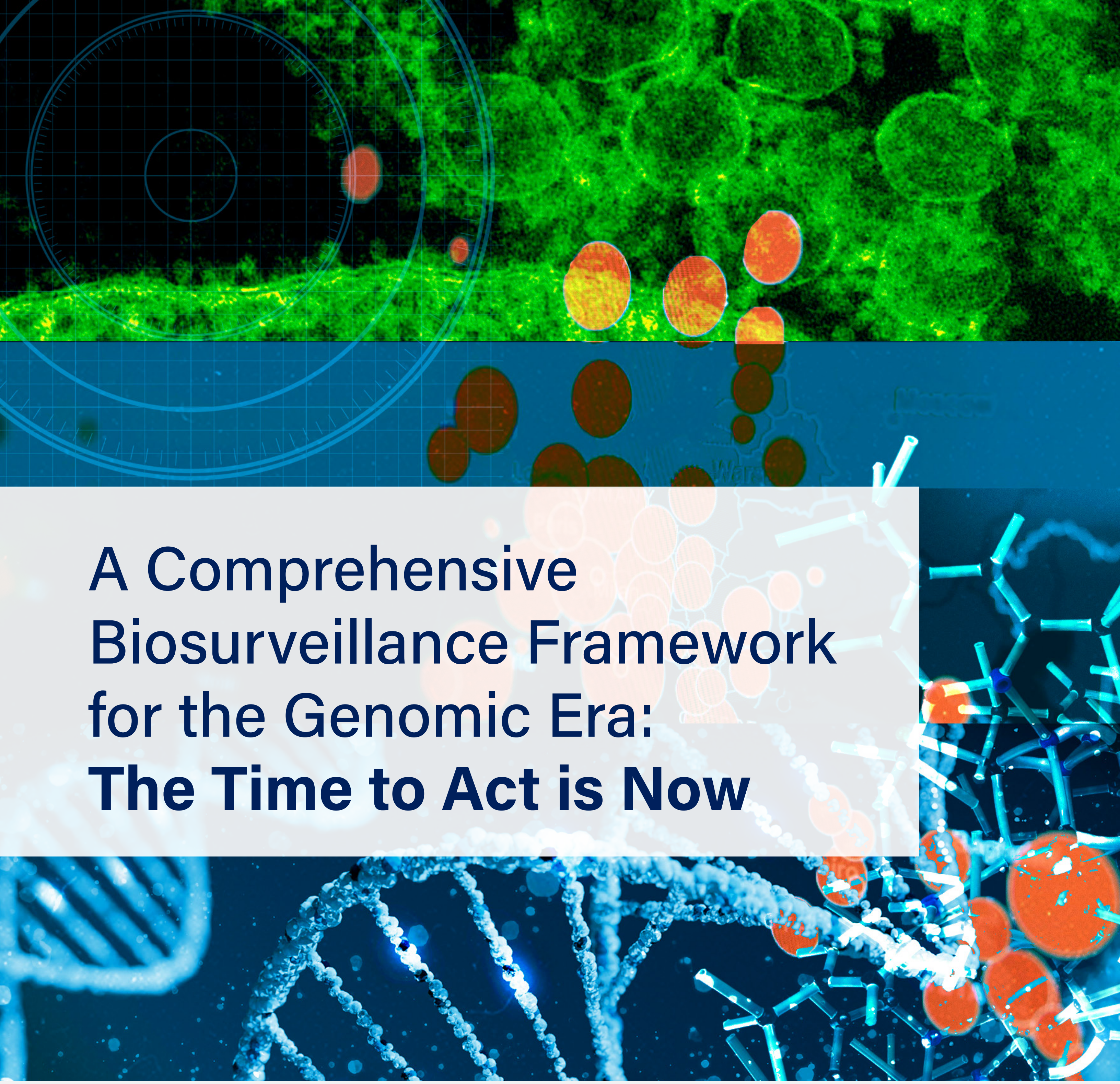
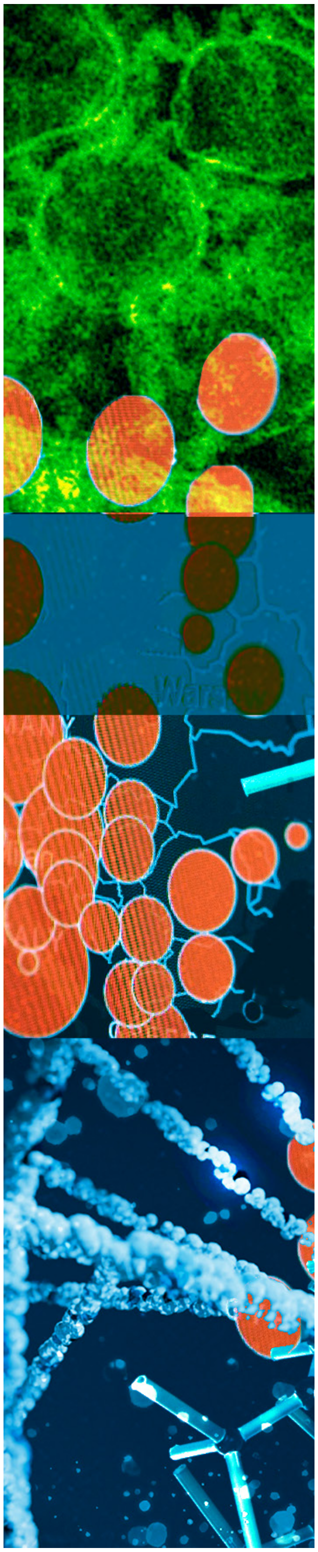


A Comprehensive Biosurveillance Framework for the Genomic Era: **The Time to Act is Now**

PREPARED FOR ILLUMINA

eurasia group politics first

Contents



Executive summary

Nearly four years since the onset of the Covid-19 pandemic, there is still no proactive global system in place to detect and respond swiftly to new biological threats, despite pledges by countries around the world to improve preparedness. Governments were caught off guard by the emerging virus early in the pandemic, and even after it spread widely, global coordination continued to suffer because of a reluctance to share vital public health data.

While the world has shifted away from active emergency responses to Covid-19, the realization that biological threats are a national security concern has reshaped government priorities, as evidenced among advanced economies by the US Biodefense Strategy[1] and the UK Biothreats Radar.[2] At the same time, a push to improve public health infrastructure and coordination has spurred negotiations on a World Health Organization (WHO) Pandemic Treaty—an agreement that would bind member states to globally coordinated pandemic prevention, preparedness, and response measures—and increased efforts to incorporate advanced diagnostics in early pathogen detection in countries at all levels of development.

The disruptive nature of biological threats necessitates a comprehensive approach including early detection and response: a robust biosurveillance system monitoring various data sources to promptly alert healthcare providers and policymakers of any threats. Such a system would combine passive and active surveillance in real time. Passive surveillance involves testing samples from patients to identify the cause of a specific outbreak but is limited to identifying threats after they have caused illness; active surveillance monitors the environment for potential biological threats, raising the chances of detecting outbreaks earlier.

A growing number of countries are developing national biosurveillance programs, and most elements of these programs currently exist, but full implementation has not been realized. A comprehensive program connecting and coordinating these activities—one that leverages the symbiotic relationship between the public and private sectors—can enhance collective resilience.

The world must adopt a global biosurveillance framework that builds upon four principles. First is **promoting innovation**: a multilayered approach combining active surveillance at several points, such as wastewater surveillance in the community and at travel hubs, with passive surveillance at strategic sites within the healthcare system. Cutting-edge genomics technologies for rapid identification of novel and emerging pathogens would complement other methods, such as polymerase chain reaction (PCR) and antigen-based testing, that can quickly detect specific known pathogens.

Second, a **collaborative network** should be established among like-minded countries to create a globally coordinated defense against biological threats. Efforts underway in the US and Europe, as well as the WHO Pandemic Treaty and the 7-1-7 framework from the Africa Center for Disease Control, provide promising starting points for partnership. Yet at the same time, national surveillance efforts within these individual countries and regions are fragmented, with distinct parties assessing biothreats from separate defense and public health perspectives.

The third principle is **strengthening these existing frameworks** to prevent duplicative efforts and enable quick adoption rather than starting from scratch. The key to streamlining processes is the fourth principle, **identifying and sharing best practices** across these national frameworks.

The urgency of addressing evolving biothreats requires governments to adopt iterative approaches for continuous improvements, allowing ongoing refinement in response to emerging threats and changing circumstances.

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[1] National Biodefense Strategy and Implementation Plan: For countering biological threats, enhancing pandemic preparedness, and achieving global health security, October 2022

[2] UK Biological Security Strategy, 2023

Introduction

Biological threats are an increasing public health and national security concern. Outbreaks from novel and emerging pathogens, including Ebola, Zika, and SARS, have been occurring yearly since well before the Covid-19 pandemic. Yet nearly four years after the pandemic began, there is no comprehensive, coordinated, proactive system in place to detect and rapidly respond to new threats.

The shortcomings of the world's pandemic preparedness were painfully obvious within the first few months of the coronavirus pandemic. Disease tracking and subsequent intervention capacities in even the most developed countries were inadequate; the virus had often traveled widely via community spread before it was detected. International coordination was also lacking, with early efforts to track the virus hindered by hesitation to share proprietary public health data. While it was the most prominent example, China was far from the only country that delayed or avoided reporting accurate disease statistics. Furthermore, many countries lacked the infrastructure and resources to test for and track the novel virus.

A new approach to biosecurity—securing the safety of a country's population from a wide range of biological threats—is needed. A comprehensive biosurveillance infrastructure will be required to monitor multiple information sources and alert healthcare providers and policymakers to potential threats. Such wide-ranging biosurveillance can build on the limited and passive activities—such as outbreak reporting—that have been in place for years, to include proactive, continuous monitoring of sources including wastewater samples and selected clinical specimens from the community. Combining these data in real time, and harnessing the power of cutting-edge genomics technologies to allow faster and more accurate identification of novel and emerging pathogens, can help authorities identify threats circulating in the community and begin responding before large outbreaks begin.

Efforts are underway to strengthen both public health preparedness on the one hand and biodefense measures for countries' armed forces on the other. These two approaches often operate in parallel with varying levels of coordination, especially among different countries. Whereas individual countries will doubtlessly benefit from investing in their own biosecurity, pathogens do not recognize national boundaries; cooperation with like-minded countries similarly willing and able to invest in comprehensive biosurveillance will vastly enhance biosecurity efforts. Fragmented geopolitics may limit a truly global system, but countries willing to cooperate and share potentially sensitive information can serve as a model for other states to join, even as they establish a sorely needed defense against biological threats.

Biosecurity

ensuring the safety of a country's population from biological threats, whether naturally occurring or manmade, through a range of efforts involving preparations with regard to adequate supplies, biosurveillance to detect threats, and coordinated, appropriate responses to minimize harm to humans and animals.

Biosurveillance

a multilayered monitoring system using a range of methods to detect potential biological threats, combining both active surveillance, which searches for potential threats in the community before they cause large outbreaks, and passive surveillance, which identifies pathogens responsible for any upticks in illness presenting to healthcare providers.[3]

[3] Defined by Eurasia Group's Healthcare & Medical Devices practice

Biosurveillance as a national priority: Lessons learned from Covid-19

Despite some notable exceptions (for example, China's opacity regarding the initial outbreak), the pandemic demonstrated the promise of cross-country coordination and data sharing to understand and study the novel pathogen. Rapid dissemination of clinical findings, therapeutic approaches, and outcomes helped inform a scientific approach to treatment. International collaboration on genomic sequencing of the virus allowed scientists to quickly identify new variants. These cross-collaborative efforts raised awareness of the need for global pathogen surveillance, even if it was not fully realized. The WHO has called attention to this need through the formation of the International Pathogen Surveillance Network, recognizing that genomics is no longer optional, but rather mandatory, for global preparedness.

At the same time, the pandemic revealed glaring deficiencies in many countries' readiness and in global attempts at cross-coordination. Early in the pandemic, timely recognition of community transmission was limited. Once outbreaks were recognized, the unclear or poorly enforced roles and responsibilities of many national and international organizations resulted in varying responses. Perhaps most troubling for future coordinated surveillance efforts was the inequity in responses to countries that alerted the world to new variants, as well as the presence of favoritism when it came to international alliances. When scientists in South Africa sounded the alarm over the omicron variant,[4] the US and the EU responded with ineffective travel bans, punishing the country rather than offering greater access to therapies and vaccines.

Representatives are currently working on a new pandemic treaty under the auspices of the WHO to reform the international response to emerging pathogens. Despite active engagement in drafting the treaty, many countries will likely be reluctant to sign an agreement that requires substantial enforceable commitments that could conflict with principles of sovereignty or other constitutional considerations. In addition to the efforts outlined in the treaty, enhancing biosurveillance capabilities within countries will need to be of utmost importance for global health and national security.

WHO Pandemic Agreement, last updated 30 October 2023[5]

The WHO's pandemic prevention, preparedness, and response agreement aims to mitigate the impact of future health threats, drawing lessons from the challenges posed by Covid-19. Negotiations among the WHO's 194 member states commenced in March 2023, focusing on legally binding these countries to cooperate, share knowledge, and address health inequities.

As of late, key disputes center on the accord's scope and the level of obligation for countries. Divisions between lower- and higher-income countries will intensify, especially concerning intellectual property (IP). European Commissioner Stella Kyriakides has voiced reservations on IP, technology transfer, and financing, emphasizing the need to avoid hindering innovation. The EU and Germany see collaboration as crucial, underlining interdependency between the International Health Regulations and the Pandemic Agreement. Belgium is raising concerns about liability shifts, while Hungary views the text as WHO-centric, expressing worries about access, supply chains, and liability. These interventions highlight complex negotiations and diverse EU perspectives on global health governance and pandemic response.

Many countries are similarly protective of proprietary public health data, especially in a context of increasing rivalry or even open animosity among major world powers. While a global treaty or agreement would improve international public health preparedness levels, the Covid-19 experience has shown the need for countries to be better prepared within their own borders; enhanced domestic biosurveillance can also support a global effort by

[4] Issued statement from the desk of the President, Cyril Ramaphosa – 28 November 2021

[5] World Health Organization's Proposal for negotiating text of the WHO Pandemic Agreement

facilitating any required disease monitoring and reporting. An ideal biosurveillance program would accurately and swiftly detect any new pathogens to understand how a disease may begin to circulate, giving policymakers sufficient time to prevent, or manage, the spread and communicate the contingency plan with other governments.

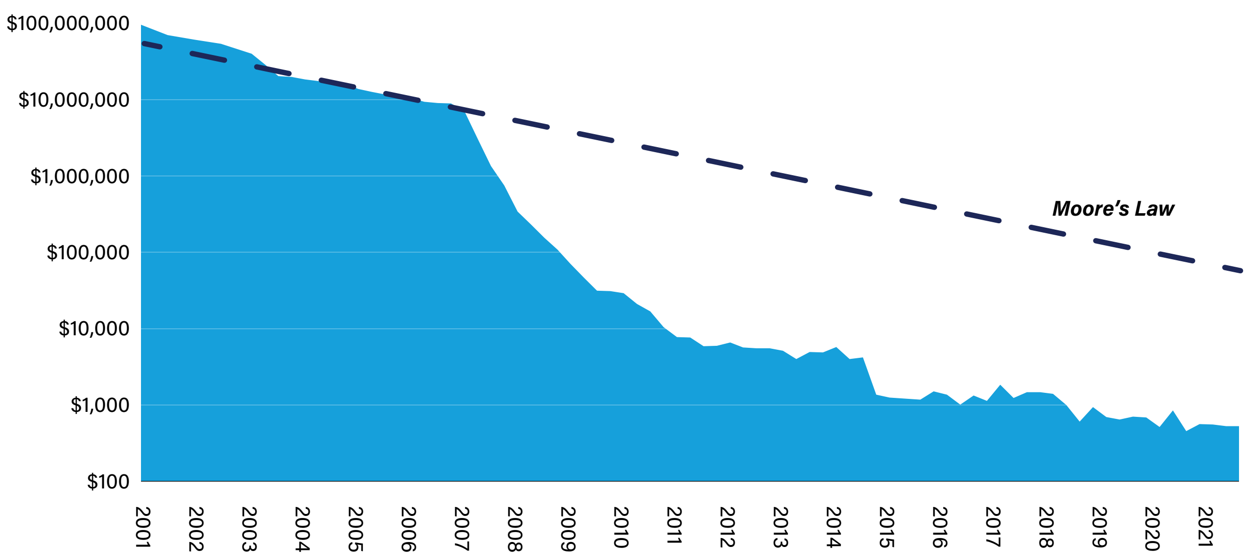
Among the best success stories is Singapore's aggressive genomic surveillance efforts, attributed to its proactive sequencing approach and implementation of travel restrictions on passengers coming from mainland China during the early stages of the pandemic. The country established a robust genomic surveillance system; sequencing many positive Covid-19 cases allowed Singapore to closely track new variants, enabling timely public health responses. Singapore's R&D investment and collaboration among academic institutions and government agencies contributed to the government's overall effective management of the pandemic.

The role of genomics-enabled biosurveillance in protecting national security

Why genomics matters: The future of healthcare

The field of genomics has advanced rapidly over the past few decades, from a distant possibility to an everyday tool. In public health, genomics has to date played an important but relatively niche role; continued breakthroughs in affordability and efficiency will allow it to become a crucial component of ongoing, widespread biosurveillance. The first human genome was fully sequenced in 2003 after 13 years of work, at a cost of nearly $3 billion over that period.[6] Just 20 years later, clinical human genome sequencing—complete with a report interpreting relevant mutations for a given patient—can be completed within 12 hours, at a tiny fraction of the cost. Ongoing improvements in efficiency and affordability mean that for the first time in history, it is feasible to leverage genomic analysis to enhance routine, ongoing biosurveillance.

Cost per human genome



Source: National Human Genome Research Institute

[6] National Human Genome Research Institute: ***Human Genome Project*** Fact Sheet

Genomics in public health: Benefits over traditional methods

The Covid-19 pandemic highlighted the potential of genomics to help inform public health efforts. Rapid sequencing of viruses helped identify which strains were responsible for a given outbreak or uptick in cases. Genomic sequencing allowed researchers to track the virus' evolution and spread. Perhaps most importantly, understanding the function of specific viral genes allowed for the creation of highly effective mRNA vaccines within months. However, in many cases, the virus was sequenced only following a substantial or unusual outbreak, after it had been identified via cheaper and faster PCR or antigen-based methods.

PCR and antigen-based tests will continue to play a vital role in any surveillance program given their ability to quickly identify specific pathogens. However, these tests are extremely limited in their ability to detect novel or emerging pathogens. PCR tests recognize pathogens via small stretches of genetic material (DNA or RNA) with a known sequence. Such an approach would be unable to detect a novel pathogen; new mutations in a known pathogen would also likely go undetected. At times, new mutations can even disrupt the ability of a PCR test to accurately identify a known pathogen. Similarly, antigen-based tests react only to specific proteins from a known pathogen.

Genomic-based pathogen detection systems, on the other hand, have far more flexibility in identifying a novel pathogen, or more rapidly recognizing new mutations in a known pathogen. Next-generation sequencing methods allow for improved agnostic pathogen identification, capable of sequencing genetic material without requiring knowledge of the target genetic material. Furthermore, as these methods generate the actual sequence, rather than simply a positive or negative result, they can detect new mutations in known pathogens. Sequencing can also enable detection of genetic signatures associated with antimicrobial resistance, an ongoing public health threat.

Figure 1: Options for biological threat surveillance

Options for biological threat surveillance

PC: most commonly used definitive lab testing method during the Covid pandemic

- *Advantages:* can detect different variants if target genetic sequence is known, infrastructure widely in place, cost-effective for small numbers of samples
- *Disadvantages:* Can not sequence genetic material to recognize new variants or detect novel pathogens, limited scalability

Antigen tests: used most frequently later in the pandemic due to convenience- largely at-home testing

- *Advantages:* easy to use, no specialized equipment or data analysis required, can rapidly screen at-risk populations
- *Disadvantages:* provide little to no information about different variants, results of at-home testing often not reported/collected, substantial development time required to create a reliable test for new pathogen

Next generation sequencing: used to sequence Covid genomes during the pandemic

- *Advantages:* Can detect new variants and novel pathogens without prior knowledge of target sequences; scalable to large numbers of samples
- *Disadvantages:* Expensive for small samples, requires dedicated data analysis workflow

Source: Eurasia Group's healthcare and medical devices practice

Comprehensive biosurveillance: Combining approaches to look forward

Successful comprehensive biosurveillance requires integrating advanced sequencing methods into a multilayered strategy that employs diverse testing methods across various settings. This proactive approach ensures that potential biological threats are identified in anticipated hotspots before evolving into significant outbreaks, avoiding inefficiencies and learning from sources that serve as early indicators. At present, genomic screening tends to focus on identifying variants that have already triggered outbreaks, but a forward-looking biosurveillance methodology embraces both passive and active surveillance for a more anticipatory and efficient response to emerging threats.

Passive surveillance involves testing a random sample from patients presenting to clinics or hospitals—for example, those with upper respiratory symptoms—and allows public health officials to track which viruses, and some known variants, are responsible for waves of illness. If clusters of cases begin to appear with unusual symptoms, or at unusual times—such as outbreaks of flu-like illness outside of flu season—a more active approach is often initiated. This involves increased sampling and comprehensive sequencing that may help identify a new variant or even a new virus.

Active surveillance also seeks out potential biological threats before they manifest in large outbreaks. The very first case in an outbreak is rarely recognized as such, especially with diseases such as Covid-19 that have symptoms of varying severity. Pathogens may circulate widely in the community before a noticeable number of patients seek medical attention. A key part of active surveillance—testing community and transit (such as aircraft) wastewater[7]—can help identify pathogens as they begin to circulate. In the later stages of the Covid-19 pandemic, the potential of wastewater surveillance was demonstrated by its ability to detect the virus, quantify population illness levels, and even track the appearance of new variants in the community. This was particularly valuable as other sources of reported testing dwindled rapidly.

Active surveillance efforts can be enhanced with genomic sequencing capabilities. In a study conducted on wastewater sampling across 20 European countries' sewage sentinel systems,[8] it was concluded that next-generation sequencing enabled the capture of sufficient SARS-CoV-2 genome from the wastewater samples to obtain information about variants based on the prevalence of key mutations. The study showed that integrating genomic and wastewater-based epidemiology can support the identification of variants circulating in a city.

Case study: Anthrax detection in the US, 2001[9]

Starting in September 2001, letters containing anthrax spores—including ones addressed to senators Tom Daschle and Patrick Leahy—entered the US mail system. The spores sickened 17 people and killed another five. The FBI conducted one of the most expensive and complex investigations in its history, but only upon the application of newly developed genomic analysis methods in 2008 were investigators able to determine the exact strain of anthrax used in the attack, enabling the identification of a suspect. The power of genomic analysis to rapidly identify which strain was being used—and thereby potential sources—could have changed the course of the attacks, given that two sets of letters were mailed weeks apart. This illustrates the importance of biosurveillance for the early detection of potential biothreats.

Case study: Influenza A discovery in the US, 2022

In a 2022 collaborative study with Northern Arizona University, the Pathogen and Microbiome Division of the Translational Genomics Research Institute (TGen North) conducted research on influenza A, aiming to identify the circulating subtype of the virus. The study utilized both wastewater and clinical samples known to be positive for influenza A. By employing the Illumina Respiratory Pathogen Infectious Disease/Antimicrobial Resistance (ID/AMR) Panel, or RPIP, the research team prepared high viral load samples for whole-genome sequencing. The RPIP approach, using bait-capture techniques, demonstrated its versatility by identifying evolving pathogens through greater mismatches and handling a wide array of probes. Subsequently, the team used the Illumina sequencing instruments and analysis pipeline to determine that the virus belonged to the H3N2 subtype of influenza A.[10]

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[7] A global aircraft-based wastewater genomic surveillance network for early warning of future pandemics - The Lancet Global Health

[8] A pan-European study of SARS-CoV-2 variants in wastewater under the EU Sewage Sentinel System

[9] Centers for Disease Control and Prevention: Investigation of Bioterrorism-Related Anthrax, United States, 2001: Epidemiologic Findings

[10] Improving public health management through broader, deeper pathogen surveillance (illumina.com)

Enhanced biosecurity efforts will complement and enhance public health monitoring and required reporting already in place

Passive surveillance

Current approach to surveillance for biological threats

Sampling from outbreaks or cases with unusual symptoms; sequencing of a small percentage of cases testing positive; cases most frequently identified via sites of healthcare delivery- clinics, hospitals

Advantages
infrastructure in place, clinical information regarding symptoms often available

Disadvantages
retrospective, only learn about those who seek care or testing services

Active surveillance

Not yet widely implemented

Ongoing sampling from community sources: wastewater surveillance in geographically representative community and institutional sites, random sampling at major transportation hubs

Advantages
proactive, can detect potential threats before they cause an outbreak, information drawn from a wide range of sources

Disadvantages
potential threats may need to be validated, greater investment in infrastructure and policies required

Comprehensive biosurveillance

Information from both sources combined and analyzed in real time; advanced computing approaches (AI?) allow identification of relevant threats, including likelihood that they will manifest as outbreaks

Threat identification leads to action:
(1) Sharing potential threats with other countries participating in joint biosecurity efforts for further monitoring
(2) Sharing demonstrated threats - those that have manifested in patients with clinical symptoms - with international bodies as required (e.g. IHR)

Source: Eurasia Group

Case study: H1N1 virus discovery in the US, 2009

Military biosurveillance efforts played a key role in recognizing the first cases of the 2009 H1N1 influenza in the US and in several other countries around the world. The first two cases in the US were recognized by the Naval Health Research Center (NHRC), one in a Department of Defense dependent enrolled in a study of influenza diagnostics, and another in an individual at the border who was sampled as part of a collaboration with the Centers for Disease Control and Prevention (CDC) Border Infectious Disease Surveillance Project. Upon recognition of the burgeoning outbreak, the NHRC increased its surveillance capabilities for influenza. Medical research units associated with different branches of the armed forces also recognized the first cases of the new influenza in several other countries, including Nepal, Bhutan, Peru, and Kuwait, among others.[11]

A truly comprehensive biosurveillance approach would combine passive and active surveillance in real time, quickly recognizing new variants or pathogens and comparing that information with data from clinical visits in the area—or even publicly available search engine queries on specific symptoms—to allow rapid identification of potential threats.

National security and economic benefits of investment in biosurveillance

Securing the safety and well-being of a country's population is vital to national security. Recent biodefense publications from multiple governments have highlighted the diverse nature of biological threats: In addition to naturally occurring pathogens, there is a growing threat of engineered pathogens owing to advances in biological engineering. Even well-intentioned research may become riskier, as high-level biosafety labs with inadequate safety

[11] BMC Public Health: Department of Defense influenza and other respiratory disease surveillance during the 2009 pandemic

protocols have proliferated, and technology has advanced faster than regulations and safeguards in many areas of the world.

Whereas novel and emerging pathogens—whether natural or manmade—are perhaps more worrying from a national security perspective, there is also mounting concern about the health and economic impacts of antimicrobial-resistant (AMR) infections. Many of these pathogens do not cause illness in otherwise healthy individuals, but they can cause dangerous infections in patients with compromised immune systems and have proven highly difficult to eradicate from healthcare settings. In 2019, there were an estimated 1.27 million deaths worldwide from AMR infections. These infections are costly as well; it was estimated that more than $4.6 billion was needed to treat a subset of six AMR pathogens in 2017 in the US alone.[12]

Biosurveillance can help fight the spread of AMR infections by detecting the spread of new resistance genes. Resistance is passed genetically from one strain of bacteria (or microbial pathogen) to another. Many AMR pathogens may survive in healthy human hosts without causing noticeable disease, allowing them to spread unnoticed. However, when new AMR genes are detected in wastewater from a given community or hospital, or in sequencing of regularly collected patient samples, that information can help guide the selection of appropriate antimicrobial drugs and other interventions to help more efficiently isolate and eradicate difficult infections.

Case study: Failure to detect resistant tuberculosis strains in Botswana, 2022

A 2022 Botswana-based study emphasized the crucial role of advanced sequencing methods for accurate drug resistance identification. The PCR-based assay most used to identify drug-resistant strains of Mycobacterium tuberculosis (MTBC) searched for mutations within only one section of the bacterial genome. After the assay failed to identify a different mutation—outside of that genomic region—that conferred rifampin resistance, no further testing was ordered (the patient's condition improved after a course of rifampin, but that may have been because of concomitant treatment of advanced HIV). It was only months later that genomic testing— performed as part of the study—identified not only rifampin resistance, but also resistance to five other commonly used antibiotics. Follow-up genomic sequencing of previously collected samples identified a highly similar strain from 2016, indicating that a pre-extensively resistant (pre-XDR) strain of MTBC had been circulating undetected for more than five years.[13]

[12] *Clinical Infectious Diseases*: National Estimates of Healthcare Costs Associated With Multidrug-Resistant Bacterial Infections Among Hospitalized Patients in the United States, Volume 72, Issue Supplement_1, 15 January 2021

[13] Tuberculosis Variant with Rifampin Resistance Undetectable by Xpert MTB/RIF, Botswana - Volume 29, Number 11—November 2023 - Emerging Infectious Diseases journal - CDC

Post-pandemic biosurveillance and early warning capabilities lack robustness

Disease detection primarily comprises passive surveillance

The current scope of disease detection activities varies across countries and consists primarily of passive surveillance. In most countries, large passive surveillance programs—including genomic testing of a proportion of patient samples—that were established during the pandemic have been drastically reduced in scale. Surveillance is somewhat augmented relative to pre-pandemic levels but remains comprised mostly of reporting cases of respiratory disease presenting to health clinics or hospitals.

These systems vary by country. In the US, the CDC employs a range of surveillance programs, whose coverage and focus vary widely. Current reform efforts aim to increase states' responsibilities to report data to the CDC, but this has encountered political resistance. In Europe, a passive surveillance system relies on sentinel sites—which mainly provide primary and secondary care—that cover 1%-5% of each country's population. The system had been in place before the pandemic to track influenza outbreak dynamics and was modified and expanded to help meet the wider surveillance and variant tracking needs of the pandemic. WHO recommendations involve building on this infrastructure as the primary means of viral surveillance in Europe; a report issued ahead of the 2022/2023 flu season called for whole genome sequencing of all positive samples identified via sentinel clinic sites.

Figure III: Present-day global disease surveillance: A snapshot of varied detection systems by governments

Country	Selected organizations and role
US	• **Health and Human Services (HHS):** National Biodefense Strategy charges the agency with ambitious goals in pandemic prevention and preparedness, with several of its component organizations • **Centers for Disease Control (CDC):** Multiple viral surveillance programs with differing scope; coordinates wastewater surveillance efforts (still under development) • **National Institutes of Health (NIH)** and **Administration for Strategic Preparedness and Response (ASPR)**
EU (Germany, France, Italy)	• **European Centers for Diseases Control (ECDC):** Disease surveillance through sentinel providers • **Health Emergency Preparedness and Response Authority (HERA):** Some wastewater surveillance; more formalized responsibilities for response and readiness
UK	• **UK Health Security Agency (UKHSA):** Regular disease surveillance • **Environmental Monitoring for Health Protection (EMHP):** Wastewater surveillance effort by UKHSA in coordination with several other departments; active during pandemic, now disbanded *Updated biosecurity strategy should be forthcoming; earlier reporting suggested it would be completed by now, but government upheaval seems to have delayed it*
Japan	• **National Institute of Infectious Diseases (NIID):** Weekly reports from sentinel providers on a range of infectious diseases *Limited attempts at wastewater surveillance underway, will need more formalized cooperation between land ministry (sewage system) and health ministry*
Canada	• **Center for Immunization and Respiratory Infectious Diseases (CIRID):** Regular disease surveillance, also plays role in response and international collaboration • **Public Health Agency of Canada:** Currently developing wastewater monitoring infrastructure

Limitations of the global system

The current system portrays known illnesses among patients who contact the healthcare system in each country but is limited in its ability to recognize new or emerging pathogens. Furthermore, any pathogens that circulate within the community but have not yet caused severe symptoms in a substantial number of individuals, as is often the case early in an outbreak, will be difficult or impossible to recognize.

Africa experiences more public health crises than any other continent annually, with an estimated 140 outbreaks per year.[14] Many of these crises remain preventable with the right deployment method and public health interventions, but current early warning and response capacities have many vulnerabilities and are ineffective in swiftly detecting and responding to disease outbreaks.

The limitations of the US system were on display in the summer of 2022; many of the same mistakes in test development and deployment seen nearly three years earlier with Covid-19 were repeated in the face of a new threat from Monkeypox (Mpox). Ultimately, Mpox proved far less infectious than Covid-19, but the speed with which it spread—and the difficulties encountered in testing for it—provided a stark reminder that the current infrastructure is insufficient to respond quickly to a new or emerging pathogen.

Even if flaws in test development and availability were corrected, the current system would still be limited by its dependence on passive surveillance. Apart from Canada's flu watcher program, which gleans information from self-reported symptoms from a regularly monitored population, every substantial disease monitoring program relies on patients who seek care from the healthcare system. Given that many diseases range in severity, or become worse over time, it is likely that a newly introduced pathogen would spread widely in the general population before more than a small handful of individuals seek care. Even the most robust passive surveillance systems do not test every patient and are therefore likely to be delayed, at best, in their ability to pinpoint the pathogen responsible for a new outbreak.

Active surveillance remains limited despite interest in environmental monitoring

Of the options available for active surveillance, the most well-developed is wastewater monitoring. Wastewater surveillance was used in the latter part of the pandemic to assess regional population viral load and has successfully identified Mpox and polio—down to the specific vaccine-associated strain. In the process, it generated data used to inform public health efforts such as vaccination campaigns. Most developed economies have implemented some level of wastewater surveillance and are actively working to improve the necessary infrastructure and governance to support such a system, but progress and commitment can vary by location.

In the US, the National Wastewater Surveillance System,[15] overseen by the CDC, is still in its early stages. Proper functioning requires coordinated participation from local municipalities, health officials, and academic or commercial labs, among others. Geographic coverage and testing capabilities vary considerably across the country, with genomic sequencing used infrequently or not at all in many areas. The country's Biodefense Posture Review, released in August, calls for better environmental monitoring via wastewater surveillance, though not all the necessary funding has been committed.

On the contrary, the newly established US Bureau of Global Health Security has a clear mission: to improve international collaboration for the proactive prevention and effective management of infectious diseases. Although the bureau's formation underscores the increasing recognition of disease monitoring as a matter of national security, and the consolidation of fragmented disease outbreak prevention initiatives to enhance efficiency, it does not explicitly address wastewater surveillance.

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[14] Africa CDC: Institute of Pathogen Genomics (IPG)

[15] Centers for Disease Control and Prevention: National Wastewater Surveillance System (NWSS)

Furthermore, the bureau primarily focuses on advancing the country's HIV policies.

The EU has announced support for increased wastewater surveillance, but the current coverage and scope vary dramatically across the region. The Digital European Exchange Platform was created during the pandemic to facilitate cross-border sharing of wastewater surveillance data and has been identified as a valuable resource to help HERA track new and (re)emerging pathogens such as Mpox or polio. Although not every member state participates, the European Commission has identified wastewater surveillance as a key part of efforts to establish integrated and coordinated surveillance systems and has pledged to support member states with up to €20 million through the EU4Health program.[16]

In the UK, a robust national wastewater sequencing program was implemented during the pandemic under the UKHSA's EMHP,[17] a collaborative monitoring effort that covered 74% of England's population. Samples were taken from hundreds of sites three to four times per week and sequenced to determine the presence of new Covid-19 variants. While the level of surveillance was reduced substantially as of March 2022, the infrastructure remains in place and can be relied upon if needed to help guide public health responses, as demonstrated when used to detect poliovirus from February to July 2022.

In addition to community wastewater surveillance, active monitoring of wastewater from international aircraft represents a promising approach to recognizing pathogens arriving from other countries. International travel helped spread the SARS-CoV2 virus and its subsequent variants around the world. Monitoring aircraft wastewater would allow the sampling of nearly every passenger on a long-haul flight via noninvasive methods, enabling the recognition of any new biological threats. In early implementation efforts during the pandemic, genomic sequencing was able to identify specific variants from aircraft wastewater, demonstrating the feasibility of this option.

Organizations and mechanisms in place to support pandemic preparedness

In response to shortcomings in their Covid-19 responses, many advanced economies have embarked on creating a new biosecurity plan or strategy to help prevent or prepare for the next pandemic. They all include similar goals of being able to detect threats early and respond appropriately. However, there is a range of formal structures and committed funding for preparedness and response.

President Joe Biden's administration has published a lengthy document outlining ambitious goals that will require participation from and coordination among multiple US agencies, but the full funding necessary to achieve these goals has not been committed, nor has all the necessary supporting legislation been enacted. Congress was due to renew the Pandemics and All Hazards Preparedness Act[18] by 30 September, yet partisan disagreements over proposed amendments have complicated the reauthorization process. It remains to be seen how Congress will overcome these challenges to authorize the renewal.

On the other hand, in the EU, HERA has been granted significant authority and funding to prepare for, detect, and respond to potential biological threats. Its efforts are supported by a committed €6 billion from the central EU budget over a six-year period (2021-2027). The organization will exist in two modes with different mandates. During the preparedness phase, HERA will coordinate threat assessment and surveillance efforts, as well as readiness activities such as ensuring sources of and stockpiling essential medicines and equipment. In the event of an EU-level public health emergency, HERA will transition to "crisis" phase with a shift in organizational structure—including a crisis board with representatives from all member states—and a mandate to ensure that resources accumulated during the preparedness phase are appropriately utilized throughout the region. During the coronavirus pandemic, HERA operated a centralized

[16] EU4Health programme 2021-2027 – a vision for a healthier European Union

[17] UK Health Security Agency: Environmental Monitoring for Health Protection (EMHP); wastewater monitoring of SARS-CoV-2 in England: June 2021

[18] US Department of Health & Human Services – Pandemic and All Hazards Preparedness Act (PAHPA)

wastewater surveillance program and purchased materials needed across member states; the system has continued during the Ukraine war to identify potential diseases coming into Europe. HERA has expressed plans to continue financing water analysis.

The UK has also devised a new framework for preparedness and response capabilities. Central to this plan is the new biothreats radar, which comprises data collection and synthesis from myriad sources to better understand potential threats. This understanding will be combined with increased investment in pathogen detection efforts and greater support for international response efforts, as well as more clearly delineated domestic response plans. The government has pledged £1.5 billion annually to support these efforts. These largely build on existing structures, including the National Situation Centre, which was created during the pandemic to synthesize information from numerous sources to guide government responses to national security challenges.

International Health Regulations require prompt reporting, but enforcement is limited

Nearly every country has signed on to the International Health Regulations (IHR), which comprise a set of commitments for outbreak detection, response, and reporting that are legally binding under international law. Included in the current IHR is a commitment for each state to be able to detect and report acute public health events in a timely manner. However, the speed and accuracy of reporting are often affected both by health system capacity and political considerations, and there is virtually no consequence—except for reputational damage—for noncompliance.

Efforts are underway to update the IHR to improve accountability and equity in how it is implemented; changes are expected to be adopted by the World Health Assembly in early 2024. Yet even perfect compliance with the IHR may not provide the advance notice needed for early warning of biological threats. Reportable public health events are necessarily only recognized after individuals have been sickened; and in many cases, even the most rapidly required reporting up the chain of public health infrastructure within a country will lag information available via social media or other sources. The current requirements for disease detection infrastructure and public reporting are simply outdated relative to the capabilities that have been developed in many countries.

Building a sustainable biosurveillance framework requires governance, infrastructure, funding, and international collaboration

A sustainable, comprehensive biosurveillance program is one that encapsulates global coverage, meticulous resource distribution, established standardizations for best practices, and data sharing with opportunities for geographical customization. It also means looking at various sources through a One Health[19] lens for a variety of threatening disease states. To truly embrace the concept of One Health requires scrutinizing diverse data sources through a holistic lens, considering the intricate interplay among human, animal, and environmental health.

Such a program merits a formalized commitment and establishment of governance, infrastructure, tools, and technologies, as well as funding. As described in the previous section, some variation of a biosurveillance program is underway across several key countries and regions—notably, the US, the UK, and the EU—all of which seek to prevent, control, and mitigate. It is reassuring that what is needed to conduct comprehensive biosurveillance is not a far cry from present-day reality. In fact, when Covid-19 tracking efforts were winding down, the uptake of sewage data increased considerably. That said, the pace of implementation and scope vary significantly, not just by country but across communities. In the US alone, many subregions and communities are excluded from national active surveillance. In the UK, data collected from sewage water is generally reported inconsistently because of

[19] WHO's One Health

unreliable funding, suggesting the need to strengthen capabilities through proper investment.

On the other hand, there is already steady infrastructure in place to conduct passive disease detection; the height of collaboration between public and private players during the pandemic demonstrated what the world can accomplish together within a short period of time. Passive detection programs worked, however, not just because of collaboration, but because there was an abundance of funding and resources from the central governments to sustain the work.

There is clear momentum to increase resource capacity as well as the political will to create a national—and ultimately global—genomic surveillance network for the future.

Governance

While governments lack any power to influence the national strategies of other countries, it is imperative to discuss and unify capabilities and accountability measures. First, countries that continue to treat biosurveillance as a public health interest will often face low resources and less political will to advance this work. Moreover, these efforts are no longer siloed and should not be seen as such; water samples that indicate the existence or spread of diseases are as much an economic interest as a public health matter. As discussed, biothreats are, and should be, a national security concern. There must be a recognition of which segments of the program are led by the defense arm versus the public health authorities to ensure governments can coordinate and align on what constitutes a national defense interest. Amid ongoing geopolitical challenges related to the nationalization of population health data, there must also be an agreement on the type of data that is shared, ensuring anonymity can be safeguarded as well as proprietary public health information and a mutual commitment for information-sharing.

Infrastructure, tools, and technologies

Countries must devise a strategic plan, leveraging existing surveillance initiatives while adding to global preparedness efforts. A well-supported and coordinated infrastructure will be critical to ensure that incoming wastewater, health, and travel data are integrated and analyzed in real time. Such an infrastructure would include digital and physical data storage capacities, physical sampling locations, rapid testing and interpretation, and collection of clinical data; timely integration and analysis of all the data generated from these systems can be enabled through machine learning capabilities.

Fortunately, the necessary tools and technologies needed to implement an advanced, comprehensive biosurveillance system already exist. Nevertheless, improvements in the implementation of advanced testing methods will be needed in both passive and active surveillance to maximize the ability to recognize new biological threats.

To improve passive surveillance, accurate testing needs to be available more rapidly, and for a greater range of patients. Limited testing availability was seen both early in the Covid-19 pandemic and as Mpox spread in 2022, linked to delays in test development and overly strict criteria defining which patients to test. More widespread testing of patients showing new or unusual symptoms will facilitate earlier recognition of new biological threats. Greater use of pathogen-agnostic testing in particular will be needed to more quickly determine which pathogens might be responsible for an unusual outbreak. Rather than testing for one or even a few known pathogens, this approach's ability to sequence genetic material allows for the identification of new or emerging pathogens and recognition of new variants that may affect transmissibility or virulence.

While active surveillance will also benefit greatly from more widespread implementation of genomic sequencing, far more work is needed to bring these systems fully online. In the countries that have begun developing wastewater surveillance systems, improvements in sampling coverage are necessary to ensure that the data accurately represent the full population. Additional work will be necessary to devise and validate testing methodologies for new pathogens—for example, how much dilution can occur before testing methods will be unable to recognize a specific virus. Furthermore, current delays in sample processing must be addressed to ensure that genetic material does not degrade, and that actionable data are generated. A delay of days or even weeks (as sometimes occurs now) from sampling to results will greatly diminish the value of widespread sampling and sequencing.

A robust data infrastructure and analysis platform will also be required to take full advantage of the information generated by active and passive surveillance. Signals from passive surveillance—for example, numbers of new patients exhibiting specific symptoms—can help guide more intensive sampling efforts in a region and provide insight into the relevance of any new variants or potential threats detected through active surveillance efforts. The detection of a new pathogen or variant via active surveillance can likewise help clinicians be more alert to those diseases—and increase testing rates—for patients with otherwise generic symptoms.

Robust data infrastructure and workflows will be required to allow real-time feedback among the different information streams. In addition, the public health community needs protocols for managing the detection of notifiable agents, as many entities are reticent to have them analyzed in the first place, for fear of the ensuing cascade of events (for example, the implications of Ebola being detected in wastewater).

Funding

Concerted and sustained funding is necessary to make a comprehensive biosurveillance system a reality, and statutory authorization from national legislatures specific to these initiatives would help ensure ongoing funding and commitment (as opposed to episodic funding offered only during public health emergencies, which dries up as soon as the central government deems the emergency is largely over).

In the aftermath of the Covid-19 pandemic, many governments pledged to improve pandemic preparedness, both within their borders and through international mechanisms such as the WHO. In practice, commitments have been mostly vague and nonspecific, such as statements pledging support for a global pandemic fund (for example, the $250 million pledged contribution from the US Agency for International Development to the pandemic fund to support pandemic prevention, preparedness, and response).

Bolstering international efforts will be crucial to help better prepare the world for the next pandemic, but countries cannot cede responsibility for biosurveillance to these organizations while expecting the same domestic systems that were in place before Covid-19 to yield better outcomes in the future. Rather, national interests require countries to invest proactively in their own biosecurity. Fortunately, such an investment has a positive externality in that the ability to provide early warning of new or emerging pathogens will benefit the world—and not just the individual country doing that surveillance.

The reality is that current investments at the national and regional levels vary and may not be sustainable. Nearly every developed country has published an updated biosecurity plan, and some have created new agencies or departments to spearhead pandemic preparedness efforts. However, as the urgency of the coronavirus pandemic has receded, funding for public health initiatives is at risk of being deprioritized. As vital as it is to national security, biosurveillance should receive dedicated funding to enable its implementation and success.

Governments must establish ongoing and sustainable funding dedicated to biosurveillance efforts within borders, not just a commitment to a broad global "pandemic fund." While the US and the EU have announced increased funding for wastewater surveillance, implementation is lacking; pressure is needed to maintain the necessary investments.

Call to action: Advance global cooperation through a comprehensive global biosurveillance framework

In the pursuit of establishing a strong biosurveillance framework, it is evident that success hinges on concerted global efforts. The challenges outlined, spanning geopolitical tensions, resource disparities, and the need for sustained funding, underscore the complexity of the task at hand. Recognizing these hurdles, the call-to-action section of this report outlines strategic imperatives designed to spur progress toward a more resilient biosurveillance ecosystem.

These actions encompass advocacy for global cooperation, strengthening existing frameworks, identifying good practices, fostering public-private partnerships (PPPs), and moving forward with available resources while striving for continuous improvement. Addressing these imperatives requires policymakers to engage in collaborative efforts with civil societies, genome sequencing entities, and wastewater surveillance data-gathering companies. Together, they can forge a path toward a collaborative and adaptive biosurveillance landscape that transcends borders, encourages innovation, and actively safeguards global health security.

Advocate for global cooperation amid geopolitical challenges

Given the complex political challenges that may hinder global cooperation in the field of biosurveillance, it becomes increasingly important to explore avenues for effective collaboration. Further compounding this issue are the growing trade restrictions between the US and China; December 2023 legislation to limit the export of human gene editing technologies is suggestive of China's determination to limit US competition, particularly in the biotech sector. China's recent overtures to the Middle East may also complicate engagement with countries in the region.

In addition, there may be reluctance to join these efforts among certain countries in Russia's sphere of influence, such as Syria, Venezuela, and several African states. In their determination to balance stable relations on all sides, they may be less receptive to a major multinational push seen as coming exclusively from the West. Gaining their cooperation will be a significant undertaking.

The pandemic also brought to the fore notable resource differences (such as a long history of inequalities in health and access to health services) between the Global North and South. Yet addressing inequalities in infrastructure may present an opportunity to cooperate in building genomic sequencing capabilities, which would serve the countries' interests while providing valuable biosurveillance points.

Within politically divided countries such as the US, complications are likely to arise from potential misunderstandings over biosurveillance. A certain level of clarity or reassurance about active detection is needed—for example, explanation of the type of data points needed for wastewater monitoring and an expanded awareness of pathogen detection for citizens. A recent report on the state of wastewater-based disease surveillance from the US National Academies of Sciences, Engineering, and Medicine[20] states that biosurveillance infrastructure should never be used by law enforcement even as detection abilities improve.

These challenges cannot be overlooked, but they can be managed. The Covid-19 pandemic reminded the world that disease outbreaks at one end of the globe can reach home overnight. As such, the cooperation of Global North and South countries—in a way that has not happened before—will be critical to the success of any global biosurveillance effort, and favoritism or alienation of countries— as was seen in 2020—will not enable this feat. What will be required is concession-making: an agreed-upon transfer of

[20] National Academies of Sciences, Engineering, and Medicine. 2023. Wastewater-based Disease Surveillance for Public Health Action. Washington, DC: The National Academies Press. https://doi.org/10.17226/26767.

information determined by participating countries and a trade of resources.

Strengthen existing frameworks

Existing frameworks provide a solid foundation for a workable model that allows for concessions and is shaped by the realities of the geopolitical environment. The WHO's extensive work in genomic sequencing for pathogen surveillance should serve as the foundation for a working model. The Genomic Surveillance Strategy,[21] endorsed by all 194 member states, aims to ensure universal and prompt access to genomic sequencing for potential pandemic and epidemic pathogens by 2032. Member states are urged to contribute SARS-CoV-2 genetic data to a publicly accessible database, fostering risk assessment on national, regional, and global scales. The strategy's focus on timely data sharing through a national pathogen genome data-sharing policy—which is vital for effective public health risk evaluation—along with close collaboration among countries' surveillance networks, is of paramount importance. In addition, the WHO's call for engagement from stakeholders such as policymakers, public health officials, the private sector, academia, laboratory experts, and information system specialists cannot be overstated, as their integration forms the foundation of a successful surveillance network.

The "7-1-7 framework" established by an African public health NGO, Resolve to Save Lives, should be seen as another prime example. The framework calls for a strategy to detect a suspected public health threat within seven days, notify the appropriate public health authority within one day, and complete the verification and initial response within seven days. The WHO's regional office for Africa adopted these targets as part of its regional strategy for health security and emergencies (2022-2030). A greater emphasis was placed on event-based surveillance: collection, monitoring, assessment, and interpretation of unstructured ad hoc data regarding health events. The system would rely on a robust frontline healthcare workforce and tailored regional approaches to threat surveillance. Rapid response inter-sectoral outbreak assessment support units would be established across five CDC locations: Zambia, Gabon, Kenya, Nigeria, and one other (to be determined).

The creation of the Common Vulnerabilities and Exposures (CVE) program[22] is an example of a contemporary framework that successfully resolved the issues of redundant and inefficient global efforts. The program, initiated by the cybersecurity community in 1999, sought to address the need for a standardized method of identifying and tracking vulnerabilities in software and hardware systems. Prior to the program, there was no standardized way to identify and reference vulnerabilities; different organizations used various names for the same issues, making collaboration challenging. The CVE intended to help international organizations share exposures more efficiently and consistently.

When the CVE was launched, it introduced a standardized naming convention and a publicly accessible database in which vulnerabilities could be assigned unique identifiers. CVE IDs are now used widely in security tools and databases. Similarly, the biosurveillance model can operate in a similar fashion, acting as an essential part of the national security landscape.

Identify good practices and leverage multiple value streams

The October 2022 meetings of the Weapons and Materials of Mass Destruction Working Group and the Conference on Biosecurity Challenges provided a solid foundation for the adoption of a comprehensive biosurveillance framework by well-resourced countries. In their May 2023 communique, the G7 health ministers emphasized the imperative of strengthening the pandemic preparedness ecosystem and achieving health innovation through international cooperation.[23] France's Sante Publique France

[21] WHO Genomic Surveillance Strategy
[22] Common Vulnerabilities and Exposures (CVE) program
[23] G7 Nagasaki Health Ministers' Communique, May 2023

(SPF), a trailblazer in virus tracking through human feces monitoring, incorporated its microbiological wastewater monitoring data into its epidemic indicators as part of its SUM'Eau system. This practice, alongside similar initiatives from other countries, highlights the potential for widespread adoption.

A compelling call to action is directed at well-resourced countries—specifically, members of the G7 and the G20—urging them to build upon calls to action proposed in the WHO Pandemic Agreement. This includes Article 12, which calls on all parties to agree to a multilateral access and benefit-sharing system for timely and equitable access to pandemic-related products.[24] Simultaneously, there is a moral responsibility transcending borders, compelling these states to rectify past actions that isolated the Global South. A renewed commitment to global cooperation includes active participation in policy dialogues and recognition of ongoing efforts outside of these "leading" countries.

Whereas identifying leverageable best practices and resources within well-resourced countries is crucial, it is equally if not more essential to recognize multiple value streams across various socioeconomic groups and countries. The Africa CDC's 7-1-7 framework, focusing on real-time early warning and response systems with localized customization, exemplifies this approach. Recognizing the pivotal work of the Africa CDC, expanding on successful frameworks such as the 7-1-7 model is important, emphasizing a push for tailored regional approaches and event-based surveillance involving frontline healthcare personnel. The establishment of a dedicated resource mobilization unit acting as an economic think tank for innovative financing mechanisms promises sustainable benefits.

HERA and the Joint Research Centre have taken a notable step in establishing a global consortium for wastewater surveillance, contributing to the growing momentum in this area.[25] Acknowledging the cost-effective potential of wastewater surveillance for early disease detection and emphasizing environmental monitoring, their initiative addresses key components that have yet to be realized to achieve the proposed "robust" system: data sharing, interoperability, capacity building, and collaboration among stakeholders. The emphasis is on crucial locations for real-time surveillance of specific pathogens, enhancing overall response capabilities. In conclusion, maximizing biosurveillance efficiency involves integrating diverse value streams. For example, samples from wastewater monitoring provide insights for biodefense, early outbreak warning, flu vaccine strains, polio monitoring, and antimicrobial resistance; such a comprehensive approach streamlines processes and showcases the potential for understanding different biological threats across various stages. This can be accomplished through identifying best practices, shared data repositories, and collaborative initiatives to strengthen the integration and flow of information and foster a unified response.

Achieve innovation through PPPs

The private sector must take on a bigger role in contributing to PPPs to advance the implementation of the WHO's guidelines and global biosurveillance initiatives. A compelling avenue for collaboration involves gene-sequencing companies and wastewater management firms. In 2023, Concentric, Ginkgo Bioworks' biosecurity unit, partnered with Ukraine's Ministry of Health to launch a pilot program for monitoring pathogens in wastewater, serving as an early warning system for disease outbreaks. The ongoing war in Ukraine has placed significant strain on the country's healthcare infrastructure, heightening the risk of infectious diseases spreading nationwide. Ginkgo will expand its pathogen-monitoring platform to establish a biosecurity program on the ground, covering wastewater systems.[26]

[24] Bureau's text of the WHO convention, agreement or other international instrument on pandemic prevention, preparedness and response (WHO CA+); 2 June 2023

[25] The European Commission lays the foundations for a global system for wastewater surveillance for public health

[26] Concentric by Ginkgo

Amid the current crisis, Ukraine has acknowledged the imperative to safeguard its increasingly vulnerable public health. Likewise, governments committed to preventing uncontrolled infectious disease transmission and protecting their national security and public health interests must closely collaborate with these companies. Together, they can consistently innovate and leverage essential data at the local and state levels, particularly through nationwide data sampling and the creation of an open-source environment. This symbiotic relationship offers mutual benefits, effectively securing the private sector's operations, supply chains, and workforce while advancing the government's security agenda.

The synergy between governments and private entities, represented by gene-sequencing and wastewater-management firms, holds vast potential for continuous innovation and data leverage even at local and state levels. In navigating the intricate landscape of biosurveillance, the involvement of the private sector emerges not merely as a strategic necessity but as a transformative force. For instance, collaboration among a country's defense agency, its public health agency, gene-sequencing firms, and wastewater-surveillance companies can be pivotal. The defense agency can contribute its expertise in threat analysis, risk assessment, and strategic planning, aligning these efforts with gene-sequencing technologies to enhance early detection of potential biological threats. By leveraging cutting-edge genomics technologies, the defense agency can work closely with the public health agency to swiftly identify novel and emerging pathogens, contributing to a more proactive and agile response to biosecurity challenges.

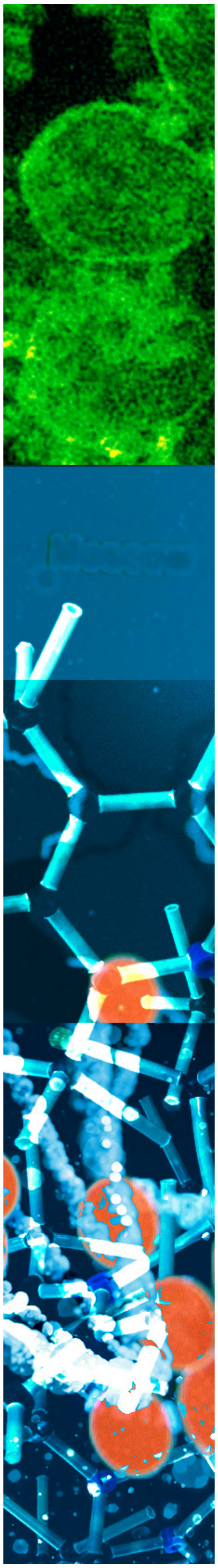
Simultaneously, wastewater surveillance companies can collaborate with public health agencies to implement environmental monitoring strategies. Wastewater surveillance offers a unique avenue for real-time monitoring of specific pathogens circulating within communities. The public health agency, with its understanding of epidemiology and community health, can work in tandem with these companies to establish comprehensive wastewater surveillance programs. This collaboration facilitates early warning systems for disease outbreaks, providing crucial data for timely public health interventions. Moreover, the combined efforts of defense agencies, public health agencies, and private sector partners create a synergistic approach to biosurveillance, enhancing a country's overall resilience against biological threats.

Move forward with available resources while striving to improve the biosurveillance framework

It is crucial not to be deterred by the perceived lengthiness of the process, as reaching a final state requires iterative refinement based on feedback from relevant stakeholders and data. The key takeaway is to promptly enact these urgent actions, fostering a comprehensive approach within and among countries, thereby proactively addressing and preventing future biological threats with the available resources. This approach involves identifying the gaps, mobilizing resources effectively, and executing actionable strategies—an imperative journey toward creating an effective model that draws upon accumulated lessons over time.

As countries enter this process, it is important for policymakers to embrace the notion that the value lies not solely in the endpoint but in the ongoing, adaptive process of refinement and improvement. A biosurveillance framework that remains agile, incorporating lessons learned and emerging practices, will stand as a testament to the enduring value of continual progress.

Conclusion



Despite commendable efforts and declarations of heightened preparedness following the Covid-19 pandemic, a *truly proactive and interconnected biosurveillance framework remains an aspiration*. The pandemic provided a sobering wakeup call, laying bare the world's vulnerability to unforeseen biological threats and instigating a recalibration of national security priorities.

Fortunately, there are tools and resources to build upon. In recognition of this, noteworthy initiatives, such as the US's Biodefense Strategy, the EU's HERA, the Africa CDC's 7-1-7 framework, and the UK's Biothreats Radar, bear witness to this paradigm shift, signaling a collective acknowledgment of the paramount importance of safeguarding against biological risks. Concurrently, a parallel surge in endeavors to fortify public health infrastructure and coordination has manifested in the ongoing process of developing the WHO Pandemic Treaty.

At the same time, as the world confronts the unpredictable nature of biological threats and their remarkable pace in transcending national borders, the imperative for a comprehensive approach within each country becomes increasingly evident. Countries must acknowledge the urgency of adopting holistic biosurveillance systems that stand as a sentinel, monitoring diverse data sources and delivering swift alerts to healthcare providers and policymakers at the first signs of a potential threat. The proposed framework encompasses seamlessly integrating passive and active surveillance in real time, with cutting-edge genomics technologies—notably, widespread genomic sequencing—to prevent the emergence of known and novel pathogens alike. It also calls for a comprehensive program that transcends silos, creating connections between defense and public health interests to fortify collective resilience.

Within a country, the blueprint for an ideal system involves a nuanced, multilayered approach—a marriage of active surveillance points, such as community and travel hub wastewater monitoring, with strategically positioned passive surveillance within the healthcare infrastructure, and harnessing the symbiotic relationship between PPPs and biosurveillance. Among countries, international collaboration and trading of necessary resources—with an understanding that this will protect everyone's public health and national security interests—will be key.

Governments should therefore also leverage the promise of collaborative endeavors among like-minded countries with shared values and objectives, particularly as geopolitical dynamics create greater rifts (both among countries and concerning resource access). Initiatives undertaken by the US, Europe, the WHO, and the Africa CDC exemplify these promising starting points, showcasing the potential when advocates for global health pool resources and expertise.

The need for decisive action is evident. Governments face the challenge of not only understanding the significance of a robust biosurveillance framework, but also actively recognizing and resolving resource gaps. It is crucial to start promptly with an "imperfect" model and iterate as more resources become available, rather than proceeding in a cautious and time-consuming way with a "perfect model." With this understanding as a cornerstone, the path forward becomes clear: prioritize global collaboration, fortify existing frameworks, identify best practices, and foster innovation.

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