., transmitted between animals and humans) [15], the optimal preparedness against emerging infections should follow a One Health surveillance approach.

Apart from wastewater surveillance to directly indicate the presence of pathogens in animals and humans, this also includes ensuring that recreational bodies of water do not pose a risk of infection. The traditional method for determining whether a river or lake is suitable for swimming and other recreational uses is to analyze for bacterial fecal indicators such as *E. coli* or enterococcus.

This practice is based on a U.S. Public Health Service study of swimmers' health on Lake Michigan in 1948. [16] Since then, researchers worldwide have confirmed the usefulness of direct pathogen surveillance in rivers and streams, especially in areas with limited or no conventional wastewater treatment or direct inputs from animal manure runoff. [17,18] In Oklahoma, fecal bacterial monitoring in rivers and streams has been ongoing by the Oklahoma Water Survey, the Oklahoma Conservation Commission, and the Oklahoma Water Resources Board for over thirty years. [19]

In collaboration with other researchers from the University of Oklahoma and with funding from the U.S. National Science Foundation grant #2200299, the Wastewater team has implemented a true One Health human, animal, and environmental surveillance approach by monitoring for pathogens through upstream manhole sampling and downstream sampling in rivers and streams that receive animal waste or treated human waste.

Through this sampling, we have detected low levels of respiratory and gastrointestinal pathogens, which indicates not only active transmission of those pathogens within the community but also a potential risk of infection with gastrointestinal pathogens for persons who ingest water from those rivers and streams.

When combined with clinical infectious disease case data in both humans and animals, pathogen concentrations in wastewater and surface-water samples have the potential to be utilized by artificial intelligence tools to detect or predict outbreaks and inform public- health decision-makers of upcoming infectious disease surges.

To view the references, please click here: https://ou.edu/disc/resources/references

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