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From Environmental Exposure to Compound Vulnerability: Reframing Public Health Governance in Environmental Planning

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From Environmental Exposure to Compound Vulnerability: Reframing Public Health Governance in Environmental Planning

Abstract

The effects of environmental determinants of public health have been investigated by individual pathways of exposure, including air pollution, unsafe water, climate stress, or waste exposure. This review discusses these risks in the light of the concept of compound vulnerabilities, which sees environmental health burdens as being not only determined by exposure, but also by governance, infrastructure, planning, social inequality and adaptive capacity. The study was carried out using a systematic review following the PRISMA 2020 guidelines, bibliometric mapping and thematic synthesis. Scopus, Web of Science and PubMed were searched to identify peer-reviewed English language articles published between 2020 and 2025. 45 articles were included after screening. The results of the bibliometric analysis indicated an increasing attention to the intersection of environmental determinants and public health, and the major themes were public health, environmental health, air pollution, water pollution, urbanization, sustainable development and policy. Thematic synthesis resulted in the development of five interrelated pathways of air pollution and household energy related health burden; water contamination and WASH and public health risks; climate related stress, heat, flooding and water scarcity; waste, landfill, industrial contamination and spatial inequality; and governance, planning and the compound of vulnerabilities. The review includes recommendations for better environmental health governance that is integrated and equity driven by linking pollution control, WASH systems, waste management, climate change adaptation, land-use planning and vulnerable communities' protection.

Keywords: Compound vulnerability; Environmental determinants of health; Public health governance; Climate-related health risks; Environmental planning and management

Introduction

The environment has a significant effect on health. Physical, mental, and daily life can be impacted by air pollution, unsafe water, poor sanitation, open dumping, industrial pollution, and climate-related stress. These risks may overlap. For instance, air pollution can be generated by vehicles, industries, and the utilization of fuel in households, burning of garbage or refuse, and power generators, while water pollution can be caused by untreated sewage, landfill leakage, industrial discharge, and inadequate waste management systems (Bashar and Fung 2020, Citton, Croonenberg et al. 2020, Chukwu, Morse et al. 2022, Osra, Elbisy et al. 2024). Urban heat, floods, droughts and water scarcity are additional climate-related stressors that can exacerbate health risks due to impacts on drinking water, sanitation, food security, livelihoods and access to health services (Hussain, Meng et al. 2024, Huynh, Hofstra et al. 2024, Zimmermann, Abadi et al. 2025). So, environmental health should not be just seen as discrete exposure issues.

Environmental health risks are not distributed equally. Low-income populations, children, women, the elderly, informal settlements, and people living close to polluted rivers, industrial sites, landfill sites, brownfields, and dump sites are exposed more and have fewer protective resources. The environmental risk is found to be influenced by location, infrastructure access,

income, public service, and institutional control of pollution and protection of vulnerable groups (Dada 2021, Flacke, Maharjan et al. 2022, Chien and Knoble 2024, Okyere, Abu et al. 2024). This implies that the issue of pollution is not the main issue. A much bigger issue is how environmental exposure translates into differential health impacts due to poor planning, weak regulation, lack of water and sanitation and social inequality.

There is evidence from previous studies on specific environmental risks including air pollution, unsafe water, household air pollution, industrial pollution, waste exposure and climate related risks. But numerous studies have looked at these hazards individually. There has been less focus on the interplay between air pollution, water pollution, climate stress, waste management, infrastructure inequity and governance failure, and how this affects public health. This represents a key research opportunity with respect to environmental planning and management.

This review attempts to fill this void by reviewing recent literature from 2020-2025 concerning environmental determinants of public health. It uses a combined bibliometric and thematic approach. The bibliometric analysis is used to map the publication trends, citation patterns, influential journals, countries, authors and keywords. The thematic synthesis then explores the reviewed studies' explanations of connections between environmental hazards, public health, governance, infrastructure and social vulnerability.

The main argument of this review is that environmental health risks are not produced by exposure alone. These are also influenced by planning and governance contexts, which determine who is exposed, who is protected and who can adapt. This review builds a compound vulnerability perspective linking the issues of air-quality regulation, water and sanitation, waste governance, climate adaptation, land-use planning, and health equity in a single, unified approach. The multiplicative effects of multiple environmental hazards on having unequal impact on human health, can be understood as a form of compound vulnerability, which occurs when multiple exposures interact, weak governance, low infrastructure, and unequal planning protection, and socially unequal adaptive capacity are present. This study is guided by the following research questions:

RQ1. How has recent scholarship conceptualised the relationship between environmental determinants and public health outcomes?

RQ2. What bibliometric patterns reveal the dominant journals, countries, themes, and knowledge gaps in compound environmental health research?

RQ3. How do governance capacity, planning systems, infrastructure inequality, and social vulnerability shape compound environmental health risks across global contexts?

RQ4. What planning and policy implications emerge for integrated environmental health governance?

2. Positioning and contribution relative to prior syntheses

Significant efforts have been made in recent years to synthesize information on environmental exposure and public health, and considerable literature is found organized by hazard, sector-specific intervention, or general policy summaries. Air-pollution reviews have drawn attention to sources of air pollution, its health impacts, and potential interventions, but they typically focus less on the interaction of air-quality risks and factors such as water insecurity, climate stress, infrastructure deficits, and social vulnerability. Climate-health reviews have analysed mitigation and adaptation policies and their implications for health inequalities; however, these reviews are typically climate policy-focused and not more broadly focused on environmental health governance (Hjelmskog, Boyd et al. 2025). There are a number of advanced indicator and measurement frameworks for multi-hazard reviews, but exposure, planning systems, and public health pathways are not always at the core of the review (White, Adnan et al. 2025). Policy-facing analyses, in turn, can be useful to decision-makers, but generally do not conduct extensive bibliometric mapping, or interpret at the study level, how risks are produced, distributed and governed among different populations and places (Paltriguera, Beamud et al. 2024)

The present review aims to fill this gap by exploring how recent research connects air pollution, water pollution, socio-economic inequality, urbanisation, information access, and adaptive capacity to public health via governance capacity and infrastructure provision, which are both stress and strain from climate change. It is not just used to identify publication trends or to provide summaries of health impacts. The review, rather, constructs a compound perspective on vulnerability, in which multiple hazards, combined with low capacity to plan, enforce regulations, provide WASH and public health services, and access to protective resources creates unequal environmental health outcomes. This framing is applicable to environmental planning and management for its attention to shift from describing environmental exposure to the conditions of institutional and policy that render the environmental exposure into unequally distributed health burden. Table 1 provides a summary of the differences between the current review and key previous syntheses and policy-oriented analyses.

Table 1. Positioning of the present review relative to representative prior syntheses and policy-facing analyses

Prior work	Main scope	Remaining gap	Contribution of the present review
(Manisalidis, Stavropoulou et al. 2020)	Air pollution and health impacts	Single-hazard focus; limited cross-hazard and governance integration	Places air pollution within a wider compound vulnerability framework
(Ji, Dominici et al. 2025)	Air-pollution interventions	Limited attention to governance-mediated vulnerability and cross-hazard interaction	Extends intervention evidence toward integrated environmental health governance
(Hjelmskog, Boyd et al. 2025)	Climate policies and health inequalities	Climate-centred framing; limited synthesis of air, water, waste, and infrastructure risks	Connects climate-health inequalities with wider environmental health governance

(White, Adnan et al. 2025)	Multi-hazard and multi-risk indicators	Indicator-centred; less focused on public health pathways and planning systems	Makes health outcomes, exposure distribution, and infrastructure inequality central
(Paltriguera, Beamud et al. 2024)	Environmental determinants of health policy analysis	Limited bibliometric mapping and study-level thematic interpretation	Combines bibliometric mapping with thematic synthesis of governance pathways

As can be seen in Table 1, previous syntheses have contributed to knowledge development by conducting single hazard reviews, intervention evidence, climate-policy analysis, multi-hazard indicators, and policy guidance. But they pay less attention to how environmental health hazards are exacerbated by governance failures, infrastructure disparities, economic and social vulnerability and the differential adaptive capacities. This review addresses this by bringing together bibliometric mapping and thematic synthesis to delineate how environmental hazards turn into inequitable public health issues because of the planning and governance contexts.

3. Methods and Materials

This study used a systematic review design guided by the PRISMA 2020 framework (Page, McKenzie et al. 2021). Bibliometric mapping and thematic synthesis were used in the review. Bibliometric analysis was applied to investigate publication trends, citation patterns, the most influential publications, country contributions, authorship patterns and keyword structures. Thematic synthesis was employed to make sense of the interpretations of how recent studies explain the relationship between environmental determinants, public health outcomes, governance, infrastructure, planning, and social vulnerability.

3.1 Search strategy

Literature search was made in Scopus, Web of Science and PubMed. These databases were chosen because they offer a wide range of information on the topic of environmental science, public health, social science, planning and interdisciplinary health research. Scopus was initially used as the major source for bibliometric metadata because it has the structured data and contains citation, affiliation, source, and keyword information, and Web of Science and PubMed were used to support systematic identification and to minimize bias arising from any particular database.

The search strategy (table 2) was designed to include studies on the intersection of air pollution, water contamination, climate-related stress, and public health. To identify records of association between these exposure domains and health outcomes or disease burden, a conjunctive Boolean structure was used. This approach was purposeful and not comprehensive, as it did not seek to reflect the entire single-hazard literature on air pollution, water pollution, climate change, waste, sanitation and land-use change. In the full-text screening and thematic synthesis, related environmental determinants mentioned in the studies retrieved (waste systems, exposure to landfills, industrial pollution, domestic energy, water deficit, flooding, land use changes, infrastructure disparities, environmental justice, and governance capacity) were coded as connected themes.

Table 2. Search strings used in the databases

Database	Search string
Scopus	TITLE-ABS-KEY (“air pollution” OR “ambient air quality” OR “particulate matter” OR “PM2.5” OR “PM10”) AND (“water contamination” OR “unsafe water” OR “waterborne diseases”) AND (“climate change” OR “global warming” OR “extreme heat” OR “climate-related hazards”) AND (“public health” OR “health outcomes” OR “disease burden”)
Web of Science	TS = (“air pollution” OR “ambient air quality” OR “particulate matter” OR “PM2.5” OR “PM10”) AND TS = (“water contamination” OR “unsafe water” OR “waterborne diseases”) AND TS = (“climate change” OR “global warming” OR “extreme heat” OR “climate-related hazards”) AND TS = (“public health” OR “health outcomes” OR “disease burden”)
PubMed	(“air pollution” [All Fields] OR “PM2.5”[All Fields] OR “PM10”[All Fields]) AND (“water contamination”[All Fields] OR “waterborne diseases”[All Fields]) AND (“climate change”[All Fields] OR “global warming”[All Fields] OR “extreme heat”[All Fields]) AND (“public health”[All Fields] OR “health outcomes”[All Fields] OR “disease burden”[All Fields])

3.2 Eligibility criteria

Articles were included if published in English between 2020 and 2025, as a peer-reviewed journal article, identified as part of the search strategy that included air pollution, water contamination, climate related stress, and public health aspects, and discussed environmental determinants of human health, health risk, well-being, disease burden, exposure vulnerability, or public health implications. The relevance of the study to environmental governance, planning, infrastructure, vulnerability, inequality, adaptation, environmental justice or public health policy was also required. Articles were excluded if not journal articles, not in English, published prior to 2020, or if it did not have an obvious connection to public health or only addressed technical aspects of environmental measurement with no health, policy, governance, planning or vulnerability relevance. Book chapters, documents with less analytical content, conference papers, opinion pieces and editorials also were excluded.

3.3 Screening and selection

A first search of the databases yielded 1,417 records. The first step was to exclude publications prior to 2020, reducing the total number to 411. An additional 779 records were excluded as they were not in the scope of the review, being outside of the environmental health, public health, social science, policy or planning fields. This resulted in 227 records for title and abstract screening. A total of 128 non-journal documents were removed in the screening process leaving 99 full-text articles for retrieval. A total of 98 full-text articles were screened for eligibility, one of

which was not in English. Following full-text screening, 53 articles were excluded as they lacked adequate consideration of the link between environmental determinants, public health outcomes, governance, infrastructure, planning, vulnerability and/or policy relevance. Finally, 45 articles were included in the review. The selection process is summarised in the PRISMA 2020 flow diagram in Figure 1.

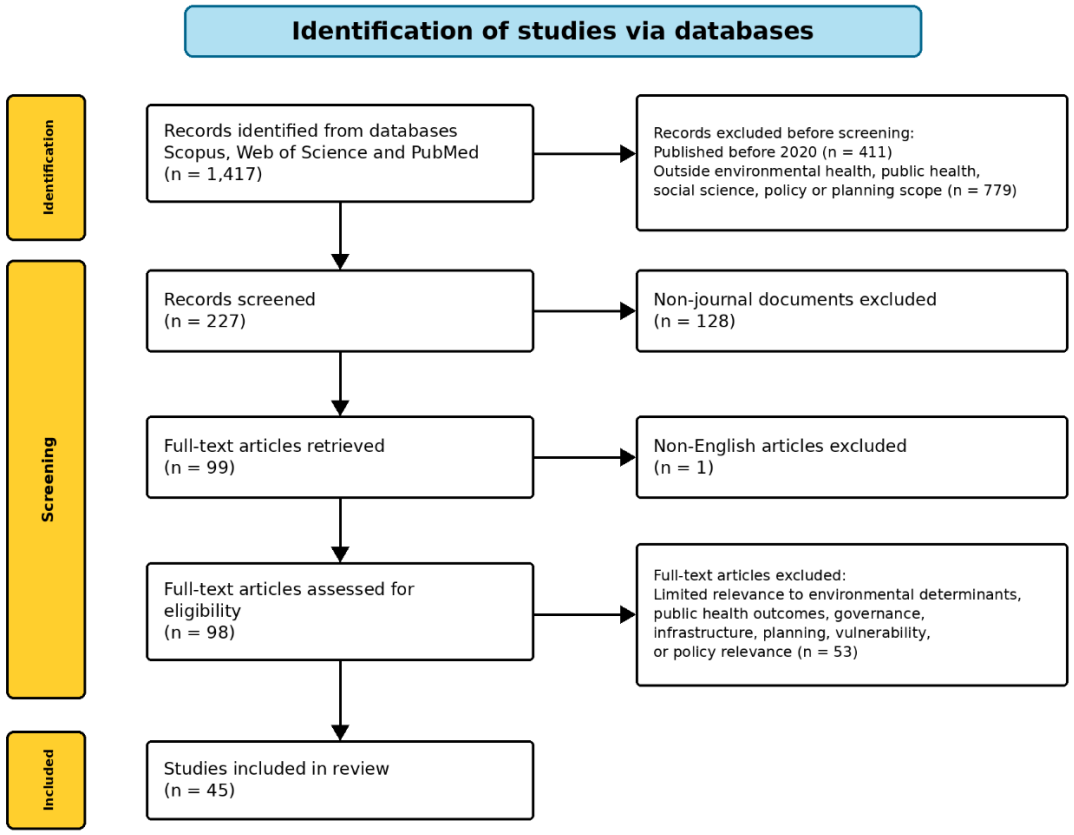


Figure 1. PRISMA 2020 flow diagram showing study identification, screening, eligibility assessment, and inclusion.

3.4 Data extraction and evidence appraisal

Using a structured extraction matrix, data was extracted from each included article. Information extracted comprised: author, year, journal, country and/or region, environmental determinant, health outcome or pathway, study design, source of data, method, governance or policy relevance, infrastructure dimension, and vulnerability group and main contribution.

The studies included varied in their design, and therefore one appraisal checklist was not applied to all articles. Rather, design sensitivity criteria (clarity of aim, appropriateness of method, transparency of data sources, analytical rigour and consistency between evidence and claims) were used to assess evidence strength. Stronger claims were supported by stronger empirical, quasi-experimental, longitudinal or well-modelled studies. Claims of association, interpretation,

governance relevance or conceptual framing were made more cautiously on the basis of a cross section, or space-based, or perception-based, or review-based, or policy-oriented studies.

3.5 Bibliometric and thematic analysis

The metadata was mainly extracted from Scopus and analysed using bibliometric analysis tools available in RStudio (Aria and Cuccurullo 2017) with the help of bibliometrix package and the biblioshiny interface. The analysis was performed on trends of publications in a year, source title, number of citations, countries cited, frequency of keywords and keywords co-occurrence to highlight the structure, dominant sources, themes and gaps in the literature reviewed.

The thematic synthesis was not based on the bibliometric signals represented as keyword treemaps and co-occurrence networks. The articles included (n = 45) were fully text coded to develop the final themes. All articles were categorised according to environmental determinant, health pathway or outcome, study context, method, governance/policy, infrastructure, vulnerability group, and key contribution. Coding was primarily inductive, however supported by the review theme of environmental determinants, public health, planning, governance, infrastructure inequity and social vulnerabilities.

Combined, bibliometric mapping and thematic synthesis reinforced the main theme of the review that environmental health risks are not merely exposure but also, governance, infrastructure and planning, social inequity and adaptive capacity.

4. Results and Analysis

Finally, 45 peer-reviewed articles from 2020 to 2025 were included in the corpus. The bibliometric profile of literature included is presented first, followed by thematic synthesis of the key environmental health pathways found in the literature.

4.1 Bibliometric profile of the included literature

4.1.1 Publications and Citations Growth Over Time

As seen in Figure 2, publication output experienced some fluctuations between the years 2020 and 2023, after which it significantly increased in 2024, followed by a decline in 2025 due to the year not yet being fully indexed and cited. The articles published in 2022 had the highest number of citations, followed by those in 2021 and 2020, while the more recent articles in 2024 and 2025 did not yet have as many citations due to the normal citation delay.

This pattern represents a growing field without being conceptualized yet. While the older studies have a stronger citation body, the newer issues of governance capacity, infrastructure disparity, failure in planning and dual vulnerability may not be fully reflected in the metrics of citations. Therefore, the study of exposure pathways will require a combination of bibliometric

measurement and thematic synthesis to demonstrate how exposure pathways can become a public health problem because of planning, infrastructure and governance.

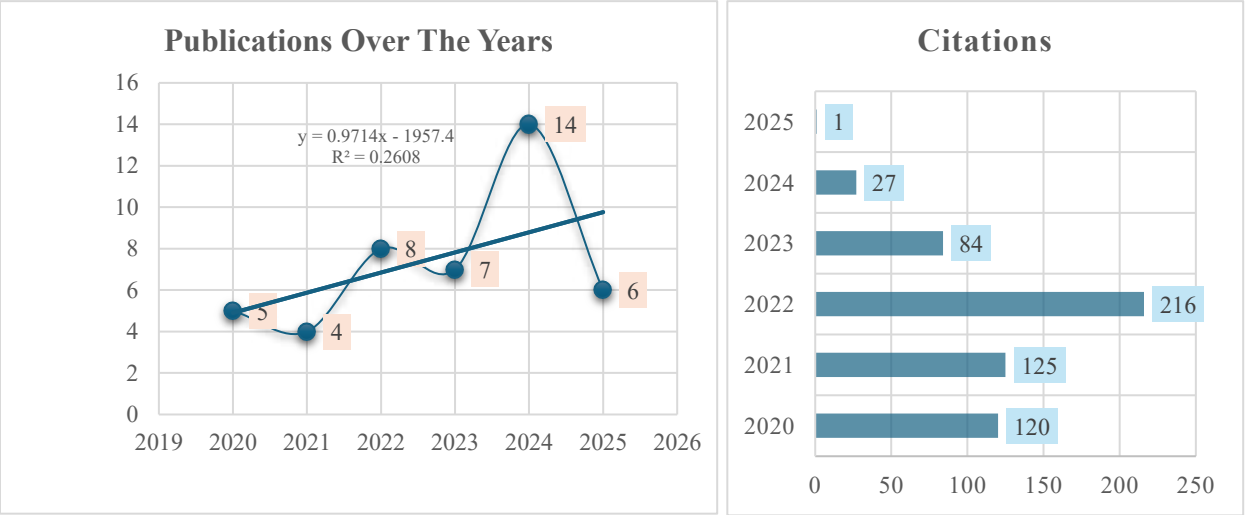


Figure 2. Annual publication output and citation distribution of studies on environmental determinants of public health (2020–2025). Source: Authors developed from Scopus database.

4.1.2 Core Journals and Publication Outlets

Table 3 reports the top journals in which studies on the environmental determinants of public health were published from 2020 to 2025. The most productive source was sustainability (Switzerland) with seven publications and 200 citations, and the highest ACPA was obtained for the journal Sustainable development (38.0). Social Science & Medicine, Water (Switzerland), and World Development also provided input to the corpus, highlighting the diversity of the field, which has traversed sustainability, public health, water and development studies.

It is an interdisciplinary and fragmentary distribution. Despite the fact that compound vulnerability is highly dependent on land use regulation, infrastructure provision, WASH systems, waste governance and institutional coordination, environmental health evidence is not focused in planning and governance outlets. Thus, the journal approach helps to meet the need for closer integration between the evidence of public health and sustainability and the practice of environmental planning and management.

Table 3. Leading journals publishing on environmental determinants of public health (2020–2025). Source: Authors developed from Scopus database.

Rank	Journal	Publications	Citations	ACPA	Publisher
1	*Sustainability (Switzerland)*	7	200	28.6	MDPI
2	*Sustainable Development*	3	114	38.0	John Wiley and Sons Ltd
3	*Social Science & Medicine*	3	76	25.3	Elsevier Ltd
4	*Water (Switzerland)*	3	44	14.7	MDPI

5	*World Development*	2	35	17.5	Elsevier Ltd
6	*Journal of Development Studies*	2	9	4.5	Routledge
7	*Journal of Environmental Planning and Management*	1	9	9.0	Routledge
8	*Remote Sensing Applications: Society and Environment*	1	35	35.0	Elsevier B.V.
9	*Annals of Regional Science*	1	7	7.0	Springer Science and Business Media Deutschland GmbH
10	*Environmental Hazards*	1	6	6.0	Taylor & Francis Ltd.

4.1.3 Country-Wise Research Contribution

Figure 3 reveals that the majority of publications come from a narrow band of countries, including the US and China, followed by Australia and fewer Asian, European, and African countries. This trend suggests that research on environmental determinants of public health is driven primarily by countries with robust research systems and publication capacity.

Geography is important as it shows unequal geographic distribution, which highlights a broad disparity between knowledge production and potential burden of exposure. The corpus also lacks visibility into unsafe water, air pollution, poor WASH infrastructure, informal urbanisation, exposure to waste and the adaptive capacity of many of the settings where these factors overlap, often in low-income and climate-vulnerable settings. This leads to a planning knowledge gap in that evidence used to develop environmental health governance might underrepresent the areas with the most severe compound vulnerabilities.

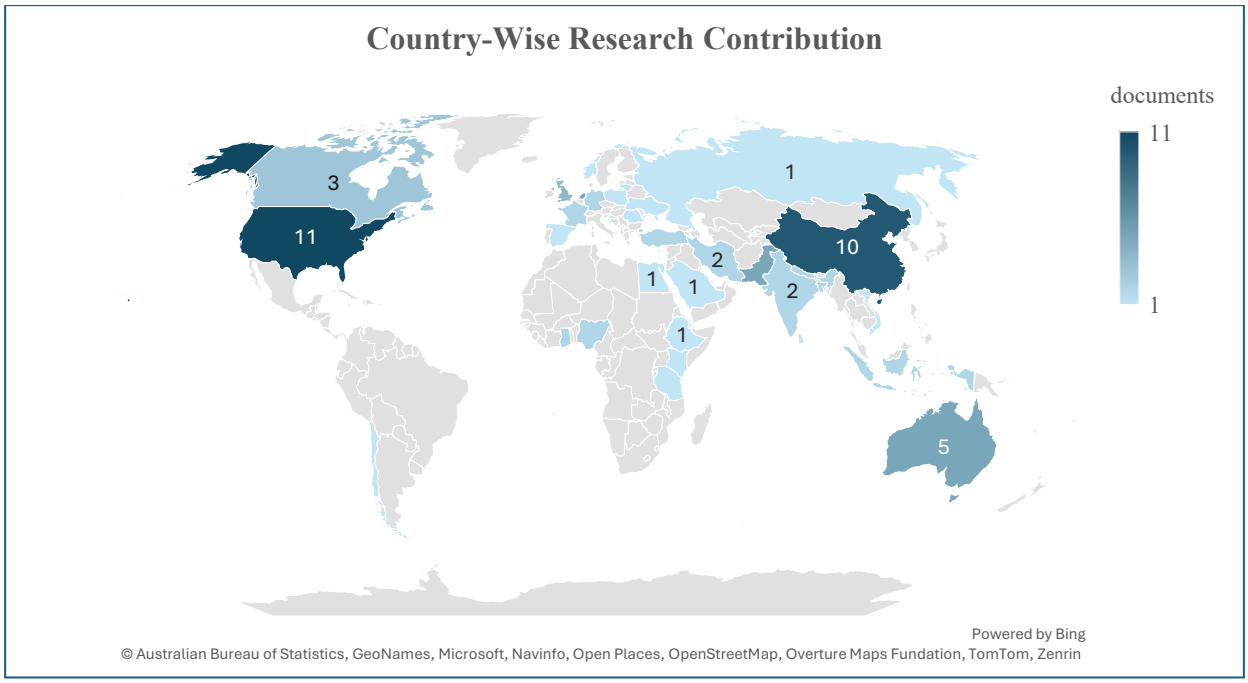


Figure 3. Geographic distribution of publications on environmental determinants of public health (2020–2025). Source: Authors developed from Scopus database.

4.1.4 Interlinkages between countries, research themes, and publication sources

Figure 4 establishes a relation between countries, dominant themes and publication sources of the included corpus. The plot reveals that the USA, China, Pakistan, Australia, Ghana, the United Kingdom and the Netherlands are linked to common topics like air pollution, health, environmental justice, urbanization, climate change, children and environmental hazards. These themes are mostly published in interdisciplinary journals like Sustainability (Switzerland), Social Science & Medicine, Water (Switzerland), World Development and Journal of Development Studies.

This is significant since the pattern reveals the existence of several interrelated issues within the field, but these are spread across countries, themes and journals, not around a single planning-oriented framework. Air pollution, health, environmental justice, urbanization and climate change are present together but their connections to infrastructure, capacity of governance and compounding vulnerability are not as obvious. This is important as it helps to show the necessity of thematic synthesis in order to tie together punctate bibliometric signals and provide an explanation of the construction of environmental health risks across contexts.

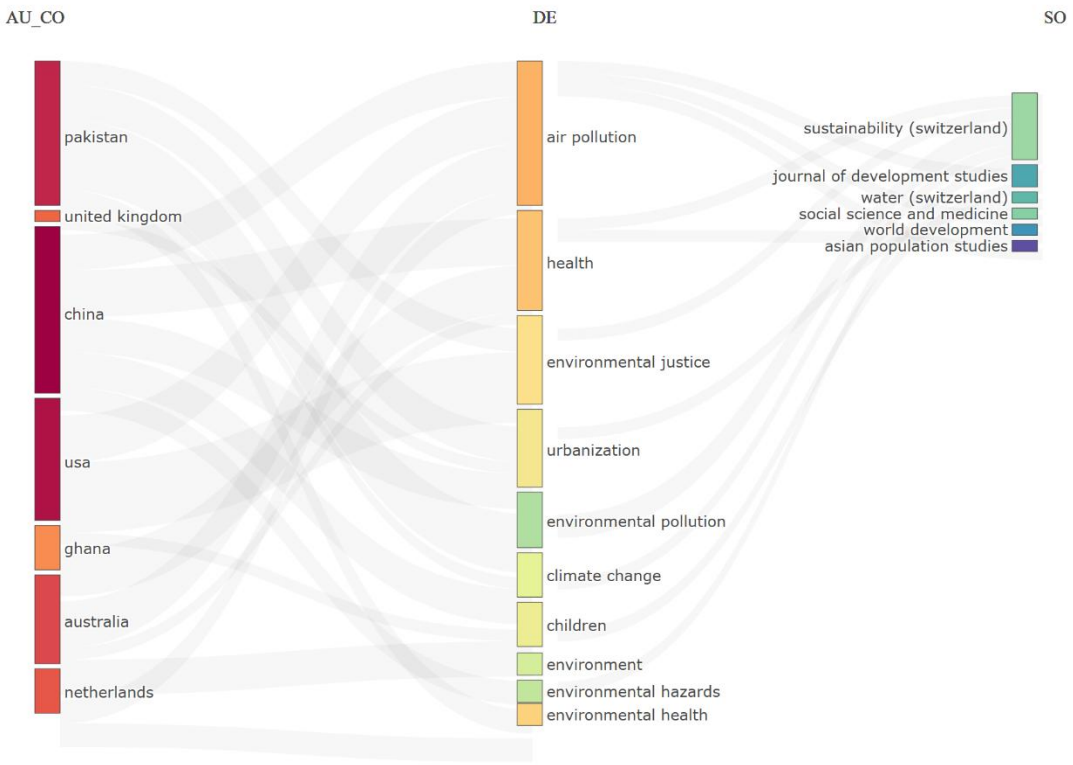


Figure 4. Three-field plot linking countries, keywords, and publication sources. Source: Authors developed from Scopus database.

4.1.5 Top 10 most-cited articles in the included corpus (2020–2025)

Table 4 illustrates that the most cited articles in the corpus focus on plastic pollution, air quality, water pollution, household energy, exposure to landfill and sustainability transitions. These studies give some valuable information on environmental health risk factors such as waste leakage, urban water pollution, biomass cooking, air pollution, and child health.

The current pattern of citations is significant for the fact that there is very limited convergence towards planning and governance-based citations, as most papers focus on a specific hazard or a specific case. Collectively, these articles do not give a unified picture of how various hazards are related to infrastructure inequities, regulatory capacity, land-use choices, and social vulnerabilities. This gap reinforces the need for a compound vulnerability perspective in the present review.

Table 4. Top 10 most-cited articles in the included corpus; citations counted in Scopus as of August 2025. Source: Authors developed from Scopus database.

Rank	Title	Year	Journal	Cited by	References

1	Plastic Pollution, Waste Management Issues, and Circular Economy Opportunities in Rural Communities	2022	Sustainability (Switzerland)	180	(Mihai, Gündoğdu et al. 2022)
2	Investigating the nexus between energy, economic growth, and environmental quality: A road map for the sustainable development	2021	Sustainable Development	93	(Khan, Godil et al. 2021)
3	Effects of objective and subjective environmental pollution on well-being in urban China: A structural equation model approach	2020	Social Science and Medicine	64	(Li and Zhou 2020)
4	Water pollution in a densely populated megapolis, Dhaka	2020	Water (Switzerland)	41	(Bashar and Fung 2020)
5	Spatiotemporal variation of air pollutants and their relationship with land surface temperature in Bengaluru, India	2023	Remote Sensing Applications: Society and Environment	35	(Suthar, Singhal et al. 2023)
6	Impacts of improved biomass cookstoves on child and adult health: Experimental evidence from rural Ethiopia	2021	World Development	23	(Lafave, Beyene et al. 2021)
7	Failing to attain sustainable development in Bangladesh: A potential comprehensive strategy for sustainability	2023	Sustainable Development	17	(Kaiser 2023)
8	Household fuel transitions have substantially contributed to child mortality reductions in China	2023	World Development	12	(Zhu, Liao et al. 2023)
9	Environmental and health hazards of residents domiciled around Africa's largest landfill	2021	Journal of Environmental Planning and Management	9	(Dada 2021)
10	Poor Air Quality in Urban Settings: A Comparison of Perceptual Indicators, Causes and Management in Two Cities	2022	Sustainability (Switzerland)	9	(Chukwu, Morse et al. 2022)

4.1.6 Keyword frequency and thematic signals

The most common keyword terms in the corpus are public health, environmental health, air pollution and water pollution (see Figure 5). This highlights that the field is primarily exposure-health focused, and that air and water pollution are the most prominent routes to exposure.

Looking at the treemap, however, one can see that overall social and planning issues are of less importance. Some keywords like urbanization, child health, sustainable development, awareness, waste management, land pollution, gender, energy and socio-economy are present in the corpus, however, with lesser visibility compared to the exposure and health related key words. This is significant, as it indicates that environmental threats and health outcomes have been more strongly acknowledged in the literature, than the governance, infrastructure and spatial planning factors that influence unequal vulnerabilities. There was thus a need for thematic synthesis to allow for linking exposure-centred evidence and compound vulnerability and environmental health governance.



Figure 5. Treemap of frequently occurring keyword terms in the included corpus. Source: Authors' analysis based on Scopus metadata.

4.1.7 Co-occurrence Analysis

To explore co-occurrence of keywords and to identify conceptual relationships within the selected articles, VOSviewer was used (Van Eck and Waltman 2017). 488 keywords have been extracted in the initial extraction. These have been cleaned by a thesaurus-based process to normalise synonyms, spelling variants, and related word forms down to 33 unique terms. Data type labels, generic linkage descriptors, and country names were dropped, since these did not provide any substantive research themes. Finally, a minimum co-occurrence threshold of three occurrences was used to yield a final list of 23 keywords which were used to create a network map. The keywords were clustered into five groups according to the strength of co-occurrence, and the total link strength showed the strength of the keywords' connection with other keywords in the network (Table 5).

Table 5. Keyword co-occurrence terms and total link strength

S/N	Keywords	Occurrences	Link Strength	Cluster Name

1	Adult	4	23	Cluster 2
2	Air pollution	16	46	Cluster 3
3	Air quality	8	33	Cluster 3
4	Child health	3	6	Cluster 4
5	Climate change	4	15	Cluster 2
6	Developing world	3	6	Cluster 3
7	Environmental health	6	23	Cluster 4
8	Environmental policy	6	13	Cluster 1
9	Environmental quality	3	7	Cluster 3
10	Female	5	26	Cluster 2
11	Health risk	5	15	Cluster 1
12	Heavy metals	3	9	Cluster 1
13	Human	8	38	Cluster 2
14	Male	4	25	Cluster 2
15	Mortality	3	10	Cluster 5
16	Perception	5	25	Cluster 2
17	Pollution	5	23	Cluster 5
18	Public health	19	54	Cluster 3
19	Sustainable development	6	12	Cluster 1
20	Urbanization	7	22	Cluster 1
21	Waste management	5	13	Cluster 1
22	Water pollution	3	14	Cluster 1
23	Water supply	3	16	Cluster 2

As can be seen in Figure 6, the most central nodes are public health, air pollution, and environmental health, which validated the predominance of exposure-health relationships in the corpus. The red cluster concerns environmental policy and sustainable development, urbanization, heavy metals, water pollution, and health risk and relates to waste management. The green cluster relates demographic and perception words (human, male, female, adult, climate change, water supply, perception). The blue cluster is focused on air pollution, air quality, public health, environmental quality and the developing world. The yellow cluster is made up of environmental health and child health, and the purple cluster is made up of pollution and mortality.

The co-occurrence pattern is important because it reveals that compound vulnerability is only partially integrated in the literature, but it shows the elements. The environment exposure terms, health outcomes, demographic vulnerability, policy concerns and water-related terms are all included in the network, but there are no strong central connections with governance capacities, infrastructure provision, land-use planning or adaptive capacities. This underpins the need for the thematic synthesis that follows, by reading these scattered relationships between key words through a planning-oriented compound vulnerability framework.

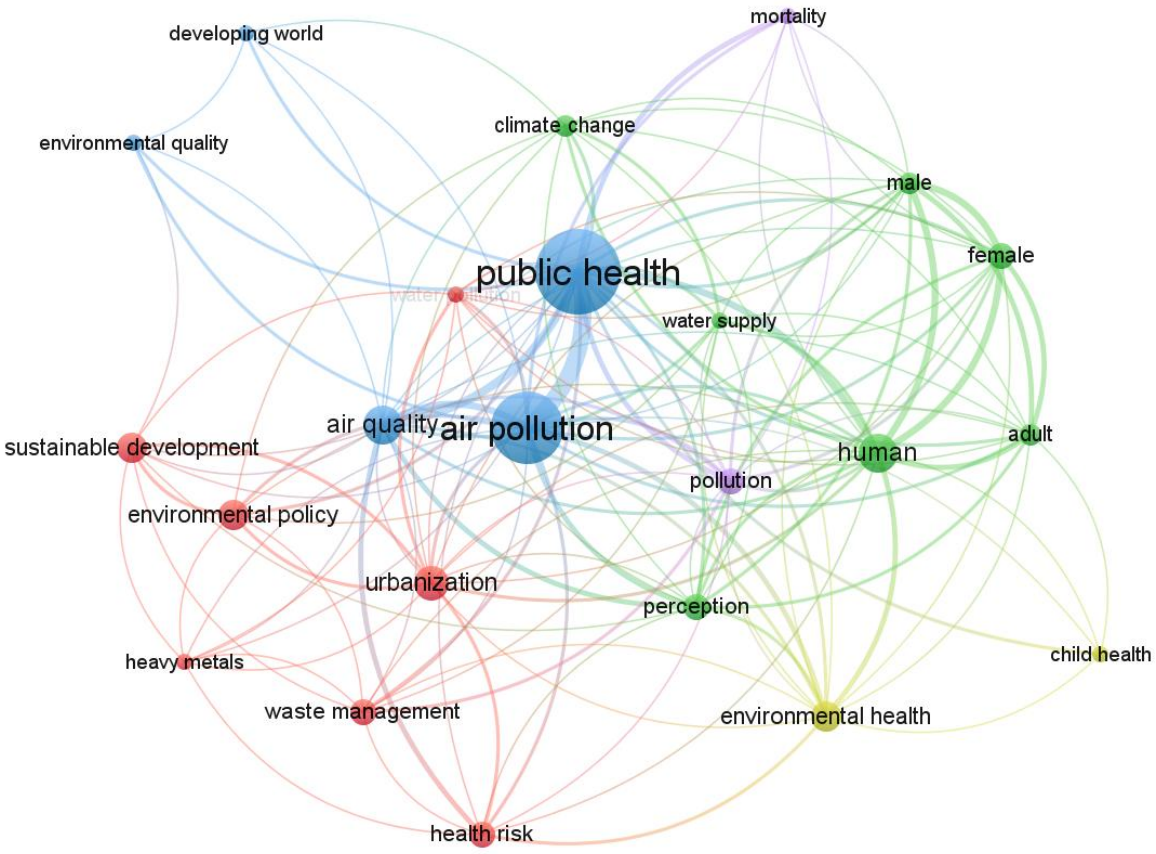


Figure 6. Co-occurrence of Terms. Source: Authors' compilation through VOSviewer

4.2 Thematic synthesis of environmental health pathways

Full-text reading and coding of the 45 included studies was used for the thematic synthesis. In contrast with the previous section with keyword co-occurrence analysis, this section presents interpretations of the substantive evidence reported in the articles. The full-text coding yielded the final themes, which were then grouped under the heading's environmental determinants, health pathways, governance mechanisms, vulnerability groups and planning relevance. Five themes that are interlinked were identified: air pollution and household energy-related health burden; water contamination, WASH and public health risk; climate related stress, heat, floods and water scarcity; waste, landfill, industrial contamination and spatial inequality; and governance, planning and compound vulnerability.

4.2.1 Air pollution, household energy, and health burden

Air pollution was one of the clearest health pathways in the corpus. Better causal studies and quasi-experimental studies were associated with the relationship between air pollution and mental health, self-assessed health, physical health, anaemia, respiratory illness, and child health outcomes (Panezai, Ali et al. 2021, Balasooriya, Bandara et al. 2022, Balakrishnan and Tsaneva

2023, Datt, Maitra et al. 2023). These results indicate that air pollution is not only an exposure, but it is also a measurable public health burden. But the nature of the health outcome differed between studies and general disease claims should be made with care.

Strong associations with unequal vulnerability were found for industrial, energy-related and household air pollution. Children and women were exposed to higher levels of PM2.5 pollution and increased risk of anaemia when living near coal-fired power generation, while households living near industrial point-sources were exposed to increased risk of respiratory illness and were required to pay higher mitigation costs for the pollution (Panezai, Ali et al. 2021, Datt, Maitra et al. 2023). Household fuel studies revealed that child and female health can be improved with clean or improved cooking transitions, but such results rely on poverty, gender roles, housing considerations, kitchen design, infrastructure and technology uptake (Lafave, Beyene et al. 2021, Zhu, Liao et al. 2023, Okyere, Abu et al. 2024). It was also found through perception-based studies that public perception of air pollution is influenced by visual cues, knowledge about the environment, risk perception, and governing entities (Chukwu, Morse et al. 2022, Suldovsky and B. Frank 2022, Li and Folmer 2023). In general, the risk of air pollution is experienced in terms of the level of pollution exposure and also in terms of social conditions, which influence the level of protection and response.

4.2.2 Water contamination, WASH, and public health risk

Water-related health risks emerged as a result of sewage contamination, industrial discharge, ground water contamination, heavy metals, unsafe drinking water and poor WASH infrastructure. The Dhaka case demonstrated that if no action is taken, urban rivers can transform into public health risk zones due to untreated sewage, tannery and textile effluents, municipal drains, clinical wastes, excessive use of heavy metals and weak enforcement (Bashar and Fung 2020). In Lebanon, multiple contamination mechanisms are possible, such as infiltration of sewage, potential influence of leachate, well corrosion, and saltwater intrusion, and source attribution of contamination is important in low data environments (Citton, Croonenberg et al. 2020).

Water risk is related to both environment and infrastructure, as supported by heavy metal and WASH related studies. The risk of heavy metals in Luoma Lake was influenced by hydrological management, dissolved oxygen, redox conditions, and retreating-polder strategies, but the study focused on modelling the risk and not on actual disease outcomes (Wang, Zhu et al. 2024). Child and household studies in Pakistan indicated that environmental health vulnerability is associated with unsafe water, sanitation, drainage and ventilation, poverty, and weak community infrastructure (Pathak and Gaire 2020, Rathnamala and Shivashankara 2022, Fatima and Ünsal 2024), while under-five diarrhoea in Pakistan showed spatial variation across districts. All these studies indicate that health risk from water is not only contamination. It is also influenced by sewage infrastructure, industrial regulation, monitoring of ground water, household infrastructure and access to safe WASH services.

4.2.3 Climate-related stress, heat, flooding, and water scarcity

The health risk due to climate change manifested in the form of heat exposure, flooding, water scarcity, ecological disruption and health system pressure. Urban heat studies revealed that built-up expansion, population growth, vehicle use, industrial activity, vegetation loss, road density, and air pollutants are associated with the land surface temperature and heat-index risk (Suthar, Singhal et al. 2023, Hussain, Meng et al. 2024). In these studies, clinical disease outcomes were not measured directly, but they do demonstrate that urban form and urban planning choices can significantly increase the exposure to climate-sensitive diseases.

Flooding and water scarcity led to increased direct connections with public health pathways. In Vietnam, contaminated floodwater was found to be able to contribute to rotavirus associated disease burden through everyday mobility, particularly when individuals were walking in flooded streets (Huynh, Hofstra et al. 2024). Moreover, water scarcity was associated with disease related to WASH, food security, livelihoods, and access to energy, as well as air quality during droughts and mental health pathways (Zimmermann, Abadi et al. 2025). There was also an ecological pathway as forest loss in Nigeria was linked to malaria incidence and neonatal mortality, likely due to maternal exposure in pregnancy (Berazneva and Byker 2024). International studies have also found that health expenditure pressure is related to CO_2 emissions and temperature change (Yılmaz and Ozaner 2025). Urban planning, drainage, water access, ecosystem change, mobility and health-system capacity all mediate the risk of climate change on health.

4.2.4 Waste, landfill, industrial contamination, and spatial inequality

Studies on waste and contamination revealed spatial variations in the environmental health risks. Findings from landfill evidence in Lagos revealed that the residents' proximity to the landfill was associated with increased environmental and health concerns and income and housing quality influenced the residential exposures (Dada 2021) (Dada, 2021). The evidence gathered from Makkah's open dumping revealed high concentration of PM10 and required integrated monitoring of air, soil, ground water and leachate surrounding waste disposal sites (Osra, Elbisy et al. 2024). Rural plastic pollution also demonstrated how fragile waste systems can contribute to contamination pathways to air, water, soil, and agriculture by open burning, illegal dumping, agricultural plastics, and lack of circular-economy infrastructure (Mihai, Gündoğdu et al. 2022).

Long-term monitoring and environmental justice were emphasized through the studies of industrial and contaminated land. The mortality trends in the industrially-exposed region of Croatia indicated a necessity for place-based surveillance of health, with caution advised when drawing causal inferences (Buterin, Doričić et al. 2022). Monitoring, factory regulation, emission-control studies, transport planning, penalties and subsidies emerged as relevant governance tools in the realm of industrial air-pollution management studies (Fehresti-Sani, Gholamazad et al. 2024). Brownfield and urban inequality studies revealed that environmental stressors, social vulnerability, lack of infrastructure, and self-reported health issues are often accumulative and present in contaminated places (Flacke, Maharjan et al. 2022, Chien and Knoble 2024). The studies show that waste management and contaminated land are not only environmental management issues, but also planning and spatial justice issues.

4.2.5 Governance, planning, and compound vulnerability

The review was unified by a common theme of governance and planning. A number of studies revealed that sometimes weak planning, poor enforcement and less public participation can aggravate the environmental health risks. The environmental degradation in Chattogram was correlated with uncoordinated urbanisation, industrial expansion, lack of proper master planning, inadequate enforcement, and environmental illiteracy, whereas in Dhaka, environmental degradation was associated with untreated sewage discharge, industrial wastewater discharge, weak zoning planning, and inadequate environmental infrastructure for treatment (Bashar and Fung 2020, Kaiser 2023). These studies demonstrate that pollution poses a threat to public health not just because it's there, but because of institutional and planning failures.

The evidence also indicated that governance can lessen or shift vulnerability. The ecological reserve policies in China were linked with physical and mental health co-benefits, and environmental taxation and renewable energy expansion were linked with better self-perceived health in EU countries (Wang, Huang et al. 2023, Postula, Kluza et al. 2024). Yet, environmental regulations can also have differential livelihood impacts where poorer households have limited adaptive capacity, such as when the polluting enterprises are closed in rural China (Deng, Niu et al. 2024). Public information and participation were also important, with studies in Ghana, Tanzania, Nigeria, the USA, and China indicating that language, timing, misinformation, risk perception, knowledge about the environment and civic engagement affect community responses to environmental hazards (Bishoge, Aremu et al. 2022, Chukwu, Morse et al. 2022, Suldovsky and B. Frank 2022, Li and Folmer 2023, Kyere and Kankam 2025).

The overall results of the thematic synthesis align with a approach of compound vulnerabilities. Air pollution, unsafe water, climate stress, waste exposure, contaminated land, and poor infrastructure are public health issues as a result of multiple and interdependent exposure and vulnerability pathways. Stronger studies demonstrate measurable health impacts or policy outcomes, and observational, perception-based, modelled and conceptual studies contribute to understanding the governance and vulnerability processes that shape the generation and distribution of risks. Evidence thus indicates that the environmental health risk is not only determined by the intensity of exposure but as well by decisions concerning land use, accessibility of infrastructure, regulatory capacity, public information, social inequality and adaptive resources.

Table 6 provides an overview of how the full-text synthesis connects environmental exposure to governance, infrastructure, vulnerability and public health outcomes in the five thematic pathways, their key supporting studies, the body of evidence present and the strength of inferences.

Table 6. Summary of thematic pathways and evidence strength

Theme	Main finding	Key supporting studies	Dominant evidence type	Inference strength
Air pollution, household energy, and health burden	Air pollution and household energy exposure are linked to mental health, self-assessed health, anaemia, respiratory illness, child growth, child mortality, and gendered illness patterns.	(Lafave, Beyene et al. 2021, Panezai, Ali et al. 2021, Balasooriya, Bandara et al. 2022, Balakrishnan and Tsaneva 2023, Datt, Maitra et al. 2023, Zhu, Liao et al. 2023, Okyere, Abu et al. 2024)	Causal/quasi-experimental, experimental, observational, household survey	Moderate to strong
Water contamination, WASH, and public health risk	Water-related health risk is shaped by sewage, industrial discharge, groundwater contamination, heavy metals, unsafe WASH infrastructure, and spatially uneven child vulnerability.	(Bashar and Fung 2020, Citton, Croonenberg et al. 2020, Pathak and Gaire 2020, Rathnamala and Shivashankara 2022, Fatima and Ünsal 2024, Wang, Zhu et al. 2024).	Water-quality assessment, spatial modelling, household survey, review/contextual evidence	Moderate
Climate-related stress, heat, flooding, and water scarcity	Climate-related health pathways include urban heat exposure, contaminated floodwater mobility, water scarcity, health-system burden, and ecological disease change.	(Suthar, Singhal et al. 2023, Berazneva and Byker 2024, Hussain, Meng et al. 2024, Huynh, Hofstra et al. 2024, Yılmaz and Ozaner 2025, Zimmermann, Abadi et al. 2025)	Remote sensing, QMRA/DALY, conceptual synthesis, causal/spatial evidence, macro-panel analysis	Moderate to strong
Waste, landfill, industrial contamination, and spatial inequality	Waste sites, open dumping, plastic leakage, industrial exposure, and brownfields create spatially uneven air, water, soil, and land-related exposure risks.	(Dada 2021, Buterin, Doričić et al. 2022, Flacke, Maharjan et al. 2022, Mihai, Gündoğdu et al. 2022, Chien and Knoble 2024, Fehresti-Sani, Gholamazad et al. 2024, Osra, Elbisy et al. 2024)	Environmental monitoring, survey, review, ecological mortality, GIS/spatial analysis	Suggestive to moderate
Governance, planning, and compound vulnerability	Environmental health burdens are mediated by planning systems, regulation, infrastructure, information access, policy design, public participation, and adaptive capacity.	(Bashar and Fung 2020, Bishoge, Aremu et al. 2022, Chukwu, Morse et al. 2022, Kaiser 2023, Li and Folmer 2023, Wang, Huang et al. 2023, Deng, Niu et al. 2024, Postula, Kluza et al. 2024, Kyere and Kankam 2025)	Mixed-methods, policy analysis, quasi-experimental, qualitative, perception-based evidence	Moderate

Note. Inference strength is based on the dominant evidence within each theme. Causal or quasi-experimental studies support stronger claims. Cross-sectional, perception-based, conceptual, and review-based studies are used more cautiously for association, interpretation, or governance framing.

5. Discussion

5.1 From exposure-centred evidence to compound vulnerability

This review analyzed the understanding of the relationship between environmental determinants and public health provided by the latest studies and how environmental health risks are determined by governance, planning, inequality of infrastructure and social vulnerability. The key message is that exposure does not necessarily result in environmental health risk. It is created by the interplay of environmental risks and the social, spatial and institutional determinants of

exposure and protection and adaptive capacity. This is the main contribution of the review. The review examines, not simply air pollution, unsafe water, climate stress, waste exposure and contaminated land as individual hazards, but rather as a 'compound vulnerability' perspective considering exposure pathways and governance capacity, provision of infrastructure, planning decisions and unequal adaptive resources. A compound vulnerability framework was created as part of this review and is presented in Figure 7. The framework illustrates that environmental hazards do not necessarily lead to burdens in public health via exposure alone. Rather, hazards act in conjunction with governance and planning, infrastructure and service delivery, public knowledge and, social vulnerability that act as exposure pathways. The framework thus connects environmental risks, exposure pathways, governing factors, adaptive capabilities and unequal public health outcomes to a single model which is relevant to planning.

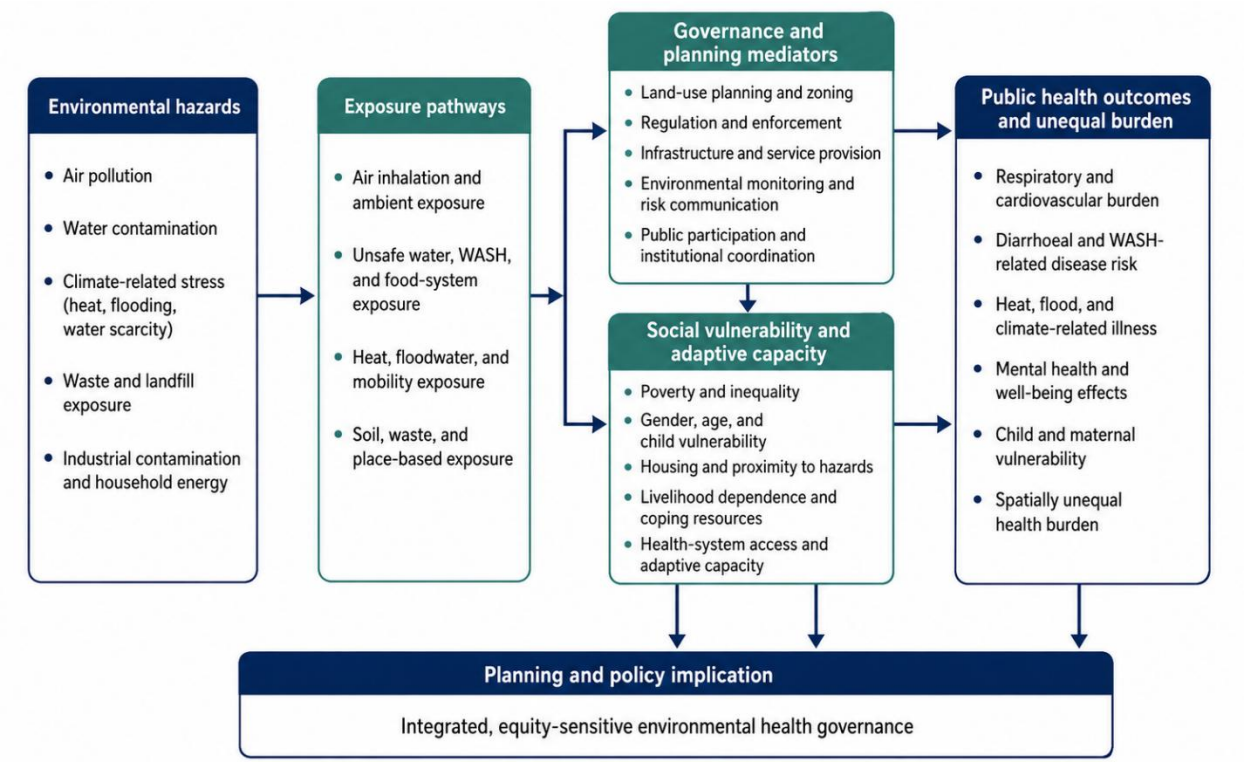


Figure 7. Compound vulnerability framework for environmental health planning. Source: Authors' synthesis based on the reviewed literature.

The main contribution of the review is to reframe environmental health risk as a planning and governance issue and not merely as a technical exposure issue, as illustrated in Figure 7. This is an extension of the previous single-hazard and exposure-centred approaches. The evidence reveals that air pollution, water pollution, heat, floods, water shortages, waste management, domestic energy and polluted soil are frequently interconnected, with common issues of governance and infrastructure deficiency. So, it is not the problem of measuring pollution in order to understand environmental health. It must also be viewed as a planning and governance issue, in which regulation and provision of services, land use planning, public information and social inequality contribute to the amount of health burden.

5.2 Bibliometric patterns and field development

The bibliometric results indicate that the visibility of the research on environmental determinants of public health has increased in recent years. The number of publications has been rising over the course of the study period, particularly in 2024, and citation impact has been higher for older publications due to normal citation delay. Interdisciplinary nature is also reflected in the leading journals. Research was published in sustainability, public health, social science, water, development, remote sensing and planning related journals. This trend indicates that environmental health studies are not just biomedical and technical exposure studies. It is increasingly connected with sustainability, governance, development, and spatial planning.

But there is an important imbalance in the geographic distribution of publications. The United States and China were the most productive countries represented in the corpus, and there were many low income, highly exposed countries that were less prominent. This is significant as communities in low resource areas are often exposed to multiple risks from unsafe water, air pollution, flooding, heat, exposure to waste and weakness in infrastructure. The lack of representation of these settings could restrict the worldwide picture of compound environmental health vulnerability.

The keyword findings also help to substantiate the broader argument of the review. Public health, environmental health, air pollution, water pollution were prominent words, indicating the exposure-health relationships continue to be the dominant concern of the field. But there are signs of an increasing focus on wider social and governance issues in the literature such as urbanisation, sustainable development, waste management, heavy metals, perception, gender, child health, environmental policy, and water supply. This bibliometric pattern corroborates the thematic synthesis indicating that environmental health risk is exposed, infrastructure, governance, public information and vulnerability.

5.3 Main environmental health pathways

Thematic synthesis provides evidence that "Air Pollution" is the most elaborate health pathway in the corpus. Causal and quasi-experimental studies also show a stronger relationship between air pollution and mental health, self-assessed health, anaemia, respiratory illness, child health and household energy related outcomes (Lafave, Beyene et al. 2021, Panezai, Ali et al. 2021, Balasooriya, Bandara et al. 2022, Balakrishnan and Tsaneva 2023, Datt, Maitra et al. 2023, Zhu, Liao et al. 2023). But the evidence also suggests that exposure is socially inequitable and risks are influenced by income, gender, education, housing, energy access and exposure to pollution (Datt, Maitra et al. 2023, Zhu, Liao et al. 2023, Okyere, Abu et al. 2024).

Another piece of evidence for compound vulnerability relates to water, climate, waste and contaminated-land. Factors such as sewage failure, industrial discharges, groundwater contamination, WASH infrastructure, and child vulnerability in a cluster are all influencing water-related risk (Bashar and Fung 2020, Citton, Croonenberg et al. 2020, Fatima and Ünsal 2024, Wang, Zhu et al. 2024). Climate-induced risks include exposure to heat, the presence of

contaminated mobile flood water, water scarcity, ecological shifts, and pressure to health systems (Suthar, Singhal et al. 2023, Berazneva and Byker 2024, Hussain, Meng et al. 2024, Huynh, Hofstra et al. 2024, Zimmermann, Abadi et al. 2025). Waste and industrial contamination studies indicate that waste and industrial contamination are spatially uneven and often intersect with social disadvantage (Dada 2021, Flacke, Maharjan et al. 2022, Mihai, Gündoğdu et al. 2022, Chien and Knoble 2024, Osra, Elbisy et al. 2024). The underlying theme of all these pathways is that environmental health risk is generated at the intersection of exposure and social arrangements which allocate protection unequally.

5.4 Planning and policy implications

The results are relevant for environmental planning and management. First, environmental health governance needs to shift away from single hazard management, and cross-sector coordination is needed for air quality regulation, WASH, waste management, land use management, climate adaptation and health protection. Secondly, planning agencies should consider compound vulnerability screening to identify priority zones, where exposure and social vulnerability intersect such as polluted rivers, landfills, open dumpsites, industrial zones, brownfields, heat-risk areas, and flood-prone streets (Dada 2021, Chien and Knoble 2024, Huynh, Hofstra et al. 2024, Osra, Elbisy et al. 2024). Thirdly, policy measures need to offer assistance for implementing equity-sensitive targeting of infrastructure as health co-benefits rely on the factors of affordability, access to services, protection of livelihoods and gender roles as well as local adaptive capacity (Wang, Huang et al. 2023, Deng, Niu et al. 2024, Okyere, Abu et al. 2024, Postula, Kluza et al. 2024). Lastly, risk communication and community participation must not be treated as an adjuvant to the planning process but rather as key planning tools as knowledge, trust, language, self-efficacy and civic participation influence public responses to environmental hazards (Chukwu, Morse et al. 2022, Suldovsky and B. Frank 2022, Li and Folmer 2023, Kyere and Kankam 2025). These implications indicate that there is a need to prioritise risks spatially, coordinate institutions and plan for communities that are exposed to multiple environmental risks, as well as plan equitably for such communities.

5.5 Research gaps and future directions

The review examines a number of gaps in the research. Additional research is required in low income and underrepresented areas where compound exposure may be extreme, yet evidence is limited. There is also a need for more longitudinal, causal, and mixed method studies as many of the studies are still cross-sectional, perception-based, modelled or conceptual. Future studies should link environmental monitoring to health outcomes in particular for WASH related disease, heavy-metal exposure, mental health, heat stress and waste-site risk. There is also a need for greater focus on governance mechanisms, such as enforcement, financing, planning and community participation and institutional coordination.

In sum, the review advocates for a governance-centred and equity-sensitive approach to environmental health, replacing the exposure-centred approach. This shift is important because communities do not experience air pollution, unsafe water, climate stress, waste exposure, and

weak infrastructure as isolated problems. They experience them as overlapping conditions that shape health, well-being, and everyday capacity to live safely.

6. Conclusion

This review demonstrates that recent studies on environmental health have progressed beyond simply analyzing one exposure to a greater understanding of risk. Bibliometric results show that, overall, there is an increasing interest in the interdisciplinary study of environmental factors affecting public health, while this research interest is not evenly distributed geographically. The thematic synthesis reveals that air pollution, contaminated water, climate stress, waste exposure, energy use in the household, and contaminated land all impact health via interconnected systems of exposure, infrastructure, governance and vulnerability.

The compound vulnerability perspective is the main contribution of this review. It demonstrates that planning policies, the ability of regulators, WASH provision, land-use, public messaging and distribution, and differential adaptive capacities are all factors affecting environmental health burden beyond just the hazard itself. Future studies should reinforce evidence lacking in underrepresented areas and link environmental monitoring with health outcomes data. The results can be used for policy and planning purposes to inform integrated and equity sensitive environmental health governance to safeguard communities who are exposed to multiple environmental risks.

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