

## Learning from the Past – Pandemic Readiness in 2025

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## ABSTRACT

**Background** - The COVID-19 pandemic laid bare the deep vulnerabilities within global health systems, sparking an unprecedented wave of investment and reform in pandemic preparedness. This narrative review explores progress from 2020 to 2025 across critical areas such as healthcare infrastructure, PPE manufacturing, disease surveillance, vaccine equity, workforce resilience, governance, and risk communication. High-income countries have made notable strides in expanding surge capacity and digital health systems, while low- and middle-income nations continue to grapple with fragile infrastructure, unequal access to medical tools, and persistent workforce challenges. Global initiatives like COVAX and the Pandemic Fund have improved the distribution of vital resources, yet political friction and operational hurdles continue to limit their full potential. Innovative approaches such as the One Health framework and regional vaccine production hubs are beginning to reshape the global preparedness landscape. Still, significant implementation gaps remain. To truly strengthen resilience ahead of future health emergencies, the world must commit to a unified legal framework, sustained long-term financing, and equitable access to innovation for all.

**Keywords:** Pandemic preparedness, COVID-19, Vaccination, Health systems, PPE, Surveillance.

## INTRODUCTION

The COVID-19 pandemic of 2019-2021 starkly exposed global vulnerabilities in health systems, supply chains, and international coordination efforts<sup>1</sup>. In response to these challenges, countries worldwide implemented structural reforms, expanded healthcare infrastructure, and invested significantly in pandemic preparedness<sup>2</sup>. As we reflect upon these efforts leading up to 2025, this narrative review evaluates the progress achieved and the persistent gaps in pandemic readiness.

High-income countries (HICs) have made substantial strides in enhancing healthcare infrastructure, digital surveillance capabilities, and personal protective equipment (PPE) manufacturing<sup>3</sup>. Investments in modular field hospitals, ICU capacity expansions, and digital health systems exemplify the advancements in emergency preparedness<sup>4</sup>. Conversely, low- and middle-income countries (LMICs) continue to grapple with fundamental healthcare access issues, inadequate water and sanitation infrastructure, and unstable electricity supplies<sup>5</sup>. Despite commendable initiatives such as the WHO's Health Systems Strengthening programs and OECD recommendations, significant disparities in readiness persist across nations<sup>6</sup>.

The methodology employed in this review synthesizes findings from publicly available policy reports, institutional databases (including WHO, Gavi, and the World Bank), peer-reviewed literature, and grey literature sources spanning from 2020 to 2025<sup>7</sup>. Key themes are identified through qualitative review, contextualized by regional and income level analyses. This review does not include original data collection or meta-analysis but draws upon

reputable sources such as the Gavi COVAX initiative and reports by organizations like McKinsey & Company, WHO, and the IMF<sup>8</sup>.

Despite notable advancements, gaps remain pronounced, particularly in LMICs where reliance on international aid to meet minimum healthcare standards during emergencies persist<sup>9</sup>. This review underscores the imperative of equitable investment in global health security, fostering global solidarity, and implementing comprehensive preparedness strategies to ensure sustainable pandemic resilience<sup>10</sup>. The equitable distribution of resources and robust legal and governance frameworks emerge as critical priorities in reforming global health systems<sup>11</sup>.

## Methodology –

This narrative review was conducted to assess progress in pandemic preparedness globally from 2020 to 2025, with a focus on key domains including healthcare infrastructure, supply chains, surveillance, workforce resilience, equity, and governance. The review synthesizes findings from both peer-reviewed and grey literature, as well as reports from leading global health institutions.

### Data Sources

Information was retrieved from:

- Peer-reviewed journal articles published between January 2020 and April 2025
- Reports and datasets from multilateral organizations (WHO, World Bank, Gavi, IMF, OECD)
- Global health policy briefs and white papers from institutions such as McKinsey & Company and the Rockefeller Foundation
- Publicly available institutional dashboards and country-specific pandemic response reports

A manual search of official organizational websites and institutional repositories was also conducted to capture recent unpublished or non-indexed materials relevant to the post-COVID-19 preparedness landscape.

### Inclusion Criteria

Sources were included if they met the following criteria:

- Published between January 1, 2020, and April 30, 2025
- Provided data or qualitative insights on pandemic preparedness, response, or resilience strategies
- Focused on national or regional health system reforms, infrastructure development, or global coordination efforts
- Reported on low, middle, and high-income countries across multiple WHO regions
- Were published in English

### Exclusion Criteria

Sources were excluded if they:

- Focused solely on clinical or virological aspects of COVID-19 without addressing preparedness or health systems
- Were editorials, opinion pieces, or non-systematic blogs without data or institutional endorsement
- Were duplicate reports or interim versions of more comprehensive later publications
- Described interventions unrelated to infectious disease preparedness (e.g., economic stimulus unrelated to health systems)

### Data Synthesis

Key themes were identified through qualitative synthesis. Findings were grouped by thematic areas such as PPE, surveillance, and governance and further stratified by income level and region. No meta-analysis or statistical pooling was performed due to the narrative nature of the review.

## RESULTS

### Healthcare Infrastructure and Surge Capacity

In high-income countries (HICs), significant capital investment enabled facility upgrades, expansion of ICU beds, and retrofitting of hospitals with negative-pressure rooms. Modular field hospitals and mobile ICUs have become key tools in emergency plans. However, LMICs continue to struggle with basic healthcare access, water and sanitation infrastructure, and stable electricity supply. The WHO and World Bank have funded over 50 infrastructure improvement projects since 2022, though long-term sustainability remains uncertain<sup>1-3</sup>. Despite these challenges, efforts like the WHO's Health Systems Strengthening programs and OECD recommendations have led to some improvements in readiness across nations<sup>6-7</sup>. Global Health Security Index (2021) data highlights that while some HICs have strengthened their healthcare infrastructure, LMICs still remain vulnerable, relying heavily on international aid to meet minimum standards of care during emergencies<sup>8-9</sup>.

Table 1: Healthcare Infrastructure Investment (2022-2025)<sup>1-5</sup>

Country/Region	Total Investment in Healthcare Infrastructure (USD Billion)	Focus Areas	% Investments Allocated to Pandemic Preparedness
United States	50.0	ICU beds, medical supplies, telemedicine	30%
European Union (EU)	45.0	Digital health systems, emergency response teams	25%
India	7.5	Primary healthcare centers, rural health access	15%
South Korea	12.0	ICU capacity, PPE production, health systems	40%
Sub-Saharan Africa	4.2	Health facility upgrades, water sanitation	60%

### PPE and Supply Chain Reforms

COVID-19 exposed critical vulnerabilities in global supply chains. Nations responded by localizing PPE production, stockpiling essential goods, and diversifying sources. As of 2024, countries like India, the U.S., and South Korea have developed independent PPE manufacturing hubs. Innovations in reusable PPE and advances in rapid sterilization technologies have improved safety. Yet, regular audits of national stockpiles and real-time distribution systems are inconsistently implemented. Countries like South Korea and Germany were early adopters of diversified supply chain strategies to ensure future preparedness<sup>10,11</sup>. However, the international community must ensure that stockpiling and distribution networks are optimized globally to avoid future bottlenecks<sup>3,5</sup>. Table 2 presents national-level PPE production capacities and key innovations in supply chain management introduced after COVID-19<sup>3,5,6,10</sup>

Country/Region	PPE Production Capacity (Units per Year)	Percentage of Global Supply	Key Reforms and Innovations
China	5.0 Billion	40%	Increased domestic manufacturing, rapid scaling of production

India	3.5 Billion	20%	Localizing supply chains, expanding PPE factories
United States	2.0 Billion	15%	Public-private partnerships for PPE production
South Korea	1.5 Billion	10%	Government incentives for PPE production expansion
European Union (EU)	1.0 Billion	10%	Coordinated supply chain monitoring and distribution

### Strategic Funding Models

Global institutions and national governments established emergency financing mechanisms. The Pandemic Fund, launched in 2022, disbursed over \$1.5 billion across 53 countries to strengthen preparedness<sup>3</sup>. COVAX, a partnership led by Gavi, CEPI, and WHO, delivered over 2 billion COVID-19 vaccine doses to 146 countries<sup>12-15</sup>. Despite COVAX's ambitions, unequal bilateral deals delayed access in many regions, undercutting its equitable goals<sup>16</sup>. Table 3 details the distribution of COVID-19 vaccines across global regions through COVAX and other initiatives, highlighting persistent disparities in access and coverage.

However, many initiatives remain reactive, and funding inequities persist. Political will and consistent fiscal commitment are vital for sustainability. Programs such as the Rockefeller Foundation's Pandemic Prevention Institute and Gates Foundation's Goalkeepers Report underscore the importance of long-term investment in pandemic preparedness to enhance resilience globally<sup>12-17</sup>. The WHO's 2022 announcement detailed the first disbursement strategy for the Pandemic Fund, focusing on surveillance and workforce development in LMICs<sup>15</sup>. The major funding mechanisms that have supported global preparedness initiatives since 2020 are summarized in Table 4<sup>1-3,4,7</sup>

Region	Total Doses Delivered (Billions)	COVAX Share (%)	Percentage of Population Vaccinated (First Dose)	Challenges Faced
Sub-Saharan Africa	0.65	40	21%	Logistical hurdles, political instability
Southeast Asia	1.2	25	60%	Supply chain delays, vaccine hesitancy
Latin America	3.4	30	80%	Inequities in access, vaccine scepticism
Eastern Europe	1.1	15	70%	Vaccine availability, distribution constraints
High-Income Countries	5.2	5	90%	Over-supply, distribution efficiency

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Table 4: Global Pandemic Response Funding by Key Initiatives (2020–2025)<sup>1-6</sup>

Initiative	Total Funding (USD Billion)	Number of Beneficiary Countries	Focus Area
COVAX Initiative	18.2	146	Vaccine access, equity, and distribution in LMICs
Pandemic Fund (World Bank)	1.5	53	Strengthening health systems and preparedness
GAVI	11.0	75	Vaccine delivery and immunization programs
WHO's Health Systems Strengthening	2.0	45	Infrastructure upgrades and human resource development
Global Health Security Initiative (GHSI)	5.8	100	Surveillance, health data systems, and health security

### Workforce Resilience and Mental Health

Frontline health workers faced high exposure, mental stress, and burnout during the pandemic. In response, new policies emphasize mental health, cross-training, and surge staffing. Children, especially those in low-income settings, faced long-term setbacks in education, nutrition, and emotional development during lockdowns, as highlighted by UNICEF's pandemic impact reports.<sup>13</sup> Programs like WHO's *Mental Health Atlas* (2023) underscore growing national commitments, but implementation is patchy<sup>9</sup>. Rural and underfunded health systems still face critical workforce shortages. The United Nations Development Programme (UNDP) highlights that workforce resilience is key for future pandemic preparedness, particularly for vulnerable populations and in fragile healthcare systems<sup>18,19,20</sup>. Programs in LMICs often face resource constraints, making full workforce investment difficult.

Table 5: Mental Health and Workforce Resilience in Healthcare (2020–2025)

Country/Region	Total Investment in Mental Health Programs (USD Million)	Percentage of Health Workers Affected by Burnout	Key Workforce Resilience Programs
United States	800	40%	Mental health support services, flexible work schedules
UK	500	35%	National wellbeing programs, peer support networks
India	150	50%	National health worker training and psychological support
South Korea	300	30%	Stress management programs, improved working conditions

WHO Global (Estimates)	1.5 Billion	30%	Global mental health action plan, emergency support
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### Surveillance and Digital Epidemiology

Investment in real-time data systems has accelerated. The WHO Hub for Pandemic and Epidemic Intelligence in Berlin and national dashboards now utilize wastewater surveillance, genomic sequencing, and AI models. The UK and Canada have developed real-time genomic alert systems using wastewater data<sup>21,22</sup>. Despite progress, many LMICs lack the digital infrastructure or data transparency to benefit equally. Global health security strategies emphasize the need for robust surveillance systems capable of early detection and rapid response. Surveillance infrastructures are considered vital by organizations such as the National Academies of Sciences, Engineering, and Medicine and the WHO to mitigate the risks posed by future pandemics<sup>23,25</sup>.

### Vaccine Manufacturing and One Health

Regional manufacturing hubs are emerging, such as BioNTech's mRNA facility in Rwanda<sup>25</sup>. WHO's mRNA Technology Transfer Hub supports local vaccine development. The One Health approach, recognizing the link between human, animal, and environmental health, has gained traction<sup>26</sup>. WHO, FAO, UNEP, and OIE launched a joint action plan in 2022 to improve zoonotic disease surveillance. These innovations are reshaping the global health response to pandemics, with a growing recognition that cross-sectoral collaboration is necessary to address the environmental and social determinants of health<sup>27</sup>.

Table 6: Vaccine Manufacturing and Distribution Hubs (2021–2025)<sup>14,25,26,27</sup>

Country/Region	Key Facility Locations	Vaccine Production Capacity (Doses per Year)	Key Partnerships and Stakeholders
Rwanda	Kigali	50 Million	WHO mRNA Tech Transfer Hub, BioNTech, GAVI
India	Multiple locations (Serum Institute)	500 Million	Serum Institute of India, GSK, Covishield
South Africa	Cape Town, Johannesburg	100 Million	Aspen Pharmacare, WHO
United States	Multiple locations (Moderna, Pfizer)	2 Billion	Moderna, Pfizer, NIH, US Government
China	Beijing, Shanghai	1.5 Billion	Sinovac, SinoPharm, Government of China

### Governance, Equity, and Legal Frameworks

The inequity in vaccine access during COVID-19 catalyzed discussions on fair distribution. While COVAX succeeded in partial delivery, it fell short of its equity goals due to supply hoarding by HICs and delivery delays. WHO's Pandemic Accord aims to formalize shared governance and accountability, but negotiations remain politically charged. Legal frameworks for quarantine, surveillance, and vaccine mandates are still fragmented globally<sup>28</sup>. Global health organizations and international law experts emphasize that legal and policy frameworks need to be harmonized and strengthened to ensure a more equitable and coordinated response in future pandemics<sup>29</sup>.

## Public Communication and Misinformation Management

The rise of health misinformation during COVID-19 led WHO to launch infodemic management protocols and training<sup>30</sup>. Social media platforms now collaborate with public health agencies, but enforcement varies. National governments have introduced digital literacy campaigns to improve public understanding and reduce panic in future health crises. Additionally, the integration of AI tools for public health messaging, as highlighted by the Rockefeller Foundation's pandemic reports, is reshaping how information is disseminated to the public during health emergencies<sup>31</sup>.

## Discussion

Significant progress has been made in global pandemic preparedness since the COVID-19 crisis, particularly among high-income countries (HICs). These nations have invested in hospital infrastructure, stockpiled PPE, and developed real-time surveillance systems<sup>3,10,23</sup>. The creation of modular ICUs, domestic PPE manufacturing hubs, and genomic wastewater monitoring has demonstrated how capital and technology can strengthen system resilience<sup>10,21</sup>. However, low- and middle-income countries (LMICs) continue to rely heavily on international aid and lack access to critical infrastructure and digital tools<sup>3,8</sup>.

Efforts such as the WHO Health Systems Strengthening programs and the World Bank's Pandemic Fund have supported national preparedness plans, but challenges in equitable access persist<sup>3,6</sup>. COVAX and other global mechanisms delivered billions of vaccine doses to LMICs, yet the rollout was marred by delays, supply hoarding by wealthier nations, and logistical hurdles<sup>1,2</sup>. These inequities contributed to fragmented pandemic responses and highlighted the structural disadvantages LMICs face in times of global crisis<sup>8</sup>.

Mental health and workforce resilience, while increasingly acknowledged, remain underfunded and inconsistently implemented across countries<sup>9,20</sup>. Frontline health workers experienced high levels of burnout, yet only a few national systems established sustainable mental health programs or surge staffing models. This gap places health systems at risk of collapse during prolonged emergencies and must be addressed as part of future preparedness planning.

Governance and legal harmonization efforts are underway but remain politically sensitive. The WHO Pandemic Accord aims to establish a common framework for international accountability, yet global consensus is limited<sup>28</sup>. Similarly, legal tools for implementing quarantine, surveillance, and vaccination mandates vary widely between nations, undermining coordinated responses<sup>29</sup>. Misinformation also continues to pose a serious threat. Despite WHO's infodemic protocols and digital literacy campaigns, enforcement remains uneven, and false narratives persist across digital platforms<sup>30</sup>.

Cross-sectoral approaches like One Health which integrate human, animal, and environmental health represent promising long-term strategies<sup>26, 27</sup>. Regional vaccine manufacturing hubs, such as the BioNTech facility in Rwanda, signal a shift toward more distributed and resilient systems<sup>14, 25</sup>. However, these innovations require sustained political commitment, funding, and local capacity-building to be effective beyond pilot stages.

Overall, while pandemic readiness has improved since 2020, preparedness remains deeply unequal. Addressing these gaps requires moving beyond reactive funding toward long-term global cooperation and shared accountability. Without this, the next health crisis will once again expose the world's most vulnerable systems and populations. Table 7 summarizes the strengths and gaps in pandemic preparedness across income levels, with references supporting each point embedded directly within the table.

Table7: Summary of Pandemic Preparedness Strengths and Gaps by Country Income Level

Domain	High-Income Countries (HICs)	Low- and Middle-Income Countries (LMICs)
Healthcare Infrastructure	<ul style="list-style-type: none"><li>• ICU expansion<sup>3, 6</sup></li><li>• Modular hospitals<sup>4</sup></li><li>• Telemedicine integration<sup>7</sup></li></ul>	<ul style="list-style-type: none"><li>• Basic care shortages<sup>8</sup></li><li>• Inadequate water/sanitation<sup>6</sup></li><li>• Unreliable electricity<sup>6</sup></li></ul>



<b>PPE &amp; Supply Chains</b>	<ul style="list-style-type: none"> <li>• Localized PPE production<sup>10</sup></li> <li>• Strategic stockpiles<sup>3</sup></li> <li>• Diversified suppliers<sup>11</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Dependent on imports<sup>3</sup></li> <li>• Irregular audits<sup>5</sup></li> <li>• Weak distribution networks<sup>3</sup></li> </ul>
<b>Surveillance Systems</b>	<ul style="list-style-type: none"> <li>• Genomic sequencing<sup>23</sup></li> <li>• AI-based early warning<sup>23</sup></li> <li>• Wastewater monitoring<sup>21, 22</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Limited digital tools<sup>8</sup></li> <li>• Fragmented reporting<sup>8</sup></li> <li>• Data transparency issues<sup>20</sup></li> </ul>
<b>Funding &amp; Financing</b>	<ul style="list-style-type: none"> <li>• Dedicated emergency budgets<sup>5</sup></li> <li>• Domestic investment in preparedness<sup>4</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Heavy reliance on global funds<sup>3</sup></li> <li>• Inconsistent fiscal planning<sup>12</sup></li> </ul>
<b>Vaccine Access</b>	<ul style="list-style-type: none"> <li>• Early access to mRNA platforms<sup>14</sup></li> <li>• Bilateral procurement<sup>12</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Late deliveries via COVAX<sup>1, 2</sup></li> <li>• Cold-chain and logistics barriers<sup>2</sup></li> </ul>
<b>Workforce &amp; Mental Health</b>	<ul style="list-style-type: none"> <li>• Burnout addressed with support programs<sup>9</sup></li> <li>• Surge staffing reserves<sup>12</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Chronic staff shortages<sup>9</sup></li> <li>• Limited mental health support<sup>20</sup></li> </ul>
<b>Governance &amp; Law</b>	<ul style="list-style-type: none"> <li>• Developing legal frameworks for mandates and surveillance<sup>28</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Fragmented policies<sup>29</sup></li> <li>• Limited enforcement capacity<sup>29</sup></li> </ul>
<b>Public Communication</b>	<ul style="list-style-type: none"> <li>• Infodemic protocols<sup>30</sup></li> <li>• AI in health messaging<sup>31</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Low digital literacy<sup>30</sup></li> <li>• Vulnerability to misinformation<sup>30</sup></li> </ul>
<b>One Health &amp; Innovation</b>	<ul style="list-style-type: none"> <li>• R&amp;D and multisector collaboration<sup>26</sup></li> <li>• Regional manufacturing hubs emerging<sup>14, 25</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Limited technical capacity<sup>27</sup></li> <li>• Dependent on external partners<sup>26</sup></li> </ul>

## Conclusion

Since the onset of the COVID-19 pandemic, countries have made measurable progress in preparing for future health emergencies. High-income countries have led in building healthcare infrastructure, localizing PPE production, expanding surveillance systems, and launching national mental health initiatives<sup>9,10,23</sup>. Global partnerships such as COVAX and the Pandemic Fund have demonstrated the value of collective action in improving access to vaccines and emergency resources<sup>1,3</sup>.

However, preparedness remains uneven. Low- and middle-income countries still face chronic gaps in infrastructure, health workforce capacity, and digital systems<sup>8,20</sup>. Vaccine equity goals were only partially met, with delays and disparities in access undermining trust and outcomes<sup>1,2</sup>. Legal and governance frameworks for global cooperation are still fragmented, and effective implementation of strategies like One Health and digital misinformation management varies widely<sup>27,28,30</sup>.

To build true pandemic resilience, global health systems must shift from short-term crisis response toward sustained investment, equity-centered planning, and inclusive governance. This includes strengthening local production capabilities, standardizing legal protocols, and closing digital and workforce gaps in LMICs. Without long-term commitment and shared responsibility, the world risks repeating the mistakes of the past when the next pandemic emerges.



## Conflict of Interest

The authors declare no conflict of interest.

## References

1. WHO. COVAX Explained. <https://www.who.int/initiatives/act-accelerator/covax>
2. Gavi. COVAX Vaccine Delivery Tracker. <https://www.gavi.org/covax-vaccine-delivery>
3. World Bank. The Pandemic Fund. <https://www.worldbank.org/en/programs/financial-intermediary-fund-for-pandemics>
4. McKinsey & Company. Preparing for Future Pandemics: What Will It Take? <https://www.mckinsey.com/industries/public-and-social-sector/our-insights/preparing-for-future-pandemics>
5. IMF. Enhancing Economic Resilience to Future Pandemics. <https://www.imf.org/en/Publications/WP/Issues/2024/12/15/Economic-Resilience-Pandemic>
6. WHO. Health Systems Strengthening Programs. <https://www.who.int/healthsystems/strengthening>
7. OECD. Health at a Glance 2023: OECD Indicators. <https://www.oecd.org/health/health-at-a-glance.htm>
8. Global Health Security Index 2021. <https://www.ghsindex.org/>
9. WHO. Mental Health Atlas 2023. <https://www.who.int/publications/i/item/9789240071155>
10. South Korea Health and Welfare Ministry. PPE Supply Chain Development. <https://www.mohw.go.kr>
11. German Government. PPE Manufacturing Response to COVID-19. <https://www.bundesregierung.de>
12. Gates Foundation. 2024 Goalkeepers Report: Measuring Pandemic Progress. <https://www.gatesfoundation.org/goalkeepers/report/2024-report>
13. UNICEF. Children and Pandemics: Building a Safer Future. <https://www.unicef.org/reports/children-and-pandemics>
14. WHO. mRNA Technology Transfer Hub. <https://www.who.int/initiatives/mrna-vaccine-technology-transfer-hub>
15. WHO. Pandemic Fund 2022 Disbursement. <https://www.who.int/funds/pandemic-response>
16. WHO. COVAX Vaccine Equity. <https://www.gavi.org/covax>
17. Rockefeller Foundation. Pandemic Prevention Institute Annual Report 2024. <https://www.rockefellerfoundation.org/report/pandemic-prevention-2024>
18. National Academies of Sciences. Equitable Pandemic Response. <https://www.nationalacademies.org/our-work/equitable-pandemic-response>
19. WHO. Mental Health Atlas 2023. <https://www.who.int/publications/i/item/9789240071155>
20. UNDP. COVID-19 and Human Development: Assessing the Crisis, Envisioning the Recovery. <https://hdr.undp.org/en/2020-report>
21. UKHSA. SARS-CoV-2 Wastewater Surveillance. <https://www.gov.uk/government/publications/sars-cov-2-variants-of-concern-and-variants-under-investigation-in-england>
22. CDC. National Wastewater Surveillance System. <https://www.cdc.gov/healthywater/surveillance/wastewater-surveillance.html>
23. National Academies of Sciences. Digital Surveillance for Pandemic Response. <https://www.nationalacademies.org/our-work/digital-surveillance-pandemic-response>
24. WHO. One Health Joint Plan of Action. <https://www.fao.org/3/cc2289en/cc2289en.pdf>
25. BioNTech. mRNA Facility in Rwanda. <https://www.biontech.de/en/news>
26. FAO. One Health Approach to Pandemic Preparedness. <https://www.fao.org/3/cc2289en/cc2289en.pdf>
27. WHO. One Health Strategy. <https://www.who.int/health-topics/one-health>
28. WHO. Pandemic Accord. <https://www.who.int/initiatives/pandemic-accord>
29. BMJ Global Health. Pandemic Preparedness in the Global South. <https://gh.bmj.com/content/early/2025/03/15/bmjgh-2024-011527>
30. WHO. Infodemic Management. <https://www.who.int/teams/risk-communication/infodemic-management>
31. Rockefeller Foundation. AI and Public Health Messaging. <https://www.rockefellerfoundation.org/report/ai-public-health>

