The following information resources have been selected by the National Health Library and Knowledge Service Evidence Virtual Team in response to your question. The resources are listed in our estimated order of relevance to practicing healthcare professionals confronted with this scenario in an Irish context. In respect of the evolving global situation and rapidly changing evidence base, it is advised to use hyperlinked sources in this document to ensure that the information you are disseminating to the public or applying in clinical practice is the most current, valid and accurate. For further information on the methodology used in the compilation of this document—including a complete list of sources consulted—please see our National Health Library and Knowledge Service Summary of Evidence Protocol.

QUESTION 131

What is the evidence for waste water surveillance to enhance other forms of surveillance for COVID-19?

SUMMARY OF EVIDENCE

The presence of SARS-CoV-2 RNA in faeces provides the potential to conduct waste water surveillance of the virus to support epidemiological monitoring of COVID-19. This is referred to as wastewater-based epidemiology (WBE) or environmental surveillance. Many countries including Ireland are now sampling their waste water for the detection of SARS-CoV-2 RNA.

Recent studies have reported the detection of SARS-CoV-2 RNA in wastewater in the early stages of local outbreaks[6, 7, 8, 9, 11, 13, 15, 16]. Results seem to suggest that wastewater could be a sensitive surveillance system and early warning tool that could predict spikes in infections. Wu et al describe water-based surveillance as a promising approach for proactive outbreak monitoring. "SARS-CoV-2 is shed in stool early in the clinical course and infects a large asymptomatic population, making it an ideal target for wastewater-based monitoring"[13].

Daughton believes that wastewater-based epidemiology could hold the potential to contain and mitigate COVID-19 outbreaks while also minimizing domino effects such as unnecessarily long stay-at-home policies that put pressure on humans and economies[5]. According to research, cost savings worldwide for one-time national surveillance campaigns are estimated to be in the range of millions to billions of US$, depending on a nation's population size and number of testing rounds conducted[10].

From September, the Netherlands will adopt a national wastewater surveillance strategy, and samples from over 300 water treatment plants will be tested daily[34]. The UK have commenced testing wastewater samples from 44 treatment sites and researchers are pioneering waste water analysis as part of a nationwide programme[33].

There are challenges involved in wastewater monitoring: eg the proportion of the virus present in wastewater can change depending on the amount of rainwater entering the sewage system; temperature and other factors could alter the amount of viral material that survives in one city's sewers compared with another's[32]. Ahmed points out that there is a need for further methodological and molecular validation for enveloped viruses in waste water[6]. Lu conducted a review of the primary concentration methods that have been adopted by the eighteen recently reported COVID-19 wastewater detection studies. In the end, two easy and well-proven concentration strategies are recommended, aiming to maximize the practical significance and operational effectiveness of the SARS-CoV-2 virus concentration from wastewater samples[30].

The World Health Organisation (WHO) say that surveillance of COVID-19 in wastewater and sludge may compliment public health data and provide, for example, information on when cases may spike 5-7 days in advance of such spikes being detected by health facilities and health authorities[3]. The WHO also point out that environmental surveillance should not be used as a substitute for robust surveillance of COVID-19 cases and there is not yet sufficient evidence to recommend environmental surveillance as a standard approach for COVID-19 surveillance[1].

The COVID-19 WBE Collaborative [https://www.COVID19wbec.org/] was launched in partnership with the Sewage analysis CORe group Europe (SCORE) network and the Global Water Pathogen Project as a hub to coordinate and promote the efforts of research groups undertaking WBE for COVID-19. The website include content such as a listing of SARS-CoV-2 WBE publications, press releases, commentaries and media content for public outreach and will be used to solicit participation in the collaborative and advertise events relevant to WBE.

Irish and/or International Guidance

What does the World Health Organization say?

World Health Organisation (2020) Status of environmental surviellance for SARS-CoV-2 virus[1]
This scientific brief explores potential use cases, considerations, and research needs for this emerging tool for SARS-CoV-2 detection that may be explored in close coordination with established public health surveillance for COVID-19. At present, there is not yet sufficient evidence to recommend environmental surveillance as a standard approach for COVID-19 surveillance.

World Health Organisation (2020) Public Health Surveillance for COVID-19[2]
This document summarizes current WHO guidance for public health surveillance of coronavirus disease 2019 (COVID-19) in humans caused by infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).
Under heading 4 Additional Surveillance Methods and Approaches for COVID-19: There are additional surveillance approaches that can be used along with the essential elements of comprehensive surveillance for COVID-19. New approaches such as environmental surveillance of non-infective viral fragments of the SARS-CoV-2 virus in wastewater are being developed but are not yet robust enough to use routinely.

World Health Organisation (2020) Water, sanitation, hygiene, and waste management for the COVID-19 virus[3]
Research is underway in many countries to detect non-infective viral fragments of SARS-CoV-2 in wastewater and sludge. Similar methods have been successfully used in the polio eradication programme to detect virus circulation in the population including among asymptomatic cases, and thereby complementing surveillance in humans. Further research and capacity building are needed on the analytical methods — particularly for settings with low sewerage

coverage — modelling, interpretation of data to inform decision making and public health actions. Surveillance of COVID-19 in wastewater and sludge may compliment public health data and provide, for example, information on when cases may spike 5-7 days in advance of such spikes being detected by health facilities and health authorities. Environmental surveillance should not be used as a substitute for robust surveillance of COVID-19 cases. In addition, the primary aim of governments, utilities and investments should focus on continuity and expanding safely managed sanitation services to protect against COVID-19 and a number of other infectious diseases.

International Literature

What does the international literature say?

Daughton (Sept 2020) Wastewater surveillance for population-wide COVID-19: The present and future[4]
Presented is an overview of why and how governments should exercise prudence and begin evaluating WBE and coordinating development of a standardized WBE methodology — one that could be deployed within nationalized monitoring networks to provide inter-comparable data across nations.

Daughton (July 2020) The international imperative to rapidly and inexpensively monitor community-wide COVID-19 infection status and trends[5]
The author addresses the ability to quickly determine the status and trends of COVID-19 within and across communities nationwide and suggests that rapid community-wide monitoring could prove of immense international importance in quickly determining trends in whether the spread of COVID-19 as well as future viral epidemics in individual communities is increasing or decreasing. The paper goes on to discuss the challenges of developing a rapid and economical WBE tool for monitoring status and trends of COVID-19 mass infection.

Ahmed et al (2020) First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community[6]
In the current work, SARS-CoV-2 RNA was concentrated from wastewater in a catchment in Australia and viral RNA copies were enumerated using reverse transcriptase quantitative polymerase chain reaction (RT-qPCR) resulting in two positive detections within a six day period from the same wastewater treatment plant (WWTP). The estimated viral RNA copy numbers observed in the wastewater were then used to estimate the number of infected individuals in the catchment via Monte Carlo simulation. Given the uncertainty and

variation in the input parameters, the model estimated a median range of 171 to 1,090 infected persons in the catchment, which is in reasonable agreement with clinical observations. This work highlights the viability of WBE for monitoring infectious diseases, such as COVID-19, in communities. The work also draws attention to the need for further methodological and molecular assay validation for enveloped viruses in wastewater.

La Rosa et al (2020) First detection of SARS-CoV-2 in untreated wastewaters in Italy[7]

Twelve influent sewage samples, collected between February and April 2020 from Wastewater Treatment Plants in Milan and Rome, were tested adapting, for concentration, the standard WHO procedure for Poliovirus surveillance. Molecular analysis was undertaken with three nested protocols, including a newly designed SARS-CoV-2 specific primer set. SARS-CoV-2 RNA detection was accomplished in volumes of 250 ml of wastewaters collected in areas of high (Milan) and low (Rome) epidemic circulation, according to clinical data. Overall, 6 out of 12 samples were positive. One of the positive results was obtained in a Milan wastewater sample collected a few days after the first notified Italian case of autochthonous SARS-CoV-2. The study confirms that WBE has the potential to be applied to SARS-CoV-2 as a sensitive tool to study spatial and temporal trends of virus circulation in the population.

Medema et al (2020) [Preprint. Not Yet Peer-Reviewed] Presence of SARS-Coronavirus-2 in sewage[8]

To determine if SARS-CoV-2 is present in sewage during the emergence of COVID-19 in the Netherlands, sewage samples of 7 cities and the airport were tested using RT-PCR against three fragments of the nucleocapsid protein gene (N1-3) and one fragment of the envelope protein gene (E). No SARS-CoV-2 was detected in samples of February 6, three weeks before the first case was reported in the Netherlands on February 27. On March 5, the N1 fragment was detected in sewage of five sites. On March 15/16, the N1 fragment was detected in sewage of six sites, and the N3 and E fragment were detected at 5 and 4 sites respectively. This is the first report of

detection of SARS-CoV-2 in sewage. The detection of the virus in sewage, even when the COVID-19 incidence is low, indicates that sewage surveillance could be a sensitive tool to monitor the circulation of the virus in the population.

Randazzo et al SARS-CoV-2 RNA in wastewater anticipated COVID-19 occurrence in a low prevalence area[9]

This research investigated the occurrence of SARS-CoV-2 RNA in six wastewater treatments plants (WWTPs) serving the major municipalities within the Region of Murcia (Spain), the area with the lowest COVID-19 prevalence within Iberian Peninsula. Firstly, an aluminum hydroxide adsorption-precipitation concentration method was validated using a porcine coronavirus (Porcine Epidemic Diarrhea Virus, PEDV) and mengovirus (MgV). The procedure resulted in average recoveries of 10 ± 3.5% and 10 ± 2.1% in influent water (n = 2) and 3.3 ± 1.6% and 6.2 ± 1.0% in effluent water (n = 2) samples for PEDV and MgV, respectively. Then, the method was used to monitor the occurrence of SARS-CoV-2 from March 12 to April 14, 2020 in influent, secondary and tertiary effluent water samples. By using the real-time RT-PCR (RT-qPCR) Diagnostic Panel validated by US CDC that targets three regions of the virus nucleocapsid (N) gene, we estimated quantification of SARS-CoV-2 RNA titers in untreated wastewater samples of 5.4 ± 0.2 $\log_{10}$ genomic copies/L on average. Two secondary water samples resulted positive (2 out of 18) and all tertiary water samples tested as negative (0 out 12). This environmental surveillance data were compared to declared COVID-19 cases at municipality level, revealing that members of the community were shedding SARS-CoV-2 RNA in their stool even before the first cases were reported by local or national authorities in many of the cities where wastewaters have been sampled. The detection of SARS-CoV-2 in wastewater in early stages of the spread of COVID-19 highlights the relevance of this strategy as an early indicator of the infection within a specific population. At this point, this environmental surveillance could be implemented by municipalities right away as a tool, designed to help authorities to coordinate the exit strategy to gradually lift its coronavirus lockdown.

Hart et al (2020) Computational analysis of SARS-CoV-2/COVID-19 surveillance by wastewater-based epidemiology locally and globally: Feasibility, economy, opportunities and challenges[10]

Computational analysis and modelling was used to examine the feasibility, economy, opportunities and challenges of enumerating active coronavirus infections locally and globally using WBE. Depending on local conditions, detection in community wastewater of one symptomatic/asymptomatic infected case per 100 to 2,000,000 non-infected people is theoretically feasible, with some practical successes now being reported from around the world. Computer simulations for past, present and emerging epidemic hotspots — Wuhan, Milan, Madrid, New York City, Teheran, Seattle, Detroit and New Orleans — identified temperature, average in-sewer travel time and per-capita water use as key variables. WBE surveillance of populations is shown to be orders of magnitude cheaper and faster than clinical screening, yet cannot fully replace it. Cost savings worldwide for one-time national surveillance campaigns are estimated to be in the million to billion US$ range, depending on a nation's population size and number of testing rounds conducted. For resource poor regions and nations, WBE may represent the only viable means of effective surveillance. Important limitations of WBE rest with its inability to identify individuals and to pinpoint their specific locations. Not compensating for temperature effects renders WBE data vulnerable to severe under-/over-estimation of infected cases. Effective surveillance may be envisioned as a two-step process in which WBE serves to identify and enumerate infected cases, where after clinical testing then serves to identify infected individuals in WBE-revealed hotspots. Data provided here demonstrate this approach to save money, be broadly applicable worldwide, and potentially aid in precision management of the pandemic, thereby helping to accelerate the global economic recovery that billions of people rely upon for their livelihoods.

Wu et al (2020) [Preprint. Not Yet Peer-Reviewed] SARS-CoV-2 titers in wastewater foreshadow dynamics and clinical presentation of new COVID-19 cases[11]

Longitudinal wastewater analysis was used to track SARS-CoV-2 dynamics in wastewater at a major urban wastewater treatment facility in Massachusetts, between early January and May 2020. SARS-CoV-2 was first detected in wastewater on March 3. Viral titers in wastewater increased exponentially from mid-March to mid-April, after which they began to decline. Viral titers in wastewater correlated with clinically diagnosed new COVID-19 cases, with the trends appearing 4-10 days earlier in wastewater than in clinical data. The researchers inferred viral shedding dynamics by modelling wastewater viral titers as a convolution of back-dated new clinical cases with the viral shedding function of an individual. The inferred viral shedding function showed an early peak, likely before symptom onset and clinical diagnosis, consistent with emerging clinical and experimental evidence. Finally, we found that wastewater viral titers at the neighbourhood level correlate better with demographic variables than with population size. This work suggests that longitudinal wastewater analysis can be used to identify trends in disease transmission in advance of clinical case reporting, and may shed light on infection characteristics that are difficult to capture in clinical investigations, such as early viral shedding dynamics.

Foladori et al (2020) SARS-CoV-2 from faeces to wastewater treatment: What do we know? A review[12]

This review aims to understand the viral load of SARS-CoV-2 in faeces and sewage and its fate in wastewater treatment plants (WWTPs). The viral load in the faeces of persons testing positive for SARS-CoV-2 was estimated at between $5{\cdot}10^3$ to $10^{7.6}$ copies/mL, depending on the infection course. In the sewerage, faeces undergo dilution and viral load decreases considerably in the wastewater entering a WWTP with a range from 2 copies/100 mL to $3{\cdot}10^3$ copies/mL, depending on the level of the epidemic. Monitoring of SARS-CoV-2 in sewage, although no evidence of COVID-19 transmission has been found via this route, could be advantageously exploited as an early warning of outbreaks. Preliminary studies on WBE seem promising; but high uncertainty of

viral loads in wastewater and faeces remains, and further research is needed. The detection of SARS-CoV-2 in sewage, based on RNA sequences and RT-PCR, requires a shared approach on sample pre-treatment and on-site collection to ensure comparable results. The finding of viral RNA in stools does not imply that the virus is viable and infectious. Viability of CoVs such as SARS-CoV-2 decreases in wastewater — due to temperature, pH, solids, micropollutants — but high inactivation in WWTPs can be obtained only by using disinfection [free chlorine, UVC light]. A reduction in the quantity of disinfectants can be obtained by implementing Membrane-Bioreactors with ultrafiltration to separate SARS-CoV-2 virions with a size of 60-140 nm. In sludge treatment, thermophilic digestion is effective, based on the general consensus that CoVs are highly sensitive to increased temperatures.

Wu et al (2020) SARS-CoV-2 Titers in Wastewater Are Higher than Expected from Clinically Confirmed Cases[13]

Researchers tested wastewater collected at a major urban treatment facility in Massachusetts and detected SARS-CoV-2 RNA from the N gene at significant titers [57 to 303 copies per ml of sewage] in the period from 18 to 25 March 2020 using RT-qPCR. We validated detection of SARS-CoV-2 by Sanger sequencing the PCR product from the *S* gene. Viral titers observed were significantly higher than expected based on clinically confirmed cases in Massachusetts as of 25 March. The approach is scalable and may be useful in modelling the SARS-CoV-2 pandemic and future outbreaks.

Wastewater-based surveillance is a promising approach for proactive outbreak monitoring. SARS-CoV-2 is shed in stool early in the clinical course and infects a large asymptomatic population, making it an ideal target for wastewater-based monitoring. In this study, a laboratory protocol was developed to quantify viral titers in raw sewage via qPCR analysis and validate results with sequencing analysis. Results suggest that the number of positive cases estimated from wastewater viral titers is orders of magnitude greater than the number of confirmed clinical cases and therefore may significantly impact efforts to understand the case fatality rate and progression of disease. This data may help inform decisions surrounding the

advancement or scale-back of social distancing and quarantine efforts based on dynamic wastewater catchment-level estimations of prevalence.

Ahmed et al (2020) Comparison of virus concentration methods for the RT-qPCR-based recovery of murine hepatitis virus, a surrogate for SARS-CoV-2 from untreated wastewater[14]

Municipal wastewater seeded with a human coronavirus (CoV) surrogate, murine hepatitis virus (MHV), was used to test the efficiency of seven wastewater virus concentration methods: (A-C) adsorption-extraction with three different pre-treatment options, (D-E) centrifugal filter device methods with two different devices, (F) polyethylene glycol (PEG 8000) precipitation, and (G) ultracentrifugation. MHV was quantified by reverse-transcription quantitative polymerase chain reaction and the recovery efficiency was calculated for each method. The mean MHV recoveries ranged from 26.7 to 65.7%. The most efficient methods were adsorption-extraction methods with $MgCl_2$ pre-treatment (Method C), and without pre-treatment (Method B). The third most efficient method used the Amicon® Ultra-15 centrifugal filter device (Method D) and its recovery efficiency was not statistically different from the most efficient methods. The methods with the worst recovery efficiency included the adsorption-extraction method with acidification (A), followed by PEG precipitation (F). Our results suggest that absorption-extraction methods with minimal or without pre-treatment can provide suitably rapid, cost-effective and relatively straightforward recovery of enveloped viruses in wastewater. The MHV is a promising process control for SARS-CoV-2 surveillance and can be used as a quality control measure to support community-level epidemic mitigation and risk assessment.

Wurtzer et al (2020) [Preprint. Not Yet Peer-Reviewed] Evaluation of lockdown impact on Sars-CoV-2 dynamics through viral genome quantification in Paris wastewaters[15]

SARS-CoV-2 is the etiological agent of COVID-19. Most of SARS-CoV-2 carriers are assumed to exhibit no or mild non-specific symptoms. Thus, they may contribute to the rapid and mostly silent circulation of

the virus among humans. Since SARS-CoV-2 can be detected in stool samples it has recently been proposed to monitor SARS-CoV-2 in wastewaters (WW) as a complementary tool to investigate virus circulation in human populations. In the present work we assumed that the quantification of SARS-CoV-2 genomes in wastewaters should correlate with the number of symptomatic or non-symptomatic carriers. To test this hypothesis, we performed a time-course quantitative analysis of SARS-CoV-2 by RT-qPCR in raw wastewater samples collected from several major wastewater treatment plant (WWTP) of the Parisian area. The study was conducted from March 5 to April 23 2020, therefore including the lockdown period in France [since March 17, 2020]. We confirmed that the increase of genome units in raw wastewaters accurately followed the increase of human COVID-19 cases observed at the regional level. Of note, the viral genomes could be detected before the beginning of the exponential growth of the epidemic. As importantly, a marked decrease in the quantities of genomes units was observed concomitantly with the reduction in the number of new COVID-19 cases which was an expected consequence of the lockdown. As a conclusion, this work suggests that a quantitative monitoring of SARS-CoV-2 genomes in wastewaters should bring important and additional information for an improved survey of SARS-CoV-2 circulation at the local or regional scale.

Peccia et al (2020) [Preprint. Not Yet Peer-Reviewed] SARS-CoV-2 RNA concentrations in primary municipal sewage sludge as a leading indicator of COVID-19 outbreak dynamics[16]

The authors report a time course of SARS-CoV-2 RNA concentrations in primary sewage sludge during the Spring COVID-19 outbreak in a north-eastern U.S. metropolitan area. SARS-CoV-2 RNA was detected in all environmental samples, and when adjusted for the time lag, the virus RNA concentrations tracked the COVID-19 epidemiological curve. SARS-CoV-2 RNA concentrations were a leading indicator of community infection ahead of compiled COVID-19 testing data and local hospital admissions. Decisions to implement or relax public health measures and restrictions require timely information on outbreak dynamics in a community.

Bhalla et al (2020) Opportunities and Challenges for Biosensors and Nanoscale Analytical Tools for Pandemics: COVID-19[17]

The authors review the technological challenges and opportunities of current bio/chemical sensors and analytical tools by critically analyzing the bottlenecks which have hindered the implementation of advanced sensing technologies in pandemic diseases. They describe in brief COVID-19 by comparing it with other pandemic strains such as that of severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) for the identification of features that enable biosensing. Visualization and characterization tools that can potentially be used not only for sensing applications but also to assist in speeding up the drug discovery and vaccine development process are discussed; as is the emerging monitoring mechanism, namely wastewater-based epidemiology, for early warning of the outbreak, focusing on sensors for rapid and on-site analysis of SARS-CoV2 in sewage. The authors provide holistic insights into challenges associated with the quick translation of sensing technologies, policies, ethical issues, technology adoption, and an overall outlook of the role of the sensing technologies in pandemics.

Al Huraimel et al (2020) SARS-CoV-2 in the environment: Modes of transmission, early detection and potential role of pollutions[18]

This article aims to examine the latest investigations on SARS-CoV-2 plausible environmental transmission modes, employment of wastewater surveillance for early detection of COVID-19, and elucidating the role of solid waste, water, and atmospheric quality on viral infectivity. Transmission of SARS-CoV-2 via faecal-oral or bio-aerosols lacks robust evidence and remains debatable. However, improper disinfection and defected plumbing systems in indoor environments such as hospitals and high-rise towers may facilitate the transport of virus-laden droplets of wastewater causing infection. Clinical and epidemiological studies are needed to present robust evidence that SARS-CoV-2 is transmissible via aerosols, though quantification of virus-laden aerosols at low concentrations presents a challenge. Wastewater surveillance of SARS-CoV-2 can be an effective tool in early detection of outbreak and determination of

COVID-19 prevalence within a population, complementing clinical testing and providing decision makers guidance on restricting or relaxing movement. While poor air quality increases susceptibility to diseases, evidence for air pollution impact on COVID-19 infectivity is not available as infections are dynamically changing worldwide. Solid waste generated by households with infected individuals during the lockdown period may facilitate the spread of COVID-19 via fomite transmission route but has received little attention from the scientific community. Water bodies receiving raw sewage may pose risk of infection but this has not been investigated to date. Overall, our understanding of the environmental perspective of SARS-CoV-2 is imperative to detecting outbreak and predicting pandemic severity, allowing us to be equipped with the right tools to curb any future pandemic.

Prado et al (2020) Preliminary results of SARS-CoV-2 detection in sewerage system in Niterói municipality[19]

This study presents preliminary results from a sewage-based surveillance to monitor the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the municipality of Niterói, State of Rio de Janeiro, Brazil. By using ultracentrifugation method associated to quantitative reverse transcription polymerase chain reaction (RT-qPCR) we detected SARS-CoV-2 in 41.6% (5/12) of raw sewage samples obtained from sewage treatment plants and sewers network in the city. This pioneer study carried out in Brazil aims to subsidise information for health surveillance concerning the viral circulation in different areas of the city and, revealed the insertion and importance of environmental virology in health public policies.

Adelodun et al (2020) Snowballing transmission of COVID-19 (SARS-CoV-2) through wastewater: Any sustainable preventive measures to curtail the scourge in low-income countries[20]

In this communication, sustainable preventive measures that may be adopted by the low-income countries to forestall the potential outbreak and transmission of COVID-19 through wastewater are proposed. Most low-income countries have poor sanitation and wastewater management policies, which create potential risks of

COVID 19 spread. Hence, the proposed measures include decentralization of wastewater treatment facilities, community-wide monitoring and testing of SARS-CoV-2 in wastewater samples, improved sanitation, developing point-of-use devices for wastewater decontamination, and more focused policy interventions. Therefore, this paper adds useful insights into the monitoring and management of ongoing COVID-19 outbreak in low-income countries.

Hata et al (2020) Potential Sensitivity of Wastewater Monitoring for SARS-CoV-2: Comparison with Norovirus Cases[21]

SARS-CoV-2 detection in sewage by Medema et al is an important step to indicate the potential of environmental surveillance to detect the presence of COVID-19 in the local population. It is likely to be as successful as the case of norovirus monitoring in wastewater. In some cities suffering from a severe epidemic, people with mild symptoms are ordered to stay at home to prevent overwhelming hospitals. In such cases, the true scale of an epidemic might be underestimated, because people with potential infections are not reported as confirmed cases. Monitoring SARS-CoV-2 in wastewater could be a powerful tool for the timely investigation of the extent of the COVID-19 epidemic and the identification of convergence of the virus in a given area. Case studies in different countries are also necessary to confirm the sensitivity and reliability of SARS-CoV-2 detection in sewage. Further studies are also expected on the correlation between the viral loads of SARS-CoV-2 in wastewater and the number of confirmed infection cases of COVID-19.

Kumar et al (2020) First proof of the capability of wastewater surveillance for COVID-19 in India through detection of genetic material of SARS-CoV-2[22]

The authors report the first ever successful effort in India to detect the genetic material of SARS-CoV-2 viruses to understand the capability and application of wastewater-based epidemiology (WBE) surveillance in India. Sampling was carried out on 8 and 27 May 2020 at the Old Pirana Waste Water Treatment Plant (WWTP) at Ahmedabad, Gujarat that receives effluent from Civil Hospital treating COVID-19 patients. All three, i.e. ORF1ab, N and S genes of SARS-CoV-

2, were found in the influent with no genes detected in effluent collected on 8 and 27 May 2020. Increase in SARS-CoV-2 genetic loading in the wastewater between 8 and 27 May 2020 samples concurred with corresponding increase in the number of active COVID-19 patients in the city. The number of gene copies was comparable to that reported in untreated wastewaters of Australia, China and Turkey and lower than that of the USA, France and Spain. However, temporal changes in SARS-CoV-2 RNA concentrations need to be substantiated further from the perspectives of daily and short-term changes of SARS-CoV-2 in wastewater through long-term monitoring. The study results SARS-CoV-2 will assist concerned authorities and policymakers to formulate and/or upgrade COVID-19 surveillance to have a more explicit picture of the pandemic curve. While infectivity of SARS-CoV-2 through the excreted viral genetic material in the aquatic environment is still being debated, the presence and detection of genes in wastewater systems makes a strong case for the environmental surveillance of the COVID-19 pandemic.

Street et al (2020) Wastewater surveillance for COVID-19: An African perspective[23]

The COVID-19 pandemic has once again highlighted the importance of access to sufficient quantities of safe water and sanitation in public health. In the current COVID-19 pandemic, an early warning wastewater system has been proposed as a platform for SARS-CoV-2 surveillance, and a potentially important public health strategy to combat the disease. This short communication on wastewater surveillance in sub-Saharan Africa highlights challenges, opportunities and alternatives taken into account the local context.

Ahmed et al (2020) Detection of SARS-CoV-2 RNA in commercial passenger aircraft and cruise ship wastewater: a surveillance tool for assessing the presence of COVID-19 infected travelers[24]

The study indicates that surveillance of wastewater from large transport vessels with their own sanitation systems has potential as a complementary data source to prioritize clinical testing and contact tracing among disembarking passengers. Importantly, sampling

methods and molecular assays must be further optimized to maximize sensitivity. The potential for false negatives by both wastewater testing and clinical swab testing suggests that the two strategies could be employed together to maximize the probability of detecting SARS-CoV-2 infections amongst passengers.

Lancaster et al (2020) Wastewater monitoring of SARS-CoV-2: lessons from illicit drug policy[25]

The authors point out that although wastewater analysis might seem to be a helpful early warning tool to inform rapid response, there are lessons to be learned from other fields about the promises and pitfalls of this method.

The authors have analysed how wastewater analysis is used for illicit drug policy decision making. Wastewater analysis promises near real-time and accurate data on illicit drug consumption in specific geographical locations. As with SARS-CoV-2, it is assumed that real-time, accurate data generated by wastewater analysis would make a difference to policy decision making and allow governments to responsively intervene in local areas. They argue that although wastewater analysis might provide early warning of localised SARS-CoV-2 outbreaks, it cannot account for dynamic population patterns or the specific social and behavioural practices that give rise to outbreak events. This knowledge is crucial for effective intervention. Without evidence that understands the social and contextual aspects of virus transmission, and how communities are responding to (or resisting) interventions, effective responses are not possible. Wastewater analysis is a limited tool for informing action. It might tell us where SARS-CoV-2 is present, but not how best to intervene.

Lodder et al (2020) SARS-CoV-2 in wastewater: potential health risk, but also data source[26]

Since the first publications reporting the detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in faeces, it became clear that human wastewater might contain the novel coronavirus. From Feb 17, 2020, onwards, we took 24-h 10 L samples once a week from human wastewater collected at Amsterdam Airport Schiphol (Haarlemmermeer, Netherlands) for virus analyses. Samples

tested positive for virus RNA by quantitative RT-PCR methodology 4 days after the first cases of coronavirus disease 2019 (COVID-19) were identified in the Netherlands on Feb 27, 2020 (unpublished data). This could be explained by virus excretion from potentially symptomatic, asymptomatic, or presymptomatic individuals passing through the airport. Furthermore, human wastewater sampled near the first Dutch cases in Tilburg, Netherlands, also tested positive for the presence of viral RNA within a week of the first day of disease onset [unpublished data]. These findings indicate that wastewater could be a sensitive surveillance system and early warning tool, as was previously shown for poliovirus. To our knowledge, this detection in the Netherlands is the first report of SARS-CoV-2 in wastewater.

Thompson et al (2020) Making waves: Wastewater surveillance of SARS-CoV-2 for population-based health management[27]

Worldwide, clinical data remain the gold standard for disease surveillance and tracking. However, such data are limited due to factors such as reporting bias and inability to track asymptomatic disease carriers. Disease agents are excreted in the urine and feces of infected individuals regardless of disease symptom severity. Wastewater surveillance - that is, monitoring disease via human effluent - represents a valuable complement to clinical approaches. Because wastewater is relatively inexpensive and easy to collect and can be monitored at different levels of population aggregation as needed, wastewater surveillance can offer a real-time, cost-effective view of a community's health that is independent of biases associated with case-reporting. For SARS-CoV-2 and other disease-causing agents we envision an aggregate wastewater-monitoring system at the level of a wastewater treatment plant and exploratory or confirmatory monitoring of the sewerage system at the neighborhood scale to identify or confirm clusters of infection or assess impact of control measures where transmission has been established. Implementation will require constructing a framework with collaborating government agencies, public or private utilities, and civil society organizations for appropriate use of data collected from wastewater, identification of an appropriate scale of sample collection and aggregation to balance privacy concerns and risk of

stigmatization with public health preservation, and consideration of the social implications of wastewater surveillance.

Mlejnkova et al (2020) Preliminary Study of Sars-Cov-2 Occurrence in Wastewater in the Czech Republic[28]
Samples of untreated wastewater were collected from 33 wastewater treatment plants (WWTPs) of different sizes within the Czech Republic. SARS-CoV-2 RNA was concentrated from wastewater and viral RNA was determined using real-time reverse transcription polymerase chain reaction (RT-qPCR). SARS-CoV-2 RNA was detected in 11.6% of samples and more than 27.3% of WWTPs; in some of them, SARS-CoV-2 was detected repeatedly. Our preliminary results indicate that an epidemiology approach that focuses on the determination of SARS-CoV-2 in wastewater could be suitable for SARS-CoV-2 surveillance in the population.

Sherchan et al (2020) First detection of SARS-CoV-2 RNA in wastewater in North America: A study in Louisiana, USA[29]
Researchers investigated the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) RNA in wastewater samples in southern Louisiana, USA. Untreated and treated wastewater samples were collected on five occasions over a four-month period from January to April 2020. The wastewater samples were concentrated via ultrafiltration (Method A), and an adsorption-elution method using electronegative membranes (Method B). SARS-CoV-2 RNA was detected in 2 out of 15 wastewater samples using two reverse transcription-quantitative polymerase chain reaction (RT-qPCR) assays (CDC N1 and N2). None of the secondary treated and final effluent samples tested positive for SARS-CoV-2 RNA. To our knowledge, this is the first study reporting the detection of SARS-CoV-2 RNA in wastewater in North America, including the USA. However, concentration methods and RT-qPCR assays need to be refined and validated to increase the sensitivity of SARS-CoV-2 RNA detection in wastewater

Lu et al (2020) Primary concentration - The critical step in implementing the wastewater based epidemiology for the COVID-19 pandemic: A mini-review[30]

This review provides new insights into the primary concentration methods that have been adopted by the eighteen recently reported COVID-19 wastewater detection studies, along with a brief discussion of the mechanisms of the most commonly used virus concentration methods, including the PEG-based separation, electrostatically charged membrane filtration, and ultrafiltration. In the end, two easy and well-proven concentration strategies are recommended, aiming to maximize the practical significance and operational effectiveness of the SARS-CoV-2 virus concentration from wastewater samples.

Corpuz et al (2020) Viruses in wastewater: occurrence, abundance and detection methods[31]

This paper presents an updated and comprehensive review on the different methods used for detection and quantification of viruses in wastewater treatment systems. The analysis of viability of viruses in wastewater and sludge is another thrust of this review. Recent studies have mostly focused on determining the abundance and diversity of viruses in wastewater influents, in samples from primary, secondary, and tertiary treatment stages, and in final effluents. A few studies have also examined the occurrence and diversity of viruses in raw and digested sludge samples. Recent efforts to improve efficiency of virus detection and quantification methods in the complex wastewater and sludge matrices are highlighted in this review. A summary and a detailed comparison of the pre-treatment methods that have been utilized for wastewater and sludge samples are also presented. The role of metagenomics or sequencing analysis in monitoring wastewater systems to predict disease outbreaks, to conduct public health surveillance, to assess the efficiency of existing treatment systems in virus removal, and to re-evaluate current regulations regarding pathogenic viruses in wastewater is discussed in this paper. Challenges and future perspectives in the detection of viruses, including emerging and newly emerged viruses such as the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), in wastewater systems are discussed in this review.

Baraniuk (2020) Sewage monitoring is the UK's next defence against COVID-19[32]

Researchers at a handful of universities around the UK have been conducting pilot programmes to detect RNA from the SARS-CoV-2 virus deposited in sewage, which ends up at wastewater treatment plants.

A UK-wide sewage surveillance programme to monitor the presence of the virus in wastewater was announced on 12 June by the Department for Environment, Food, and Rural Affairs (DEFRA). During the initial phase, around 50 wastewater treatment sites around the UK will be sampled a few times a week. Researchers are sampling a few sites already, with the rest to follow by the end of the summer. Other countries, including Australia and Spain, had previously committed to similar monitoring programmes.

Other

Gill (2020) Coronavirus: Sewage testing for COVID-19 begins in England[33]
Sewage testing is being conducted across England in a bid to develop wastewater-based COVID-19 surveillance. Samples will be checked for signs of the virus, to get early warning of spikes in infection levels.

Dutch Water Sector (2020) Nationwide COVID-19 sewer surveillance at all Dutch wwtps[34]
As of 1 September the influent of all 323 Dutch municipal waste water treatment plants must be monitored daily on the presence of SARS-CoV-2 RNA gen material and the data must be processed to the national COVID-19 dashboard.

University College Dublin (2020) SARS-CoV-2 in Sewage and Bodies of Water[35]
Science Foundation Ireland is funding a new project at UCD to measure levels of SARS-CoV-2 at wastewater treatment plants.

Jefferson et al (2020) SARS-CoV-2 and the role of orofecal transmission[36]
Sentinel surveillance of SARS-CoV-2 in wastewater has been shown to anticipate the occurrence of COVID-19 cases. Even at low COVID-19 prevalence, sewage surveillance could be a sensitive tool to monitor the viral circulation Environmental screening may, therefore, be a very sensitive tool to gauge viral presence before clinical symptoms become apparent.

Produced by the members of the National Health Library and Knowledge Service Evidence Team†. Current as at [13 August 2020]. This evidence summary collates the best available evidence at the time of writing and does not replace clinical judgement or guidance. Emerging literature or subsequent developments in respect of COVID-19 may require amendment to the information or sources listed in the document. Although all reasonable care has been taken in the compilation of content, the National Health Library and Knowledge Service Evidence Team makes no representations or warranties expressed or implied as to the accuracy or suitability of the information or sources listed in the document. This evidence summary is the property of the National Health Library and Knowledge Service and subsequent re-use or distribution in whole or in part should include acknowledgement of the service.

The following PICO(T) was used as a basis for the evidence summary:

Population P person location condition/patient characteristic	GENERAL POPULATION
Intervention I length location type	WASTE WATER SURVEILLANCE FOR COVID-19
Comparison C another intervention no intervention location of the intervention	
Outcome O	IMPROVE THE DETECTION OF COVID-19

The following search strategy was used:

2019-nCoV OR 2019nCoV OR COVID-19 OR SARS-CoV-2 OR (wuhan AND coronavirus) AND 2019/12[PDAT]:2030[PDAT])

AND

"waste water"[Title/Abstract] OR "wastewater"[Title/Abstract] OR "sewage"[Title/Abstract] OR "sewerage"[Title/Abstract] OR
"wastewater-based epidemiological monitoring"[MeSH Terms]

† Marie Carrigan, HSE Librarian, St. Luke's Radiation Oncology Network[Author]; Julia Reynolds, Librarian, Mayo University Hospital, Castlebar [Editor]; Brendan Leen, Area Library Manager, HSE South [Editor].

[1] WHO (2020) Status of environmental surveillance for SARS-CoV-2 virus. https://www.who.int/publications/i/item/WHO-2019-nCoV-sci-brief-environmentalSampling-2020-1 [Accessed 10 August 2020]
[2] World Health Organization (2020) Public Health Surveillance for COVID-19. https://www.who.int/publications/i/item/who-2019-nCoV-surveillanceguidance-2020.7 [Accessed 10 August 2020]
[3] World Health Organization (2020) Water, sanitation, hygiene, and waste management for the COVID-19 virus https://www.who.int/publications/i/item/water-sanitation-hygiene-and-waste-management-for-COVID-19 [Accessed 10 August 2020]
[4] Daughton CG. Wastewater surveillance for population-wide COVID-19: The present and future. *Sci Total Environ.* 2020;736:139631. doi:10.1016/j.scitotenv.2020.139631
[5] Daughton CG. The international imperative to rapidly and inexpensively monitor community-wide COVID-19 infection status and trends. Sci Total Environ. 2020;726:138149. doi:10.1016/j.scitotenv.2020.138149
[6] Ahmed W, Angel N, Edson J, et al First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. *Sci Total Environ.* 2020;728:138764. doi:10.1016/j.scitotenv.2020.138764
[7] La Rosa G, Iaconelli M, Mancini P, et al First detection of SARS-CoV-2 in untreated wastewaters in Italy. *Sci Total Environ.* 2020;736:139652. doi:10.1016/j.scitotenv.2020.139652
[8] Medema G et al Presence of SARS-Coronavirus-2 in sewage [preprint, 25 July 2020] Available at Medrxiv: https://www.medrxiv.org/content/10.1101/2020.03.29.20045880v2
[9] Randazzo W, Truchado P, Cuevas-Ferrando E, Simón P, Allende A, Sánchez G. SARS-CoV-2 RNA in wastewater anticipated COVID-19 occurrence in a low prevalence area. *Water Res.* 2020;181:115942. doi:10.1016/j.watres.2020.115942
[10] Hart OE, Halden RU. Computational analysis of SARS-CoV-2/COVID-19 surveillance by wastewater-based epidemiology locally and globally: Feasibility, economy, opportunities and challenges. *Sci Total Environ.* 2020;730:138875. doi:10.1016/j.scitotenv.2020.138875
[11] Wu F, Xiao A, Zhang J, et al SARS-CoV-2 titers in wastewater foreshadow dynamics and clinical presentation of new COVID-19 cases. Preprint. *medRxiv.* 2020;2020.06.15.20117747. Published 2020 Jun 23. doi:10.1101/2020.06.15.20117747 https://pubmed.ncbi.nlm.nih.gov/32607521/
[12] Foladori P, Cutrupi F, Segata N, et al SARS-CoV-2 from faeces to wastewater treatment: What do we know? A review [published online ahead of print, 2020 Jun 24]. *Sci Total Environ.* 2020;743:140444. doi:10.1016/j.scitotenv.2020.140444 https://pubmed.ncbi.nlm.nih.gov/32649988/
[13] Wu F, Zhang J, Xiao A, et al SARS-CoV-2 Titers in Wastewater Are Higher than Expected from Clinically Confirmed Cases. *mSystems.* 2020;5(4):e00614-20. Published 2020 Jul 21. doi:10.1128/mSystems.00614-20
[14] Ahmed W, Bertsch PM, Bivins A, et al Comparison of virus concentration methods for the RT-qPCR-based recovery of murine hepatitis virus, a surrogate for SARS-CoV-2 from untreated wastewater [published online ahead of print, 2020 Jun 5]. *Sci Total Environ.* 2020;739:139960. doi:10.1016/j.scitotenv.2020.139960
[15] Wurtzer S et al Evaluation of lockdown impact on Sars-CoV-2 dynamics through viral genome quantification in Paris wastewaters [Preprint, 6 May 2020] https://www.medrxiv.org/content/10.1101/2020.04.12.20062679v2
[16] Peccia J et al SARS-CoV-2 RNA concentrations in primary municipal sewage sludge as a leading indicator of COVID-19 outbreak dynamics [Preprint, 12 July 2020] https://www.medrxiv.org/content/10.1101/2020.05.19.20105999v2
[17] Bhalla N, Pan Y, Yang Z, Payam AF. Opportunities and Challenges for Biosensors and Nanoscale Analytical Tools for Pandemics: COVID-19 [published online ahead of print, 2020 Jun 26]. ACS Nano. 2020;acsnano.0c04421. doi:10.1021/acsnano.0c04421https://pubmed.ncbi.nlm.nih.gov/32551559/
[18] Al Huraimel K, Alhosani M, Kunhabdulla S, Stietiya MH. SARS-CoV-2 in the environment: Modes of transmission, early detection and potential role of pollutions [published online ahead of print, 2020 Jul 15]. *Sci Total Environ.* 2020;744:140946. doi:10.1016/j.scitotenv.2020.140946https://pubmed.ncbi.nlm.nih.gov/32687997/

[19] Prado T, Fumian TM, Mannarino CF, Maranhão AG, Siqueira MM, Miagostovich MP. Preliminary results of SARS-CoV-2 detection in sewerage system in Niterói municipality, Rio de Janeiro, Brazil. *Mem Inst Oswaldo Cruz.* 2020;115:e200196. doi:10.1590/0074-02760200196https://pubmed.ncbi.nlm.nih.gov/32725059/
[20] Adelodun B, Ajibade FO, Ibrahim RG, Bakare HO, Choi KS. Snowballing transmission of COVID-19 (SARS-CoV-2) through wastewater: Any sustainable preventive measures to curtail the scourge in low-income countries? [published online ahead of print, 2020 Jul 2]. *Sci Total Environ.* 2020;742:140680. doi:10.1016/j.scitotenv.2020.140680
https://pubmed.ncbi.nlm.nih.gov/32629273/
[21] Hata A, Honda R. Potential Sensitivity of Wastewater Monitoring for SARS-CoV-2: Comparison with Norovirus Cases. *Environ Sci Technol.* 2020;54(11):6451-6452. doi:10.1021/acs.est.0c02271
https://pubmed.ncbi.nlm.nih.gov/32421334/
[22] Kumar M, Patel AK, Shah AV, et al First proof of the capability of wastewater surveillance for COVID-19 in India through detection of genetic material of SARS-CoV-2 [published online ahead of print, 2020 Jul 28]. *Sci Total Environ.* 2020;746:141326. doi:10.1016/j.scitotenv.2020.141326
[23] Street R, Malema S, Mahlangeni N, Mathee A. Wastewater surveillance for COVID-19: An African perspective [published online ahead of print, 2020 Jul 3]. *Sci Total Environ.* 2020;743:140719. doi:10.1016/j.scitotenv.2020.140719
https://pubmed.ncbi.nlm.nih.gov/32659559/
[24] Ahmed W, Bertsch PM, Angel N, et al Detection of SARS-CoV-2 RNA in commercial passenger aircraft and cruise ship wastewater: a surveillance tool for assessing the presence of COVID-19 infected travelers [published online ahead of print, 2020 Jul 14]. *J Travel Med.* 2020;taaa116. doi:10.1093/jtm/taaa116
https://pubmed.ncbi.nlm.nih.gov/32662867/
[25] Lancaster K, Rhodes T. Wastewater monitoring of SARS-CoV-2: lessons from illicit drug policy. *Lancet Gastroenterol Hepatol.* 2020;5(7):641-642. doi:10.1016/S2468-1253(20)30158-8
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7295476/
[26] Lodder W, de Roda Husman AM. SARS-CoV-2 in wastewater: potential health risk, but also data source. *Lancet Gastroenterol Hepatol.* 2020;5(6):533-534. doi:10.1016/S2468-1253(20)30087-X
https://pubmed.ncbi.nlm.nih.gov/32246939/
[27] Thompson JR, Nancharaiah YV, Gu X, et al Making waves: Wastewater surveillance of SARS-CoV-2 for population-based health management [published online ahead of print, 2020 Jul 13]. *Water Res.* 2020;184:116181. doi:10.1016/j.watres.2020.116181 https://pubmed.ncbi.nlm.nih.gov/32707307/
[28] Mlejnkova H, Sovova K, Vasickova P, Ocenaskova V, Jasikova L, Juranova E. Preliminary Study of Sars-Cov-2 Occurrence in Wastewater in the Czech Republic. *Int J Environ Res Public Health.* 2020;17(15):E5508. Published 2020 Jul 30. doi:10.3390/ijerph17155508 https://pubmed.ncbi.nlm.nih.gov/32751749/
[29] Sherchan SP, Shahin S, Ward LM, et al First detection of SARS-CoV-2 RNA in wastewater in North America: A study in Louisiana, USA [published online ahead of print, 2020 Jun 30]. *Sci Total Environ.* 2020;743:140621. doi:10.1016/j.scitotenv.2020.140621 https://pubmed.ncbi.nlm.nih.gov/32758821/
[30] Lu D, Huang Z, Luo J, Zhang X, Sha S. Primary concentration - The critical step in implementing the wastewater based epidemiology for the COVID-19 pandemic: A mini-review [published online ahead of print, 2020 Jul 25]. *Sci Total Environ.* 2020;747:141245. doi:10.1016/j.scitotenv.2020.141245 https://pubmed.ncbi.nlm.nih.gov/32768768/
[31] Corpuz MVA, Buonerba A, Vigliotta G, et al Viruses in wastewater: occurrence, abundance and detection methods [published online ahead of print, 2020 Jul 19]. *Sci Total Environ.* 2020;745:140910. doi:10.1016/j.scitotenv.2020.140910
https://pubmed.ncbi.nlm.nih.gov/32758747/
[32] Baraniuk C. Sewage monitoring is the UK's next defence against COVID-19. *BMJ.* 2020;370:m2599. Published 2020 Jul 15. doi:10.1136/bmj.m2599 https://pubmed.ncbi.nlm.nih.gov/32669267/
[33] Gill V (August 2020) Coronavirus: Sewage testing for COVID-19 begins in England.
https://www.bbc.com/news/science-environment-53635692 [Accessed 10 August 2020]
[34] Dutch Water Sector (June 2020) Nationwide COVID-19 sewer surveillance at all Dutch wwtps
https://www.dutchwatersector.com/news/nationwide-COVID-19-sewer-surveillance-at-all-dutch-wwtps
[Accessed 10 August 2020]
[35] UCD COVID-19 response. SARS-CoV-2 in Sewage and Bodies of Water]
https://www.ucd.ie/research/COVID19response/news/wimmeijersewagemonitoring/[Accessed 12 August 2020]
[36] Jefferson et al (July 2020) SARS-CoV-2 and the role of orofecal transmission
https://www.cebm.net/COVID-19/sars-cov-2-orofecal-transmission/ Accessed 12 August 2020]