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Strengthening Health Security through Climate-Resilient Environmental Health Systems: A Narrative Review

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Abstract
Global health security has expanded beyond infectious disease control to include multidimensional threats arising from climate change, environmental degradation, and social vulnerability. The COVID-19 pandemic demonstrated that medical response capacity alone is insufficient without resilient environmental health systems. This study aims to examine the role of climate-resilient environmental health systems in strengthening global health security during the post-pandemic recovery era. The study employed a narrative review method using literature from Scopus, PubMed, and Web of Science, as well as reports from WHO, IPCC, UNICEF, and UNEP published between 2020 and 2026. The findings indicate that climate change increases public health risks through heatwaves, air pollution, floods, droughts, sanitation disruption, and climate-sensitive diseases. The pandemic also highlighted the importance of ventilation, WASH (water, sanitation, and hygiene) systems, waste management, environmental surveillance, and cross-sector governance in supporting public health preparedness. Strengthening strategies include developing resilient WASH infrastructure, early warning systems, environmental quality monitoring, low-carbon healthcare facilities, and community capacity building. In conclusion, environmental health systems are strategic components in building adaptive and sustainable global health security amid ongoing climate change challenges.
Keywords: *health security, climate resilience, environmental health, post-pandemic recovery, climate change*

Abstrak
Keamanan kesehatan global kini tidak hanya berfokus pada pengendalian penyakit menular, tetapi juga mencakup ancaman akibat perubahan iklim, degradasi lingkungan, dan kerentanan sosial. Pandemi COVID-19 menunjukkan bahwa kapasitas medis saja tidak cukup tanpa didukung sistem kesehatan lingkungan yang resilien. Penelitian ini bertujuan mengkaji peran sistem kesehatan lingkungan tangguh iklim dalam memperkuat keamanan kesehatan global pada era pascapandemi. Metode yang digunakan adalah narrative review melalui penelusuran literatur dari Scopus, PubMed, Web of Science, serta laporan WHO, IPCC, UNICEF, dan UNEP periode 2020–2026. Hasil kajian menunjukkan bahwa perubahan iklim meningkatkan risiko kesehatan melalui gelombang panas, pencemaran udara, banjir, kekeringan, gangguan sanitasi, dan penyakit sensitif iklim. Pandemi juga menegaskan pentingnya ventilasi, sistem WASH, pengelolaan limbah, surveilans lingkungan, dan tata kelola lintas sektor dalam kesiapsiagaan kesehatan masyarakat. Penguatan sistem dilakukan melalui pengembangan infrastruktur WASH resilien, sistem peringatan dini, pemantauan kualitas lingkungan, fasilitas kesehatan rendah karbon, dan peningkatan kapasitas masyarakat. Sistem kesehatan lingkungan menjadi komponen strategis dalam membangun keamanan kesehatan yang adaptif dan berkelanjutan.
Kata Kunci: *keamanan kesehatan, ketahanan iklim, kesehatan lingkungan, pemulihan pascapandemi, perubahan iklim*

1. Introduction

The global health landscape has undergone a profound transformation over the last decade. While infectious disease outbreaks remain a central concern, the concept of health security has expanded to include interconnected threats arising from climate change, environmental degradation, rapid urbanization, and social inequities [1], [2]. The COVID-19 pandemic exposed critical vulnerabilities in health systems worldwide, demonstrating that preparedness cannot rely solely on biomedical response capacity [3]. Instead, resilient public health systems require strong environmental health foundations, including safe water and sanitation, clean air, effective waste management, healthy built environments, and integrated surveillance systems [4], [5]. In the post-pandemic era, strengthening health security demands a broader

and more adaptive framework that addresses both biological and environmental determinants of health [6], [7].

Health security from the traditional lenses has been defined through the lens of outbreak prevention, detection, and response [7]. However, recent global events have shown that environmental hazards can generate health emergencies with impacts comparable to infectious disease crises [7]. Heatwaves, floods, droughts, wildfires, and severe air pollution events are increasing in frequency and intensity due to climate change [8]. These hazards contribute to excess mortality, respiratory and cardiovascular diseases, mental health burdens, food insecurity, displacement, and disruptions to healthcare delivery [9]. Moreover, climate-sensitive infectious diseases such as dengue, malaria, and cholera are expanding into new geographic areas, further blurring the boundaries between environmental and epidemiological threats [10], [11]. As a result, health security must be reconceptualized as the capacity of societies to anticipate, withstand, and recover from multiple overlapping risks [12].

Environmental health systems play a pivotal role in this broader security agenda [7]. Access to safe drinking water, sanitation, and hygiene services remains essential for preventing infectious disease transmission and protecting vulnerable populations [6], [13]. Indoor and outdoor air quality management is increasingly important in reducing chronic disease burdens and limiting exposure during wildfire smoke episodes or urban pollution crises [14]. Proper management of healthcare and municipal waste prevents secondary environmental contamination and occupational hazards [15]. In addition, urban planning, housing quality, ventilation, and climate-sensitive infrastructure influence exposure patterns and community resilience [16]. These domains are often treated separately from emergency preparedness, yet they constitute the operational backbone of population health protection [16], [17].

The COVID-19 pandemic generated important lessons regarding the relationship between environmental health and crisis preparedness [13], [18]. Evidence from multiple settings highlighted the importance of indoor ventilation in reducing airborne transmission, hygiene infrastructure in public spaces, continuity of waste services, occupational protection for sanitation workers, and real-time monitoring systems capable of informing rapid interventions [19], [20]. The pandemic also revealed structural inequalities, as communities with inadequate housing, overcrowding, poor sanitation, or limited access to environmental services experienced disproportionate risks [21]. Recovery strategies that focus only on healthcare capacity without addressing environmental determinants may therefore leave societies vulnerable to future crises [12], [22].

At the same time, climate change is creating new pressures that require environmental health systems to become more adaptive and resilient. Rising temperatures can compromise labor productivity, increase heat-related illnesses, and strain electricity-dependent cooling systems [23], [24]. Flooding can damage water infrastructure and contaminate drinking water supplies, droughts threaten sanitation services and food production [25]. Extreme weather events can interrupt waste collection, healthcare access, and disease control programs. In many low- and middle-income countries, these risks are intensified by rapid population growth, informal settlements, governance constraints, and limited investment in preventive infrastructure [5], [26], [27]. Consequently, climate resilience should be understood as a core component of health security rather than a separate environmental objective [28], [29].

A climate-resilient environmental health system is one that can maintain essential public health functions under changing environmental conditions while adapting to emerging risks [28], [30]. Such systems require multisectoral governance, evidence-based planning, community engagement, robust surveillance, sustainable financing, and equitable service delivery [31], [32], [33]. Interventions may include resilient water and sanitation infrastructure, heat-health action plans, climate-informed disease surveillance, air quality early warning systems, greener healthcare facilities, and risk communication strategies tailored to vulnerable populations [1], [34]. Strengthening these capacities can reduce disaster losses, improve routine population health outcomes, and enhance preparedness for future pandemics or compound emergencies [35].

Despite growing recognition of the links between climate change and health, the role of environmental health systems within the broader health security discourse remains insufficiently synthesized [36], [37]. Much of the existing literature focuses either on emergency response mechanisms or on specific environmental risks in isolation [38]. A more integrated perspective is needed to identify how environmental health functions can support preparedness, response, recovery, and long-term resilience simultaneously [38], [39].

Therefore, this narrative review aims to examine how climate-resilient environmental health systems can strengthen health security in the post-pandemic era. Specifically, the review synthesizes evidence on evolving health security concepts, lessons learned from COVID-19, major climate-related environmental

health risks, and strategic interventions relevant to policymakers and public health practitioners, particularly in low- and middle-income settings.

2. Material and Methods

Study Design

This study employed a narrative review approach to synthesize current evidence regarding the contribution of climate-resilient environmental health systems to strengthening health security in the post-pandemic era. A narrative review was considered appropriate because the topic spans multiple disciplines including public health, environmental health, climate science, health systems, and policy studies and requires an integrative interpretation of diverse forms of evidence rather than statistical pooling alone. This approach enables the inclusion of empirical studies, policy analyses, technical reports, and conceptual frameworks relevant to emerging global health challenges.

Search Strategy

A structured literature search was conducted using major scientific databases, including Scopus, PubMed, and Web of Science. To complement peer-reviewed publications, relevant institutional documents and technical reports were also identified from international organizations such as the World Health Organization (WHO), United Nations Environment Programme (UNEP), Intergovernmental Panel on Climate Change (IPCC), World Bank, and United Nations Children's Fund (UNICEF).

The search covered publications from 2020 - 2026, reflecting the period from the onset of the COVID-19 pandemic to the current phase of post-pandemic recovery and accelerating climate adaptation agendas. Searches were performed using combinations of keywords and Boolean operators, including: "health security", "climate resilience", "environmental health systems", "pandemic recovery", "COVID-19 lessons learned", "climate change AND health", "air pollution AND public health", "WASH AND resilience", "environmental surveillance", "health systems adaptation". Keyword combinations were adjusted across databases according to indexing systems and search functionalities.

Eligibility Criteria

Literature was selected based on relevance to the review objective. Documents were eligible if they:

1. Discussed health security, environmental health systems, climate resilience, or interactions among these themes;
2. Examined lessons from the COVID-19 pandemic applicable to preparedness or resilience;
3. Addressed environmental determinants of health such as water, sanitation, air quality, waste management, housing, or surveillance systems;
4. Presented evidence, policy analysis, frameworks, or practical interventions relevant to strengthening resilience

Documents were excluded if they:

1. Focused solely on clinical treatment without broader public health or environmental relevance;
2. Were unrelated to health security or resilience;
3. Were duplicate records;
4. Provided insufficient methodological or substantive information;

Were editorials or opinion pieces lacking analytical contribution, unless highly influential for conceptual framing.

3. Results and Discussion

The reviewed literature demonstrates that health security can no longer be interpreted solely as the prevention and control of infectious disease outbreaks. Contemporary risks are increasingly shaped by climate change, environmental degradation, demographic transitions, and structural inequalities that amplify population vulnerability. Across the selected sources, a consistent theme emerged: resilient environmental health systems are foundational to effective preparedness, emergency response, and long-term recovery. The findings are presented through five interrelated domains. The reviewed literature consistently shows that climate resilience and environmental health systems are central to future health security (**Table 1**).

Table 1. Summary of Selected Literature

No	Author(s)	Year	Method	Main Findings
1	Romanello et al. [40]	2025	Global annual monitoring report	Climate change continues to intensify health risks globally, while mitigation and adaptation policies provide major co-benefits for population health and health security.
2	Golden et al. [34]	2025	Policy analysis / conceptual review	Climate-smart public health approaches can strengthen resilience through multisectoral planning, prevention, surveillance, and adaptive governance.
3	Myhre et al. [29]	2025	Scoping review	Climate-resilient health systems in low-resource settings require financing, workforce capacity, infrastructure adaptation, governance reform, and community participation.
4	Dubas-Jakóbczyk et al. [41]	2025	Umbrella review of systematic reviews	Health systems adaptation strategies include early warning systems, service continuity planning, resilient infrastructure, and integrated risk governance.
5	Gkouliaveras et al. [42]	2025	Narrative review	Climate change affects health systems through increased disease burden, infrastructure stress, workforce strain, and resource disruption.
6	Romanello et al. [43]	2024	Global monitoring report	Delayed climate action increases exposure to heat, food insecurity, and environmental hazards, particularly among vulnerable populations.
7	Romanello et al. [44]	2023	Global monitoring report	A health-centered climate response is urgently needed because irreversible environmental harms are already affecting morbidity and mortality.
8	Romanello et al. [45]	2022	Global monitoring report	Dependence on fossil fuels worsens air pollution, climate-related illness, and energy insecurity, undermining sustainable health security.
9	Romanello et al. [46]	2021	Global monitoring report	Climate change has reached a critical stage, requiring immediate transformation of health systems and environmental governance.
10	Watts et al. [47]	2020	Global monitoring report	The convergence of pandemic and climate crises demonstrates the need for integrated preparedness and resilient public systems.
11	World Health Organization [48]	2023	Operational framework	Climate-resilient and low-carbon health systems should integrate leadership, financing, workforce, infrastructure, technologies, and service delivery.
12	IPCC [30]	2022	Global scientific assessment report	Climate impacts are widespread and escalating, with serious implications for water systems, food systems, settlements, ecosystems, and human health.
13	UNEP [49]	2024	Global policy report	Adaptation efforts remain insufficient compared with accelerating climate risks, especially in lower-income countries.
14	World Bank [50]	2024	Framework report	Vulnerability assessment can guid investment priorities for climate and health resilience in low and middle income countries.
15	UNICEF [51]	2025	Technical report	Climate-resilient WASH systems are essential to protect child health, reduce disease transmission, and sustain services during shocks.
16	Ebi & Hess [22]	2020	Perspective / policy analysis	Climate change creates unequal health burdens, with populations contributing least to emissions often experiencing the greatest risks.
17	Jagals & Ebi [52]	2021	Policy paper	Rapid climate action is necessary to protect health and reduce long-term healthcare and economic costs.
18	Agache [53]	2021	Review	Global health security frameworks should explicitly include climate change as a core transnational health threat.
19	Shaman & Galanti [54]	2020	Perspective article	Future preparedness requires long-term surveillance and adaptive systems because emerging pathogens may become endemic.

A total body of evidence published between 2020 and 2026 consistently demonstrates that environmental determinants are central to contemporary health security. Across global reports, review

studies, policy analyses, and technical frameworks, five major themes emerged: expanding definitions of health security, lessons from the COVID-19 pandemic, climate-related environmental health risks, system resilience strategies, and policy priorities for low- and middle-income countries.

First, the literature indicates a significant conceptual shift in health security. Earlier approaches primarily focused on infectious disease preparedness, outbreak detection, and emergency medical response. However, recent evidence shows that climate-related hazards including heatwaves, floods, droughts, wildfire smoke, and air pollution now produce substantial mortality, morbidity, healthcare disruption, and economic loss. These findings suggest that health security must be redefined as the capacity of societies to manage both biological and environmental threats through resilient systems.

Second, multiple studies identified the COVID-19 pandemic as a critical turning point for environmental preparedness. Evidence from pandemic-era research highlighted the importance of indoor ventilation, air filtration, hygiene infrastructure, continuity of waste management services, and multisectoral governance. Areas with poor housing quality, overcrowding, or inadequate access to water and sanitation experienced disproportionate risks. This demonstrates that emergency response effectiveness depends heavily on underlying environmental conditions and infrastructure.

Third, climate change was consistently linked to growing public health risks through several pathways. Heat exposure increases cardiovascular stress, renal illness, and excess mortality. Floods and droughts threaten drinking water systems, sanitation services, food production, and healthcare operations. Changes in temperature and rainfall also alter the transmission dynamics of vector-borne diseases such as dengue and malaria. In addition, worsening air pollution and wildfire smoke episodes contribute to respiratory and cardiovascular disease burdens. Several reports emphasized that these threats frequently occur simultaneously, creating compound crises that challenge conventional single-hazard preparedness models.

Fourth, the reviewed literature identified a common set of strategies for building climate-resilient environmental health systems. These include strengthening climate-resilient WASH infrastructure, implementing real-time environmental monitoring, integrating environmental and health surveillance systems, expanding early warning systems, improving ventilation and healthy building design, developing low-carbon and climate-smart health facilities, and enhancing workforce competencies. Community engagement and risk communication were also repeatedly identified as essential components of adaptive capacity.

Finally, evidence specific to low- and middle-income countries shows that vulnerability is intensified by rapid urbanization, informal settlements, limited financing, fragmented governance, and unequal access to basic services. For these settings, preventive investment in environmental health systems may yield greater long-term benefits than repeated reactive crisis responses. Strengthening interoperable data systems, targeting vulnerable populations, and embedding climate risk assessments into national health planning were consistently recommended.

Overall, the results demonstrate that environmental health resilience is not peripheral to health security. Rather, it is a strategic prerequisite for preparedness, recovery, and sustainable protection of population health in an era defined by climate uncertainty and complex global risks.

Redefining Health Security Beyond Pandemics

Health security has been dominated by outbreak-oriented frameworks emphasizing surveillance, laboratory capacity, border control, vaccination, and emergency response [55], [56]. While these remain essential, recent crises have shown that environmental hazards can trigger disruptions of similar or greater magnitude [57], [58]. Extreme heat events, floods, droughts, wildfire smoke, and severe air pollution episodes now generate substantial mortality, morbidity, healthcare strain, and economic loss across multiple regions [5], [52].

This broader understanding requires a shift from pathogen-centered security toward systems-based resilience [56]. Health security should be viewed as the ability of institutions and communities to prevent, absorb, adapt to, and recover from diverse health threats, whether biological, environmental, or compound in nature [59]. For example, a flood may simultaneously damage health facilities, contaminate water supplies, displace communities, interrupt vaccination programs, and increase vector breeding sites [60]. Such cascading effects illustrate that public health preparedness depends on infrastructure, governance, and environmental management as much as on biomedical response capacity [61].

The literature also highlights that risks are unevenly distributed, low-income households, informal settlements, older adults, children, outdoor workers, and populations with pre-existing illness are disproportionately affected by environmental shocks [30], [62], [63]. Therefore, equity must be integrated

into health security planning, systems that protect only the average population while neglecting vulnerable groups cannot be considered secure [64].

Lessons from COVID-19 for Environmental Preparedness

The COVID-19 pandemic provided a global stress test for environmental health systems, one of the clearest lessons concerns the role of indoor air quality and ventilation [3], [65]. Evidence accumulated during the pandemic confirmed that poorly ventilated indoor environments facilitated airborne transmission, particularly in workplaces, schools, public transport, and healthcare settings [60], [66]. As a result, ventilation standards, air filtration, occupancy management, and healthy building design gained renewed importance as preventive public health measures [60], [67].

The pandemic also reaffirmed the centrality of water, sanitation, and hygiene (WASH), hand hygiene campaigns were only feasible where reliable water access and sanitation facilities existed [66], [68], [69]. In many underserved settings, inadequate WASH infrastructure constrained implementation of basic infection prevention measures [69]. This demonstrated that public health recommendations are only as effective as the environmental systems that support them [70].

Waste management emerged as another critical domain, large increases in healthcare waste, personal protective equipment, and disposable materials created logistical and occupational challenges [71], [72]. Where waste systems were weak, risks of secondary contamination and unsafe disposal increased, maintaining municipal services during lockdowns also proved essential for preventing broader environmental deterioration [73].

The pandemic exposed deep social inequalities, communities facing overcrowded housing, insecure employment, limited water access, and poor environmental conditions experienced higher exposure and lower adaptive capacity [74], [75]. These findings suggest that preparedness planning must move beyond emergency stockpiles and include structural investments in healthy living environments [76].

At the end, multisectoral coordination was repeatedly identified as a determinant of success [6]. Effective responses often involved collaboration among health authorities, local government, environmental agencies, education sectors, transport systems, and community organizations [77][78]. This governance lesson is equally relevant for climate-related health threats [79].

Climate Change and Environmental Health Risks

Climate change is intensifying both acute and chronic health risks through multiple pathways [50], [80]. Heat exposure is one of the most immediate threats, rising temperatures and more frequent heatwaves are associated with dehydration, heat exhaustion, cardiovascular stress, renal complications, adverse pregnancy outcomes, and excess mortality [81], [82]. Urban heat islands can further magnify exposure in densely built environments with limited green space [83].

Hydrological extremes also present major challenges, flooding can damage sanitation systems, overwhelm drainage networks, contaminate drinking water sources, and displace populations [84]. Post-flood conditions may increase diarrheal disease, skin infections, injuries, and vector proliferation [85]. Conversely, drought can reduce water availability for hygiene, sanitation, agriculture, and healthcare operations, thereby undermining both health and livelihoods [86].

Climate change also influences infectious disease ecology, altered rainfall, humidity, and temperature patterns may expand habitats suitable for vectors such as mosquitoes and ticks [85]. This increases the geographic and seasonal transmission potential of diseases including dengue, malaria, chikungunya, and other vector-borne infections [53], [85]. In parallel, food system disruptions linked to extreme weather can worsen malnutrition and micronutrient deficiencies [74].

Air quality is another major pathway, higher temperatures can increase ozone formation, while droughts and wildfires generate smoke containing fine particulate matter and toxic compounds [87]. These exposures are associated with asthma exacerbation, chronic respiratory disease, cardiovascular events, and premature death [88]. Repeated smoke episodes can also affect mental health, mobility, and school attendance [84], [89].

These risks often occur simultaneously, a community may face heat stress, poor air quality, disease outbreaks, and economic instability at the same time. Such compound risks challenge conventional single-hazard planning and reinforce the need for integrated resilience strategies [6], [23].

Building Climate-Resilient Environmental Health Systems

The reviewed evidence points to several strategic priorities for strengthening resilience. First, investment in climate-resilient WASH infrastructure is fundamental [69]. Water systems, sanitation

networks, and hygiene facilities should be designed to withstand floods, droughts, service interruptions, and population surges [51]. Decentralized and backup systems may improve continuity during emergencies [90], [91].

Second, environmental monitoring and surveillance require modernization [92]. Real-time air quality monitoring, wastewater surveillance, heat alerts, vector surveillance, and geospatial risk mapping can support earlier detection of threats and more targeted interventions [93], [94]. Integrating environmental indicators with health surveillance systems enables faster and more anticipatory decision-making [4], [95].

Third, healthy and resilient buildings are increasingly important [28]. Schools, workplaces, housing, and healthcare facilities should incorporate adequate ventilation, thermal comfort, passive cooling, energy efficiency, and safe occupancy design [96] [97]. Green and climate-smart health facilities can maintain service delivery while reducing environmental footprint [98].

Fourth, risk communication and community engagement are indispensable [16]. Early warning systems are most effective when translated into clear, culturally appropriate guidance that communities can act upon [99]. Public education on heat protection, water safety, household air pollution reduction, vector control, and emergency preparedness strengthens local adaptive capacity [100].

Fifth, public health practitioners, environmental health officers, planners, and emergency managers require competencies that bridge climate science, risk assessment, surveillance, and community-based adaptation. Institutional resilience depends not only on infrastructure, but also on human capacity [42], [101], [102].

Policy Implications for Low and Middle-Income Countries

The need for integrated resilience is especially urgent in low- and middle-income countries (LMICs), where climate vulnerability often intersects with constrained resources, rapid urbanization, informal settlements, and uneven service coverage [23], [30]. In these contexts, reactive crisis management is particularly costly and less effective than preventive investment [103].

Policy frameworks should therefore prioritize environmental health as a core component of national health security strategies [33], [104]. This includes embedding climate risk assessments into health planning, expanding equitable access to WASH services, strengthening urban environmental governance, and financing preventive infrastructure [8], [68]. Donor and development programs should support long-term system strengthening rather than short project cycles focused only on emergencies [9], [102].

Data systems also require improvement, many LMICs face fragmented monitoring systems, limited local exposure data, and insufficient integration between meteorological, environmental, and health information [105]. Strengthening interoperable data platforms can improve risk forecasting and resource allocation [11].

Equity should remain central to policy design, adaptation measures that fail to reach marginalized communities may widen existing disparities [106]. Targeted interventions for informal settlements, remote populations, children, older adults, and workers in high-exposure occupations are essential [43], [107].

Overall, the findings indicate that advancing health security in the current era depends on treating environmental resilience not as a peripheral issue, but as a strategic pillar of national and global public health protection [29], [34], [41], [42], [108].

Research Limitations

This study has several limitations that should be acknowledged. First, the review employed a narrative review design, which emphasizes conceptual synthesis and interpretative discussion rather than quantitative analysis. Consequently, the study did not perform a formal meta-analysis or statistical assessment of pooled effect sizes. The absence of standardized quantitative synthesis may limit the ability to measure the magnitude of relationships between climate-related environmental factors and health security outcomes.

Second, the literature selection process may be subject to interpretive bias because narrative reviews rely partly on the authors' judgment in identifying and synthesizing relevant evidence. Although a structured search strategy and explicit inclusion criteria were applied, the possibility of selective interpretation cannot be entirely eliminated.

Third, the review focused primarily on publications written in English and indexed in major international databases such as Scopus, PubMed, and Web of Science. As a result, potentially relevant studies published in local journals, regional databases, or non-English languages may not have been included. This limitation may reduce representation of evidence from certain low- and middle-income countries that are highly vulnerable to climate-related health risks.

Fourth, the topic of climate resilience and health security is rapidly evolving. Policies, technologies, and adaptation frameworks continue to develop across countries and institutions. Therefore, some emerging evidence or newly implemented interventions may not yet be fully reflected in the literature reviewed during the study period.

Fifth, the review synthesized evidence across diverse environmental health domains including WASH, air quality, surveillance systems, climate adaptation, and healthcare infrastructure which vary substantially in methodology, geographic context, and operational definitions. This interdisciplinary breadth strengthens the comprehensiveness of the discussion but may also reduce specificity for particular intervention areas.

Finally, most of the reviewed literature originated from global reports, policy frameworks, and international perspectives, while context-specific implementation evidence from developing countries remains comparatively limited. Further empirical studies, especially in low- and middle-income settings, are needed to evaluate the effectiveness, feasibility, and sustainability of climate-resilient environmental health interventions within local health systems.

4. Conclusion

The contemporary health security agenda has expanded far beyond the traditional focus on infectious disease outbreaks. While pandemic preparedness remains essential, the evidence reviewed in this study shows that climate change, environmental degradation, and social vulnerability are now equally critical determinants of population health risk. Heatwaves, floods, droughts, air pollution, water insecurity, and climate-sensitive diseases increasingly threaten human health, strain healthcare systems, and disrupt social and economic stability. Consequently, strengthening health security in the post-pandemic era requires a more comprehensive and forward-looking framework.

This narrative review highlights that environmental health systems constitute a fundamental pillar of such a framework. Safe water and sanitation services, clean air management, waste systems, healthy buildings, environmental surveillance, and resilient infrastructure are not secondary public services; they are core protective mechanisms that determine whether societies can prevent, withstand, and recover from health emergencies. Lessons from the COVID-19 pandemic further reinforced that effective preparedness depends not only on clinical care capacity, but also on the environmental conditions in which people live, work, learn, and seek care.

The findings also indicate that climate resilience must be operationalized through practical and integrated strategies. Investments in climate-resilient WASH systems, early warning systems, air quality monitoring, adaptive healthcare facilities, workforce capacity, and community engagement can simultaneously reduce routine disease burdens and improve emergency readiness. These co-benefits make environmental health interventions particularly valuable for sustainable health system strengthening.

For low and middle income countries, the challenge is more urgent because environmental risks often intersect with infrastructure gaps, rapid urbanization, and constrained fiscal capacity. In these settings, preventive and equitable investments are likely to generate greater long-term returns than repeated reactive responses to crises. National health security strategies should therefore incorporate environmental risk assessment, multisectoral governance, interoperable data systems, and targeted protection for vulnerable populations.

In conclusion, advancing health security from pandemic recovery to climate resilience requires repositioning environmental health systems at the center of policy and practice. Future preparedness will depend not only on the ability to respond to the next outbreak, but also on the capacity to build healthier, more adaptive, and more equitable environments for all.

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