Sewage Testing as a Pandemic Monitoring Tool

NITYA JACOB

An overflowing sewer in New Delhi on July 22, 2020. Photo: Sandeep Saxena

A common challenge faced by governments across the world during the COVID-19 pandemic is to identify patients affected by the virus. The two tests adopted now come with their own cost and time constraints. Keeping track of the spread of the virus is another daunting task, especially for city and local governments.

In this article, Nitya Jacob, a water, sanitation and hygiene policy analyst, proposes the use of wastewater-based epidemiology (WBE). In simple terms, this would mean testing sewage samples for the presence of SARS-CoV-2 virus. Although WBE is an accepted testing method in certain developed countries, it has not found favour in developing countries including India where the initial efforts commenced in Chennai. The article, which also discusses the limitations of WBE in the Indian context, argues that the COVID-19 pandemic provides a perfect entry point to promote sewage testing and, more importantly, to upgrade the poor infrastructure and ensure equity in access to safe and good quality sanitation.

A s governments struggle to keep track of the spread of the COVID-19 pandemic by testing individuals, new hotspots show up in India, where the numbers have increased sharply over the past month. Individual testing is slow and expensive: the more reliable Real Time Polymerase Chain Reaction (RT-PCR) test yields results after several hours, while the far less reliable rapid antigen test indicates the presence of the SARS-CoV-2 virus faster.

The management of the pandemic rests on three pillars—testing, isolation, and treatment. Over the past several months, a sharp fissure has opened up on testing approaches followed in India, and between developed and developing countries. More than a dozen developed countries have tested sewage for the SARS-CoV-2 virus and, finding it a reliable and quicker tool than individual testing, are preparing protocols for national testing. In contrast, there is hesitancy on the part of most of the developing world, including India, to adopt testing sewage samples for the virus.

Despite recognising its potential and conducting these tests, no government appears enthusiastic in developing a protocol to institutionalise this method of pandemic testing and surveillance. Indeed, several developing countries have followed the developments in sewage testing but have not adopted it. The issues relevant to India and developing countries were discussed by a group of experts who met in May and June 2020 to deliberate on the manner in which WBE can be

adapted for India. The discussions, compiled by the author was brought out as a Thematic Paper[1].

Authorities in India test individuals directly using the RT-PCR test and the rapid antigen test. As States ramped up testing and increased the number of antigen tests in the past several months, the numbers of people detected with COVID-19 has risen rapidly. What this indicates is there are limits to testing individuals due to costs, logistics, and social considerations.

Detecting COVID-19 cases by testing sewage for the presence of the SARS-CoV-2 virus traces, however, has not got much traction in India. The number of COVID-19 patients detected in a population is directly proportional to the number and types of tests being used. Low testing rates and methods such as the antigen test give a false impression of a low prevalence of the disease. Alternatives like wastewater-based epidemiology (WBE) are available and are gaining currency.

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Internationally, sewage testing, technically called WBE, has been tried and accepted as a means of surveillance to predict the spread of the pandemic. The World Health Organization (WHO) avers that WBE has the potential to be used to complement clinical surveillance or to trigger more comprehensive surveillance in areas with poor performance, for example in crowded, extremely low-resource settings such as informal settlements or, more generally, in marginalised populations[2]. This method has also been used to keep tabs on polio and use of drugs, especially cocaine[3].

Research findings from past coronavirus epidemics, such as the Severe Acute Respiratory Syndrome (SARS), which indicated that viruses are excreted by infected humans through their stools, form the basis for WBE in the context of COVID-19. As the traces of these viruses are detected in sewage, mapping such locations can help determine the presence of infections in a geographic area. In such situations, individual testing and social distancing are difficult. Although

WBE cannot pinpoint where COVID-19 positive cases exist, it can be a sensitive tool to monitor circulation of the virus in a population in specific geographical areas from where samples are drawn.[4]

Thus, around the world, especially in Europe and North America, there is a lot interest and research into fine-tuning sewage testing into a surveillance method. Detection of non-infective RNA fragments of SARS-CoV-2 in untreated wastewater and/or sludge has been reported in several settings, such as Italy, Spain, Australia, the Netherlands,

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the U.S., France, and Germany. Researchers in the Netherlands, France, and the U.S. have also demonstrated a correlation between wastewater SARS-CoV-2 RNA concentrations and the number of COVID-19 clinical case reports. France and the U.S. have suggested that the RNA concentrations could provide a 4- to 7-day advance notice ahead of COVID-19 confirmed case data. In other words, the case load in a given geography is proportional to the number of SARS-CoV-2 fragments detected in the sewage.

The Netherlands was among the first to test and detect the virus in sewage. In a paper published in March 2020, researchers from KWR Water Research Institute, Nieuwegein, wrote how they found virus fragments in sewage from six locations[5]. Since then, the Dutch government has developed plans to incorporate daily sewage surveillance into its national COVID-19 monitoring.[6]

France has set up an Epidemiologic Observatory to share information between scientists and wastewater utilities in France. This government-supported Observatory has expanded surveillance to 150 wastewater treatment plants across France[7]. In addition, a European laboratory is being established for continent-wide surveillance.

Similarly, Australia's National Science Agency reported in April that the virus was detected in two wastewater catchments in Southeast Queensland. The

paper[8] published by the Agency estimated a median range of 171 to 1,090 infected people in the region—roughly what clinical observations predicted. In other words, the number of SARS-CoV-2 virus fragments detected in the wastewater is proportional to the expected number of COVID-19 patients.

Studies of samples from 12 treatment plants in Switzerland pointed in the same direction. But the correlation between the actual number of viral fragments per unit of wastewater (usually a litre) and COVID-19 patients appeared lower than it should, given the number of people known to be infected or asymptomatic. This suggested that refinements were needed to quantify the number of infected people.

There is well-researched and documented evidence from several countries that sewage can be tested for SARS-CoV-2 as a quick way to predict the COVID-19 pandemic's spread in a community. There are several reasons this has worked:

- Firstly, most of these countries have well-established sewage networks and wastewater treatment plant managers know from where the sewage comes.
- Secondly, this reduces the guesswork in collection as all samples have been collected from the intakes of sewage treatment plants.
- Thirdly, all have followed similar procedures to collect and test samples.
- Fourthly, they have successfully correlated the number of virus fragments detected in sewage samples to the number of patients in areas from where the sewage comes.

India's start from Chennai

Despite international evidence, WBE has not found favour in India or even other developing countries. In India, a few water utilities tested sewage samples in May and found the SARS-CoV-2 virus but stopped short of widespread, continuous testing that is needed for surveillance.

The Chennai Metropolitan Water Supply and Sewerage Board (Chennai Metrowater) was among the first in India to conduct a preliminary study in early May in which it detected traces of the virus in wastewater[9]. The utility collected two samples each from areas that had COVID-19 patients and were free of infections. Traces of the virus were found in samples from the former locations.

It planned to develop a protocol for testing sewage for the virus with the WHO. However, a few weeks later, the Indian Council of Medical Research (ICMR) advised Chennai Metrowater to stop the study, according to a newspaper report[10]. A source close to ICMR said that since COVID-19 was an infection of the pulmonary system, testing sewage for its presence as a means of surveillance or understanding the dynamics of its epidemiology would be of limited utility.[11]

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Nonetheless, the same newspaper report said that the ICMR had asked governments in New Delhi, Maharashtra, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, and Madhya Pradesh to take up similar studies to develop a protocol and standard operating procedures. Emails to ICMR elicited no response. However, it is reliably learnt that ICMR has developed a protocol based on the results of tests from Maharashtra. The Ministry of Health and Family Welfare (MoHFW) has passed it onto the Cabinet for a decision on whether to roll it out across the country.

There have been other test ventures as well. Researchers from the Indian Institute of Technology, Gandhinagar (IIT-G), Gujarat[12], also started testing sewage later in May and found traces of the virus, and are working with about 50 research organisations to develop a systematic way of testing. Wastewater is an important source to monitor the presence and progress of the infection because excreta of both symptomatic and asymptomatic individuals had the virus.[13] The city municipal corporation, however, has not been cooperative. Instead, the Gujarat State Pollution Control Board allowed permission to the researchers to collect and test samples from Gandhinagar.

A consortium of organisations in Bengaluru is also working towards developing a protocol for testing sewage. It first sought permission for collection and testing from the Bruhat Bengaluru Mahanagara Palike (BBMP); it took over a month for

the consent letter to be issued. Tests from several locations have indicated SARS-CoV-2 virus fragments, again proving the hypothesis.

The Delhi Jal Board, when contacted about plans to test sewage for the virus, responded in the negative via email:

> **"No plans of conducting test on sewage for COVID-19 as volume of sewage at STP [sewage treatment plants] is very high and in case of any chance of virus in coming sewage, that will be too diluted to be harmful. Moreover, there is no testing facility for collecting sample and testing of sewage for COVID-19 virus in and around Delhi."**[14]

This reluctance to test sewage appears to be more to do with a view to manage the results than the pandemic. Traces of SARS-CoV-2 in sewage would indicate a much higher spread of the disease than is currently stated in official statistics. Rough calculations can predict the number the infected or exposed individuals in a given area. Refinements in sampling can isolate specific areas. For example, sampling sewage emerging from a particular ward, or a smaller area, can predict if there are active or even recovered cases there.[15]

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Therefore, although researchers from several Indian cities, both from government and independent academic institutions, have tested and found the SARS-CoV-2 virus, official recognition of its potential to predict the pandemic is not forthcoming.

Reluctance in other developing countries

Elsewhere in the developing world too, sewage testing has not caught on. Agua y Saneamientos Argentinos (AySA), Argentina, teamed up with Aguas de Murcia, Spain, to understand how to test sewage for the virus. Its finding: viruses have been found but they have so far not been successful in isolating the SARS-CoV-2 type from sewage because it is highly contaminated with other microorganisms.[16]

Malaysia's water utility, the Indah Water Konsortium (IWK), is not monitoring wastewater for SARS-CoV-2 as it lacks test kits that have been prioritised for clinical testing of patients. Malaysia's health authorities have been supportive of the idea to test sewage.[17] Similarly, in Uganda, the national Water and Sewerage Corporation has not yet started testing for the virus in sewage.[18] The Kampala Capital City Authority, National and Water and Sanitation National Task Force led by the Ministry of Health, have instead prioritised worker safety, like their Malaysian counterparts. They are trying to better understand the link between wastewater monitoring and identifying COVID-19 hotspots.

The challenges in India

Testing in the Indian context is incredibly challenging as sewage systems are fragmented.[19] Only about a third of all towns have any form of sewers, either underground or open drains, according to the 2011 Census. The rest of the population is served by on-site sanitation, including septic tanks. Testing these is problematic and will be possible only if there is a systematic process of emptying and treating faecal sludge. Then, most of the time, sewers and septic tanks are cleaned manually exposing human beings to another potential pathogen, even though the virus in sewage is said to be non-infectious.

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In most other developing countries too, sewage systems are very fragmented. In Uganda and Argentina, people in cities rely on a combination of sewer networks and septic tanks. Although the water utilities follow the developments around testing sewage for COVID-19, they have not adopted it.

A limitation of WBE is that it cannot help identify infected individuals and pinpoint their specific locations. Rather, it predicts infection trends in the sewer shed. Another challenge in developing an India-specific protocol, linked to the fragmented and inefficient sewage systems, is the effect of temperatures on the

virus. Ambient sewage temperatures in India were much higher than in the Netherlands and North America, from where initial tests for the virus in sewage were carried out. Not compensating for temperature differences renders WBE data vulnerable to severe under-/over-estimation of infected cases.

Large floating populations of cities complicate the prediction of infections based on sewage testing as these individuals could use toilets in their offices or public toilets. Therefore, if virus traces were found from sewage in these areas, tracing COVID-19 positive patients would be like finding a needle in a haystack.

The cost-benefits of each part of the WBE protocol need to be analysed.[20] Sewage testing of households in hotspots would be more valuable than testing sewage from hospitals designated to treat COVID-19 patients. But this would hold true only if the sewage test was simpler, faster, and cheaper than individual tests. The test data was time-sensitive; a negative result on one day could indicate no infections, but the situation could change within hours with new people getting infected.

The need for an Indian protocol

An Indian protocol, factoring in sewage conditions, low resources, lack of political and bureaucratic will, and mitigation measures to quell mass panic, needs to have the following components:

1. Sampling strategy,
2. Transportation methods,
3. Testing methods,
4. Addressing stakeholder concerns, and
5. Communicating with the public.

1. **Sampling Strategy:** For sampling to make sense, a town needs to be mapped and divided into zones. The sanitation and sewage or faecal sludge system needs to be mapped in detail for each zone. Where there are sewers, collection points from places where sewage from about 10,000 houses collect need to be identified. In areas using on-site sanitation systems (OSS) connected to septic

tanks, the timings and routes of pit-emptying machines need to be mapped. However, testing from individual pit latrines will not be possible. The following classification of collection sites can be considered from where there have been reported active/cured COVID-19 cases:

1. Residential areas that have community toilets (CTs) connected to a sewer line to be mapped to determine collection points. These could either be manholes or pumping stations of STP inlets and should ideally have a 'sewershed' of a maximum of 10,000 households for meaningful follow-up decision-making.
2. In residential areas that use OSS and have community toilets (CTs) connected to septic tanks that are periodically emptied, the pit emptiers need to be mapped and faecal sludge collected at regular interval to trace possible infections, if and when they occur.
3. Sewage samples from COVID-19 hospitals, quarantine, or isolation centres (where sewerage is existing), to ensure validity of the hypothesis that excreta from patients contains fragments of the virus will also help in calculating the correlation between the number of fragments in sewage/sludge and the patients. This equation can be used when sewage/sludge is collected from other areas.
4. Sewage samples from septic tanks of COVID-19 hospitals, quarantine, or isolation centres.
5. Raw sewage from the inlets of municipal sewage STPs of areas demarcated as hotspots.
6. Sludge samples before biological treatment from the collection points of faecal sludge treatment plants (FSTPs).

To collect samples, experts have quoted the method used in the Netherlands (by KWR Water Research Institute) and North America. KWR's paper stated the operators of a wastewater treatment plant (WWTP) took a 24-hour flow-dependent composite sample of 250 ml that was stored at 4°C during sampling. Biobot, a U.S.-based wastewater epidemiology company, also recommended a similar method.

However, they add a note of caution that in India, continuous sampling is possible only in extremely limited conditions – where sewer networks are connected to WWTPs or at sewage pumping stations. Grab sampling over a period of 3-4 hours during peak toilet usage, usually between 7

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a.m. and 11 a.m. is better suited to Indian conditions.[21] This was used in Queensland, Australia[22]. The individual grab samples can be stored in an ice box and combined in the laboratory.

Sampling personnel need standard personal protective equipment (PPE) for sewage or faecal sludge sampling, such as long pants, steel-capped boots, hard hats, safety glasses, and gloves. They need training to collect and disinfect the sample bottles so there is no danger of contamination or catching the infection. The WHO and others have stated that there is no evidence to date that the COVID-19 virus has been transmitted via sewerage systems with or without wastewater treatment[23].

2. **Transportation**. The second part of the process is transporting samples to a laboratory for testing. Nearly all places where tests have been conducted have used the same method. This is done in a cool pack container (a normal ice box) to minimise the sample degradation. The optimum temperature is 4°C. Samples must reach the laboratory within one hour of collection. This is how researchers from the KWR Water Research Institute, the Netherlands, transported samples and is now the gold standard: samples were transported to the laboratory on melting ice and the RNA isolated on the day of sampling[24].

For an Indian protocol, transport methods will require modifications for local traffic conditions and testing for the SARS-CoV-2 virus fragments at high levels of dilution and contamination as is found in regular sewage. Transport times may be much longer than an hour as mentioned above. It will be necessary to use individual sample storage boxes that maintain the prescribed temperatures, instead of larger ice boxes.

3. **Testing methods**. In the laboratory, any viable virus needs to be inactivated under ultra-violet light for half an hour followed by immersing in water at 60°C. Virus fragments are extracted using established methods and the RNA isolated from them tested for the presence of SARS-CoV-2. The test most commonly used, and established as the default method, is the real-time Reverse Transcription-Polymerase Chain Reaction (RTe-PCR) assay.

The tests establish the presence of the virus. It is also possible to determine the number of RNA fragments, the number of viruses and, therefore, the range of COVID-19 positive individuals from the excreta emptied into the sewer shed.

Up to this point, the process is under scientific control. From here onwards, it falls into the domain of bureaucrats, technocrats, and politicians. It becomes critical to manage how the information generated by the preceding steps will be shared with the public, if at all. Experts say much groundwork is needed before letting information out, failing which it can lead to mass panic and further disinformation of the kind that states COVID-19 is spread from toilets and sewage.

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4. **Addressing the concerns of the public**. Tracking sewage or faecal sludge is complicated, especially in the context of India, where most many effluent streams are mixed—black water, grey water, bio-medical waste, and industrial effluents—and wastewater systems are very fragmented. WBE is, therefore, focused on sewered areas as mentioned earlier.

Consequently, slums and rural areas remain untested largely because most people use OSSs. Their overflow usually goes into open drains. Occasionally, there are systematic collection processes in place where population densities are high enough to financially sustain operations of desludging machines.

The Department of Drinking Water and Sanitation claimed that India had become open defecation free (ODF) last year. However, a report by the National Sample Survey showed that just about 70 per cent people had a toilet[25]. Usage levels were around 94 per cent. Other surveys around the same time on hygiene behaviour showed handwashing with soap after using the toilet was as low as less than 30 per cent.[26]

Sometimes, the toilets are not hygienic enough to convince people to use them, especially in the case of shared or public toilets[27]. The government appears to

have focused on building toilets and did not consider facility maintenance and sewage management. Hands that are not washed thoroughly with soap and water after visiting the toilet could be a source of virus transmission. Unsanitary quarantine centres also pose a risk. In a New Delhi quarantine centre there were 50 people in the room with only a few toilets, mostly clogged[28].

Competing priorities often tend to overshadow WBE. And, in the absence of clarity on testing protocols, guidelines, and regulations, Urban Local Bodies (ULBs) were hesitant to adopt sample testing. The handling of human waste renders sanitation workers particularly susceptible. Formalising the entire spectrum of sanitation work is not feasible. Likewise, the available PPEs may not be suitable for the range of activities associated with sanitation work as there are persisting issues related practicality and comfort, which hinder, rather than aid, work.

5. **Public communicating**. Once the tests results were in, city and State governments need to act if COVID-19 cases are found. However, they don't appear to have a clear and credible approach to inform people of the findings, far less take action, such as individual testing, to find and isolate COVID-19 cases. In the absence of this follow-up, the testing is superfluous.[29]

Multiple channels filled with scientific and accurate information can be used for public outreach. Local WhatsApp groups can be set up for the purpose. Kerala has instituted a daily press conference at a fixed hour. Local leaders can use Facebook Live and local TV channels.

To ensure scientific fidelity, these should quote the original science publication or organisational report and mention the constraints or limitations the original authors have raised. A reality check on how the virus was transmitted, chances of contracting an infection, the chances of falling seriously ill or dying need to be clearly stated in communication material. It needs to be stated clearly that as on date, the WHO says there is no evidence to suggest a person can get COVID-19 from sewage.

Social media platforms, conventional print and electronic media, and community radio and other forms of media can be populated with content on a fixed schedule so people know when and what to expect.

For the Swachh Bharat Mission, Information, Education, and Communication (IEC) strategies were prepared for cities with messages, timings, media, and person(s) responsible. The people trained as *swachhata doots* (sanitation envoys) can be brought back and

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incentivised to work as COVID-19 communicators. For example, the Government of Andhra Pradesh has introduced ward volunteers (1 for every 50 households) who were the point of contact with the households to note grievances, extend support for availing of government services, and for enhancing awareness and, hence, demand for government schemes. "Effective communication with "at-risk" populations is integral to minimising panic, illness, and potential fatality. Local governments and others, therefore, need to identify and plan the approach as well as the channels of communication in advance."[30]

The way forward

Wastewater-based epidemiology will not fix systemic issues with India's sanitation and sewage system or its health infrastructure crumbling under the pandemic's load. A lot of infrastructure has been built under successive sanitation programmes, the Smart Cities Mission, and other government schemes. What all have missed are concerted hygiene promotion and infrastructure maintenance.

Poorly maintained and carelessly used toilets are a potential source of transmission since the SARS-CoV-2 virus survives on contaminated surfaces for several days. Community or public toilets are usually the only sanitation option in poor, densely populated urban sprawls. Paradoxically, although sewage or faecal sludge testing would be most useful in slums, chawls or other densely

populated urban areas, these are the same places that have poor basic services despite the National Health Mission and urban infrastructure programmes. Faecal sludge management is poor with informal pit emptiers dumping untreated sewage in open areas, canals, or water bodies.

Although faecal-oral transmission has not been established due of a lack of studies, the presence of viable viruses in water bodies or fields receiving untreated faecal sludge and sewage cannot be ruled out. Again, testing sewage is not a sufficient way to predict the pandemic, or even attempt to control it, in these settings.

Sewage and faecal sludge treatment is a problem not just in poor or densely populated areas but in affluent areas as well. In Bengaluru, for example, that there are more than 500,000 on-site systems comprising pit toilets, community septic tanks, and temporary toilets.[31] These were serviced by more than 500 honeysuckers, which collected waste form the onsite systems and took it to either the STPs or dumped it on farms or storm water drains.

It is also important to take into consideration the movement of sewage. In most cities, it flows through a vast hinterland. In the case of Bengaluru, for example, treated sewage from the formal STPs flows up to 90 km from the city, filling up lakes and recharging aquifers in the process. Farmer unwittingly draw such water through shallow open wells for agriculture.

In terms of the informal set up, only half of sewage gets collected and treated. The rest flows through stormwater drains and enters river systems. In such cases too, farmers use the untreated sewage—containing a cocktail of chemicals—for agricultural purposes. It is important to mention here that there were no standards for ground water recharge using treated sewage in India.

As noted earlier, competing priorities often tend to overshadow sewage testing. In Malaysia, Uganda, and Argentina, authorities are focusing on individual testing and prevention. And, in the absence of clarity on testing protocols, guidelines, and regulations, ULBs were hesitant to adopt sample testing.

Manual handling of human waste renders sanitation workers particularly vulnerable. In India, the unique sanitation infrastructure implies that sanitation work comprises a spectrum of activities: manual scavenging, cleaning stormwater drains, collection and segregation of solid waste, construction work, and more. Informality in sanitation work is widespread which, in turn, increases the risk factor associated with such work.[32]

Formalising the entire spectrum of sanitation work is not feasible. And mechanisation does not address the gamut of work involved. Likewise, the available PPEs are not suitable for the range of activities associated with sanitation work. Moreover, unresolved issues related to practicality and comfort hinder, rather than aid, work.

Testing sewage can be a powerful tool in low-income areas but these communities are also the hardest to reach with follow-up actions.

While testing sewage for the presence of SARS-CoV-2 has been well-established, India has a long way to go to take advantage of this non-invasive method. It can be a powerful tool in low-income areas but these communities, who may be most at risk, are also the hardest to reach with follow-up actions. Urban sewage/faecal sludge infrastructure that forms the basis of this method is in poor shape and may undermine the efficacy of this method of predicting the pandemic. The COVID-19 pandemic provides a perfect entry point for promoting sewage testing but more than that, for upgrading infrastructure and ensuring equity in access to safe and good quality sanitation.

Note:

This article draws from a [Thematic discussion on 'Testing Sewage for Early Warnings about COVID 19'](#) conducted by the Sustainable Sanitation Alliance (SuSanA). The author, who is also Coordinator for the SuSanA India Chapter, compiled the Thematic Discussion paper based on the proceedings held in May and June 2020. [https://www.susana.org/_resources/documents/default/3-3886-193-1592910651.pdf]. Parts of this article were written based on correspondence by the author with experts.

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