Environmental surveillance for SARS-COV-2 to complement public health surveillance

Interim Guidance

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World Health Organization

Contents

1. Introduction

Management of the COVID-19 pandemic continues to prove challenging in the face of an evolving virus, and uncertainties in designing proportionate and evidence-based public health interventions. The primary source of evidence about the incidence of SARS-CoV-2 infection is PCR and rapid antigen diagnostic testing of upper respiratory tract samples.

In an increasing number of settings globally, routine COVID-19 surveillance programmes have augmented diagnostic testing with community-scale COVID-19 environmental surveillance (ES) of SARS-CoV-2 in wastewater samples. Similarly, ES have been done for other diseases and risks such as for polio *(1),* typhoid *(2)(3)* and antimicrobial resistance (AMR) *(4, 5, 6).*

The objective of ES is to provide early warning and additional evidence regarding the virus in circulation in the population, including its presence or absence, trends in concentrations, and variants of concern or interest. ES can help to inform decisions on, and help measure the effect of, interventions *(7)*.

Purpose

The purpose of this guidance is to provide globally applicable advice on the following questions:

- Why, or in what situations, does ES add value to public health decision making at different stages of the pandemic, and in different settings and contexts? (section 3)
- What are the minimum requirements for planning and coordinating an effective SARS-COV-2 ES programme in different resource settings? (section 4)
- How should data collection, analysis and interpretation and communication of results be carried out? (section 5)

Target audience

This guidance is targeted at public health officials and COVID-19 incident management team members who want to understand and integrate complementary ES, into their national, sub-national or local COVID-19 control strategy. The guidance also provides general information on coordination, capacity and methods for laboratory scientists and water and sanitation services providers. This document is intended to:

- help public health professionals make informed, evidence-based decisions on the value of ES for their context to help decide whether to implement such a programme;
- show how entities would set up a successful ES programme;
- support public communication of SARS-COV-2 ES results;
- promote sharing and harmonization of SARS-COV-2 ES methods and approaches between localities, countries and regions;
- guide utilisation of SARS-COV-2 ES results along with other COVID-19 surveillance modalities in means of public health decision making; and
- support sharing of lessons and case studies from implementation experiences for more efficient application of ES globally.

Scope

Air, surface and water matrices have been subjected to SARS-CoV-2 testing. However, only the testing of wastewater has been of value in assessing the levels of SARS-COV-2 circulating at the population scale.

This document discusses SARS-COV-2 ES of wastewater containing SARS-CoV-2 (RNA) shed in excreta and upper respiratory system secreta from symptomatic and asymptomatic COVID-19 cases in populations living, working or visiting in a defined catchment area. It describes use cases, planning and coordination and emerging best practice methods for data collection analysis and interpretation. This document does not provide specific recommendations on uses or standards methods for ES since approaches and details of the methods being used are evolving rapidly. However, there is sufficient experience to describe features and good practice in a range of contexts.

ES programmes normally draw wastewater samples from sewer systems at the inlet of wastewater treatment plants in setting with high coverage of sewers to gain a representative sample of people living in the catchment. This document also discusses SARS-COV-2 ES in areas that have limited sewer network coverage where this emerging and important work is being applied to environmental water (e.g., surface water or stormwater in open drains influenced by human excreta) *(8, 9)*.

Background

This interim guidance updates the World Health Organization (WHO) scientific brief *Status of environmental surveillance for SARS-CoV-2 virus: scientific brief, 5 August 2020*.

At the time of publication of the scientific brief, many countries including Italy *(10)*, Japan *(11)*, China *(12)*, India *(13)*, the United States of America *(14)*, and countries in Latin America and the Caribbean *(15),* had published or demonstrated proof of concept of ES for SARS-COV-2 by detecting SARS-CoV-2 in environmental samples. Since then, numerous SARS-COV-2 ES programmes have been established and become a routine component of national COVID-19 surveillance programmes *(16–21)*. SARS-COV-2 ES programmes began with SARS-CoV-2 detection, moved to increasingly reliable quantification, and some now include testing for targeted known variants *(22)* and finding novel variants *(23)*. Some countries (e.g., the Netherlands *(24)*, Hungary and the United Kingdom) have moved to some form of national SARS-COV-2 ES system and others are coordinating and consolidating data at a national level, and working with regional or state governments. Governance arrangements are diverse, and all involve complex multiple stakeholder arrangements.

Data and evidence available on implications of SARS-COV-2 ES have greatly expanded in amount and quality enabling new interim guidance. Advances in ES for SARS-COV-2 have been documented in many journal articles, technical reports, expert opinion of SARS-COV-2 ES programme managers *(25, 26)* public health and COVID-19 incident management websites, global data-sharing platforms *(27, 28)* and media communications. Collectively, they have demonstrated a variety of applications including challenges, costs and limitations (Section 3 and Annex 1), and lessons have been learned to optimize planning, coordination and capacity for a credible programme (Section 4). Techniques for sampling *(5, 6, 29, 30, 31, 32, 33, 34, 35)* and analytical methods have been validated and routinely used for detection and quantification of SARS-CoV-2 and, in some cases, its variants (see section 5). Innovations being trialled or at proof-of-concept stage have been expanded, and formal research agendas have been prepared (see section 6).

2. Environmental surveillance in the broader public health surveillance context

A growing body of experience and specific added value of SARS-COV-2 ES can justify inclusion of this surveillance method into routine COVID-19 surveillance. ES is used to complement rather than replace public health surveillance based on compilation of individual diagnostic testing results (Figs. 1 - 3). Therefore, this document should be read in conjunction with the WHO interim guidance on public health surveillance for COVID-19 *(36)* which describes the range of COVID-19 surveillance methods.

There are useful similarities and differences between ES and diagnostic testing methods and approaches for those familiar with diagnostic testing.

Within the laboratory, the molecular detection methods used for SARS-COV-2 ES are comparable, and in some cases identical, to those used for diagnostic testing. That is, the same RT-PCR test kits are often used for the final testing component. What is different about SARS-COV-2 ES in comparison to diagnostic testing programmes, is the design and interpretation of the community-scale sampling programmes, as well as concentration and extraction of the RNA from the wastewater and environmental water samples *(37–39)*. An understanding of the wastewater catchment and the communities represented by the sample points as compared with health reporting regions and local municipalities is required to design and interpret a representative SARS-COV-2 ES programme. Experience with environmental samples, and often some minor adaptation of clinical molecular testing, is required to conduct reliable virus detection assays as part of a SARS-COV-2 ES programme.

An important benefit of SARS-COV-2 ES is that it is not susceptible to biases inherent in diagnostic testing, which include health seeking behaviour, disease severity, health care and test accessibility, physician and personal disposition to test and cost and reporting limitations. These biases change over time in ways that ES methods do not. In contrast, SARS-COV-2 ES is independent of diagnostic testing practices and capacity, and so far, provides an objective indicator of virus circulation in the population.

SARS-COV-2 ES has potential to play an important role in the overall surveillance picture by providing an additional line of evidence to inform pandemic and endemic disease surveillance to support management programmes and other public health and social measures *(40)*. Presently, SARS-COV-2 ES is a tool to observe trends and change in viral circulation at a population level, rather than to make firm conclusions about the incidence and prevalence of COVID-19 cases in the community, however correlation with hospitalizations has been show in several settings.

The results from SARS-COV-2 ES are particularly helpful in providing early indication of a change in COVID-19 incidence at a population level *(41)*. Viral RNA can be shed into wastewater before the onset of symptoms and before diagnostic testing. Therefore, results can inform public health agencies before diagnostic test results are reported. As such ES can provide earlier and more representative warning of trends *(42)* in COVID-19 incidence and the emergence of variants *(43, 44)* than diagnostic testing – albeit over time this may change for different variants. This can, for instance, help plan for surges in demand for healthcare services and for identifying when such demand may have peaked. In higher-prevalence contexts SARS-COV-2 ES is helpful at documenting trends *(45, 46, 47*), whilst in lower prevalence contexts or in the absence of evidence of clinical testing ES provides an early warning of SARS-CoV-2 emergence *(48, 49)*. The role of ES and the early warning of (re)emergence is expected to become more relevant now interest in clinical testing is waning.

Viral loads in sewage can be used to monitor the impact of public health social measures including increasing or relaxing restrictions. Results from SARS-COV-2 ES can be used to augment risk communication warn communities about virus (re)emergence and to inform community behaviour with respect to testing, quarantine, isolation, vaccination, and healthcare seeking behaviours.

When diagnostic testing capacities are overwhelmed during periods of elevated prevalence, or willingness to test is low in certain times or areas, ES methods can provide a more cost-effective and reliable means to track trends and test for variants. Likewise, during low prevalence or no known case situations, ES methods can be cost-effective for early warning. As diagnostic testing becomes more targeted to specific sites and situations, ES can provide a means of cost-effectively monitoring population-level trends and emergence.

SARS-COV-2 ES also have potential benefits of scalability and efficiency since a single sample can provide evidence of SARS-CoV-2 circulation at a population level in wastewater catchments ranging from small populations to populations of tens of thousands of people, and if carried out ethically can be a non-intrusive approach that doesn't target individuals (50). Disadvantages of SARS-COV-2 ES as compared with other surveillance approaches are the lack of individual sampling and test results, and thus the ability to link to clinical care, particularly during periods of limited shedding and few cases when method sensitivity becomes limiting *(51)*.

ES for other diseases

WHO has produced ES guidance for other diseases, including polio *(1)* and typhoid *(52, 3),* and AMR *(5, 6)*, some of which dates back more than 70 years. Many of the standard methods, approaches and global reporting processes for Polio ES are applicable or adaptable to SARS-CoV-2. Some countries, such as South Africa, have already built on that experience and created comprehensive SARS-COV-2 ES programmes for the presence and concentrations of SARS-CoV-2 *(53, 54)* and in some cases its variants *(43, 44)*. However, there are two important differences.

- The main use cases of ES for polio are early detection of an outbreak and confirmation of the absence of circulation of wild-type and vaccine-derived poliovirus in a population *(55)*. Therefore, ES for polio has not depended on quantitative data to look at trends in prevalence. Presence/absence use cases were relevant in the early stages of the COVID-19 pandemic, but are less relevant in the situation of global spread and high incidence.
- Standard methods from selection of sites to sewage concentration and poliovirus genetic characterization, are available for Polio ES but as yet, there is not enough experience with ES for SARS-COV-2 to specify equivalent standard methods since the approaches and details of the methods being used are evolving rapidly. At this stage standardising methods between different laboratories and sites is less important than having consistent methods and quality at any one site. Some studies have begun to address questions such as sample representativeness, quantifying sensitivity, specificity, other performance characteristics of the methods and cost *(51, 56)* and there is also an ISO initiative to address them *(57)*.

Learning from existing ES programmes has the potential to inform public health surveillance for other diseases and risks such as chemicals of emerging concern, antimicrobial resistance, illicit drugs, or understanding of populations and their movements and behaviours.

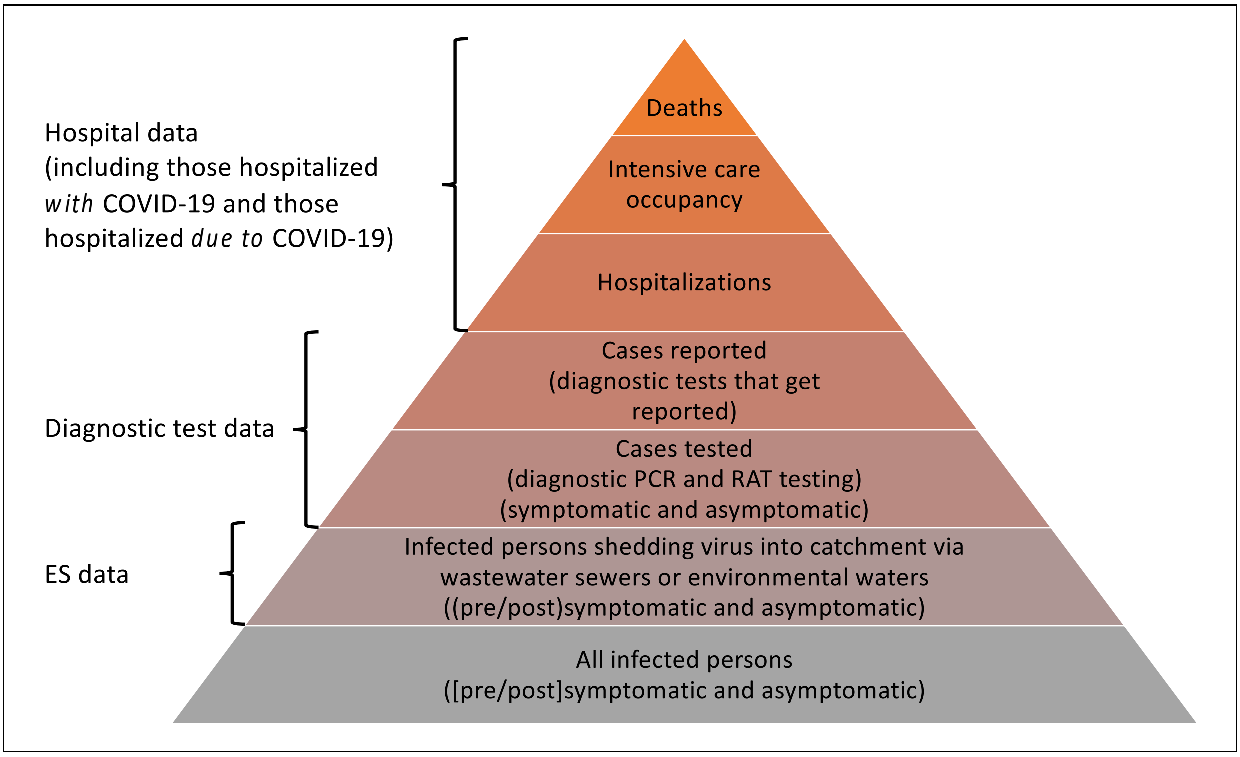


Fig. 1. Illustration of the role of SARS-COV-2 ES as a source of data on COVID-19 and SARS-CoV-2 shedding in communities via a defined wastewater catchment.

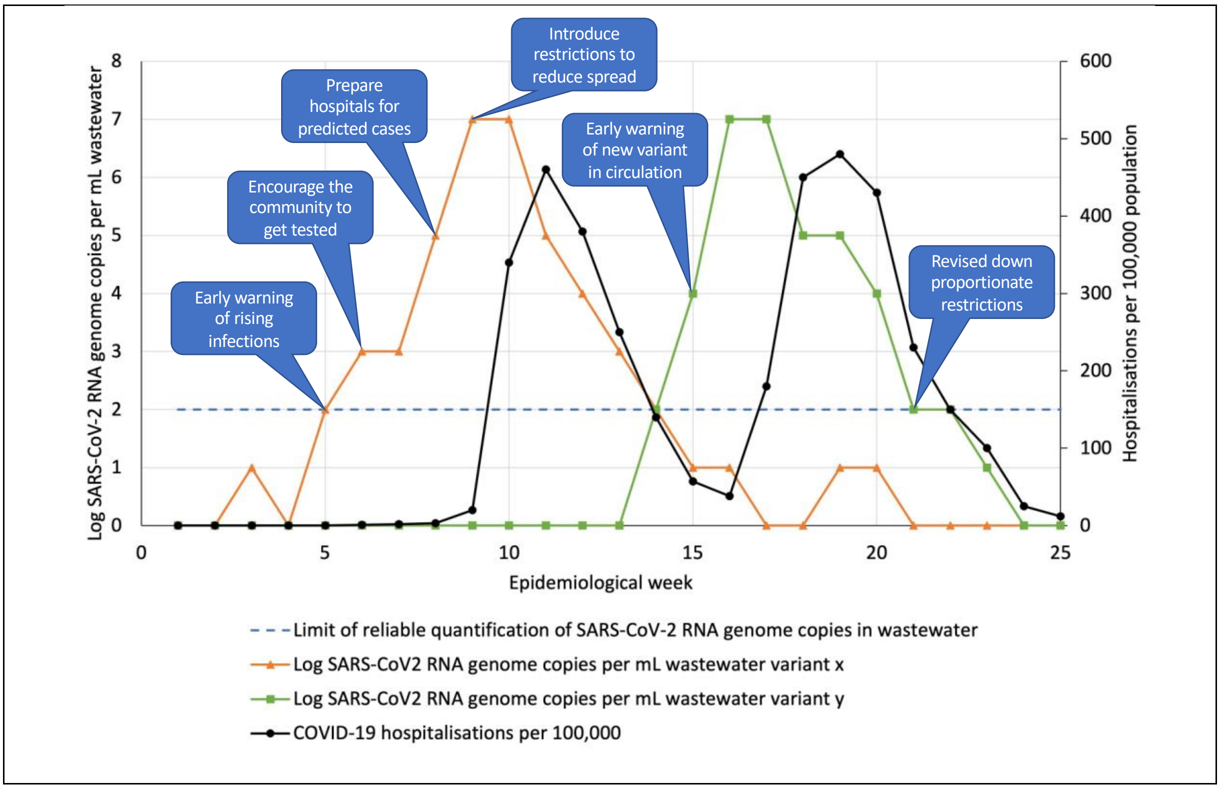
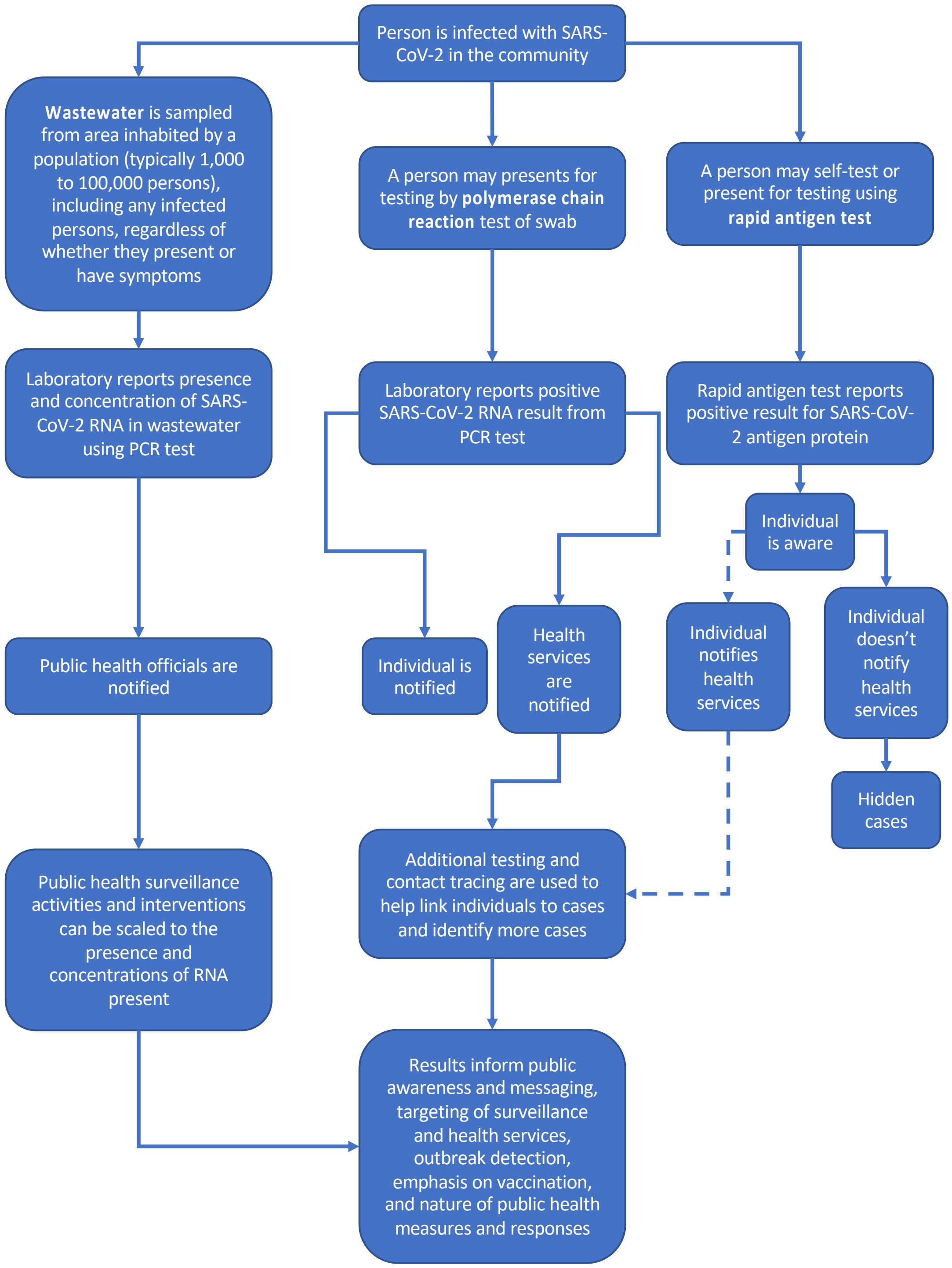


Fig. 2. Illustration ES data compared to hospitalization data and potential use cases for public communication, public health decision-making and targeting restrictions.



NB:

- *The emphasis on different test methods may vary during different phases of the pandemic.*
- *The timeframe from sampling to visualising test results is of the order 15 min for rapid antigen diagnostic tests and approximately 0.5 to 2 days for both diagnostic and ES PCR tests (sometimes more depending on backlogs and turnaround times).*
- *The early warning offered by ES comes from its ability to detect virus in pre-symptomatic and asymptomatic persons in the community that shed the virus but that might not have presented for diagnostic testing.*
- *In some contexts, results are shared directly with the community at the same time as the public health agency.*

Fig. 3. Illustration comparing the use of surveillance methods based on rapid antigen testing, nasopharyngeal testing and wastewater testing from the perspective of a public health agency.

3. Applications of environmental surveillance for COVID-19

Public health leadership

Leadership by the agencies responsible for public health, and with overall responsibility for COVID-19 management and control, is critical to SARS-COV-2 ES programmes. Multidisciplinary, cross-sector coordination is required for SARS-COV-2 ES programmes, involving key stakeholders, such as environment agencies, regional and local authorities, wastewater operators and managers, and laboratories.

However, the health sector is the end user of the information and therefore needs to take the lead in designing surveillance programmes, merging and linking the SARS-COV-2 ES data with other surveillance platforms, and coordinating interpretation and communication of the findings. Public health agencies, working in partnership with a multidisciplinary team, should be responsible for leading SARS-COV-2 ES initiation, coordination and implementation to ensure a health-led and integrated decision-making process. The public health agencies should ensure complementarity between the SARS-COV-2 ES and other surveillance activities. The public health agency should fund the SARS-COV-2 ES program since it is not a water and sanitation sector function – it is about accessing the information encoded in wastewater to provide an unbiased indicator of COVID-19 incidence.

Uses of SARS-COV-2 ES to support public health surveillance

Before initiating a SARS-COV-2 ES programme, it is important to consider how SARS-COV-2 ES is anticipated to add value to health sector decision-making for the COVID-19 response (Table 1).

All ES applications provide a population-level indicator for COVID-19, covering relatively large populations for each sample collected (Figs. 3). SARS-COV-2 ES data is independent of healthcare-seeking behaviours and access to and use of clinical testing. The benefits of SARS-COV-2 ES vary according to factors such as phase of the pandemic, the method used to collect wastewater samples, spatial coverage, sampling frequencies, analytical methods, and the interventions triggered in response to SARS-COV-2 ES results.

From least to most advanced, SARS-COV-2 ES programmes can provide the following evidence:

- At their most basic, SARS-COV-2 ES programmes indicate whether SARS-CoV-2 is above (present) or below (absent) the limits of detection of the testing methods used at the level