LAC COVID-19 TESTING SERIES

WORLD BANK GROUP

Guidebook for Effective National Testing and Surveillance Strategies for SARS-CoV-2:

Latin America and the Caribbean

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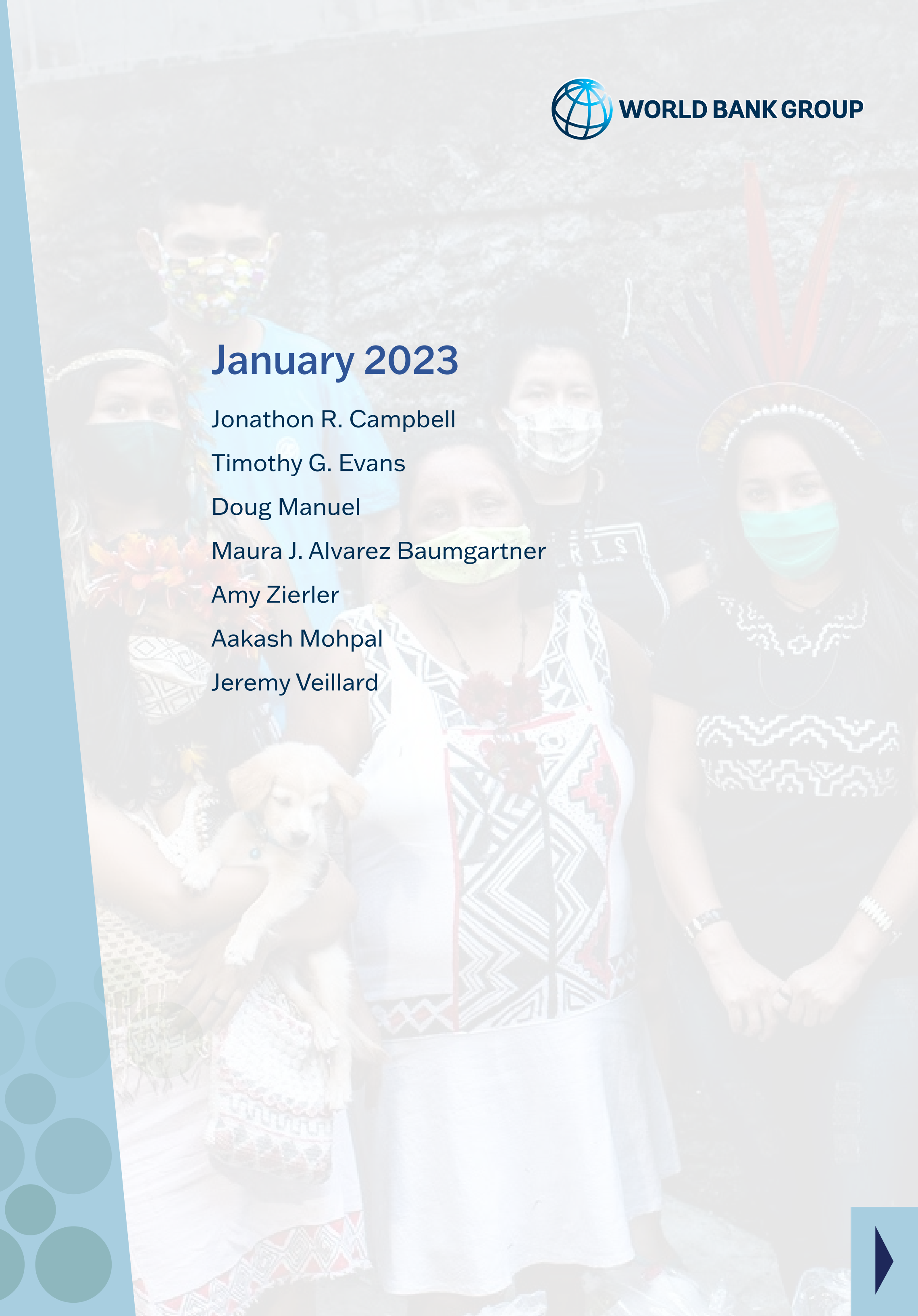

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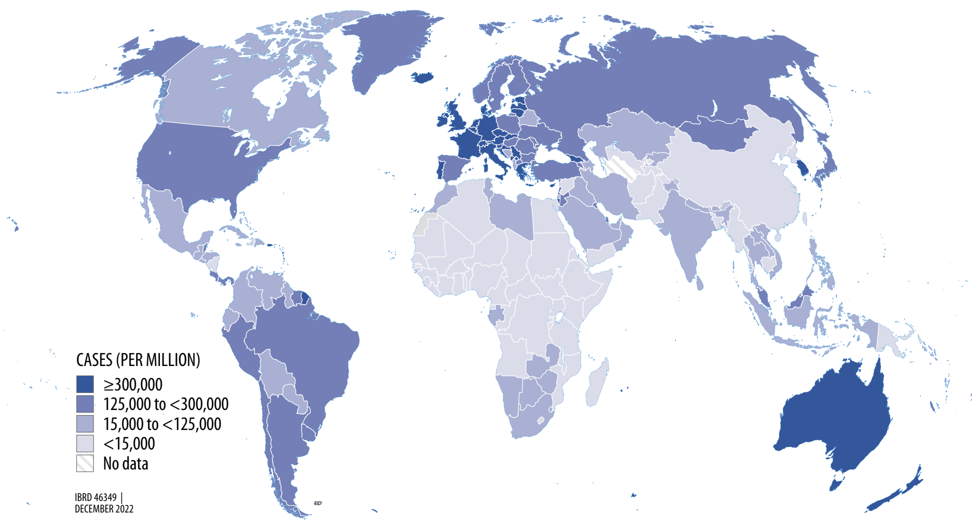
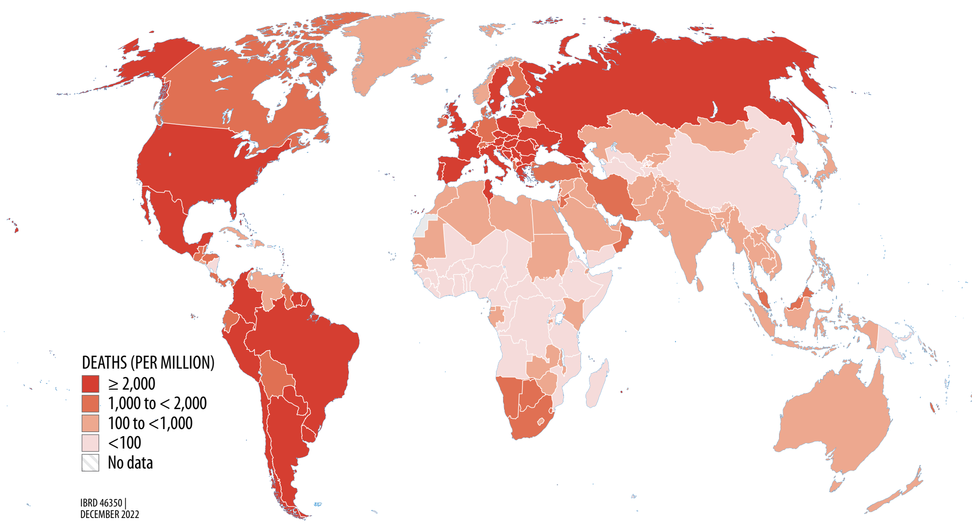
Executive Summary

Why Do Countries Need Effective, National Surveillance for SARS-CoV-2?

Latin America and the Caribbean have been hit hard by the COVID-19 pandemic, which continues to undo years of progress on health and human capital in the region. As of December 1, 2022, **over 78 million cases of COVID-19 have been diagnosed and over 1.7 million deaths have occurred in the region.** As SARS-CoV-2 transmission continues throughout the region, testing capacity—and thus the ability to perform comprehensive surveillance—has failed to increase along with it. Over the past year, the omicron variant and its subvariants have laid bare these shortcomings, straining testing and health care systems, and threatening human activity in the region.

As our experience and understanding of SARS-CoV-2 have evolved, it is clear we will need to prevent and control SARS-CoV-2 for years to come. Comprehensive, national, public health strategies will therefore be required to protect vulnerable populations and human capital, keep economies open, and minimize the social impacts of SARS-CoV-2, future pandemics, and other public health threats.





Key Reasons for National Testing and Surveillance

Investing in testing and surveillance systems is essential—for the immediate response to SARS-CoV-2 and to prepare for the next public health threat. Developing and implementing effective national testing and surveillance strategies for SARS-CoV-2 and proactively leveraging the resultant data to inform public health responses must be a key part of national strategies.

Why?

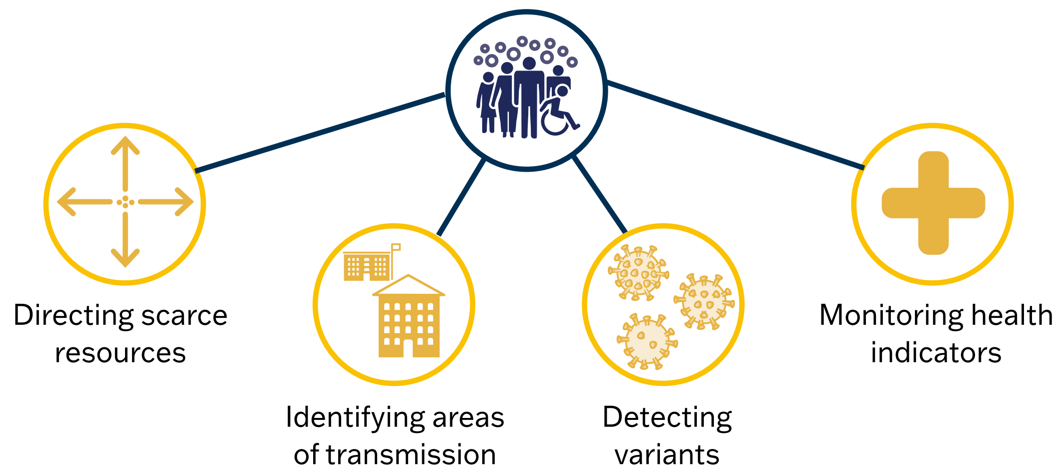
- We need to stay ahead of future waves of infection.
- Symptom-based testing alone is insufficient.
- Variants of concern continue to emerge.
- Inequities will continue to persist with a passive approach to SARS-CoV-2

What Do Effective, National Surveillance Activities for SARS-CoV-2 Provide?

Vital data

Population-level testing and surveillance are an underappreciated but vital component of national strategic plans. These activities produce data to inform where to direct scarce health resources, identify areas of transmission, detect variants, and monitor population health indicators. In short, population-level testing and surveillance can bring indispensable value to the public health response.

Activities testing and surveillance helps support:



Case Examples

In this guidebook, a series of case examples highlight real-world experience with testing and surveillance approaches in this global pandemic. These case examples demonstrate the value of designing, implementing, and evaluating testing and surveillance strategies and how they can be leveraged as an essential support for proactive, evidence-based decision-making in the ongoing prevention and control of SARS-CoV-2. Strategic, systematic planning and action on testing capabilities at a national level will put countries in a stronger position not only for the ongoing challenges of SARS-CoV-2 but for other public health emergencies over time.

Photo credit: Tim Dennell

Representative Population Surveys in the United Kingdom

Implemented in the first few months of the COVID-19 pandemic, representative household surveys for current and previous SARS-CoV-2 infection continue to be conducted throughout the UK. Supported by collaboration between public, private, and academic sectors, such surveys have been used to identify populations at increased risk of infection and have been used for modeling, supporting proactive—rather than reactive—decision-making.


Photo credit: Joel Bradford

Population-Wide Antigen Testing in Slovakia

In response to rising cases identified through clinical testing, Slovakia enacted public health measures and initiated population-wide antigen testing, with isolation of people testing positive and their contacts. Following the initial wave of testing, a second wave of population-wide testing was targeted to high-prevalence counties. Subsequent epidemiologic analysis suggested the combination of interventions led to an estimated 82 percent reduction in SARS-CoV-2 prevalence, providing critical information for the public health response moving forward.

Photo credit: Pouw Vervoer

Wastewater-Based Surveillance in the Netherlands

The city of Rotterdam evaluated the correlation of wastewater-based surveillance with clinical testing data, concluding that wastewater-based surveillance worked as an early warning system, identifying surges six days before clinical testing could. Proactively leveraging this information, the city increased clinical testing, successfully narrowing this detection delay to only 1.5 days.

Case Examples

Photo credit: ©2011, Sokomoto Photography for International AIDS Vaccine Initiative (IAVI)

Genomic Surveillance in South Africa

In response to rising clinical cases in Gauteng in November 2021, genomic surveillance efforts increased in the province—shortly thereafter identifying six highly mutated clinical samples that would eventually be classified as the omicron variant. These findings were proactively used to further intensify genomic surveillance, conduct epidemiologic analysis, share the genomes of the samples, and disseminate the information globally, successfully alerting the global community to omicron.

Photo credit: HM Treasury

Argentina's Targeted Testing and Surveillance

Over the first few years of the pandemic, Argentina proactively conducted targeted testing and surveillance activities where community transmission was recognized, such as door-to-door epidemiologic investigations. Based on evolving epidemiology, Argentina pivoted in April 2022, implementing an epidemiological surveillance strategy for several acute respiratory infections to monitor their frequency, distribution, severity, and population impact.

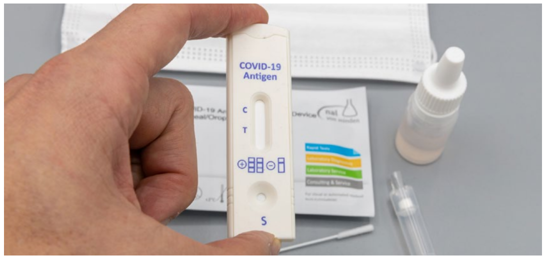


Photo credit: dronepicr

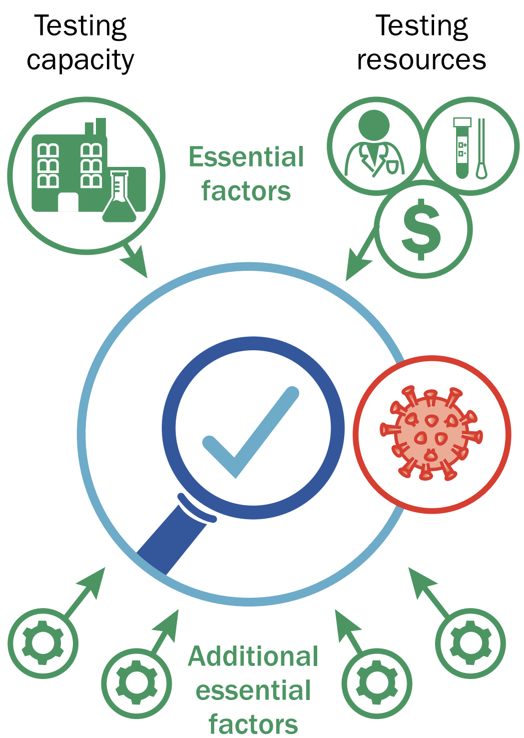
Uruguay's Active Approach to Testing and Surveillance

The primary strategy for testing and surveillance in Uruguay involves widespread availability of testing, coupled with aggressive contact tracing, targeted testing during outbreaks, and sentinel surveillance. As the pandemic and resource capacity have evolved, Uruguay's strategies have as well, to emphasize implementation of centralized genomic surveillance for variants and supplementation of testing capacity with antigen testing.

What Is in the Strategy Toolbox?

Surveillance Requirements

For nearly all surveillance activities in this guidebook, testing capabilities are required, meaning requisite testing capacity and resources are essential for the success of surveillance activities.



> In public health terminology, **surveillance** is "the ongoing, systematic collection, analysis, and interpretation of health-related data essential to planning, implementation, and evaluation of public health practice."
> (definition from United States Centers for Disease Control and Prevention [USCDC])

Surveillance Methods

The guidebook describes how the two methods of collecting surveillance data—passive and active—can be leveraged to proactively inform public health measures for the control of SARS-CoV-2. Both have a role to play in a comprehensive, national population-level testing strategy.

Passive Surveillance

Passive surveillance is opportunistic and reactive, often using existing activities or resources to collect data on SARS-CoV-2. Passive surveillance may not require substantial new investment, but the data captured may underrepresent groups in the population because a passive approach does not intentionally set out to collect a representative sample or engage hard-to-reach groups. For SARS-CoV-2, examples of passive surveillance include:

- *Syndromic surveillance*
- *Hospital-based surveillance*
- *Mortality-based surveillance*
- *Serosurveillance*
- *Wastewater-based surveillance*
- *Genomic surveillance*

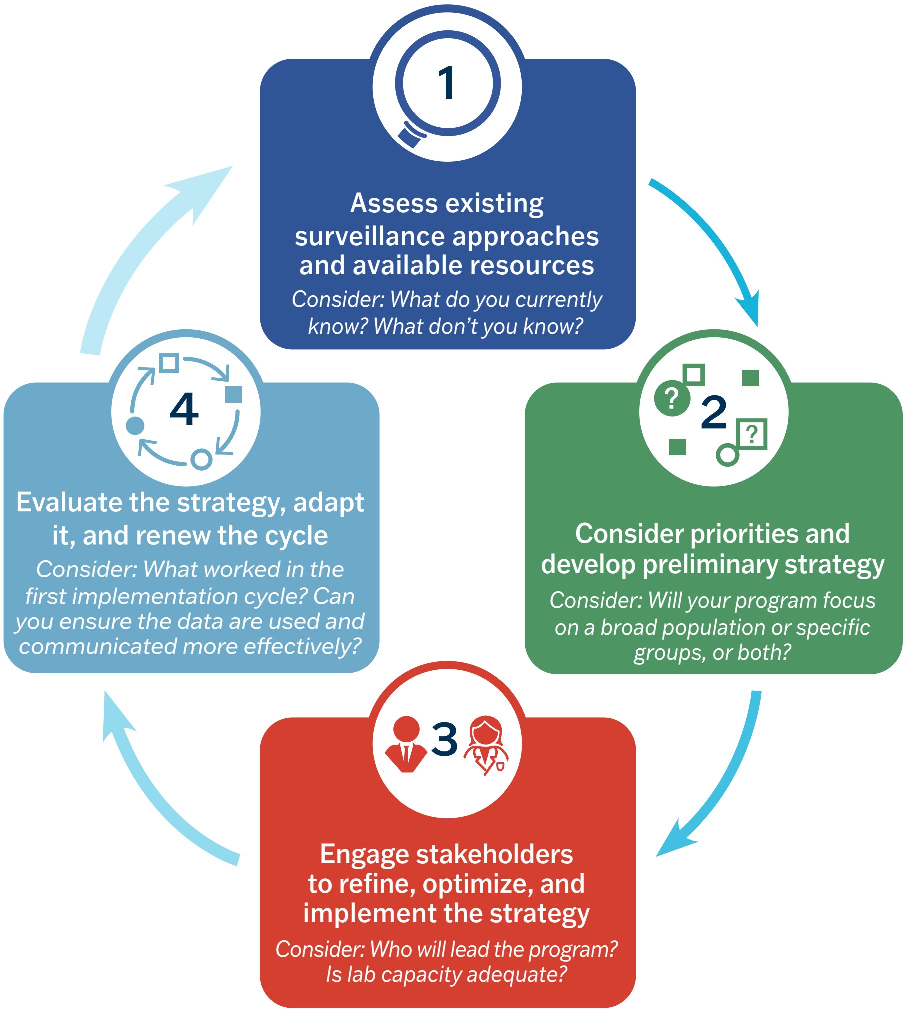
Active Surveillance

Active surveillance is more purpose-built. It involves actively reaching out to capture new data for a specific purpose and to support action towards achieving specific goals. Active surveillance may require additional resources, specimen collection, and planning, but the data collected will better represent the whole population or a specific group that may need attention. For SARS-CoV-2, examples of active surveillance include:

- *Contact tracing and testing*
- *Serial testing in workplaces, schools, health facilities, or congregate settings*
- *Representative population and sentinel surveys*
- *Targeted testing and surveillance*
- *Prospective epidemiologic studies*

What Is Required to Implement National Testing and Surveillance Strategies?

The process of implementing national testing and surveillance strategies occurs in four key phases—and these should be repeated as necessary in response to changing context, resources, and epidemiology. This approach of thinking about your strategy as a cycle—rather than as a static, one-time process—emphasizes the need to stay nimble and responsive to the ever-changing landscape of the pandemic.



Why Do Effective National Testing Strategies Matter?

Large disparities exist among countries in their management of SARS-CoV-2. Few countries have performed well across all waves and stages of the pandemic. This is due, in part, to the effectiveness of their testing and surveillance systems.

Well-designed national strategies for SARS-CoV-2 testing and surveillance make a difference in overall pandemic control. As the pandemic continues and is exacerbated by increasingly transmissible variants of concern, a national testing and surveillance strategy—using the cyclical process described in this guidebook—is vital to ensure efficient delivery of scarce resources, protect population health, and mitigate the social and economic impacts of COVID-19.

Countries that have been more successful tend to:

- Have a **multifaceted surveillance approach to understand transmission**—not relying on a single approach to surveillance
- Have the ability to proactively use surveillance to **inform effective control and prevention responses**
- Have effective systems to quickly **test, trace, and isolate contacts** of identified cases
- Be **committed to carrying out targeted community testing** where necessary
- Have **capacity to perform sequencing to identify, monitor, and respond** to emerging variants of interest and concern

Contents

Figures

Tables

Boxes

Acknowledgments

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1 Situation Overview

Effective Testing and Surveillance Systems Remain Critical

Photo credit: Herry Lawford

Since early 2020, COVID-19, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has taken hold and spread across the world. All countries in Latin America and the Caribbean (LAC) have been affected, with over 78 million diagnosed cases of COVID-19 and over 1.7 million deaths occurring by December 1, 2022 (figures 1a, 1b) (Ritchie et al. 2022).

Figure 1a. Cases Associated with COVID-19 as of December 1, 2022

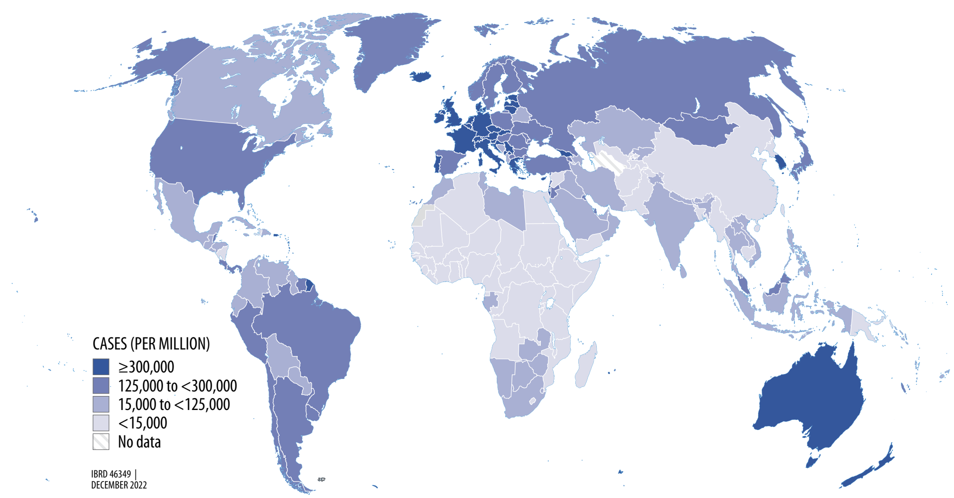
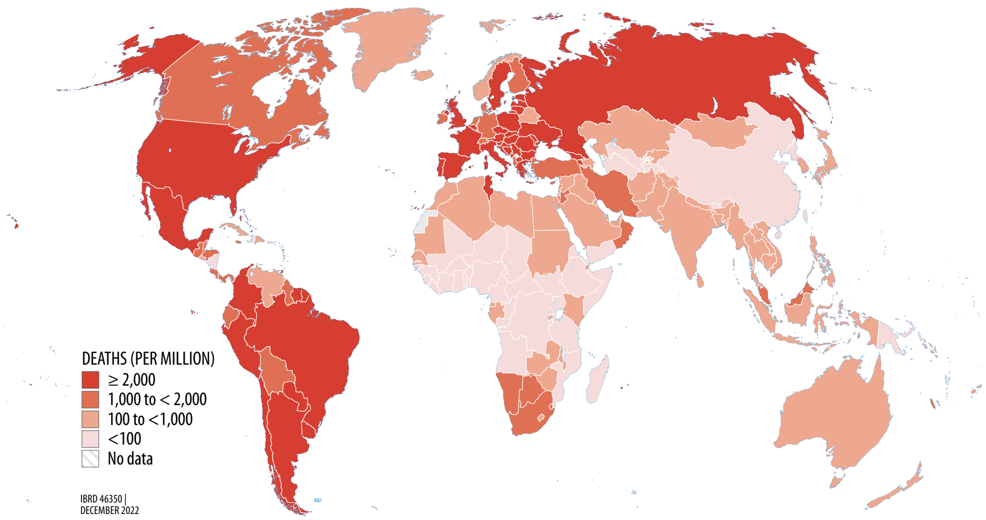
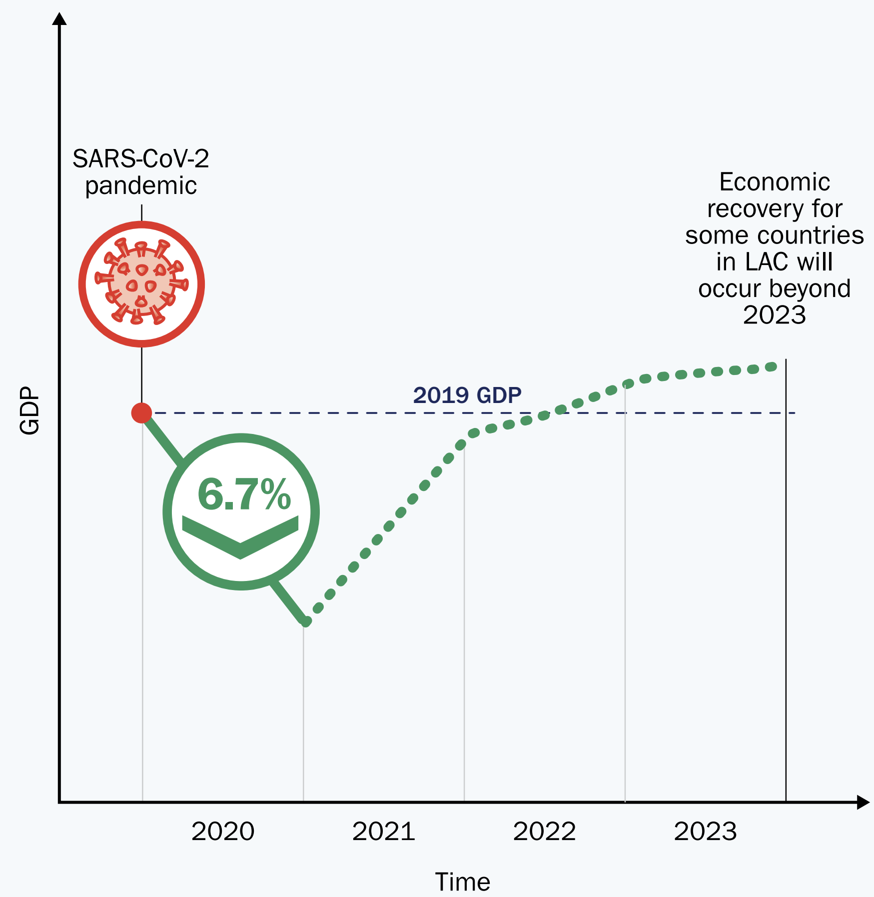


Figure 1b. Deaths Associated with COVID-19 as of December 1, 2022



The emergence of highly transmissible variants of concern—such as delta and omicron—and the evolving path to community immunity may continue to perpetuate the COVID-19 pandemic for years to come. In 2020, gross domestic product (GDP) in the region contracted by 6.7 percent. Although 2021 was a year of economic recovery for many countries in LAC, economic growth slowed somewhat in 2022 and may slow further in 2023; moreover, it is projected that some of the region's countries will see rebounds in their GDP to 2019 levels in 2023 or beyond (figure 2) (World Bank 2022; IMF 2022). The continued health, social, and economic impacts of COVID-19, and of ongoing world events, threaten to reverse decades of advances in Latin America and the Caribbean and disrupt further progress on remaining health sector challenges.

Figure 2. The Impact of the SARS-CoV-2 Pandemic on GDP in LAC



Testing and Surveillance Systems Remain Underdeveloped and Underresourced

Testing and surveillance systems (box 1) are cornerstones of the COVID-19 pandemic response. They track the evolution of the COVID-19 pandemic; identify emerging mutations, variants of interest, and variants of concern; support our understanding of the individual- and population-level impacts of the pandemic; and help guide public health policy. Yet, more than three years after SARS-CoV-2 was first identified, testing and surveillance systems in many countries remain underdeveloped and underresourced—sometimes critically. At the onset of the pandemic, testing was one of the most critical nonpharmaceutical interventions available, supporting contact tracing efforts and early insight into SARS-CoV-2 epidemiology. Indeed, without pharmaceutical interventions (such as vaccines and therapeutics), testing and other nonpharmaceutical measures (such as masking, ventilation, and distancing) were the only defenses against SARS-CoV-2, and strong testing and surveillance systems supported effective responses. Although polymerase chain reaction (PCR) testing capacity was scaled up early in the pandemic, and the Pan American Health Organization (PAHO) distributed millions of diagnostic test kits throughout LAC, further bolstering of PCR testing capacity—and the infrastructure and human resources required to sustain it—has not been a top priority.

Box 1. Definition of Testing and Surveillance Systems

The term "testing and surveillance systems" in this guidebook describes the collective approaches employed for the purposive, ongoing, and systematic collection, analysis, and interpretation of health data for the purposes of planning, implementing, and evaluating public health interventions and programs (German et al. 2001).

This lack of action has had substantial consequences. As the omicron variant and its subvariants have become dominant and led to an explosion in infections, limited testing capacity has led to countries in LAC—and indeed many others worldwide—to prioritize PCR testing for only the highest risk groups, with others either unable to get tested or left to search for often expensive antigen tests that are in short supply. This has necessarily limited the ability of governments to respond with precision to the levels of transmission seen with the omicron variants and potentially fueled community transmission due to many individuals' being unaware of their infection status. Indeed, overwhelmed testing and surveillance systems have largely failed during the omicron wave and beyond. However, it is not too late for countries to strengthen testing and surveillance systems to be better prepared for subsequent phases of the pandemic and future public health threats.

Moving From "Pandemic" to "Endemic"

Although the world has safe, effective vaccines for SARS-CoV-2—with many other candidates in development—and there are effective therapeutics, countries face many challenges as they move through the next pandemic phases. Even though endemicity is near certain, the path countries will follow to reach it can still be shaped. Underdeveloped and underresourced testing systems pose a great barrier to control, as do inequities in access and delivery of vaccines. Meanwhile, the potential arrival of variants of concern that may be more transmissible and/or lethal threaten to overrun health systems and perpetuate new waves of disease. The world is tasked with preventing and controlling SARS-CoV-2 for years to come.

Comprehensive national public health strategies are required to protect vulnerable populations, keep economies open, and avoid the consequences of future waves. Population-level testing and surveillance must be a key component of those strategies. Such testing and surveillance provide epidemiological information on how COVID-19 is affecting communities and can be used proactively to inform decisions on public health measures. This guidebook outlines how to design, implement, and monitor population-level testing and surveillance strategies to support evidence-based decision-making for ongoing prevention and control of SARS-CoV-2 and future public health threats.

The Pandemic Has Several Key Drivers

There are several characteristics of SARS-CoV-2 that help drive the pandemic in Latin America and the Caribbean and globally (figure 3). People infected with SARS-CoV-2 exhibit a wide range of responses. An infected person may have no or mild symptoms, or they may become extremely ill and die from the disease. Gold standard diagnosis of SARS-CoV-2—polymerase chain reaction (PCR) testing—requires adequate laboratory infrastructure and is expensive and resource intensive, and the necessary materials and reagents have sometimes been difficult to obtain due to fractured global supply chains. These challenges make diagnosis of SARS-CoV-2 difficult. SARS-CoV-2 is highly transmissible, making it difficult to control. This is compounded both by asymptomatic and presymptomatic transmission and by heterogeneity in transmission among those infected—where some individuals will never transmit and others will transmit to dozens of people. Over the evolution of SARS-CoV-2, variants of concern such as delta and omicron have increased the efficiency of transmission—a pattern that may continue but is impossible to predict. Finally, SARS-CoV-2 is difficult to monitor effectively and equitably. Inequities in income, living conditions, flexibility of employment, and access to health services (including SARS-CoV-2 testing) make it hard to reach certain groups for testing and hard for some groups to follow public health measures.

To address the multiple drivers of the pandemic, multifaceted approaches to case detection and population-level surveillance are required. Even as countries achieve high vaccination coverage, maintaining national testing and surveillance strategies will be essential to detect and understand breakthrough infections, understand correlates of protection, identify early indicators of resurgence, and detect new variants. Country by country, the approach to testing and surveillance will shift with SARS-CoV-2 epidemiology. Testing and surveillance approaches support our understanding of current transmission dynamics, help monitor for resurgence during periods of low transmission, and allow evidence-based responses.

The aim of this guidebook is to provide ministries of health, policy makers, and implementers with the rationale for increased investment in testing and surveillance systems—for SARS-CoV-2 and beyond—and for the value national testing and surveillance strategies offer. We first provide this rationale in Section 2, and then delve into the key testing and surveillance approaches that should be considered when developing national strategies in Section 3. From a public health perspective, in Section 4 we propose an iterative framework that countries can leverage to design, implement, and evaluate their testing and surveillance strategies.

> **Inequities in income, living conditions, flexibility of employment, and access to health services (including SARS-CoV-2 testing) make it hard to reach certain groups for testing and hard for some groups to follow public health measures.**

Figure 3. Drivers of the COVID-19 Pandemic and How National Testing Strategies Address Them

Drivers of the Pandemic	When an Effective, National Testing and Surveillance Strategy Is Implemented	*Benefits of National Testing Strategy*
COVID-19 is: ***Difficult to detect*** Response to infection varies from no symptoms to extreme illness and death	→	***Supports expanded detection*** People with either asymptomatic or symptomatic infection or previous infection can be identified
Difficult to diagnose Diagnosis is resource intensive, requiring people to have capacity, opportunity, and motivation to be tested	→	***Supports surveillance activities*** Comprehensive strategies contribute greatly to all levels of surveillance, improving forecasting and detection of variants of concern
Readily transmissible Even with adequate vaccination, SARS-CoV-2 transmissibility is high, regardless of symptoms	→	***Supports prevention and care activities*** Identification of transmission hot spots and changing epidemiology helps allocate resources and timely response to break transmission chains
Difficult to equitably and completely measure Case detection is poor for some groups (many cases are not diagnosed), leading to inequitable health burden	→	***Supports equity and population-based surveillance*** Representative samples of the population are covered, unveiling inequities and permitting targeted responses

2 The Value of National Testing and Surveillance Strategies

The Critical Role Testing and Surveillance Play in Public Health Emergency Response

Photo credit: World Bank / Sarah Farhat

To prevent and control SARS-CoV-2, countries need **comprehensive** strategic plans. Important elements include **social and financial support** to help people manage through the pandemic; strategies to increase and maintain **vaccination** coverage; **nonpharmaceutical measures** such as distancing, masking, ventilation, contact tracing, and testing; and **population-level surveillance activities.**

Testing and population-level surveillance activities are an underappreciated but vital component of national strategic plans. As part of a national testing strategy, testing and surveillance activities bring indispensable value to a country's public health response, providing information that can support proactive rather than reactive measures. Testing and surveillance activities continually inform where to direct scarce health resources (including therapeutics); identify areas of transmission; monitor population health indicators (for example, for vaccines); and are essential for tracking emerging mutations, variants of interest, and variants of concern. We describe each of these values in more detail below. But first, we will look further into the "business case" for building a comprehensive approach to testing and surveillance.

Effective National Testing and Surveillance Strategies Matter

Large disparities exist among countries in their management and response to SARS-CoV-2. Few (if any) countries have performed well across all waves and stages of the pandemic. This is due, in part, to how effective testing and surveillance systems are and how effectively they can proactively apply testing and surveillance data to their pandemic response.

Well-designed national strategies for SARS-CoV-2 testing and surveillance make a difference in overall pandemic response and control. Countries that have been more successful—as measured by COVID-19 deaths per million population—tend to have a strong commitment to testing, as well as:

- A multifaceted surveillance approach to understand transmission
- The ability to proactively use surveillance to inform effective control and prevention responses
- Effective systems to quickly test, trace, and isolate contacts of identified cases
- Commitment to carrying out targeted community testing where necessary
- Capacity to perform sequencing to identify, monitor, and respond to emerging variants of interest and concern

New Zealand and the Republic of Korea embraced many of the above principles and mounted effective responses to SARS-CoV-2 through integration of testing and surveillance activities as core components in public health strategies during the first few years of the pandemic.

For New Zealand, a combination of clear, consistent messaging from political leaders, strong surveillance, very high vaccine uptake, and evidence-based implementation of public health interventions were critical to its success in navigating the pandemic in 2020 and 2021—and achieving one of the lowest COVID-19 death rates in the world during this time. Though cases and deaths have increased with omicron and its subvariants in 2022, New Zealand's death rate continues to remain low compared to many other countries. Throughout the pandemic, including before the arrival of vaccines, testing and surveillance activities have been used to inform the intensity of public health restrictions. Early on, genomic surveillance was leveraged to inform track-and-trace efforts and the timing and intensity of restrictions (Geoghegan et al. 2021), and New Zealand submitted sequences for a large fraction of its COVID-19 positive samples to GISAID. However, this effort has waned in 2022, and now only 1.4 percent of all COVID-19 positive samples have been sequenced and submitted to GISAID as of December 2022.[1]

For the Republic of Korea, experience with middle east respiratory syndrome (MERS) proved useful in developing an effective response to SARS-CoV-2. Taking lessons from the past, the republic has made transparency and communication paramount since the start of the pandemic, building public confidence in the response to SARS-CoV-2 and providing evidence to support mitigation strategies (Oh et al. 2020). Though the scale of transparency with genomic surveillance is not ideal—only around 0.4 percent of all positive sample have had their sequence shared with GISAID as of December 2022[2]—vaccination rates in the country remain high. One of the most important aspects of the country's success, particularly early on, was a commitment to developing testing capacity; aggressive contact tracing and testing, largely relying on digital technologies and analytics; and targeted testing and surveillance, which were leveraged from the onset of the pandemic and before the arrival of vaccines. These approaches made the Republic of Korea one of the global leaders in testing by the end of 2021—testing over 70 individuals for every SARS-CoV-2 infection identified. However, throughout 2022—and like many countries worldwide—testing fell sharply, and by June 2022, only around five tests were performed per infection.

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1 GISAID. COVID-19 Sequence Submission Tracking. Available: https://www.gisaid.org/.

2 Ibid.

Why Else Do Countries Need a National Testing and Surveillance Strategy?

- **To get ahead of the next wave of infections.** Countries have struggled to catch up to and flatten the surges in SARS-CoV-2 infections. National testing and surveillance strategies can help countries forecast what is coming and plan their response (figure 4).
- **Symptom-based testing alone is insufficient.** Although we have nearly two years of experience with the SARS-CoV-2 virus, most of the world is flying blind with respect to variants of concern during the pandemic, and many countries still lack epidemiologic data on the dynamics of the virus—data that are useful for prioritizing vaccination and public health measures.

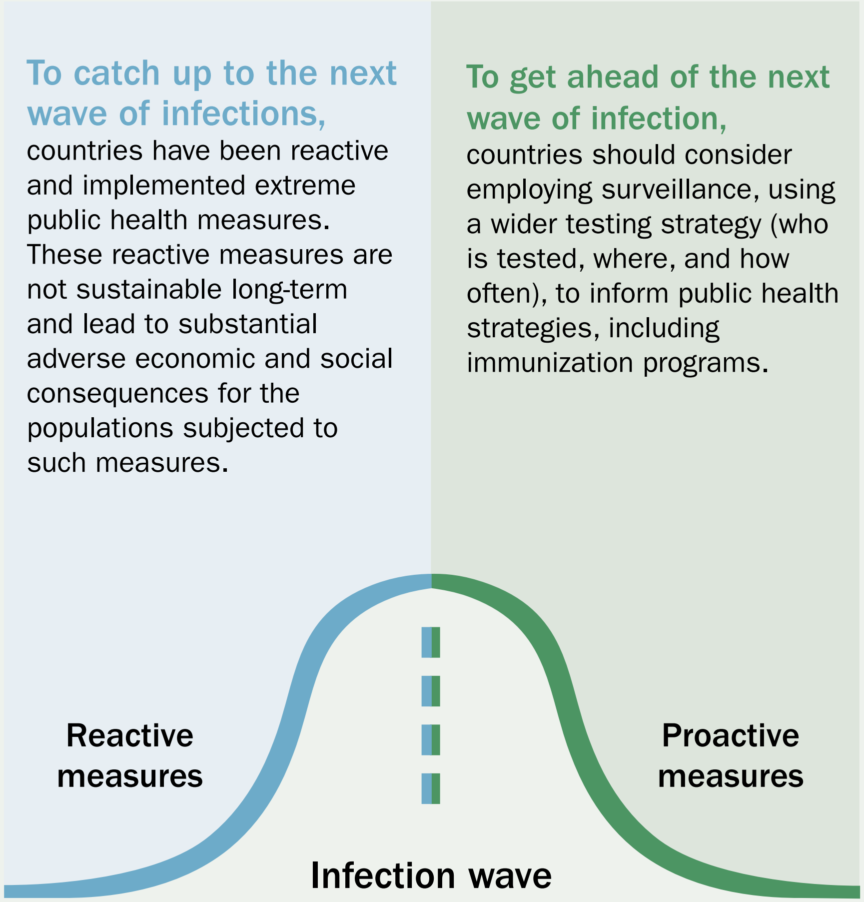
  The backbone testing approaches for SARS-CoV-2 prevention and control are important, but by themselves they are not enough to provide adequate information for public health strategies. These backbone approaches include:

  » ***Testing clinically presenting cases*** (that is, people with symptoms) and people who self-present to assessment centers. Countries with more comprehensive testing systems have generally managed the pandemic better.

  » ***Tracing and testing contacts.*** To break chains of transmission, engage people with the health system, and understand transmission dynamics, tracing and testing of contacts is a critical nonpharmaceutical intervention available to countries.
- **SARS-CoV-2 variants continue to emerge.** Variants that are more transmissible and/or virulent than the wild-type SARS-CoV-2 strain consistently emerge—and three have originated in LAC.[3] As we

3 WHO (World Health Organization). Tracking SARS-CoV-2 Variants. Available: https://www.who.int/en/activities/tracking-SARS-CoV-2-variants/.

Figure 4. National Testing and Surveillance Strategies Support Proactive Responses



have seen with the delta and omicron variants, these variants can take hold quickly, overwhelming underprepared health systems. As SARS-CoV-2 is in animal reservoirs, zoonotic transmission (transmission from animals to humans) is possible, and variants may continue to emerge despite widespread population immunity.

- **Inequities will continue to persist with a passive approach to SARS-CoV-2.** A national testing and surveillance strategy considers the factors that help perpetuate community transmission:
  - » ***Severity.*** Severe clinical disease occurs in a minority of all SARS-CoV-2 infections. People who are more likely to have milder disease are also those most likely to have more contacts (and may never be diagnosed).
  - » ***Transmissibility.*** Some people can infect many others. Spread occurs more in crowded and confined spaces, particularly those with poor ventilation.
  - » ***Identification.*** People with no symptoms (asymptomatic) or few symptoms (pauci-symptomatic) are unlikely to self-present to assessment centers and receive a diagnosis. The potential for appreciable transmission during the asymptomatic phase of infection means cases and their contacts may never be identified.
  - » ***Age.*** Younger people are more likely to present with no or minimal symptoms.
  - » ***Access.*** Vulnerable populations often have less access to health care and find it harder to follow public health guidance. These inequities place them at higher risk of infection and severe outcomes such as death.

Photo credit: Tim Dennell

What Is the Public Health Value of a National Testing and Surveillance Strategy?

There are numerous benefits to having a national testing and surveillance strategy. Such strategies may leverage testing for several purposes: diagnostic testing, screening testing, and/or testing for public health surveillance (figure 5).[4] The scale to which each of these testing approaches are implemented is influenced by the available resources (financial, human, and infrastructure) and current epidemiology.

National testing and surveillance strategies are a key link in the chain of public health responses (figure 6) and support several aims, as outlined below.

To Inform Resource Allocation

Countries should design a testing and surveillance strategy to provide as much information as possible on which populations are being affected by COVID-19, where they are, and how and when transmission is happening. Such information is critical to proactively inform the use of pharmaceutical and nonpharmaceutical interventions, to direct population-level supports, or to direct use of scarce sequencing resources, among other actions.

To Understand Transmission Dynamics Among Priority Populations

Effective national testing and surveillance strategies are an invaluable nonpharmaceutical intervention that can contribute to reducing transmission. A national strategy allows a country to implement proactive preventive strategies to mitigate transmission where they might have the most impact.

4 USCDC (United States Centers for Disease Control and Prevention). Testing Strategies for SARS-CoV-2. Available: https://www.cdc.gov/coronavirus/2019-ncov/lab/resources/sars-cov2-testing-strategies.html.

Figure 5. The Different Purposes of Testing in Public Health

Diagnostic

Testing is performed on individuals with a prior suspicion of infection to confirm a diagnosis. This includes people presenting with symptoms consistent with COVID-19 or those with known or suspected recent exposure to someone with SARS-CoV-2.

Screening

Testing is performed on individuals without symptoms consistent with COVID-19 and without known or suspected recent exposure. Testing serves to identify people with unknown infection, particularly in settings with elevated risk of transmission or among populations at elevated risk of severe outcomes.

Surveillance

Testing data is aggregated or collected in a nonidentifying manner (that is, data are not linked to an individual) for the purposes of public health surveillance. Surveillance data for SARS-CoV-2 may be collected for purposes of monitoring transmission, estimating or monitoring the incidence or prevalence of disease or outcomes, or estimating or monitoring population immunity.

Figure 6. National Testing and Surveillance Strategies Support Many Aspects of the Public Health Response

When all links in the response chain are *strong*:

A coordinated response to the emergency can be developed and robustly implemented, with ongoing monitoring, evaluation, and forecasting to proactively update strategies to evolving circumstances. Transparent, clear, and consistent messaging can be delivered to promote trust in recommendations. Inequities can be identified and addressed, and required population-level supports can be provided to encourage adherence with public health recommendations.

When *weaknesses* exist in the response chain:

The overall effectiveness of the emergency response is hindered. For example, weaknesses in monitoring, evaluation, and forecasting impair how quickly new variants may be identified or other changes in epidemiology are detected, leading to reactive responses. This can also mask inequities, leading to their exacerbation. Weaknesses at any part of the response chain are felt throughout, limiting the impact of the overall response.

Minimizing transmission is essential for economic recovery. Robust testing systems, along with vaccination, are key inputs in broader public health responses that keep schools and businesses open. The omicron variant and its subvariants have demonstrated that even among highly vaccinated populations, transmission can readily occur. In populations without very high vaccination coverage, transmission can be expected to continue for years.

Beyond contacts of identified cases, areas and populations that may be prioritized by focused testing strategies can include:

- **Vulnerable populations,** such as the elderly or those in congregate settings.
- **Geographic transmission hotspots,** which may not be detected by clinical testing until there is substantial community spread.
- **Schools,** which may form a high-risk environment for close contact and can lead to transmission occurring outside the school.
- **High-risk employment sectors,** such as health care. Undetected spread in hospitals and health facilities can impede functionality and lead to transmission to vulnerable populations. High-risk sectors include other jobs that put people into repeated contact with co-workers and the public: people in these jobs may be exposed and never know it, which can lead to closing of workplaces.
- **Key economic sectors,** which will vary specifically by country. Proactive use of testing and surveillance data can support keeping jobs and economies protected.

To Support Vaccine Surveillance

Strong testing and information systems are essential for vaccine surveillance (for example, coverage, effectiveness, safety). There is extensive synergy between systems required for vaccine monitoring and roll-out and those required for testing. With over two years of experience with SARS-CoV-2 vaccines and the emergence of numerous variants, understanding the correlation between vaccination and protection against both infection and severe outcomes (for example, hospitalization and death) is essential to guide vaccination plans and estimate population protection.

Testing is a critical tool to be used alongside vaccines, as it helps a country track population **immunity** (the current degree of vulnerability to SARS-CoV-2), understand the local **effectiveness of vaccines**, and **monitor vaccine coverage**.

- **Vaccine-acquired immunity and infection-acquired immunity** must be monitored via population testing.
  - » This type of surveillance allows targeted revaccination among populations with waning immunity (such as immunocompromised populations).
  - » Monitoring population immunity also indicates the duration and extent of vaccine protection, particularly in the context of emerging variants.
- **The real-world effectiveness** of SARS-CoV-2 vaccines varies across populations and variants of concern.
  - » This is important for understanding where additional support and public health measures may be required.
  - » Testing will continue to play a role in detecting transmission, even in vaccinated populations.

Photo credit: Erick Kaglan / World Bank

- **Vaccine inequity is a major global problem** (figure 7), and vaccine hesitancy puts even areas with high levels of vaccination at risk.
  - » Transmission will continue to occur in populations that do not have high vaccination coverage and, with the emergence of variants, may continue to occur at high levels among vaccinated populations.
  - » Continued testing and monitoring of both vaccinated and unvaccinated populations remains imperative.

To Support Genomic Surveillance

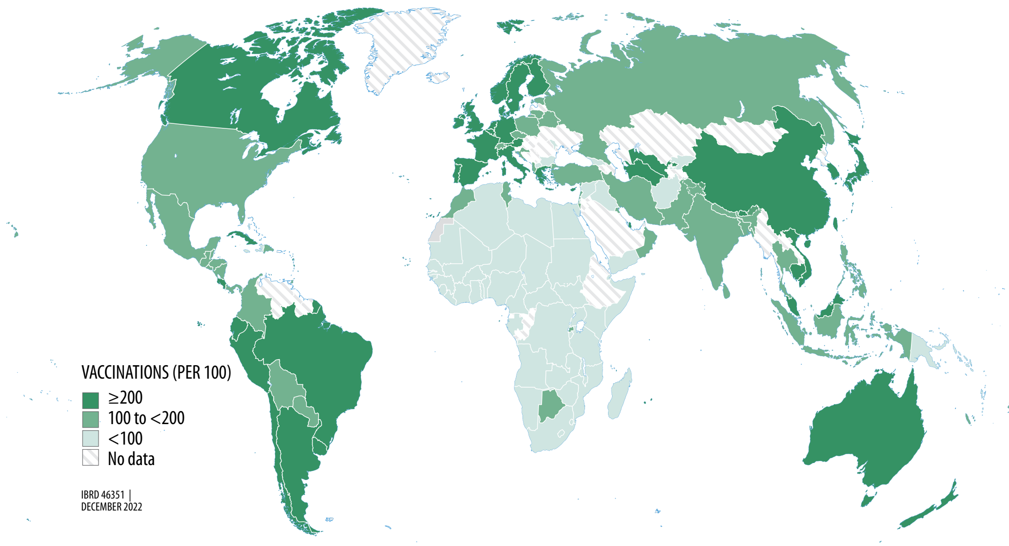
A key integration into robust testing systems is that of genomic surveillance. In its simplest form, genomic surveillance supports the rapid identification of emerging mutations that may lead to SARS-CoV-2 variants of interest and variants of concern. As SARS-CoV-2 replicates, new mutations occur approximately once every two weeks (Robishaw et al. 2021). PAHO has created the COVID-19 Genomic Surveillance Regional Network to help support collection, analysis, and action on emerging variants.[5]

The World Health Organization (WHO) recommends that 5 percent of all SARS-CoV-2 specimens be sent for genome sequencing to support genomic surveillance efforts (WHO 2021). Although this is a high bar, there are numerous benefits to incorporating genomic surveillance into testing strategies, even as countries work to expand capacity to achieve WHO levels.

- **SARS-CoV-2 variants will continue to emerge**—including from zoonotic reservoirs—and timely identification can support global efforts to understand transmissibility, virulence, and immune-evasion potential.

5 PAHO (Pan American Health Organization). COVID-19 Genomic Surveillance Regional Network. https://www.paho.org/en/topics/influenza/covid-19-genomic-surveillance-regional-network (accessed April 25, 2021).

Figure 7. Global Vaccination Rates as of December 1, 2022



- » Robust genomic surveillance systems in Botswana and South Africa (see the case example), contributed to the rapid identification and dissemination of the omicron variant after cases surged in Gauteng province, South Africa. Previously, systems in the UK were leveraged to quickly identify the alpha variant after an expanding cluster of COVID-19 cases was recognized in southeastern England. These systems alerted the world to variants of concern and permitted extensive, rapid evaluation of their characteristics.
- » A library of global SARS-CoV-2 genomes further supports development of new diagnostics, therapeutics, and vaccines that may overcome loss of efficacy associated with new variants.[6]

6 GISAID. COVID-19 Sequence Submission Tracking. Available: https://www.gisaid.org/.

Photo credit: Nenad Stojkovic

- **Genomic surveillance supports molecular epidemiological investigations** aimed at understanding transmission dynamics in local outbreaks.
  - » As more of the world becomes vaccinated against SARS-CoV-2, genomic surveillance improves our understanding of transmission between vaccinated and/or unvaccinated individuals, immune evasion potential (mutations that may allow the virus to evade detection by antibodies), and the risk of overdispersion in transmission (that is, superspreader risk).
- **Infrastructure and networks for genomic surveillance** can support the development of mitigation measures and be leveraged for other pathogens.
  - » Early identification of a variant of interest or concern can support rapid response and mitigation measures to quell its spread while more information is gathered, giving other regions and countries time to prepare.
  - » Beyond SARS-CoV-2, genomic surveillance infrastructure can be readily leveraged for many other purposes, such as monitoring antimicrobial resistance or epidemiological investigation of other pathogens, such as tuberculosis.

3 The Strategy Toolbox

The Advantages and Disadvantages of Different Testing and Surveillance Approaches and Their Applications

Photo credit: Tim Dennell

Passive and Active Surveillance Approaches

There are two basic approaches to SARS-CoV-2 testing and surveillance—passive approaches and active approaches. Both have a role to play in a comprehensive, national strategy that proactively informs public health response (figure 8).

Passive approaches are opportunistic and reactive. Passive approaches often make use of existing activities, events, resources, or specimens typically not collected for the primary purpose of surveillance, to collect data on SARS-CoV-2. Testing blood samples available from donations or routine blood tests is an example of passive surveillance. So too is using testing data emerging from symptomatic people who self-present to testing centers.

The main advantage of passive approaches is that they typically do not require substantial new or ongoing investment and make use of existing systems, samples, and/or data. The primary disadvantage is that passive approaches may not

Figure 8. Comparison of Passive and Active Surveillance Approaches

Passive strategies

- Passive strategies are generally opportunistic and reactive.
- These approaches make use of resources and/ or events that generally would occur without any additional intervention.
- Where testing is performed on individuals, the onus to present for testing is on the person.
- Data collected are more likely to be subject to biases than in active approaches.
- Syndromic surveillance and wastewater-based surveillance are examples of passive approaches.

Active strategies

- Active strategies attempt to carefully gather information.
- Active approaches should be based on clear goals and a sustainable implementation plan.
- They require additional resources to collect data or samples necessary for testing.
- Where testing is performed on individuals, the health care system generally works to collect samples.
- Data collected through active approaches are less likely to be subject to biases than in passive approaches, as details such as participant selection are more controlled.
- Contact tracing and testing and serial workplace testing are examples of active approaches.

provide a full, accurate picture of the whole population; data captured from passive approaches can underrepresent groups that are less likely, for example, to self-present at testing centers or to donate blood. As a result, data from passive approaches may be subject to biases. A key example is selection bias, in which the data we collect may lead to erroneous conclusions if we try to generalize to a population level, because the people included in the strategy are not representative.

Active approaches are more purpose built and are undertaken with the primary goal of collecting data for surveillance. This category traditionally includes approaches that reach out to capture new data for a specific purpose or to ensure a representative sample of the population. Aggressively tracing and testing contacts of people with COVID-19, regular testing of essential workers, and targeted community testing are examples of active surveillance approaches.

The main advantage of active approaches is that they can provide data above and beyond what passive approaches can produce and, when applied appropriately, are less subject to biases inherent to many passive approaches. The key disadvantage is that active approaches are generally more resource intensive. Such approaches require careful planning, monitoring, and evaluation, with attendant investment of both financial and human resources. For example, effective implementation of tracing and testing of COVID-19 contacts requires dedicated infrastructure (for example, computing capabilities, secure data repositories, office space), routine monitoring and evaluation activities, and the staff and money necessary to achieve high coverage of reported cases and their contacts.

Passive Approaches to Testing and Surveillance

This guidebook covers six approaches to passive, population-level surveillance of SARS-CoV-2: **syndromic surveillance, hospital-based surveillance, mortality-based surveillance, serosurveillance, genomic surveillance, and wastewater-based surveillance** (table 1).

Table 1. Passive Testing and Surveillance Approaches Summary

Passive approach	Primary aim	What it measures	Main advantages	Main disadvantages	Future applications
Syndromic surveillance	To monitor self-reported symptoms in the community; notifications for specific illnesses at sentinel sites, purchasing or internet search trends, and others	Current COVID-19 in the community	Laboratory confirmation not necessary; can cover a large proportion of the population, including those that don't typically seek care; potential early-warning system	Requires engagement with the specific surveillance activity—may be subject to selection bias; potentially not highly specific	Already in place in many areas for influenza-like illness; can be readily adapted to validated algorithms for other illnesses
Hospital-based surveillance	To systematically (based on indication or at random) test individuals presenting to hospital	Current and previous SARS-CoV-2 infection in the community	Can leverage existing staff and resources for in-hospital testing; good coverage of people with severe disease	Population presenting to hospitals is selected and unlikely to represent the community (selection bias)	Hospital resource allocation; efficacy of nosocomial (in hospital) protections; morbidity and mortality outcomes of other illnesses
Mortality-based surveillance	To monitor trends in all-cause mortality and COVID-19-specific mortality	COVID-19 in the community and net harms of pandemic	Can capture excess mortality (diagnosed and undiagnosed COVID-19); tracks most patient-important outcome	Typically slow and lags case data; represents historic burden and not current situation	Mortality (all-cause and cause-specific) trends in various strata; long-term study of health impacts
Serosurveillance	To monitor trends in population immunity	Previous SARS-CoV-2 infection and immunization in the community	Specimens should be readily available; may be used to distinguish vaccine-acquired vs. disease-acquired immunity	Populations contributing specimens unlikely to be representative of general population (selection bias)	Application for other pathogens (for example, hepatitis, HPV); systems widely applicable beyond serology
Wastewater-based surveillance	To monitor community- or setting-specific trends in active infection	Current SARS-CoV-2 infection in the community	Leverages existing infrastructure; representative of communities or settings; potential early-warning system	Requires careful precautions and analysis; targeted responses require a sufficiently small population to be sampled	Directly translatable to other pathogens (such as influenza, polio) and to drugs and toxins in the community
Genomic Surveillance	To track currently known variants and identify new ones	Incidence and prevalence of SARS-CoV-2 variants	Provides a view into circulating variants in the community and newly emerging mutations	High barriers to entry including sequencing capacity, sampling methods among acute infections, safe transport of specimens and timely reporting	Broadly applicable to other pathogens—such as tuberculosis—that acquire mutations

Syndromic Surveillance

Leveraging syndromic surveillance systems for SARS-CoV-2 allows programs to passively follow trends of self-reported symptoms in the community, trends in purchasing or internet searches, or trends in specific medical visits at sentinel sites. Such systems may flag potential surges in SARS-CoV-2 before clinical presentation and confirmation could do so, constituting an early-warning system. Many countries in Latin America and the Caribbean already have strong syndromic surveillance systems for influenza-like illnesses, which could be adapted and leveraged for SARS-CoV-2. These systems offer a particular advantage as they can cover a large proportion of the community, including many people who may not typically seek care. However, they necessarily exclude people who do not engage with the particular avenue of data collection (for example, visits to primary care, internet use), which may lead to selection bias. Despite this, syndromic surveillance systems may support early identification of surges, and systems and infrastructure can be readily adapted to other illnesses for use in the future (Elliot et al. 2020; Lapointe-Shaw et al. 2020).

Hospital-Based Surveillance

Many hospital programs have systems in place to track reasons for hospital admission and provide testing for a variety of pathogens. These systems can be leveraged to track the number of admissions for COVID-19 and the positive test rate of people presenting to hospitals. Testing could be performed among people being admitted for specific indications (for example, with an immunocompromising condition, or for antenatal examinations), among a random sample of people, or among everyone being admitted. A major benefit is that hospital staff and resources can be readily used to perform such testing, and existing information systems should be able to track reasons for hospital admission. Testing can be done for both current and previous infection, increasing the breadth of information that can be collected. Like syndromic surveillance and other passive approaches, hospital-based surveillance is subject to selection bias, as those presenting or admitted to the hospital are likely to be different from the population in the community. Well-designed hospital surveillance systems offer value beyond simply tracking admissions and positive tests: they can give a view of the efficacy of the hospital's infection prevention and control measures, help with resource allocation, and provide insight into characteristics associated with severe outcomes.

Mortality-Based Surveillance

In health systems with high coverage and quality of medical death certification, mortality-based surveillance is a useful tool to track the most important outcome of COVID-19 and the net harms of the pandemic in terms of excess deaths. Mortality-based surveillance data supports monitoring of trends in COVID-19-specific mortality and all-cause mortality. Such data can be compared with historic mortality data to understand excess harms of the pandemic in terms of mortality, which may be caused by delays in health care or lower quality care due to health system stresses. The success and utility of mortality-based surveillance is dependent on the strength of death registration systems. These systems need clear coding for cause of death classifications, accuracy and timeliness in cause-of-death reporting, and linkages from reporting facilities to a central registry. Key limitations include that mortality data reflect the historic burden of disease, rather than the current burden (as COVID-19 deaths lag cases by several weeks and medical death certification may also delay reporting of cause of death), and the reporting of deaths occurring outside the health system (such as at home), which poses serious challenges. In systems with strong death registration systems, these data are informative for future pandemic waves, support identification of the populations most vulnerable to COVID-19, and permit evaluation of long-term trends in health impacts of COVID-19 in the community (such as excess mortality).

Serosurveillance

Passive approaches to serosurveillance can leverage residual blood from donations or routine blood tests to test for specific antibodies to SARS-CoV-2. This method of ascertaining population-level immunity to SARS-CoV-2 is an invaluable tool to understand population protection, need for nonpharmaceutical interventions, and necessity of additional vaccinations. Importantly, in settings where vaccination has largely used the currently available mRNA or viral vector vaccines, serosurveillance can allow programs to understand the prevalence of infection-acquired versus vaccine-acquired immunity (in these populations, seropositivity for anti-N antibodies suggests infection-acquired immunity [Duarte et al. 2022]). Selection bias is again a limitation of passive serosurveillance, however, as people donating blood or having blood taken for testing may not be representative of the larger community. Nevertheless, this remains a useful approach to augment data on vaccinations, waning immunity, and other infectious pathogens beyond SARS-CoV-2.

Wastewater-Based Surveillance

In areas with sewered sanitation systems, routine sampling of wastewater from these systems can be used to detect presence of SARS-CoV-2. People infected with SARS-CoV-2 expel the virus in their feces, making the virus readily measurable in wastewater systems. Because SARS-CoV-2 can be detected in feces before symptoms present, wastewater-based surveillance can be used as an early-warning system, detecting surges before people in the community know they are infected. See the "Spotlight on Wastewater-Based Surveillance" and the case example from Rotterdam for further information (Kaiser 2020).

Genomic Surveillance

SARS-CoV-2, like other RNA viruses, is always mutating. In some instances, these mutations may lead to different viral properties that impact characteristics like transmissibility, virulence, and the ability to evade immunity. Genomic surveillance is a tool that can be leveraged to track currently known SARS-CoV-2 variants and identify new mutations. Such surveillance has immense value at both national and international levels. In national contexts, identification of case clusters sharing the same mutation may allow for early response, constraining the variant's potential to spread. In international contexts, open sharing of genomic data supports rapid characterization of emerging mutations, to help understand their potential significance. More broadly, robust genomic surveillance data can help identify regions of the SARS-CoV-2 genome that are more likely to change and regions more likely to be conserved, supporting development of therapeutic options (such as treatments, vaccines) that remain effective against future variants. Although it is challenging to initially implement and develop a genomic surveillance network, the potential benefits are immense (Robishaw et al. 2021). See the case example from South Africa for how genomic surveillance played an integral role in the early identification and global notification of the omicron variant.

Spotlight on Wastewater-Based Surveillance

An emerging passive surveillance approach for COVID-19

Aim:

Wastewater-based surveillance offers comparatively low-cost, population-wide surveillance that does not rely on individuals accessing health care or the availability of clinical testing.

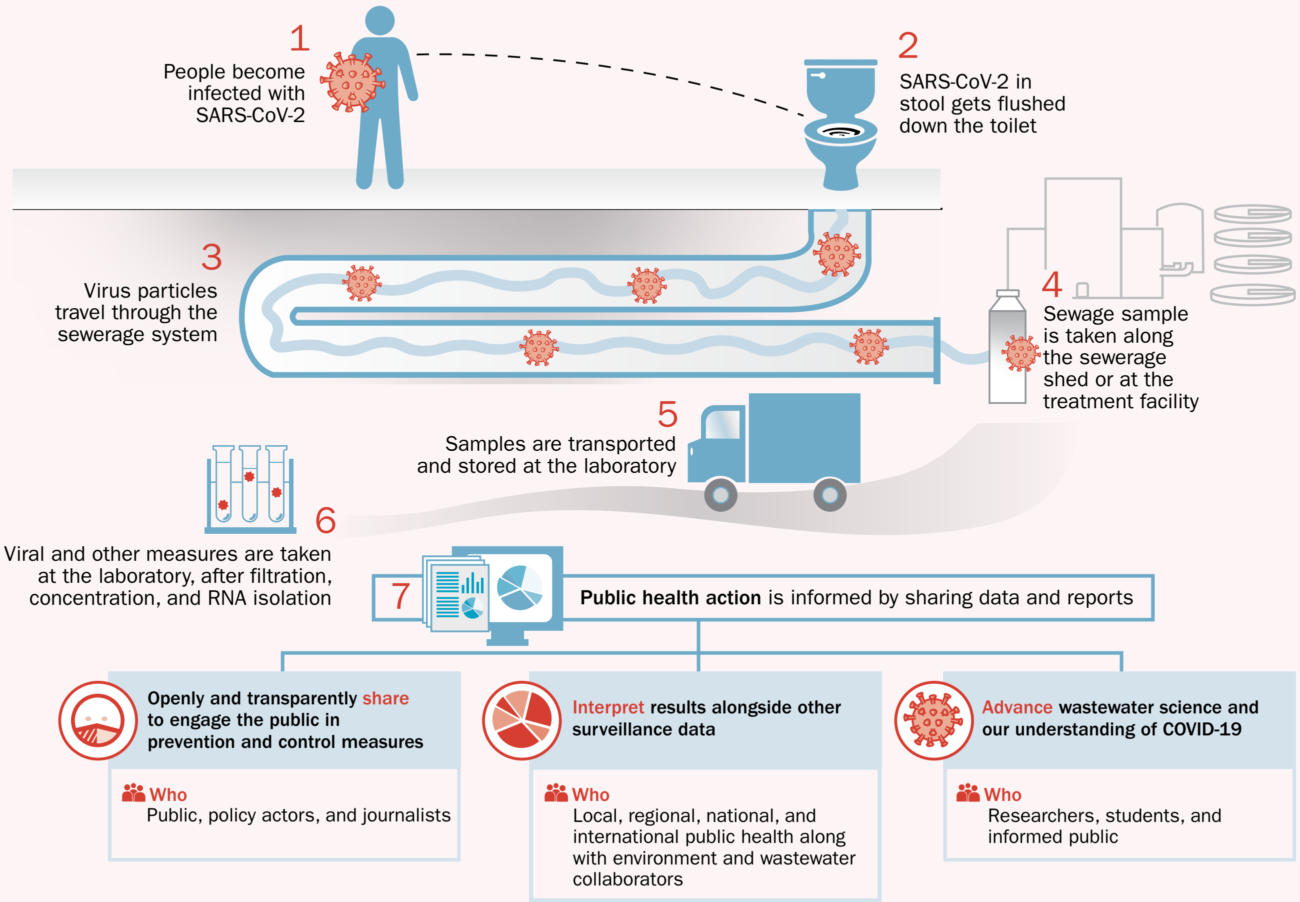
Approach:

Test wastewater for SARS-CoV-2 using the same assay methods as clinical testing but adapted for wastewater samples. Sample wastewater at wastewater facilities prior to treatment, or further upstream in the wasteshed, or at specific congregate settings (figure 9).

Outcome:

A single wastewater test can provide an estimate of COVID-19 prevalence for an entire community.

Figure 9. Steps for Wastewater Testing



Spotlight on Wastewater-Based Surveillance

An emerging passive surveillance approach for COVID-19

Potential utility:

Four uses of wastewater-based surveillance have been described.

- **Early detection of outbreaks and surges.** SARS-CoV-2 RNA can be detected in wastewater in advance of laboratory-confirmed clinical cases in a community or population. This enables countries to detect SARS-CoV-2 where there is no confirmed transmission and to identify surges or waves in settings where there is established transmission.
- **Population-wide surveillance.** Wastewater testing is a population-wide approach that is complementary to clinical laboratory-based surveillance. Together, these approaches can inform the need for and effectiveness of prevention and control measures such as vaccination.
- **Population-specific surveillance.** Wastewater testing is useful for early detection of SARS-CoV-2 in specific populations and congregate settings such as long-term care facilities, correctional facilities, shelters, university residences, and workplaces.
- **Early identification of mutations, variants of concern, and variants of interest.** Wastewater testing can be used to quickly identify which SARS-CoV-2 variants are circulating in the community and monitor the proportion of variants at the population level.

Some future uses:

- **Later-stage surveillance.** Wastewater testing can be used to monitor for SARS-CoV-2 outbreaks, surges, and re-emergence once countries have achieved widespread vaccination coverage.
- **Monitoring of other pathogens and health risks.** Wastewater testing can be applied to other pathogens of significance and health risks such as antimicrobial drug resistance, as well as to drug monitoring.

Potential limitations:

- **Viral measurement** in wastewater is affected by a range of factors including infection rate, variation in individuals' fecal shedding, configuration of wastewater sewer systems, environmental degradation, and laboratory assay performance.
- **Evidence** regarding the use and benefit of testing is limited but rapidly increasing.
- **Wastewater testing and interpretation** require the expertise of public health agencies, wastewater laboratories, and the respective regions—and, equally important, ongoing collaboration among them.

For more information, see *Strengthening Public Health Surveillance Through Wastewater Testing: An Essential Investment for the COVID-19 Pandemic and Future Health Threats*, another resource in the LAC COVID-19 Testing Series.

Wastewater surveillance requires people from different disciplines to work together.

Samples can be taken anywhere there is wastewater.

Active Approaches to Testing and Surveillance

Passive approaches may not capture a representative sample of the population, potentially biasing results. Active approaches to surveillance can reduce bias through purposeful, often more intensive, testing and surveillance (figure 10). This guidebook covers five approaches to active, population-level surveillance of SARS-CoV-2: **contact tracing and testing; serial workplace-, school-, health facility-, and congregate setting-based testing; representative population or sentinel surveys; targeted testing and surveillance;** and **prospective epidemiologic studies** (table 2).

Figure 10. Active Approaches to Surveillance Reduce Bias

The major advantage to active testing and surveillance is that they can ***yield data above and beyond*** what may be gathered by passive approaches.

This permits ***proactive, data-driven tailoring of responses*** to the pandemic by giving a more accurate picture that may overcome sampling biases from passive surveillance.

Photo credit: Henitsoa Rafalia / World Bank

Table 2. Active Testing and Surveillance Approaches Summary

Active approach	Primary aim	What it measures	Main advantages	Main disadvantages	Future applications
Contact tracing and testing	To identify contacts and provide testing to inform quarantine and isolation requirements, as well as other measures and supports	Current SARS-CoV-2 infection and attack rates (risk of secondary transmission) among contacts	Identify persons unknowingly at high risk of exposure, provide testing and guidance, and reduce transmission	Can be time consuming and may require unsustainable health resources when cases are high	Readily transferable to outbreaks arising from other infectious pathogens
Serial testing in high-risk settings	To pre-emptively identify infections in settings at high risk for transmission, permitting public health responses	Current SARS-CoV-2 infection and acquisition of infection in workplaces, schools, health facilities, or congregate settings	Permits development of ongoing snapshots of infection in each setting, allowing for early response to spikes	Can be laborious to organize and implement; can be expensive to the health system and inconvenient to participants	Testing platforms can be leveraged for vaccination and active monitoring
Representative population or sentinel surveys	To collect population-representative information on current or previous infections at a point in time and to track how these change over time	Current and/or previous SARS-CoV-2 infection in the population	Can help identify underestimation in case counts, identify groups that are not getting tested, detect variations in distribution in infection, and track population immunity	Is generally resource intensive and requires clear sampling strategy, logistics of administering home-based tests, and multiple rounds of testing to be of most use	Survey platforms can be leveraged for other health or social applications (such as census or health surveys)
Targeted testing and surveillance	To collect additional information on prevalence, transmission risk, and variants in response to changes in epidemiology or unusual signals	Current and/or previous SARS-CoV-2 infection, and/or prevalence of variants in the targeted population	Can be leveraged in communities or other settings when clinical cases increase, when other changes in epidemiology occur (such as identification of a cluster of mutations), or unusual signals are seen	May be resource intensive depending on the size of the population targeted and whether repeated testing is required	Surge capacity in human resources, labs, and other resources necessary for targeted, intensified testing can be leveraged for other emergencies or uses
Prospective epidemiologic studies	To increase the breadth and quality of evidence and answer questions of high public health importance	Varied, specific to study aim and design	Can be tailored to pressing questions, as identified by stake-holders, and provide setting-specific information	Requires research capacity with adequate funding and independence; study design and deployment, including ethical approval and data sharing, often very time consuming	Development of a re-search platform at the national level allows self-directed study and discovery in all areas of health

Contact Tracing and Testing

Contact tracing and testing are a cornerstone of public health responses to infectious pathogens. Identification of people who may have been exposed to infected individuals allows appropriate mitigation measures to be instituted, which may include testing and quarantine of contacts, as well as provision of necessary social support. Further, this approach provides critical information on epidemiologic parameters, such as serial intervals (time between illness onset and primary and secondary cases) and attack rates (proportion of contacts who become infected), which may change with emerging variants. Through contact tracing, individuals at high risk of exposure—and who may be unaware of the exposure—are notified, and appropriate actions taken. Although contact tracing and testing can become resource intensive when unmitigated transmission occurs in communities, they can be augmented with digital tools to support their implementation (O'Connell and O'Keeffe 2021) (countries with such infrastructure from previous emergencies responded to COVID-19 quickly). Countries with strong public health responses to SARS-CoV-2 typically had robust contact tracing and testing systems—systems readily transferable to other infectious pathogens, such as middle east respiratory syndrome and measles.

Serial Testing in High-Risk Settings

Hotspots of transmission may exist within workplaces, schools, health facilities, and congregate settings where people tend to gather in close quarters for long periods of time. As SARS-CoV-2 is transmissible even in the absence of symptoms, symptom-based case detection may result in high levels of transmission before a primary case is reported. Serial testing in these different settings can pre-emptively identify infections, limiting the potential for continued transmission. Such testing could also be employed in outbreak situations to support identification of newly infected individuals—allowing for their prompt isolation and potentially limiting outbreak growth. Developing an active strategy like this is resource intensive in terms of human resources, logistical support, and cost, requiring high-level commitment from all stakeholders. However, setting up such testing platforms can reap future benefits as they can be leveraged for onsite vaccination programs. See the "Spotlight on School-Based Testing" for additional discussion.

Representative Population or Sentinel Surveys

A key limitation of passive approaches to surveillance is that they are unlikely to be generalizable to the population at large, making their use limited for some applications. Representative population surveys can overcome this barrier and produce data that are generalizable beyond the participating sample. Well-designed national prevalence and seroprevalence surveys provide a lens into the health of the community. When done cross-sectionally, they provide key data on current infections, as well as on the impact that previous waves of infection have had. If done in sufficient size, they can reveal group-specific trends (such as by sex, age, location, occupation). When repeated, they provide further critical information on how prevalence in the community is changing, supporting modeling efforts and development of proactive mitigation strategies. Setting up a platform to conduct such surveys where one does not exist takes time and resources, which may discourage their use in practice. Success stories of their use highlight the extensive collaboration and support that are critical for this approach. See the case example from the United Kingdom for how a representative population survey was put into action.

Targeted Testing and Surveillance

Both passive and active testing and surveillance activities may identify populations and/or settings that are experiencing high levels of transmission, unexpected clusters of cases or mutations, or unusual changes in epidemiology. Targeted, intensified testing involves focusing testing and surveillance resources following these changes to collect additional information to support proactive responses. Such testing may take the form of broadening who can be tested (based on age, symptoms, location, occupation, and other factors), actively seeking individuals and offering SARS-CoV-2 testing, focusing wastewater-based surveillance on the population or setting being targeted, or increasing the proportion of clinical samples or wastewater effluents that are sent for sequencing to identify known or novel mutations. The scale of the targeted response is necessarily limited by available resources, but implementing such activities can provide critical information to inform public health strategies. See the case example in Slovakia, where targeted testing was used in counties with particularly high population prevalence of SARS-CoV-2, and the case example in South Africa, where targeted genomic surveillance helped identify the variant of concern, omicron.

Prospective Epidemiologic Studies

Despite the best surveillance methods, certain questions simply cannot be answered with currently available data or with other surveillance approaches. In some cases, prospective epidemiologic studies, which seek to answer specific questions, are necessary. Prospective epidemiologic studies can shed light on the potential risks, benefits, costs, and feasibility of different approaches to monitoring and responding to SARS-CoV-2, while also providing valid comparative information on SARS-CoV-2 characteristics such as transmissibility, virulence, and risk for immune evasion. For example, prospective epidemiologic studies may help elucidate attack rates among household contacts of persons infected with SARS-CoV-2, may help estimate real-world vaccine effectiveness, and may help discern differences in transmissibility between two or more circulating variants. Such studies may also provide data that can help answer questions on different interventions, such as mask mandates, widespread testing, and improving ventilation. These large-scale studies can be initiated by industry, academics, or existing research capacity at the national level. The latter may take time to develop but can pay dividends: a sufficiently funded and independent research program can help gather answers to questions of national importance, which may differ from those being investigated globally. See the case example from Slovakia for how the utility of population-wide rapid antigen testing was prospectively evaluated.

Spotlight on School-Based Testing and Surveillance

An approach to complement symptomatic testing and other preventive interventions in schools

Rationale and Aim:

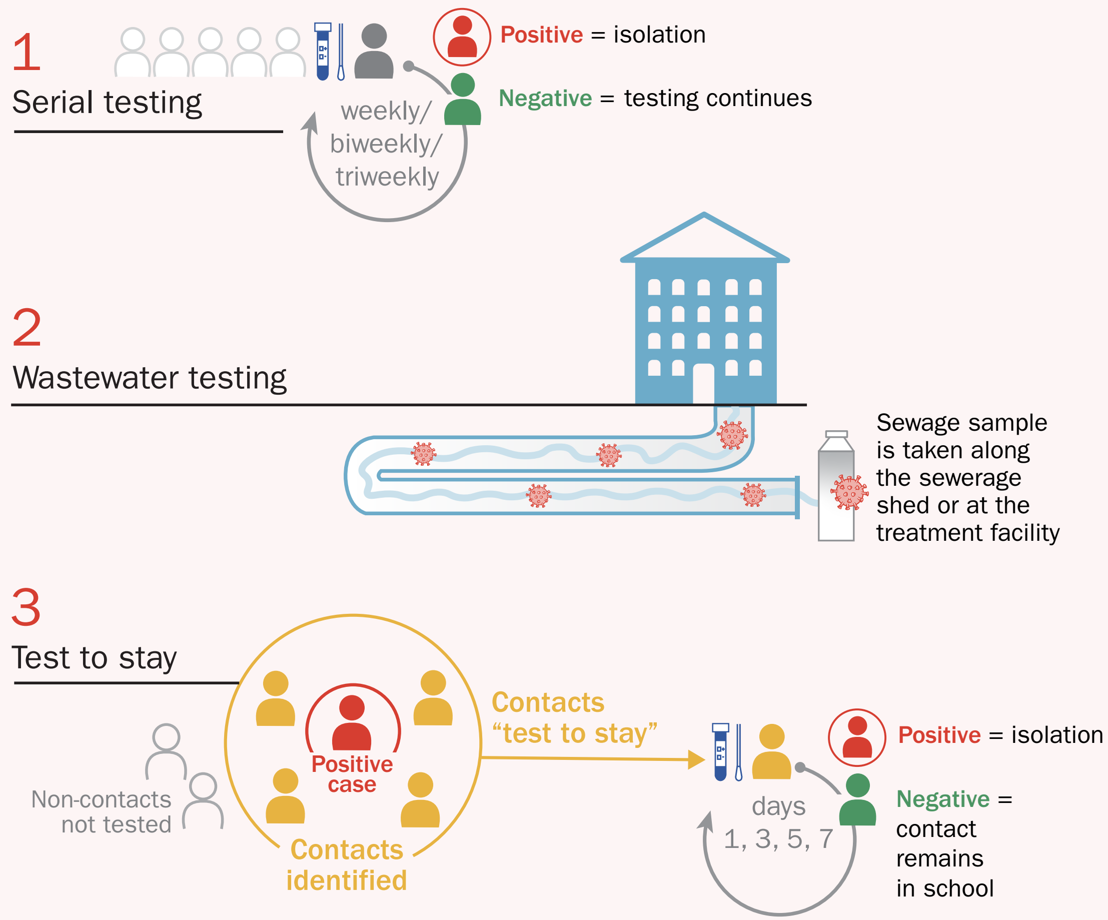
The COVID-19 pandemic has led to substantial disruptions to in-school learning. Even in September 2021 (around 18 months into the pandemic), around 86 million children and adolescents in Latin America remained out of classes. School closures have a detrimental effect on children, particularly those from marginalized groups. Studies have shown losses in reading and numeracy and higher rates of dropout compared to previous years, which may, in part, be due to disruptions to in-school learning.[7]

Minimizing the risk of SARS-CoV-2 transmission within schools is imperative to keep schools open safely. Even though symptomatic testing and preventive interventions—including universal masking, adequate ventilation, and high rates of vaccination—are the backbones of strategies to mitigate in-school transmission, additional testing and surveillance strategies can add another layer of protection and proactively guide mitigation strategies.

We describe three potential approaches (figure 11) to school-based testing and surveillance that can complement other preventive interventions. The approaches are not mutually exclusive and can be used in combination to add value and increase utility.

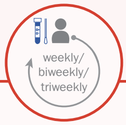
7 UNICEF. Available: https://www.unicef.org/lac/comunicados-prensa/casi-2-de-cada-3-ninos-ninas-y-adolescentes-siguen-fuera-de-las-aulas-en-america-latina-y-el-caribe.

Figure 11. Three Approaches to School-Based Testing and Surveillance



Spotlight on School-Based Testing and Surveillance

An approach to complement symptomatic testing and other preventive interventions in schools

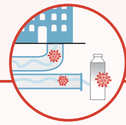


Approach 1: Serial testing (PCR or antigen) of teachers, students, and staff to identify asymptomatic infections.

Intended outcome. Serial testing on a routine basis (weekly, biweekly, triweekly, etc.) supports early detection of SARS-CoV-2 infection among asymptomatic people and may be implemented with self-collection kits for PCR or onsite testing with antigen tests.

Potential utility. Early detection of asymptomatic infections prevents opportunities for transmission and may limit the size and scale of potential outbreaks. Such programs have been successfully implemented at several universities, often with testing frequency proportional to on-campus activity. Implementation in elementary schools and high schools has been shown to increase case detection and highlighted that many infections were community acquired, underscoring the potential value of the strategy.

Potential challenges/limitations. The costs of PCR and even antigen tests for universal serial testing are high, with additional costs associated with logistics. Costs may be reduced through self-testing, although this may result in lower quality specimens and impact test accuracy. Consistent adherence with the testing schedule may also be a challenge.



Approach 2: Wastewater-based surveillance to monitor changes in SARS-CoV-2 RNA at the school.

Intended outcome. After establishing a baseline, this approach enables identification of changes in SARS-CoV-2 in wastewater.

Potential utility. Wastewater-based surveillance primarily supports early identification of surges in infection—likely days before symptomatic-based detection. This supports proactive intervention, such as targeted testing or more stringent nonpharmaceutical interventions, to mitigate infection surges. Evidence suggests that wastewater-based surveillance correlates with detection of infections in schools. In universities, it has been used in student residences and supported identification of asymptomatic individuals, limiting outbreak potential.

Potential challenges/limitations. Although relatively low-cost on a "per-person covered" basis, this tool relies on necessary infrastructure being available to support precise surveillance. Testing of wastewater samples must be frequent enough to establish a baseline and to identify surges. It also necessitates that students, teachers, and staff use bathroom facilities (difficulties may arise in childcare centers where young children might not be using the bathroom facilities).

Approach 3: In response to identifying a case of SARS-CoV-2, the class, cohort, or close contacts are tested (often repeatedly, as on days 1, 3, 5, and 7 after exposure), with those testing negative and being asymptomatic permitted to remain—in a "test to stay" approach.

Intended outcome. To continue in-school learning while minimizing the number of students, teachers, and staff who need to isolate due to exposure.

Potential utility. The test-to-stay approach complements symptom-based detection, limits the number of school days missed by students, and does not result in more secondary or tertiary cases compared to approaches entailing quarantine of classes, cohorts, or close contacts in response to an in-school exposure. A cluster randomized trial suggests test-to-stay is not inferior to quarantine after in-school exposures, and a retrospective study identified no difference in case rates after implementation of the strategy. Additionally, up to eight in-person school days could be preserved for asymptomatic, negative-testing students through implementation of this strategy, compared to a 10-day quarantine.

Potential challenges/limitations. This strategy generally relies on symptom-based detection of an index patient, and approximately one third of all infections are asymptomatic. During periods of high community spread, resources required to implement it will also increase.

References: Nemoto et al. 2021; Harris-McCoy et al. 2021; Young et al. 2021; Corchis-Scott et al. 2021; Crowe et al. 2021.

The Testing Armamentarium

Different types of tests can be used to detect either current or previous infection. All have roles to play in gathering SARS-CoV-2 surveillance data and informing reactive and proactive measures.

Tests for current infection include reverse transcription polymerase chain reaction (RT-PCR) and rapid antigen tests. Tests for current infection can provide data on changes in epidemiology, informing reactive measures to any changes. Additionally, when used serially, they can help predict how SARS-CoV-2 epidemiology may change in the future, proactively informing measures that should be implemented. When used in this way, these tests can provide additional data on how mitigation measures are working and whether measures should be increased, continued, or scaled back. As discussed in previous sections, specimens taken for PCR testing can readily be subjected to genotyping or sequencing to identify known variants or new mutations—contributing to local, national, and global genomic surveillance efforts.

Tests for previous infection include antibody tests. They can provide data on how different mitigation strategies have worked to protect populations from infection and to monitor population-level immunity. They can help inform future mitigation strategies and inform future scheduling of SARS-CoV-2 vaccines based on changing population immunity.

Table 3 describes fours types of tests, the information they provide, their advantages and disadvantages, and their costs[8] (Simonetti et al. 2021).

Photo credit: U.S. Pacific Fleet

8 UNICEF. UNICEF Supply Catalogue. Available: https://supply.unicef.org/.

Table 3. Breakdown of the Four Types of SARS-CoV-2 Testing

Characteristic	PCR	Antigen	Antibody	Genotyping/Sequencing
Types of technologies available	Laboratory-based PCR Point-of-care PCR (using loop mediated isothermal amplification [LAMP] technology)	Collected and assessed by point-of-care health care worker Point-of-care self-collected and assessed	Laboratory-based antibody detection Point-of-care antibody detection (by health care worker or self-test)	Various platforms to support virus genotyping and sequencing
Information provided	Presence of SARS-CoV-2 above the lower limit of detection of the assay (typically encompassing the preinfectious, infectious, and postinfectious periods) Information can be quantitative or qualitative	Presence of SARS-CoV-2 antigens above the lower limit of detection of the assay (typically only encompassing the infectious period) Information is qualitative (positive vs. negative)	Presence of IgG and/or IgM antibodies; may also detect presence of specific S- and N-antibodies, to support vaccine-acquired vs. infection-acquired immunity Information can be quantitative or qualitative	Presence of target mutations and or whole genomes, which can be compared to identify target mutations for further investigation Information is qualitative
Costs ($US)	~$20 per patient (clinical samples) for materials and reagents; personnel costs potentially reduced through pooling or noninvasive sample collection $300 per test (wastewater samples), equivalent to <$0.30 per patient if population covered is >1000	~$5 for the test device; additional costs associated with health care worker collection, assessment, and recording, if necessary	~$10 for materials and reagents for laboratory-based detection ~$5 for point-of-care test device; additional costs associated with health care worker collection, assessment, and recording, if necessary	~$40 per sample, if sufficient volumes of samples are collected and run simultaneously
Advantages	Highly sensitive and specific diagnostic; gold standard method for SARS-CoV-2 detection; can be leveraged with a variety of specimen types (for example, nasopharyngeal, oropharyngeal, nasal, saliva, gargle)—each of which has different access, acceptability, and cost considerations	Inexpensive to manufacture and distribute; very sensitive during the infectious period of infection; can be used at the point of care and via self-testing—improving access and enabling more people to be tested	Simple to use and generally inexpensive; can be used with a variety of specimen types; may help prioritize persons for vaccination when supply is limited	Can be leveraged with a variety of specimen types; can provide a view into circulating variants in the community and identify new mutations
Disadvantages	Generally, requires sophisticated laboratory infrastructure; comparatively expensive and time consuming; collection, transport, preparation, analysis, and communication of results may take upwards of 48 hours in overburdened labs; may miss infections in the first day or two after infection	Test conduct and interpretation subject to user error; not very sensitive early in infection and will miss infections PCR will detect; high specificity, but positive predictive value ~50%–70% at lower levels of circulating virus	Limited utility on an individual level; antibodies tend to wane over time especially among older age groups and the immunocompromised, thereby limiting the temporal value of tests	Generally, very expensive on a per-specimen basis; requires sophisticated laboratory infrastructure and analytic capabilities

Surveillance Case Examples

Six case examples, including one each from Argentina and Uruguay, illustrate passive and active surveillance approaches are being used for SARS-CoV-2 prevention and control.

United Kingdom's Representative Population Survey

Context. Repeated testing for current and previous infection in a representative population sample to estimate prevalence of SARS-CoV-2 (current infection) and seroprevalence of SARS-CoV-2 (previous infection) in the UK.

Situation overview. In April 2020, the University of Oxford, along with multiple government agencies and other universities, began recruiting participants in England—later expanding to Wales, Northern Ireland, and Scotland—for SARS-CoV-2 infection surveillance to estimate the prevalence of SARS-CoV-2 in the United Kingdom. This included repeated sampling to detect current infection and previous infection among randomly selected households intended to be representative of the UK population.

This ongoing effort aimed for a target population of 179,000 participants (two years of age and older) each fortnight from randomly selected private households across the UK. To estimate the positivity rate of SARS-CoV-2 (even in asymptomatic cases), each participant was asked to complete a monthly survey and provide weekly nose and mouth swab tests for the first five weeks, followed by monthly swabs for a year. In addition, a subset of the positive swab samples underwent genomic testing. Finally, a smaller subset of participants aged 16 and older provided blood samples to analyze antibodies from past infections. The data collected are published weekly in public reports. As of April 2022, recruitment targets were reduced by ~25 percent per fortnight.

As vaccine rollout started, the approach was adapted to reflect new realities of population immunity. The serosurveillance program increased the percentage of blood samples from participants aged 16 years and older, and subsequently included samples from children five years and older. In addition, the reports began including summaries from genomic surveillance as well as reinfection data.

These repeated cross-sectional surveys provide critical data. These data allow estimation of prevalence and seroprevalence at national and subnational levels, and they can be stratified by participant characteristics such as age, sex, and occupation, allowing targeted public health approaches to be employed. As vaccination programs are rolled out, this method can further support monitoring and evaluation of the impact of vaccination programs on the immunity of the population. As the pandemic has continued, these data provide insight into changing transmission and reinfection risks, and a robust sequencing platform supports monitoring for variants. Finally, such comprehensive data support public health officials in forecasting and modeling, supporting proactive—rather than reactive—decision-making.

Challenges and lessons learned. The survey has encountered challenges with respect to recruitment and retention of participants. Given the number of tests needed from each participant, people are increasingly lost to follow-up as the study continues. Another challenge has been the high cost of PCR testing and the need to have specialized centers to process the samples. Pooling of samples can save some resources during periods of low prevalence, but this becomes increasingly inefficient as prevalence increases. The initiative exemplifies the value of collaboration between the public, private and academic sectors for implementing testing and surveillance strategies. It also highlights the importance of longitudinal studies (that can make repeated observations over time) to characterize the epidemiology of SARS-CoV-2 and understand its changing impact on the population.

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2. COVID-19 infection survey of the UK general population (ISRCTN21086382). ISRCTN Registry. Available: https://www.isrctn.com/ISRCTN21086382.

Slovakia's Country-Level Rapid Antigen Testing

Context. Multiple rounds of population-wide rapid antigen testing, with isolation and contact tracing to control SARS-CoV-2 in a country with a population of 5 million people.

Situation overview. Before the summer of 2020 in Slovakia, daily cases of COVID-19 were below 100 per day. In August 2020, cases started to precipitously increase. As a result, restrictions in the country grew to include no outdoor gatherings and early closure of restaurants. On October 1, 2020, the government declared a state of emergency for 45 days and increased restrictions in the country even further. However, COVID-19 cases continued to rise, with around 2,000 new cases per day by mid-October.

As the situation worsened, Slovakia began evaluating population-wide testing using rapid antigen tests while applying lockdown restrictions. People testing positive, their household members, and any contacts in the previous two days would need to quarantine. A pilot study was conducted in late October 2020 in four counties with the highest prevalence of SARS-CoV-2. In the subsequent two weeks, these counties were tested a second and third time. The success of the pilot study led to national mass testing. After an initial round of testing, counties with the highest prevalence were tested a second time. Overall, around 60 percent of the total population was tested during this period—representing about 80 percent of the eligible population aged 10 years and older.

In the weeks following the testing campaign and the imposed restrictions, the prevalence of SARS-CoV-2 decreased significantly. Between the pilot phase and the first round of country-wide testing, the prevalence decreased by 56 percent; after the targeted second round of testing in high-prevalence counties, prevalence further decreased by 60 percent. Overall, the total decrease in prevalence was estimated to be 82 percent, with minimal variation across Slovakia.

Population-wide antigen testing identified people with infection, and their own and their contacts' self-isolation, coupled with country-wide restrictions, appears to have substantially contributed to slowing transmission. This case example demonstrates how testing can play a role in a country's larger public health response. Proactively leveraging the data collected to target subsequent rounds of testing and conducting an epidemiologic analysis of the resultant data to understand drivers of transmission reduction provide critical information for the public health response moving forward.

Challenges and lessons learned. Although the rollout of rapid antigen tests can be highly efficient, fast, and associated with a lower cost on a per-test basis than PCR testing, the approach in Slovakia also faced several challenges. Contrary to jurisdictions where antigen tests are self-performed, such as the United Kingdom, in Slovakia the samples are collected by medical personnel, which presents barriers in terms of human resources and costs. Second, rapid antigen tests typically have positive predictive values in the range of 50 percent to 70 percent at lower prevalence, so the risks of incorrectly isolating individuals need to be considered. Finally, rapid antigen tests are best suited for use as a screening test—not a diagnostic like PCR—as sensitivity is low in early and late stages of infection, but generally much higher during infectious periods.

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1. Reuters Staff. Slovakia Reports Record Spike in Coronavirus Cases. 2020. Available: https://www.reuters.com/article/us-health-coronavirus-slovakia-idUSKBN25W0I5.
2. Pavelka M, Van-Zandvoort K, Abbott S, et al. 2021. "The Impact of Population-Wide Rapid Antigen Testing on SARS-CoV-2 Prevalence in Slovakia. Science 372: 635–41.

Population-Wide Surveillance in Rotterdam, the Netherlands

Context. Population-wide testing in a European city with a population of 400,000.

Situation overview. The Dutch are leaders in wastewater-based surveillance and were one of the first settings to isolate SARS-CoV-2 in wastewater. Wastewater testing in Rotterdam began as a research project to identify its added value and assess whether detected SARS-CoV-2 reflected clinical COVID-19 infection. Six local and national partners collaborated closely on testing, interpretation, and public health action. Early success showed that wastewater surveillance reliably identified SARS-CoV-2 before clinical case resurgence, and the program was integrated into public health practice.

Wastewater testing is performed three times each week at nine wastewater sites: four pumping stations and five treatment plant influents of different city areas. A careful match was made via zip codes with the population served and the clinical surveillance data. Wastewater and clinical test results are analyzed after adjustment for sewage flow and population, and clinical tests are adjusted for test delays and the number of tests. Models of wastewater data were developed by comparing results to wastewater tests. The city continues to monitor COVID-19 using both clinical and wastewater surveillance.

Value in surveillance strategy. Wastewater surveillance provides Rotterdam with valuable information beyond what clinical testing can provide. Benefits of added value include:

- **Early identification of resurgence.** In September 2020, wastewater surveillance provided a six-day advance warning. Since then, clinical testing increased, and by December 2020 the advance warning narrowed to 1.5 days.
- **Identification of undertesting in one city area.** In response, the program added 10 clinical testing locations including the use of mobile "test buses" to improve access.
- **Additional evidence.** Local authorities value an assessment of COVID-19 status in city areas that is independent of clinical tests or syndromic surveillance.

Challenges and lessons learned. Rotterdam's program initially faced challenges with its supply chain for wastewater collection and testing; the complex data analyses that involved examining and correlating both clinical and wastewater test results; and the limited number of wastewater collection sites located across the city, which did not allow a surveillance of the complete city in high resolution.

Key lessons learned are that success depends on these factors:

- Collaboration between local public health and water authorities
- Normalization of clinical data for test delays and number of tests
- Normalization of sewerage data for flow and population
- Continuous evaluation of sewerage data versus incidence data
- Frequent sampling to support trend analysis of the normalized SARS-CoV-2 concentration in wastewater

Reference:

1. https://storymaps.arcgis.com/stories/8888f5bfb4704180afeda3d476f2aa63.

Photo credit: Pouw Vervoer

Genomic Surveillance in South Africa: Detecting Omicron

Context. Genomic surveillance as an integral part of SARS-CoV-2 surveillance in South Africa.

Situation overview. Scientists in South Africa have pioneered the discovery of two variants of concern, beta (B.1.351) in September 2020 and omicron (B.1.1.529) in November 2021. Genetic sequencing for SARS-CoV-2 in South Africa began in May 2020 with the creation of the Network for Genomic Surveillance (NGS-SA) and a goal to sequence several thousand genomes to inform public health responses.

By December 2021, over 24,000 genomes had been sequenced across seven sequencing centers, accounting for over 40 percent of all sequences published in Africa. To ensure that samples are processed in a timely manner, each laboratory partners with a neighboring academic sequencing center. To track and detect new variants, the NGS-SA established a process to collect the samples based on a random sample approach. This approach uses ongoing surveillance to create representative samples of the geographical spread of the virus across South African provinces.

In 2020, early in South Africa's second wave, the beta variant was discovered. Less than 48 hours after the discovery, a public health response in the form of increased restrictions was made. This rapid response was repeated when the delta variant was identified in the country.

In November 2021, COVID-19 cases started to rise in Gauteng province. By the end of the month, genomic surveillance had increased in the province, and, shortly after, six samples with a highly mutated genome were discovered. To determine the spread of these mutations and facilitate research into this variant, the NGS-SA proactively proceeded to (1) test the genome of more than 100 randomly selected samples from over 30 different clinics in Gauteng; (2) examine the surge of cases and the positivity rate; (3) upload the genome to a regional data base (this pointed to the variant first being identified in Botswana); and (4) disseminate the information, allowing global research to be conducted to understand transmissibility, virulence, and immune evasion characteristics of the variant and give other countries time to prepare for the new surge.

Challenges and lessons learned. Genomic testing has shown to be an important component of testing strategies during the COVID-19 pandemic, and the WHO recommends that 5 percent of all processed samples should undergo genomic testing. This will necessitate investment to create networks, share data and protocols, and train teams. Speed and transparency in identifying and reporting new mutations should be prioritized and supported—practices that penalize jurisdictions for doing so will discourage transparency and may prolong the pandemic.

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1. European Centre for Disease Prevention and Control. SARS-CoV-2 Variants of Concern. Available: https://www.ecdc.europa.eu/en/covid-19/variants-concern.
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Country Case Example: Argentina

Context. The first case of SARS-CoV-2 was reported in Argentina on March 3, 2020. A strict national lockdown was enacted early in the pandemic, and a comprehensive preparedness and response plan was formulated. However, after the lockdown was eased, cases precipitously increased and as of the end of 2021, over 5.3 million cases had been detected with over 116,000 deaths. The omicron variant—first detected in early December 2021—presented new challenges, but progress made in the vaccination campaign reduced the impact on mortality and hospitalization in intensive care units. Since mid-November 2022 new confirmed COVID-19 cases started to increase again, with almost 27,000 new cases during the first week of December 2022 (a 115 percent increase in one week). As of December 2022, over 9.7 million cases had been detected with over 130,000 deaths, while approximately 83 percent of the population was considered fully vaccinated.

Testing and surveillance. By the end of March 2022, 35 laboratories across the 24 provinces in Argentina were able to perform PCR testing. In April 2020, a special committee of medical and scientific experts was formed, to provide advice and guidelines to health authorities for the design of policies to address the pandemic, including testing and surveillance. These policies were later implemented by the federal ministers of health through the Federal Council of Health (COFESA).

Testing for COVID-19 was initially offered to all those with symptoms of COVID-19, with close monitoring offered to contacts. As cases rose, testing criteria had to be modified to preserve laboratory capacity. Testing criteria varied across provinces. When outbreaks were identified or when increases in the number of cases in an area were recognized—particularly in lower socioeconomic areas—close surveillance was implemented, with active efforts to identify cases through the "Dispositivo Estratégico de Testeo para Coronavirus en Terreno Argentino" (DETECTAR). This involved volunteers and community health care workers visiting households in the area. People who tested positive were asked to isolate and offered necessary care, while their close contacts were monitored daily for two weeks.

Since April 2022, a new epidemiological surveillance strategy for acute respiratory infections is being implemented with the aim of monitoring the frequency and distribution of SARS-CoV-2, influenza, RSV, and other respiratory viruses, as well as characterizing their severity and impact on the population. Therefore, COVID-19 testing is only prioritized for people with respiratory symptoms belonging to specific at-risk groups

Successes and challenges. The initial rapid response to the first cases of COVID-19 in the country, coupled with decentralization of testing to build capacity and implementation of targeted testing and surveillance, was a clear success in Argentina's national response. The challenge in the current epidemiological context, characterized by a lower severity of COVID-19 cases and the increase circulation of other respiratory viruses, is to implement a transition strategy which includes a comprehensive approach to respiratory viruses, strengthening epidemiological surveillance to monitor both the impact of COVID-19 on at-risk groups and the population, and the changes that may necessitate a modification in the approach to COVID-19 control.

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5. https://bancos.salud.gob.ar/recurso/instructivo-para-la-notificacion-de-caso-covid-19.
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Country Case Example: Uruguay

Context. Uruguay started to prepare for the pandemic as early as January 2020, with measures such as border control, the creation of a contingency plan, and the training of the Department of Public Health Laboratory. On March 13, 2020, Uruguay confirmed its first case of SARS-CoV-2; it was successful in managing the population impacts throughout 2020—with only 180 total deaths. However, the emergence of the more transmissible gamma variant in 2021 led to increases in cases far beyond what could be managed by existing contact tracing systems, and by the end of 2021 the death toll exceeded 6,000. Though Uruguay went through a new wave led by the highly transmissible omicron variant in 2022, deaths by December 2022 stand at ~7200 and 82 percent of the population is considered fully vaccinated (two doses).

Testing and surveillance. Testing and surveillance strategy design and evaluation are the responsibility of the "Honorary Scientific Advisory Group (GACH)," a group that was created on April 16, 2020, to provide advice to the government on the COVID-19 emergency response. The team includes 55 multidisciplinary science experts forming three divisions: the technical secretariat, the scientific health team, and the data team. In addition to its responsibilities on testing and surveillance, the GACH makes scientific recommendations in the areas of health and data science to the government team, which evaluates and submits the reports and suggestions to the president of the republic for final decision-making. Recommendations from the GACH are implemented by the Ministry of Public Health through the Directorate of General Health.

A major reason for Uruguay's early success in the pandemic was its "made-in-Uruguay" PCR tests, developed at the Instituto Pasteur, with the support of the Universidad de la Republica. Test production and distribution were bolstered through the creation of the "COVID-19 diagnostic lab network." This network shared technical knowledge with research institutes, public hospitals, and academic laboratories from all around the country, supporting rapid scaling of testing capacity.

The primary strategy for testing and surveillance focused on the widespread availability of testing through COVID-19 assessment centers, aggressive contact tracing, targeted testing in outbreaks, enhanced testing approaches around the border, and use of sentinel- and hospital-based surveillance. However, as cases increased, testing and surveillance policy has shifted. From the beginning of 2022, PCR and antigen testing is limited to symptomatic people from selected population and risk groups.

Although started independently by several organizations, genomic surveillance was centralized through the creation of the Interinstitutional Working Group (GTI) on Surveillance of SARS-CoV-2. The aim of this group is to centralize and monitor real-time genomic information for SARS-CoV-2 across the country. GTI is comprised of seven different institutions, including IP, Universidad de la República and the Ministry of Public Health, that receive around 100 specimens each week from the public diagnostic network and other groups.

Successes and challenges. The establishment of ad hoc advisory groups composed of multidisciplinary experts to guide testing and surveillance policy and coordinate genomic surveillance in the country, together with the use of locally developed and distributed test kits, resulted in a successful national response to the COVID-19 pandemic in Uruguay. However, key challenges still exist, and testing and surveillance strategies can still be improved, through approaches such as wastewater-based surveillance, which has been piloted in Uruguay.

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4 Toward a Proactive Approach to National Testing and Surveillance

Overview of the National Testing and Surveillance Program Cycle

Photo credit: Henitsoa Rafalia / World Bank

As we enter the fourth year of the COVID-19 pandemic, national testing and surveillance programs remain essential for countries worldwide—including those in Latin America and the Caribbean. With the availability of low-cost testing and surveillance tools, global vaccination and therapeutics, and the need to monitor emerging variants, national testing and surveillance programs will necessarily need to shift with the current context and epidemiology.

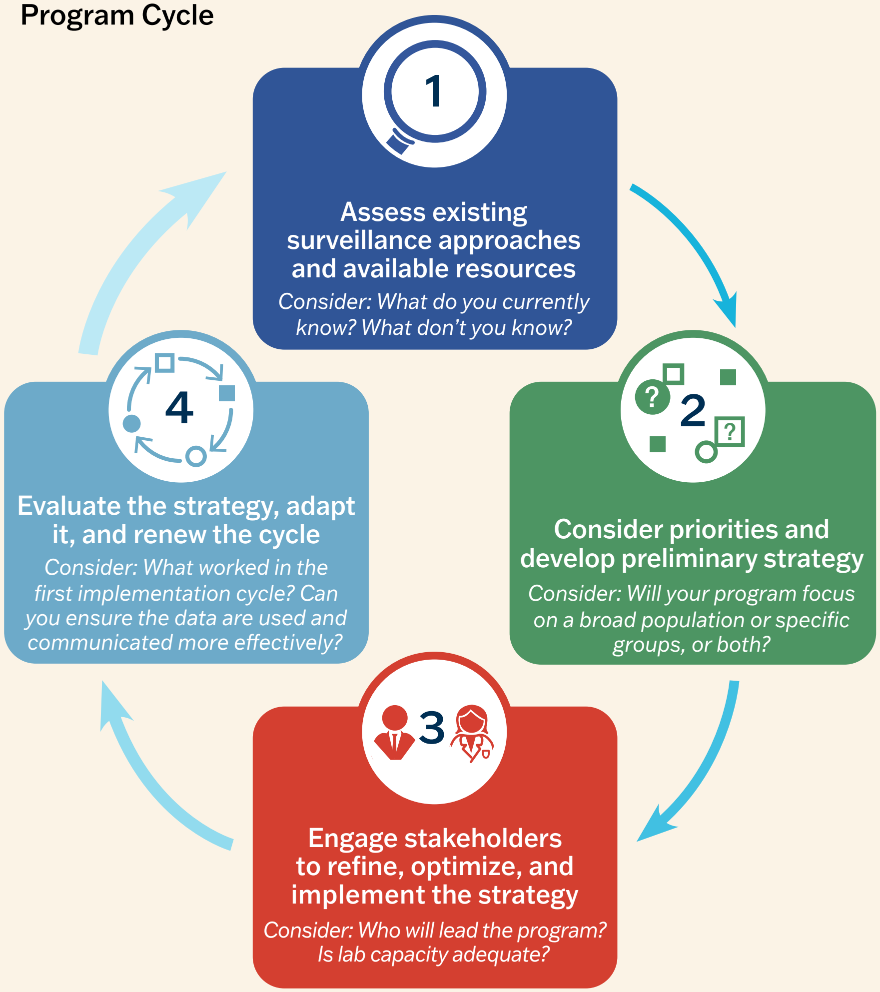
For all countries, the process of designing a national testing and surveillance program is cyclical, with four key phases (figure 12):

1) **Assess** existing surveillance approaches and available resources.
2) Consider priorities (goals, objectives, and outcomes) and **develop** a preliminary strategy.
3) Engage stakeholders to refine, optimize, and **implement** the strategy.
4) **Evaluate** the strategy, adapt it (based on findings and new realities), and renew the cycle.

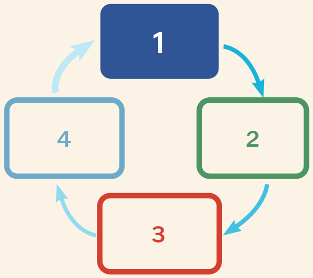
National testing and surveillance programs will vary country to country depending on available resources, priorities, and epidemiologic context. Countries with low case counts and high rates of vaccination will have national testing and surveillance programs that are likely to differ from those in countries grappling with emerging COVID-19 waves and/or with limited access to vaccines and therapeutics. Despite these differences, the implementation phases of national testing and surveillance programs are identical, providing a framework for all countries to follow. For each implementation phase, the planning processes will be informed by:

- The types of testing and surveillance infrastructure and programs already implemented
- The country's capacity to replace, expand, or add testing and surveillance programs within its health system
- The country's ability to successfully implement these programs and proactively leverage such data to inform public health responses

Figure 12. Phases of the National Testing and Surveillance Program Cycle



It is key to consider how testing and surveillance data can be proactively leveraged to add value to the current national strategy and how existing testing and surveillance systems can be adapted to support the implementation of more active methods. Thinking about the strategy as a cycle—rather than as a static, one-time process—emphasizes the need to stay nimble and responsive to the changing landscape of the pandemic.



Assess

Phase 1

- Overall surveillance approach within public health response
- Current surveillance inventory
- Human resource inventory
- Laboratory and information systems inventory
- Inventory of political and public receptivity

Phase 1 — Assess

Undertake a comprehensive inventory of your existing and emerging testing and surveillance approaches and resources and how they fit within your overall surveillance approach. Identify your gaps and needs.

Prior to starting or expanding a national testing and surveillance strategy, it is important to take a comprehensive inventory of your country's current testing and surveillance activities and capacity. This assessment can help elucidate emerging tactics and how they may fit within your country's broader approach to surveillance and existing resources. This will further identify current areas of weakness and blind spots (data gaps). It is helpful to consider this inventory with two key questions in mind: What is the country's overall approach to SARS-CoV-2 surveillance? How would implementing additional testing and surveillance approaches complement the current surveillance strategy and support proactive public health responses?

There are five key areas to consider: (1) the overall surveillance approach within the broader public health response to SARS-CoV-2; (2) a current inventory of surveillance data; (3) a current inventory of human resources and capacity; (4) a current inventory of laboratory, information, and analytic systems; and (5) an inventory of political and public receptivity.

These foundational considerations will help guide assessments of other areas, supporting the stepwise implementation, improvement, and sustainability of new approaches within national testing and surveillance strategies.

Overall Surveillance Approach Within Public Health Response

What is your country's approach to using different methods of surveillance to support the public health response?

Beyond measuring the current or previous burden of SARS-CoV-2 infection, comprehensive public health responses leverage multiple other surveillance metrics to inform an overall strategy. These other metrics may include: measuring the direct and indirect health consequences of the pandemic, monitoring public health interventions, monitoring social and behavioral trends, and monitoring epidemiologic trends in SARS-CoV-2 (table 4).

Implementation of active testing and surveillance approaches can provide information beyond who is currently or was previously infected. Active approaches also provide critical information that supports several other aims that an overall surveillance program may have. Articulating your overall surveillance strategy will help you transparently assess how new testing and surveillance approaches can be proactively leveraged.

Table 4. Other Surveillance Metrics to Inform Overall Approach

Measuring the direct and indirect health consequences of the pandemic	Monitoring public health interventions	Monitoring social and behavioral trends	Monitoring epidemiologic trends in SARS-CoV-2
• Hospital-based surveillance, which includes the number of COVID-19 patients in hospital, overall utilization, and existing capacity • Mortality-based surveillance, which includes the number of people dying from COVID-19 (diagnosed and undiagnosed) and excess mortality associated with unintended consequences of the pandemic • Monitoring mental health and well-being indicators • Monitoring continuity of essential health services and wait times for health care • Monitoring rates of COVID-19 recovery and long COVID	• Vaccine uptake and coverage • Population mobility and social interactions • Adherence to and acceptability of nonpharmaceutical interventions • Uptake and access to COVID-19 therapeutics	• Social determinants of SARS-CoV-2 infection • Vaccine hesitancy • Willingness and ability to follow public health measures • Trust in science and the government • Unemployment rates, food and housing insecurity, poverty	• Modeling to inform both short- and long-term forecasts • Transmission dynamics • Health inequities • Correlates of protection • Vaccine effectiveness with respect to preventing infection, symptomatic disease, hospitalization, and death and assessing waning protection over time • Variant-of-concern assessments (for example, transmissibility, virulence, immune evasion, and vaccine effectiveness)

Surveillance Data Inventory

What are the weaknesses and gaps in your current approach to surveillance?

It is helpful to place your current methods of collecting data on levels of current and previous SARS-CoV-2 infection in the context of the overall goals of your SARS-CoV-2 surveillance. Consider your previous experience during this pandemic and the experience of other countries to enrich your overall assessment. Use this exercise to develop a blueprint of:

- Which goals you are currently achieving
- Which goals you are not currently achieving
- Which goals you would like to prioritize moving forward

Within the context of fiscal space considerations, consider how implementing additional approaches to testing and surveillance could work to address the current gaps and weaknesses in your current strategy. With the resources you have available, consider the ranking of the goals you have prioritized moving forward—which surveillance approaches might be feasible immediately and which might require further investment? To support this exercise, consider your current testing and surveillance system with the following elements in mind (figure 13):

- Timeliness
- Population-wide surveillance
- Targeted surveillance
- Available resources
- Variants of concern

Figure 13. Considerations to Support the Selection of Surveillance Approaches

Timeliness
Are there delays in reporting of testing or surveillance data? Have current approaches to testing and surveillance missed outbreaks or surges or identified them too late?

Population-wide surveillance
Do you have current gaps in testing coverage? If a surge of infections were to occur, do plans and capacity exist to accommodate a response? Will proactive approaches support your public health response?

Targeted surveillance
Are common SARS-CoV-2 hotspots (such as health care settings, congregate settings, certain workplaces, low-income neighborhoods) known? Are surges in cases in these hotspots easy to identify? Are the populations impacted difficult to reach?

Available resources
Are there available resources (expertise, financial, human resources, lab capacity) to expand your surveillance approach? Are there efficiencies that could be made to free resources? Which resources are "fundamental" to your overall approach?

Variants of concern
Do you have current gaps in understanding circulating variants of concern in the country? Do you have local capacity or access to international capacity to perform sequencing on SARS-CoV-2 specimens to estimate the spread and prevalence of variants of concern?

Human Resource Inventory

Who is needed to implement, analyze, communicate, and oversee your approaches to testing and surveillance?

A national testing and surveillance strategy is human resource intensive. It requires a diverse group of individuals with different areas of expertise in the right numbers and, importantly, these groups must work together efficiently. The scope and scale of human resources needs to be actively monitored and managed within the ever-changing context of national strategies.

Review the human resources you can leverage as part of an expanded testing and surveillance strategy (for example, consider the potential for task shifting). Key groups include implementing partners, laboratory personnel, data managers, data communicators, logistics supply chain) experts, health care personnel, and scientists. Who will be involved, and in what capacity, will be determined in the development phase, but assessing what is feasible early on is imperative.

Laboratory and Information Systems Inventory

Which laboratory, information, and analytic systems are required to support implementation and data collection, analysis, interpretation, and communication?

National testing and surveillance approaches require reliable and integrated infrastructure to ensure data arrive in the right hands in a timely manner. In the case of testing, this requires efficient sample transportation networks and strong supply chains for materials required by laboratories and for the tests themselves. A key consideration—particularly when considering PCR testing—is understanding the lab capacity that is currently used and lab capacity that could be leveraged elsewhere. For forms of surveillance less reliant on testing (such as mortality-based or wastewater-based surveillance), this inventory should consider the completeness, utility, and potential limitations of data generated by existing information systems. Beyond this, national testing and surveillance approaches require knowledgeable analysts who can work efficiently and in parallel with communicators for rapid dissemination of findings to both stakeholders and the public.

Several potential issues in laboratory and information systems warrant particular attention. For example, it may be important to reflect on how such systems are structured (for example, are information systems interoperable, with the ability to link different types of testing and surveillance data?), how quickly test results and surveillance reports are generated, how completely and efficiently data are transferred between public and private partners and health system levels, what current protocols for data protection and privacy exist, and which data quality assurance and improvement processes are implemented. Overall, a comprehensive understanding of the capacity limitations in existing laboratory and information systems is essential to begin to address such issues and optimally use data gathered from proactive testing and surveillance approaches.

Inventory of Political and Public Receptivity

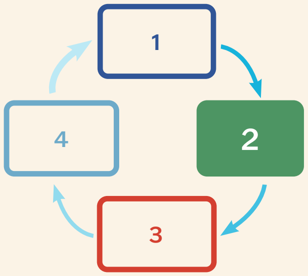
How ready for and receptive to new approaches to testing and surveillance are the government and the public?

The success of any surveillance program relies on buy-in not only from government departments and political organizations, but also from members of the health care system, private industry, and the public. Moreover, depending on the current structure of testing and surveillance system governance, institutional responsibilities around managing surveillance systems could lie at various levels of government. Understanding who needs to be brought to the table and engaged during the design and implementation of new testing and surveillance activities is crucial for their success.

As with any new program, stakeholders will want to know the potential risks and benefits associated with implementing new approaches to testing and surveillance, as well as how their value compares to already existing programs. Some stakeholders may be sensitive to added costs associated with increased testing and surveillance, may be concerned with the incremental benefits that can be obtained, or may have valid ethical concerns about how such programs would be implemented and data proactively used for decision-making. In the assessment stage, it is important to understand the various sensitivities and concerns from the stakeholders involved so that potential issues can be addressed accordingly.

For the public, it is important to transparently communicate the rationale and value added by these new testing and surveillance approaches. The scientific basis for the new approaches needs to be clear, as well as how the data will be proactively leveraged to inform the public health response. If members of the public are being asked to take on tasks themselves (such as self-testing), transparency is all the more important, and special consideration should be given to how logistical barriers will be addressed and access supported. Public media campaigns with clear messaging are one method to try and achieve this. Informing the public and stakeholders at the outset on how different approaches will be measured in terms of their added value or utility, and subsequently communicating how successful these approaches were in achieving their desired goal, will build trust in the process.

Photo credit: Diverse Stock Photos



Develop

Phase 2

Set goals and objectives

Gather your team

Consider these key implementation questions

Estimate costs and required resources

Ensure results will inform public health action

Phase 2 — Develop

Consider priorities and develop a preliminary program

The assessments completed in phase 1 should make clear the major goals of your country's overall surveillance approach. In line with these goals, the development phase articulates the priorities and objectives of the surveillance approach, highlights the key personnel that will be required to implement your approach, reveals key implementation areas to address, helps you estimate required resources, and allows you to plan implementation in such a way that results will inform public health response.

Set Goals and Objectives

Following national goals for SARS-CoV-2 testing and surveillance, develop your overall priorities for new testing and surveillance approaches and how their data will be proactively used. Obvious goals will be to reduce the incidence of SARS-CoV-2 nationally and particularly within disproportionately affected groups. However, consider other goals as well, including earlier identification of future waves of infection, reduced laboratory burden, better targeting of public health measures, identification of populations for vaccination or revaccination efforts, capacity to maintain essential health services, and identification of emerging mutations. Recall that active surveillance approaches can provide a wealth of data, and how you wish to proactively leverage data collected from such approaches should be clear. Organize your goals into short-, medium-, and long-term objectives for your surveillance program, which will make clear what you hope to achieve in a measurable fashion.

Although implementing new surveillance approaches is highly useful, these tools are not silver bullets and cannot replace robust public health responses to the pandemic. Remember, these new approaches:

- Complement other testing and surveillance approaches and do not remove the need for other public interventions.

- Take careful planning and may require sophisticated infrastructure that can take time to develop.
- Can provide various types of information that should be interpreted according to local context and epidemiology, rather than in a vacuum.
- Represent a future investment in public health infrastructure. The platforms necessary to implement many testing and surveillance approaches are readily translatable to many other public health issues.

With your goals and objectives in mind, begin also to develop how you will assess the success of your strategy—in the short, medium, and long terms. Success may mean different things in different contexts but should be clear and measurable. By developing such an evaluation plan early on, you are in a better position to identify implementation challenges early, increase the likelihood that your surveillance program will provide the data you need, and improve its overall quality.

Gather Your Team

Identify the personnel who will be needed to implement your testing and surveillance strategy. This may include people involved directly with implementation, with the laboratory system, with data management, with the supply chain, with different health care sectors, with the private sector, and with different governmental agencies (see Phase 3 — Implement, for more detail).

Review the overall surveillance program's support structures. Will rearrangement or new roles be required with implementation of new testing and surveillance approaches? Ensure all involved have clarity on their roles and agree to their responsibilities. Consider:

- **Accountability structures.** Who is responsible for decision-making and oversight at different levels of the surveillance program? Who is taking ownership of different forms of surveillance?
- **Steering or advisory structures.** Are there groups of experts and stakeholders to determine the overall program direction and whether its goals are being reached?
- **Implementation structures.** Which organizations, personnel, and other stakeholders will be involved, and what will their responsibilities be? How will the correct groups be linked with each other during implementation? How will support from each implementing partner be gathered?
- **Reporting and public health action structures.** How will different findings and reports from your surveillance program be communicated and to whom? How will different testing and surveillance approaches be proactively used to make decisions on the public health response? Are the correct groups and structures in place to support said response?

Consider Two Key Implementation Questions

What population will you sample, and how often?

Active testing and surveillance approaches can be targeted to specific populations or locations, can be population-wide, or both. Although contact tracing and testing are an essential public health tool, local realities may mean that decisions on where this approach can be implemented fully will need to be made. Similarly, although genomic surveillance may leverage passively collected samples and is highly useful, it is resource intensive. Reaching a WHO-recommended threshold for the proportion of specimens sequenced may not be possible, and if genomic surveillance is implemented, it will be important to clearly define which specimens will be sequenced. The frequency of testing will also need to be decided upon, depending on the approach, such as for representative population surveys and serial testing. It is critical to make these decisions in the context of existing resources and the potential for changing operating conditions. Therefore, strategies should be flexible and designed in a way that allows modifications without compromising the overall integrity and utility of data obtained.

How will you address cross-cutting issues?

With partners who will support implementation of your overall surveillance strategy, consider how your approaches will potentially be impacted by each of the following areas:

- **Laboratory infrastructure, capacity, and supply chain.** The addition of new testing and surveillance approaches are likely to put pressure on existing laboratory infrastructure, capacity, and supply chains. Will certain testing and surveillance approaches require new infrastructure or validation? If so, this is likely to take time to develop. Existing public RT-PCR capacity may be used by clinical testing. Are approaches amenable to using point-of-care tests without significant loss in utility and impact? Could capacity be leveraged from the private sector or academic institutions? How will this be accomplished? To maintain testing and surveillance programs, secure supply chains are essential. Are avenues of purchase, procurement, and distribution solidified? Consider looking forward to project demand and plan accordingly.
- **Human resources.** Consider the necessary human resources across all levels of implementation. Do you have sufficient clinical staff to collect specimens? Will these resources be strained during infection waves? Are laboratories sufficiently staffed to analyze specimens in a timely manner? Based on the data you expect to generate from your surveillance approach, do you have the required data managers, analysts, and communicators? If current human resources are insufficient, are there pathways to increase capacity—such as task shifting or leveraging the private sector?
- **Transportation networks.** Critical to effective public health response during the COVID-19 pandemic is the timely communication of test results. This can prevent undue quarantine or ensure people who test positive can be notified in a timely manner and isolated. This necessitates the transport of clinical samples from collection facilities to laboratories, and then of results back to the patients. Scaling testing, while straining transportation networks, may have unwanted consequences.
- **Information systems.** For data to be useful and actionable, timely turnaround and analysis of results are necessary. Consider whether information systems are robust and have the necessary support in place: reliable and integrated data collection, laboratory information systems, database or data repository for analyses and visualizations, and established pathways for dissemination of results.

Estimate Costs and Required Resources

The costs and resources required for implementing a surveillance strategy are some of the most important factors that need to be considered. Given the variety of different surveillance approaches that can be included in a national strategy, it is beyond the scope of this guidebook to give prescriptive guidance on potential costs and resources required for all possible surveillance approaches; however, an underlying principle is that strategies should be developed to be sustainable and adaptive to changing fiscal constraints. In general, standardized methodology should be used when assessing the costs and resources required for each surveillance approach, with similar metrics and outcomes to permit comparability. This is particularly important when resources are limited and the expected benefits of different approaches are similar.

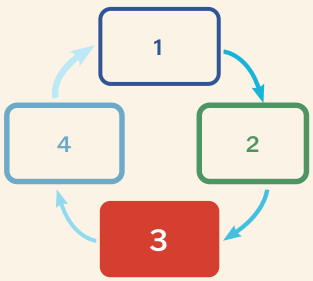
The most tangible costs are those associated with operation—for example, the cost of collecting, analyzing, and reporting results for a specimen. These can typically be thought of in three distinct categories: personnel, materials, and overhead. It is important to also consider start-up costs, which may include large capital purchases (such as building infrastructure, equipment, and information technology), ongoing costs of implementation and maintenance (such as quality control, monitoring and evaluation, and technical support), opportunity costs (such as hidden costs associated with diverting resources from other programs), and costs associated with underuse. Each of these costs will be unique to the country (and even locality) where the surveillance approach is implemented.

In general, costs associated with each surveillance approach can be compared to the costs averted through public health responses that result from the information gained through the specific surveillance approach you are considering. This may include costs associated with reduced hospitalizations and intensive care stays, mortality, work absenteeism, or economic consequences of highly restrictive public health measures. Although this is often hard to estimate, one approach could be to compare lead time offered by different surveillance approaches to new waves of infection. Another approach could be comparing time to identification of emerging variants with currently implemented clinical testing or surveillance approaches. Both approaches can be combined with modeling to estimate potential cost trade-offs.

Ensure Results Will Inform Public Health Responses

Surveillance programs should be built to be capable of proactively informing the country's public health response. In developing the overall surveillance strategy, it is important to also prepare for how data will be monitored, analyzed, reported, interpreted, and used. There are several factors to consider:

- **Multidisciplinary approach.** Collecting, analyzing, interpreting, and communicating surveillance data requires a multidisciplinary team that works in harmony toward a common goal. Good partnerships between stakeholders involved in all aspects of surveillance are essential to keep programs running smoothly and efficiently.
- **Data quality benchmarks.** With so many different sources of surveillance data, it is imperative to ensure the data collected are high quality. Pilot studies in more controlled environments can help set data quality benchmarks and permit validation. What will your response be if strange signals are seen? How will irregularities be investigated and corrected? These data quality assurance and improvement procedures should be transparent to build and establish trust between stakeholders and the public.
- **Establish a response plan before implementation.** Given that there may be multiple avenues of public health response based on testing and surveillance data, it is critical to establish early on the different potential responses that could result. Are there already mechanisms in place to support communication among stakeholders and with the public? Are there criteria established to trigger different public health measures?



Implement

Phase 3

Engage stakeholders

Pilot and scale your program

Strengthen, Adapt, Sustain

Phase 3 — Implement

Engage stakeholders and optimize your testing and surveillance strategy. Put your new strategy into action.

Engage Stakeholders

When a preliminary strategy has been developed, the next key phase is to broaden the scope of stakeholders engaged as you prepare to fine-tune and implement the strategy.

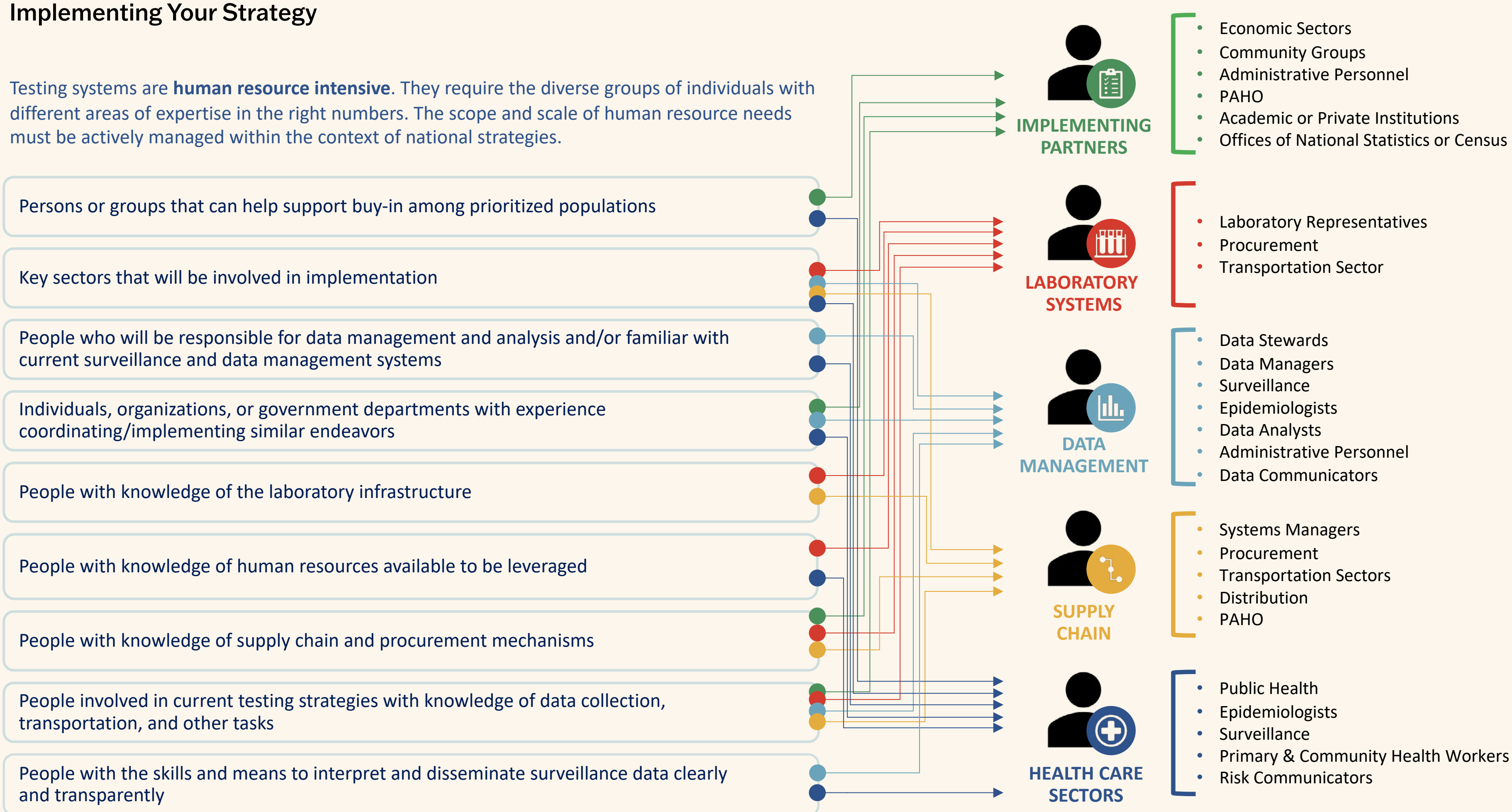
The success of a national testing and surveillance strategy relies on leveraging individual and institutional resources throughout all phases of the cycle. The people and agencies (including implementing partners and laboratory, supply, and data teams) that will be involved in putting the strategy into action are vital partners. Engaging them will help you refine the strategy and optimize its implementation, so this process should begin as soon as the general approach has been defined. This will help cultivate ownership and buy-in of the strategy and improve the chances of success in every phase of the cycle. Successful strategies have ongoing cooperation and input from diverse groups of stake-holders, with effective communication on goals and processes to ensure that available resources are used efficiently.

Putting your strategy into action involves the following key groups of personnel (figure 14):

- Implementing Partners
- Laboratory Systems
- Data Management
- Supply Chain
- Health Care Sector

Figure 14. Key Human Resources to Engage When Implementing Your Strategy

Testing systems are **human resource intensive**. They require the diverse groups of individuals with different areas of expertise in the right numbers. The scope and scale of human resource needs must be actively managed within the context of national strategies.



Implementation Considerations for Each Group of Personnel

With your engaged group of stakeholders, revisit several preliminary considerations on the scope of your testing and surveillance strategy. This will ensure that what you seek to accomplish is possible and potential issues are identified early. Many considerations are cross-cutting among the groups of personnel.

Implementing Partners

Engaging with implementing partners early is vital to increase the likelihood that testing and surveillance strategies will be successful. Implementing partners may include people in public or private sectors; community organizations; and local, regional, national, and international organizations. These people should have experience in engaging the populations you are prioritizing or in implementing similar strategies and can share lessons learned.

- If certain economic sectors are prioritized in the national testing and surveillance strategy, bring sector representatives to the table so that methods and logistics around testing and surveillance can be discussed. This should include defining what sector-specific metrics are most important to them and how the overall success of the program will be measured.
- Community groups offer extensive experience and insight with population groups that may be prioritized for testing and surveillance. They generally have good insight into existing barriers and facilitators to participation in testing and surveillance activities and mechanisms to address or support these. This also brings the groups impacted by your program to the table, making them part of the process and supporting buy-in.
- International entities like the WHO or PAHO offer global insight into implementation successes and challenges that may be translatable to your context. They can offer guidance on best practices for population sampling, potential use cases (that is, when you might consider using such approaches), and strategies for testing, and available technologies.

Laboratory Systems

The laboratory systems in your country are critical to the success of any testing and surveillance strategy. Engaging with representatives in the laboratory system will provide insight into procurement schedules, transportation networks, and available capacity. These people will be able to provide guidance on what is feasible and potential mechanisms to speed up procurement and expand capacity.

- Laboratory representatives will have insight into procedures for specimen accessioning, analysis, and result dissemination. They can help define expected laboratory turnaround times at different volumes of clinical specimens and give realistic estimates of overall capacity, highlighting what might be feasible and useful moving forward. They will also be able to provide insight into quality control and quality assurance mechanisms that are in place, building confidence in the validity and reliability of results.
- Engaging with personnel involved in procurement of laboratory supplies will allow forecasting of required lab materials, reagents, and personal protective equipment, minimizing the risk of interruption of testing and surveillance activities are interrupted due to material shortages.
- Integrated specimen transportation networks—for clinical specimens arriving from testing facilities or for SARS-CoV-2 specimens sent for sequencing—are necessary to ensure the testing and surveillance data collected are actionable rather than historical. Delays in specimen transport can significantly impact turnaround time and impede appropriate action. Considering how the areas or

populations targeted for testing and surveillance will be served by transportation networks is essential in this phase.

Data Management

Working with the groups of personnel who will handle and manage testing and surveillance data from the time of collection to time of dissemination to stakeholders and the public is essential. Testing and surveillance are done for specific purposes, and if data gleaned from such endeavors are not suited for purpose, resources are wasted, with high opportunity costs.

- Engage with end users of testing and surveillance data: surveillance managers, epidemiologists, and decision-makers. What do they wish to do with the data collected? Work with them to think forward to other potential uses of the data down the line—how can such data address future questions? For example, hospital-based surveillance mechanisms may have a primary aim of monitoring capacity and the number of hospitalized COVID-19 patients. However, data from such mechanisms, if they also capture certain characteristics of hospitalized patients, can serve a second purpose—identifying at-risk populations who may benefit from more intensive monitoring or use of therapeutics. Be aware that this will require careful development of appropriate data collection systems. Be alert, also, to the volume and burden of data collection—too little data may be of little utility, but a goal of collecting too much information might not be achieved.
- Working with groups of personnel involved in the management of data collection systems—such as data stewards, analysts, and managers—can make clear how information is collected and communicated between institutions. Bottlenecks can be identified, and systems or approaches can be adapted to ensure key data are collected and communicated between actors in a timely manner. With these groups, criteria for action and escalation when unusual signals are identified can be established.
- Work with data analysts and data communicators to establish processes for how data will be interpreted and communicated to stakeholders in a timely, clear, and transparent manner. Set dissemination schedules and mandatory reporting items that are needed by end users.

Supply Chain

The COVID-19 pandemic has stressed supply chains globally, in terms of both supply and demand. Current realities—reduced production capacities, reduced staffing, shortages of raw materials—mean that implementation plans may need to be rapidly adjusted to changing landscapes. Working with all groups involved in the supply chain, including those involved in forecasting demand, procurement, and distribution, can permit development of contingency plans should supply chain issues arise.

- Speak with those involved in executing your testing and surveillance activities to fully understand the types of items they need to successfully complete their tasks. Whereas laboratory reagents and test kits are important, so too are ancillary items such as test tubes, cleaning materials, and personal protective equipment. Gather information on whether items have been in limited supply in the past so you can pre-emptively make contingency plans.
- Work with local, regional, national, and international organizations responsible for procurement. Understand logistics of ordering and receiving items and alternative pathways of procurement. The responsibility for procurement of materials necessary to implement a testing and surveillance program at the national level may not lie only with national organizations. Navigating the procurement system efficiently is critical for continuity of surveillance programs.

- Distribution of purchased materials often relies on transportation sectors, and delays between ordering and receipt may vary by region and locality. Understanding lead-time and distribution barriers early allows for proactive planning to minimize supply-chain disruptions.

Health Care Sector

The success of testing and surveillance activities hinges on the participation and active involvement of members of the health care sector. Engagement of both private and public health care workers is essential. For nearly all forms of testing and surveillance, the people being tested or surveyed will interact directly with a member of the health care sector. Clear and transparent communication on how and why different testing and surveillance approaches are being implemented will support uptake by both participants and members of the health care sector.

- Discuss implementation of testing and surveillance activities with primary care and community health workers. Ensure the rationale is transparent and the specific procedures are clear. For example, if a specific subgroup of individuals is now to be prioritized over others for PCR testing, the rationale for such a decision should be explained. Consider feedback and concerns, and make sure they are acknowledged and addressed as much as possible. Particularly for active testing and surveillance, primary and community health workers will be front-line implementers and need to trust and believe in the approach.
- Work with public health representatives to ensure the testing and surveillance approach, as well as its timeline, are feasible. Discuss potential issues that may stem from new responsibilities, and develop contingency plans. For example, if contact tracing is to be carried out, responsibility to implement will normally fall on public health. In many countries, large infection waves have overwhelmed such programs. How to deal with these potential realities should be addressed.
- Public health and risk communication is an essential aspect of effective responses to SARS-CoV-2. Effective, clear, and transparent communication builds trust in the science and the proposed approach. Work with people in the health care sector responsible for communicating between different levels within the sector and with the public. Anticipate potential issues and address uncertainties around the proposed testing and surveillance approach early. Clear, consistent messaging should be a priority.

Photo credit: Tim Dennell

Pilot and Scale Your Program

As you roll out your new testing and surveillance program, beginning with pilot projects is a useful way to identify challenges and promote buy-in to the overall program prior to scale-up. During the pilot phase, close collaboration between all actors involved is crucial as they will all be involved with progressive scale-up of the program. As seen in the case example from Slovakia (on the use of population-wide antigen testing), pilot counties were selected prior to country-wide scale-up. Regardless of whether you are implementing tried and tested surveillance methods or innovative approaches, pilot phases are an important step in the implementation pathway:

- They help you better understand the potential resource demand upon scale-up, allowing you to refine projections and return to key groups of personnel to adjust implementation plans.
- They allow you to estimate the potential yield and added value of different testing and surveillance approaches. When resources are limited, not all testing and surveillance approaches can be used. Implementing several different approaches as pilots can help elucidate which approaches should be brought forward for country-wide scale-up, and which could be abandoned.
- They allow you to identify logistical challenges across the entire implementation pathway. The success of programs relies on all actors and processes working seamlessly, and pilot phases are useful in identifying and addressing difficulties—ranging from simple misalignment of required data points between health facilities and national surveillance units, to more fundamental issues related to capacity and supply chain or collaboration between required actors.

Photo credit: Roberto Jorge Freire Esteves/CDC

Strengthen, Adapt, Sustain

Strategies within your overall testing and surveillance program are likely to have different aims, applications, and sampling characteristics. When a new strategy (or strategies) is implemented, there is a period of adaptation and learning—such as learning how best to implement specimen collection, specimen transport, and information systems, or understanding which populations may benefit from different strategies, what barriers exist, and how data generated compare to existing methods. When new strategies are implemented, collaborations between different stakeholders are likely to be formed. Taken together, this amounts to a period of strengthening, where your program should see quick efficiency gains and improved understanding of new data collected from your testing and surveillance program.

Adapting to Innovation

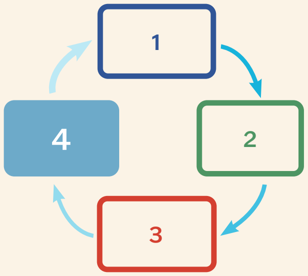
Collaboration between different sectors and with the international community provides researchers with the know-how and resources to innovate. As more tools become available, it is key to consider how they might be used, as this can have important impacts on cost-benefit calculation or address existing barriers.

Contextualizing innovation is as essential as having resources and knowledge. An example of this can be seen in Vietnam. Even before the first case of COVID-19 was reported in Vietnam, the private and public sector worked together to develop PCR test kits that were more affordable and could be completed more rapidly than existing options. They worked to understand how these new kits could be validated and implemented in their context. They realized that the preliminary, time-consuming steps in more widely available test kits (such as those provided by the WHO and US-CDC) were unnecessary based on coronavirus epidemiology in Vietnam. This dropped analysis time to a little over an hour, with costs as low as US$20 per test (Klingler-Vidra, Tran, and Uusikyla 2021). Adapting testing protocols to use these test kits would thus save time and money, changing the cost-benefit calculus of testing and surveillance strategies. Similar innovations are occurring globally.

Future Applications

Experience with testing and surveillance strategies has potential benefits beyond the COVID-19 pandemic. For example, strengthening of information systems to permit robust testing and surveillance not only will pay dividends for other existing health threats, but will make health systems better prepared to detect and react to the next public health threat. Similarly, development of laboratory PCR capacity can be leveraged for testing of other pathogens, such as tuberculosis. Experience with deploying population self-testing with rapid tests can similarly be leveraged for at-home testing of pathogens like human immunodeficiency virus (HIV). Finally, beyond obvious technological and process benefits associated with implementing a testing and surveillance program, health and human resource capacity will be bolstered, collaborations with different stakeholders will be forged, and public health infrastructure will be developed, increasing health system resiliency.

Phases of a National Testing and Surveillance Program



Evaluate **Phase 4**

Purpose of the program

Utility of the data

Costs and acceptability

Feasibility, flexibility, and sustainability

Barriers and facilitators

Equity and ethical issues

Potential adaptations for the next cycle

Phase 4 — Evaluate

Evaluate your overall surveillance approach, adapt it, and renew the cycle

The implemented surveillance approach needs to be critically and comprehensively evaluated to understand its successes and challenges and, if necessary, to adapt or refine the strategy. An evaluation should look carefully at whether strategies are reaching their goals. Consider the development and implementation of an overall surveillance strategy as an iterative process, cycling again through the four phases used to initiate and integrate new approaches into your testing and surveillance program.

A careful evaluation will prepare you to improve your overall surveillance strategy and be ready to adapt it to the rapidly changing pandemic landscape and your local context. Established recommendations for evaluating surveillance systems build on seven key areas:

- Purpose of the program
- Utility of the data
- Costs and acceptability
- Feasibility, flexibility, and sustainability
- Barriers and facilitators
- Equity and ethical issues
- Potential adaptations for next cycle

Purpose of the Program

You have implemented a testing and surveillance program and collected data for a specific purpose—primarily, to proactively inform public health measures and better understand the extent and dynamics of SARS-CoV-2 infection. However, your program may serve several other purposes, such as to establish baseline epidemiologic data as a foundation for future monitoring and research, or to be sensitive to specific signals in certain populations. Once your testing and surveillance program is in place, revisit the purpose and the objectives of the program. Consider whether the program is providing you the information you require to reach its goals, whether the program is efficient and performing as you envisioned, and whether the context has changed and adjustments might be required.

Utility of the Data

Data evaluation begins right after data have been collected and analyzed. If the data collected from your testing and surveillance program did not prove useful for its intended purpose (for example, informing public health measures), review the possible explanations. Solutions should be examined in the context of other considerations, including added costs and any impacts on acceptability and feasibility. Consider both strengths and weaknesses in the collected data. It is likely the cost-benefit calculus you estimated for your testing and surveillance program may now be different and come with important opportunity costs. Identify whether issues in data utility are possible to address, and attempt to arrive at solutions.

To help your evaluation of data utility, consider the following areas:

- **Data quality.** Did the testing and surveillance program provide the required data? Were quality assurance and control methods applied? Are the data complete and valid?
- **Efficiency.** Was the implementation of the testing and surveillance program an efficient use of resources (financial, human, lab, and so forth)? What barriers need to be overcome?
- **Sensitivity, specificity, and positive predictive value.** Did the testing and surveillance program do what you intended—for example, did it accurately identify new outbreaks, surges, and waves, or yield data useful to target vaccination and booster programs?
- **Reliability.** Were the data operational when needed? Were there data issues during collection, analysis, or dissemination?
- **Standards use.** Were appropriate protocols followed when collecting, managing, and analyzing the data? Did the technologies follow approved algorithms or use cases (that is, appropriate recommendation of PCR testing, use of rapid antigen tests, or referral of positive specimens for sequencing)?
- **Availability.** Were testing and surveillance data available to all stakeholders and provided/presented in a transparent manner? Were data publicly available? Were data held in a confidential and private manner when required? Were potentially identifiable data handled appropriately?
- **Timeliness.** Were testing and surveillance data analyzed and disseminated in a timely manner for public health decision-makers and other end users? Were there time delays between steps in the surveillance process?

Costs and Acceptability

Testing and surveillance programs are designed to fit within specific budgets and serve specific purposes. Anticipated costs before implementation should be reviewed against the actual realized costs after implementation. This review should investigate areas where realized costs were higher or lower than anticipated and consider why costs deviated.

- Are there areas where costs could be saved moving forward? Economies of scale should be considered.
- Where were excess expenditures most common in terms of types of cost (such as personnel, materials) and when they were incurred (such as during coordination, sampling, transport, analysis, communication)?

These evaluations are key to ensure cost-benefit calculations regarding the implemented strategy hold, moving forward, and to inform the development of other strategies and improve implementation efficiency. Take careful stock of the opportunity costs of your program in terms of human, laboratory, and other community resources required for efficient and effective implementation.

- Was implementation of the testing strategy an efficient use of resources?
- Can efficiency be improved? Are new technologies available to increase this efficiency?

Uptake of the strategy by all participants (the people being tested or surveyed) is paramount to its effectiveness and utility. Throughout implementation it is necessary to maintain indicators of acceptance (for example, adherence to protocols, participation in surveillance programs). Reasons for suboptimal uptake should be explored. Factors vary and may include those associated with convenience, test-specific characteristics, logistics, or buy-in from the population. Future strategies will benefit from this evaluation to ensure more participant-centered approaches are employed.

- Was there sufficient uptake and was the strategy acceptable to both the people participating in testing and surveillance and the personnel involved in implementation?

Feasibility, Flexibility, and Sustainability

When examining whether your overall testing and surveillance program or a specific approach should be repeated and/or continued, it is important to consider how feasible and sustainable it is and how flexible each approach can be moving forward. Consider:

- What was the financial, human resource, and lab capacity strain imposed by the testing and surveillance program? Can it be maintained? What changes could support sustainability?
- What was the overall cost of the program, and how does this relate to existing budgets? Even cost-effective programs may burn through existing cash flow and become infeasible.
- What materials and supplies were required? If reliable procurement is not possible, strategies will be unsustainable.

Barriers and Facilitators

Consider barriers that had to be overcome and which factors supported implementation of your testing and surveillance program. Qualitative assessments to understand barriers and facilitators are vital components of quality improvement frameworks. Such assessments engage the personnel involved in implementing the strategy, as well as program participants, to learn what helped them carry out their tasks, what got in the way, and what would make a difference in the future. Combine such qualitative assessments with quantitative assessments of certain program indicators—such as lab turnaround time and population coverage—to better understand barriers and facilitators. This process is iterative, with constant evaluation.

Open or structured discussion with personnel and with program participants is a useful method to elicit information about what helped or hindered success. Often, respondents provide useful insights and offer possible solutions to commonly encountered barriers. Results from the qualitative assessments should be used to support and reinforce facilitators and attempt to remove or mitigate potential barriers to improve efficiency in delivery.

Equity and Ethical Issues

Different populations may be engaged with different testing and surveillance approaches within your overall program. A major goal of comprehensive testing and surveillance programs is to have a complete view of the population, with specific approaches used to reach underrepresented populations and address inequities. Was your program successful in this regard? If not, why? Consider:

- Were certain population groups missed by your program? What was the population coverage?
- Were the included populations representative of the entire population? Can findings be readily generalized?
- Was equity achieved? Did your program consider key groups that are at increased risk of infection or severe outcomes or that are typically under-represented (such as those in informal settlements or congregate settings)?
- Did any ethical issues arise? Did anyone or any group experience harm from the testing and surveillance program?

Potential Adaptations for the Next Cycle

Testing and surveillance strategies are rapidly evolving, and so too is the pandemic context. Not only is the technology we use changing, but also who can be leveraged to perform tests (trained personnel, the subject through self-testing), where tests are analyzed (for example, laboratories, within the home), and the types of surveillance needed (for factors such as variants of concern, waning population immunity, vaccine coverage, mental health). Innovations and changing needs have implications for the cost-effectiveness of testing and surveillance programs, the testing capacity required, and the personnel needed. New iterations of immune assays or antigen tests may have key changes in performance (that is, sensitivity and specificity) that require careful reassessment of use cases. Likewise, the number of people reached within strategies may change with innovations.

Testing and surveillance strategies cannot remain stagnant and need to be responsive to innovations. Therefore, they must be constantly evaluated. You should review your current practices against the best practices worldwide. Consider innovations that can shift the accuracy, cost, and efficiency of testing and surveillance approaches. Your evaluation should help you prepare to adapt the next iteration of the strategy to benefit from new methods, technologies, or other innovations.

The Process Is Cyclical

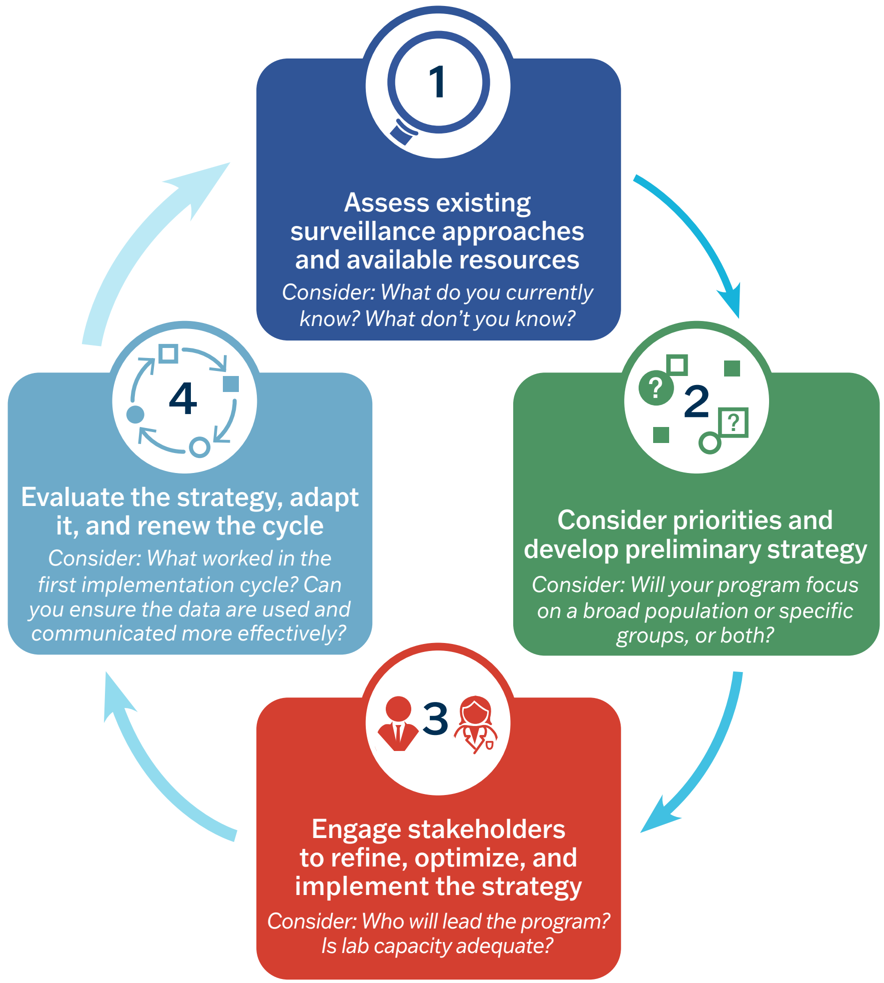
In the context of a continuing, changing pandemic, a repetitive strategic cycle is vital to ensure efficient delivery of scarce resources, maximize population health, and mitigate the social and economic impacts of COVID-19.

An iterative process—of assessing your resources, renewing or redesigning a strategy around identified priorities, engaging with key players to give your implementation the best chance of success, and re-evaluating the processes and outcomes—will help your surveillance approaches respond to new conditions and new opportunities.

First iteration: When a thorough evaluation has been performed, the process of prioritizing populations, developing and optimizing a strategy, and implementing the strategy repeats.

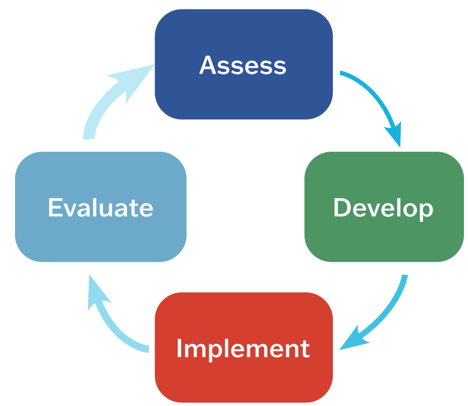
Subsequent iterations: This process can be expedited in comparison to the first iteration, using the experience and knowledge gained, but the process should not be omitted. Priorities shift and so, too, do available resources. What is needed now? What is realistic?

First iteration



It is not always possible to implement and evaluate a national testing and surveillance strategy in tidy, distinct phases. Speed trumps perfection in public health emergency response. Whereas the first iteration may be quickly put together, subsequent iterations offer an opportunity to improve and apply lessons learned. As the world grapples with emerging variants of concern and vaccine inequity, it is clear that testing and surveillance will remain essential for the public health response to SARS-CoV-2 for the foreseeable future. Endeavoring to create a well-designed, adaptive, and integrated approach to testing and surveillance that provides data for proactive action today will pay dividends in the future.

Subsequent iterations
This process can be expedited in comparison to the first iteration, using the experience and knowledge gained.



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