

Wastewater surveillance, an interview with Dr. Medini Annavajhala

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Using wastewater surveillance to track the spread of infectious diseases has become more common since COVID-19. To learn more about the process, history, and future of wastewater surveillance, we spoke with Dr. Medini Annavajhala, an assistant professor at the Children's Hospital of Philadelphia (CHOP) and the University of Pennsylvania, whose research involves wastewater surveillance. Dr. Annavajhala received her doctorate in Earth and Environmental Engineering from Columbia University and completed a postdoctoral fellowship at Columbia University Medical Center before coming to Philadelphia. We are grateful that Dr. Annavajhala took the time to talk with us shortly after arriving on campus.

Could you tell us a little bit about what wastewater surveillance is and what it entails?

Basically, the idea behind wastewater surveillance is how do we get information on a ton of people at one time without having to test every single person for a disease?

Because everyone produces wastewater and it all goes to a central place, with a single sample we can get a snapshot of a whole community, such as a neighborhood, a hospital, or an office building. And so most recently, we've been applying that to pathogens and infectious diseases, but there's a whole host of things you can test for in wastewater.

Compared with other ways to monitor pathogens and infectious diseases, what are the pros and cons of wastewater surveillance?

I think the easiest one to point out is the cost, because you can test a hundred people for COVID, or you can test one wastewater sample that they all contributed to.

So, it's just fewer samples to test, and you can look for multiple things at once. Most of the time, as long as it's a disease that's passed through the digestive tract, you can test for it. In addition, you can test not only for biological targets like an infectious disease, but also biochemical substances, like caffeine or medications.

The downsides are that your data tell you about the group, not individuals within the group. So, if you're testing samples from a wastewater treatment plant in a community, you can see when quantities of influenza increase in the community, but the data do not tell you anything about which people are infected with the virus. So, taking the raw data and translating that to something either the public or officials can use to make decisions, I think that's what's missing right now.

Can you speak a little bit about how data are collected and processed?

Yeah, so it's not very glamorous, but it's kind of nice that it's actually pretty low tech. At the end of the day, all you need is a pump and access to the wastewater stream. For example, we would identify the main sewer line of the building or treatment plant where we want to collect samples. Then at a safe location, we would insert the pump, so that it pumps out wastewater samples at regular intervals.

We collect a daily snapshot, which is called a composite sample of the day, meaning that all the samples for the day go into the same bottle to produce that day's sample. From there, we take the sample to the lab and concentrate it because most of the sample is just water. The concentrated sample is then treated in different ways based on which pathogens are being evaluated. We can then use more techniques to study the genetic material of the microorganisms in the sample and get additional information about which strains or types of the microorganism are spreading among the test population.

Our readers might be wondering, does the sample smell when it gets back up to you?

No, it's actually crazy how not gross most of the samples are. You would think, it's sewage, you know? It is, but there's so much water content that many samples we collect really don't have the odor we all think of when we think of sewage.

So, taking a step back and thinking about this in the bigger picture, when did the process of wastewater monitoring start to be viewed as a tool in the modern toolbox of public health?

Actually, it's surprising! I mean, everyone immediately thinks of the COVID-19 pandemic, but in the 1930s to 1950s, the polio epidemic was actually one of the first uses for wastewater surveillance, using old-school culturing and wastewater testing methods to detect where the virus was coming from in the municipal wastewater stream.



After that, many different approaches were used to track norovirus, hepatitis and other targets through the 1980s and 1990s, but then there was sort of a hiatus especially in the public realm. I think when COVID-19 emerged, a lot of people had the infrastructure in place and knowledge about wastewater surveillance, so it was easy enough to adapt to monitoring for SARS-CoV-2, the virus that causes COVID-19. I think this is definitely the first time I've seen wastewater testing in mainstream media or public understanding, but it's been around.

So, we've talked about wastewater monitoring, what it is, and how it can help communities. There's always more to learn, though. Could you speak a little bit about your own research and what you're focused on understanding next in this story?

That gap between interpreting the data and packaging it for decision making is a big part of my research, which doesn't sound much like lab science, but it is a lot of analysis of molecular and sequencing data — visualizing it and packaging it in a way that can be useful for decision makers.

A lot of my work focuses on considering what the data actually mean for a community, like "What is the threshold where we have to do something?" You know, a lot of these pathogens are just around all the time, so we need to think carefully about when is it concerning? When is it not concerning?

The other, more technical arms that we'd like to focus on are really working on those sequencing approaches in the wastewater. If you think about a microbe passing through wastewater, it's going through a lot! It's interacting with other microbes; it's bouncing against the pipe walls, things like that. So, the bacteria or viruses themselves change, or can be destroyed or fragmented as they move through the wastewater stream. Understanding those processes and how they impact what we measure at the end is another important aspect of our work.



The last arm of our research is basically, how to use the data to get ahead of concerning developments, like new antibiotic resistant bacteria or new viral strains that are spreading from person to person in a community.

When you first got into this field, you were studying science policy. Do you think that there are any particular obstacles or promising avenues ahead in that interface between wastewater science and policy?

A hundred percent. There's so much data we have from the wastewater, but it's a little like screaming into the void. How do you interpret this data in a way that means something? I think part of it is the science itself, and part of it is, "Okay, we know it's here. What do you want us to do about it?" I think that's sort of the hurdle from the policy side. Many people might just say, "Okay, we know COVID is here, and the flu comes every year. Tell me more details so that I can make an informed decision about what to do." Part of what we're trying to do to address that is sampling not just at the community or hospital level, but to figure out if we can sample upstream, which not many people are doing, so that more targeted interventions can potentially be put in place.

It's clear how tracking levels of particular pathogens, for example, can be really useful. But you mentioned also being able to track, say, levels of caffeine or other compounds. Could you speak more to the other things that aren't infection-related that we might be able to glean from wastewater monitoring?



Many researchers have recently been turning to caffeine as a useful biomarker in wastewater because it is specific to people. Since many of us love to drink coffee every day, caffeine is actually quite a good marker for how many people are contributing to a wastewater sample.

What we can also do is, going back to the pathogens a little bit, we only know how much of a pathogen is in the wastewater, but I can't tell you if it was one person who shed a lot of it or many people who shed a little. So, one thing we're doing is basically using either caffeine metabolites or other normalizing biomarkers in the wastewater to normalize to how many people we think are contributing to the wastewater we are sampling. It's one of the better ways to figure out an average amount of the pathogen in question that's being shed into the wastewater per person.

The NIH's National Institute for Drug Abuse has also been very interested in looking at pharmaceutical drug levels in different areas. There have been a lot of ethical concerns that come up with that, as you can imagine. So, there's still a debate in the field about the best way to do this. The good thing about wastewater is that you're not tracking any one individual, but you can get community-level data that can inform community-based interventions.

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