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UNDERGROUND
SEWER

A deep dive into wastewater disease monitoring

What can we learn from analysing wastewater and what potential roles could the surveillance method play in the future? We look at the issues.

In June, polio – a disease that was eradicated in Europe nearly 20 years ago – made a grand return in the headlines. In the UK, public health officials had to declare a national incident after routine surveillance of wastewater in London found evidence of community transmission of poliovirus. The good news? This timely identification of the poliovirus allowed public health measures to be taken quickly.

In recent years, wastewater surveillance – where sewage systems are monitored for the presence of pathogens such as viruses and bacteria but also chemical compounds such as drugs and pharmaceuticals – has gained in popularity.

The COVID-19 pandemic, during which gathering data on infections was essential to develop an appropriate response, has further reignited the interest in this area of research.

From polio to COVID-19

The story of wastewater surveillance for virology really took off in the 1960s when researchers at Yale University in the US decided to look at the effects of the polio vaccination campaign by analysing sewage water for traces of different strains of the virus.

Since then, research teams all around the world have used surveillance of wastewater as a tool against polio epidemics. In some cases, the poliovirus was detected in sewage before the first cases were reported in the community, allowing for the implementation of robust measures to identify those who were infected and to prevent the disease from spreading. In the last decades, some experiments have also successfully showed the benefits of this approach to predict and prevent epidemics linked to other pathogens, such as the hepatitis A virus or noroviruses.

Wastewater surveillance has also been used in a public health context not just to monitor diseases but also to study pharmaceutical and illicit drug consumption in the population. "Before the pandemic, public health officials had often been unsure what to do with this unusual source of data. But there had been academic interest in looking for other compounds in wastewater, especially chemicals such as illicit drugs that could indicate

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ILLUSTRATIONS: NEIL WEBB

behavioural patterns and predict risk of addiction", says Dr Andrew Singer, Principal Scientist at the UK Centre for Ecology and Hydrology.

The COVID-19 pandemic was clearly a turning point, both in the UK and abroad. Suddenly, there was a need for robust data to follow the epidemic trends and to back up decision-making relating to prevention, treatment and vaccination strategies. The disease was spreading fast and innovative approaches that could generate accurate information for public health officials were needed in order to complement more traditional surveillance tools, such as mortality and morbidity rates, prescription or hospital admission data.

In this context, researchers with experience working in the field of wastewater surveillance were quick to react. They knew it was a tool that could help people understand how the pandemic was unfolding and what kind of strategies could work to protect and save lives.

However, in order for this approach to be effective, it had to be set up in the right way, with the right methodologies and the right scientific questions asked. One challenge for instance is that different methods can be used to collect wastewater samples, which can yield different results if the data are not analysed correctly. It's also important to think about how often you need to analyse samples for the method to be useful in a pandemic context.

Furthermore, wastewater is a complex environment to work in as it contains an abundance of chemical and biological compounds. While this provides rich information about the health of a population, it can also make interpretation much more difficult.

As Colleen Naughton, a Professor of Environmental Engineering at the University of California Merced, explains : "Wastewater detection is more challenging than respiratory sample analysis since the virus is more fragmented when it is excreted and goes through the sewer system. However, you get a larger sample of people contributing to a sewer system than going to get tests. Method sensitivity can be an issue and you also want to take at least two to three samples per week to get trends."

Population fluctuations due to commuters and tourism can also be a challenge when conducting wastewater surveillance because it makes it more difficult to estimate the exact size of a population and thus to model the number of cases based on the amount of virus found in the water. While this was much less of an issue during lockdowns, thinking about all the potential limits of the approach was a priority to get things right.

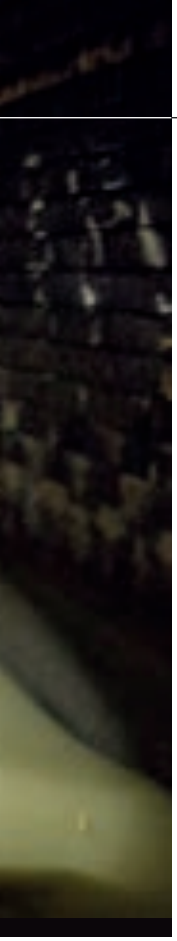
"In the UK, we set up an academic network focused on setting up a national programme and on thinking about which approaches should be developed for sampling. There were many questions to think about, such as how you translate the data you gather into a number of cases, how often you have to sample to be able to use wastewater as an early warning, how long does SARS-CoV-2 last in wastewater, how do you reliably recover SARS from wastewater, and is the instrumentation

SOCIAL MEDIA AND EPIDEMIOLOGY

Other innovative tools may be used alone or in combination with wastewater surveillance to generate more data that epidemiologists can use. For instance, some studies have suggested that analysing the content of social media posts is a powerful tool to identify hotspots of infection.

Used in conjunction with more traditional surveillance tools, these new ways of tracking down pathogens and other markers of health will be crucial to save lives.

A recent review has highlighted the main opportunities and issues associated with this kind of research showing that promising developments include integrated systems that couple traditional surveillance data with data from search queries, social media posts, and crowdsourcing.



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for collecting sewage fit for purpose?" Andrew Singer says.

Alongside the robust academic work that was conducted with pilot studies in schools, prisons and local businesses, a programme led by the UK Health Security Agency in partnership with other agencies and other companies and water companies was set up in England, covering approximately 74% of the population. The programme tested sewage for fragments of SARS-CoV-2 RNA at different locations. Scotland, Wales and Northern Ireland also developed their own programmes – as did many other countries and cities globally.

As the months went by, this surveillance tool showed its usefulness and not only for surveillance and prevention purposes at city or country level. In some places, the data that were collected were used to take more robust actions against the virus. What occurred in some universities – where young students typically display fewer symptoms – is a good example. In some cases, identification of SARS-CoV-2 in wastewater on campuses helped identify an outbreak early on and to contain it.

Wastewater surveillance has also facilitated access to more qualitative information regarding the evolution of the pandemic, such as whether the vaccination campaign was having a beneficial effect in reducing the number of infected individuals, how many hospital beds would be required at a given time or how the virus was mutating.

"Wastewater surveillance is a cost-effective way to get quantitative, but also qualitative, data. We can determine how much virus is in the water and also track the emergence of new variants and whether they are becoming more important", says Sally Cutler, Professor in Medical Microbiology at the School of Health, Sport and Bioscience at the University of East London.

Looking to the future

While a number of national and local programmes linked to the COVID-19 pandemic are now coming to a halt, wastewater surveillance has proven its value as a public health monitoring tool. Many research teams around the world are now looking to use it to improve our knowledge of population health and behaviours.

Studying in greater depth biomarkers linked to lifestyle choices, such as drugs and alcohol consumption, will remain a key aspect of wastewater surveillance, but this will be extended to investigate general health through oxidative stress markers, exposure to pollutants or endocrine disruptors or even markers of psychiatric health.

"Future expansions of wastewater surveillance will leverage a wider range of microorganisms and chemicals for a holistic insight into public health. Future research may also attempt to use this tool to monitor populations' mental health, for instance by trying to identify hormones such as serotonin and cortisol in the samples. There is so much information sitting there in

WASTEWATER IN NUMBERS

1940s

The potential usefulness of wastewater surveillance was proposed as far back as the **mid-1940s** to monitor the polio virus.

21ST century

However, it only began to **gain popularity** as an epidemiological tool in the **early 21st century** with applications to monitor polio outbreaks and pharmaceutical/drug consumption.

74%

In England, the COVID-19 EMHP programme provided coverage of almost **74% of the population**.

302

In this programme, samples were taken from approximately **302 Sewage Treatment Works** in England, **3 times a week**. Samples were also taken at approximately **197 sewer network sites** in England, **4 times a week**.

67 countries

Since the beginning of the pandemic, **67 countries** have launched wastewater surveillance programmes – with the help of **279 universities**, as shown by a dashboard from UC Merced.

IMAGES: ALAMY, GETTY

wastewater, still untapped and it can very likely tell you a lot of actionable information for improving personal and public health decision-making," Andrew Singer points out.

Moving forward with this kind of research, there will be ethical questions to consider, to make sure that the data are not misused or misrepresented. As this kind of tool does not collect data on individuals, the ethical risks are low, but it is crucial to think about privacy issues and the potential for stigmatisation of specific communities.

"At the larger city scale, you cannot trace back the testing to individuals but if you are doing neighbourhood or building level, some areas require that you aggregate the data and/or it is only shared with health departments. In the case of the COVID-19 pandemic at the larger city and neighbourhood scales, our team has been advocating for open data and transparency as an ethical imperative to the public and other researchers", Colleen Naughton says.

In specific cases, thinking even more carefully about these issues will be crucial. For instance, a pilot study conducted in UK prisons was helpful to identify and contain outbreaks but it posed a number of questions related to the rights of prisoners.

"In prisons, there was a real value in conducting wastewater surveillance as it allowed previously unachievable insight into the health of these populations without violating individual privacy. However, there were ethical concerns to make sure the data that were collected didn't include information about illicit drug use, which could theoretically be used for enforcement, as we were trying to conduct research and monitoring to benefit people's health."

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With all this in mind, one thing is certain – wastewater surveillance will be central to public health planning and policy in the long term. This is especially the case since emerging infectious diseases are now recognised as a major critical threat to global public health.

Being able to identify new pathogens and monitor the spread of diseases is key for prevention, intervention and control, but since current surveillance systems have shown some limits during the COVID-19 pandemic, it's essential to develop new, complementary answers, such as wastewater surveillance. "It's not going to tell you who is infected, who are the people in close proximity and what is their vaccination status but it's a great tool to complement other surveillance methods and will definitely be part of the toolbox going forward," Sally Cutler concludes. BMS

FURTHER READING

Learn more about the legal and ethical questions associated with wastewater surveillance

- The World Health Organization has published guidelines on the topic **bit.ly/3o14OGI**
- A recent paper has shown the ethical imperatives associated with collecting and handling human data **bit.ly/3nYWG9L**
- A viewpoint, "Preventing Scientific and Ethical Misuse of Wastewater Surveillance data", has shown that there are issues regarding the protection of privacy; balancing individual rights with population interests, and the communication and use of findings will be needed **bit.ly/3O26Tgf**