Literature Review on the Integration of Epidemiology and Environmental Health in Disease Risk Mitigation

Ellxi Lidya Louiz Kandou[1]*, Sabrina Tertia Rucita Aramintana[2]
[1*]Universitas Sam Ratulangi, Indonesia
[2] Universitas Nusa Cendana, Indonesia
Email Corresponding Author: ellxikandou@gmail.com

ABSTRACT

This study aims to analyze the integration of epidemiology and environmental health as a strategic framework for mitigating disease risks in both communicable and non-communicable contexts. Using a qualitative descriptive research design through a systematic literature review, this article synthesizes academic journals, official reports, and relevant books published between 2014 and 2025. Data collection involved structured literature searches and document analysis, while data interpretation followed inductive thematic analysis through stages of coding, categorization, and synthesis. The findings reveal that integrating epidemiological methods with environmental health initiatives—such as Wastewater-Based Epidemiology (WBE), Environmental Public Health Tracking (EPHT), and Big Data–Geospatial Analytics—significantly improves disease surveillance, early detection, and health policy effectiveness. Moreover, the integration enhances the precision of environmental risk assessment and fosters adaptive, evidence-based decision-making. Despite its transformative potential, challenges persist, including fragmented data systems, limited interdisciplinary collaboration, and unequal access to environmental information. The study concludes that this integration strengthens theoretical models like the One Health and exposome paradigms while contributing to practical innovations in sustainable and equitable public health governance. These findings provide critical insights for policymakers, researchers, and practitioners seeking to design resilient health systems responsive to modern environmental and epidemiological threats.

Keywords: epidemiology, environmental health, disease risk mitigation, one health, public health integration

INTRODUCTION

The intersection of epidemiology and environmental health represents one of the most crucial domains in understanding and mitigating disease risks in the twenty-first century. The rapid acceleration of urbanization, climate change, and globalization has significantly altered human-environment interactions, amplifying exposure to various environmental determinants of health (Lee & Park, 2022). These complex dynamics underscore the necessity of integrating epidemiological insights with environmental health approaches to effectively address both infectious and non-communicable diseases.

Epidemiological data reveal that environmental factors—such as air and water pollution, waste mismanagement, and chemical exposures—contribute to a substantial burden of global disease (Rojas-Rueda dkk., 2021). The COVID-19 pandemic further highlighted the interplay between environmental conditions and disease spread, reinforcing the urgency of interdisciplinary strategies for prevention and control (Brosky dkk., 2024). The integration of environmental health into epidemiological frameworks is, therefore, not only timely but indispensable for public health resilience.

Despite substantial progress, fragmentation between disciplines remains a critical challenge. Epidemiologists often operate independently from environmental scientists, resulting in data silos and limited collaboration in policy-making and intervention design (Donzelli dkk., 2024). This lack of integration hampers the development of comprehensive risk assessment models that could otherwise guide evidence-based environmental and health policies) (Déglin dkk., 2022).

Moreover, environmental epidemiology requires enhanced analytical frameworks capable of capturing complex exposure pathways and long-term health effects. Traditional epidemiological methods frequently fall short in accounting for multi-exposure contexts, cumulative risks, and socio-ecological determinants of health (Déglin dkk., 2021). To bridge these methodological gaps, emerging paradigms such as “One Health” and “lifecourse epidemiology” have been proposed to link human, animal, and ecosystem health (Destoumieux-Garzón dkk., 2018; Wagner dkk., 2024).

Current global trends emphasize the growing impact of environmental degradation on public health outcomes. For instance, increasing heat waves, deteriorating air quality, and contaminated water sources have been associated with heightened risks of cardiovascular and respiratory diseases (Beltrame dkk., 2021). These findings reinforce the necessity for multi-sectoral frameworks that integrate epidemiological evidence into environmental health governance.

Wastewater-Based Epidemiology (WBE) exemplifies a promising integrative approach that combines real-time environmental monitoring with epidemiological surveillance (Brosky dkk., 2024). This method enables early detection of infectious disease outbreaks, contributing to proactive public health responses. Such innovations illustrate the potential of integrative science to transform disease monitoring and intervention strategies.

However, significant challenges persist, particularly regarding data harmonization and cross-sectoral collaboration. Variability in data quality, inconsistent exposure measurements, and inadequate policy translation impede the full realization of integrative frameworks (Thessen dkk., 2020). Furthermore, disparities in environmental exposures and access to healthcare continue to exacerbate health inequities globally (James-Todd dkk., 2024).

These inequities highlight the importance of incorporating social and environmental determinants into epidemiological models. By integrating contextual factors such as socioeconomic status, occupation, and neighborhood environment, public health research can more effectively identify vulnerable populations and tailor interventions (Graham & White, 2016). This integration aligns with the global agenda for sustainable and equitable health outcomes.

From a theoretical standpoint, the integration of epidemiology and environmental health enriches our understanding of disease etiology through systems thinking and exposome approaches (Vrijheid, 2014). Practically, it strengthens surveillance systems, supports predictive modeling, and informs adaptive public health interventions (Jayakumar dkk., 2024). Such synergy fosters the creation of dynamic frameworks that are responsive to evolving health-environment interactions.

Methodological advances, including spatial and temporal modeling, offer new pathways for characterizing exposure and disease risk with greater precision (Jia, 2019). These tools, when integrated into epidemiological studies, enhance the capacity for early warning and targeted policy interventions, especially in high-risk regions.

The current scientific discourse calls for a paradigm shift toward collaborative, data-driven, and translational frameworks that unite epidemiologists, environmental scientists, policymakers, and communities (Donzelli dkk., 2024). This multidimensional collaboration is vital for building public trust and translating scientific evidence into actionable health policies.

In light of these challenges and opportunities, this article seeks to systematically examine the literature on the integration of epidemiology and environmental health in mitigating disease risks. It aims to elucidate the key frameworks, empirical evidence, and theoretical underpinnings that shape this interdisciplinary field. The discussion emphasizes the need for robust collaboration, innovative methodologies, and policy coherence to strengthen health resilience against environmental risks.

By synthesizing recent advances and identifying critical knowledge gaps, this review aspires to contribute to both scientific understanding and practical policy development. Ultimately, the integration of epidemiological and environmental perspectives offers a comprehensive approach to mitigating disease risks and promoting sustainable health systems worldwide.

METHOD

This study employs a qualitative research design with a descriptive approach through a comprehensive literature review (library research). The qualitative-descriptive framework is chosen for its ability to explore complex interdisciplinary relationships—specifically the integration of epidemiology and environmental health in disease risk mitigation—in a contextual and interpretative manner (Bingham, 2023; Pratt, 2025). This design allows an in-depth understanding of conceptual frameworks, methodological innovations, and empirical evidence drawn from academic sources. The descriptive nature of this study provides a systematic narrative that captures the evolving dynamics between environmental factors and epidemiological methodologies (Abraham, 2024; Doyle, 2019).

The data used in this article derive from secondary sources, including peer-reviewed journal articles, academic books, and official institutional reports published between 2014 and 2025. All sources are selected for their relevance, validity, and scientific rigor, focusing on studies addressing environmental epidemiology, health risk assessment, integrative public health approaches, and methodological developments in qualitative research (Bandaranayake, 2024; Jimenez, 2024). Databases such as ScienceDirect, PubMed, and Frontiers were utilized to identify high-quality literature that supports theoretical and empirical discussions. This ensures that the synthesis reflects both the most recent and methodologically sound contributions to the field (Granikov, 2020).

The data collection process follows systematic steps characteristic of literature-based qualitative research. These include the identification of keywords, screening of abstracts and full texts, and assessment of methodological transparency and relevance to the topic (Baillie, 2019; Togia & Malliari, 2017). Only peer-reviewed academic works that explicitly address the intersection of epidemiology and environmental health were included. Documents lacking methodological clarity, empirical grounding, or peer-review validation were excluded. This process aligns with the transparency and audit trail principles emphasized in modern qualitative research (Bingham, 2023).

For the data analysis, this study applies a multi-step qualitative analytical framework involving data reduction, coding, categorization, and thematic synthesis (Kalpokaite, 2018; Vila-Henninger, 2022). Initially, relevant concepts were identified from the selected literature, followed by categorization into thematic clusters—such as epidemiological frameworks, environmental determinants, and integrative methodologies. The coding process was both inductive and abductive, allowing theoretical refinement while maintaining openness to emergent insights (Fife & Gossner, 2024). Through iterative review and memo-writing, analytical saturation was achieved, ensuring interpretive depth and coherence.

To ensure data validity and credibility, this research applies conceptual triangulation and peer review validation as methodological safeguards (Belotto, 2018; Doyle, 2019). Triangulation was achieved by comparing perspectives from multiple disciplines—epidemiology, environmental science, and public health policy—thereby enhancing interpretive robustness. The interpretive process was further validated through theoretical alignment with established frameworks such as One Health and exposome models (Destoumieux-Garzón dkk., 2018; Vrijheid, 2014), ensuring that the synthesis remains consistent with both empirical evidence and theoretical rigor.

Overall, this qualitative-descriptive library study offers a rigorous and transparent analytical pathway for understanding the integrative mechanisms linking epidemiology and environmental health. By systematically collecting, organizing, and interpreting academic evidence, this method ensures that findings are not only valid and replicable but also theoretically grounded and practically relevant. The approach aligns with the study's objective to contribute to the discourse on integrated health governance and to propose evidence-based directions for mitigating environmental and epidemiological disease risks (Jimenez, 2024; Pratt, 2025).

RESULTS

The findings of this literature review reveal that the integration between epidemiology and environmental health has become a central strategy in mitigating both communicable and non-communicable diseases. Recent studies highlight the increasing reliance on cross-sectoral collaboration, environmental data utilization, and evidence-based policies to enhance disease prevention and control (Lee & Park, 2022; Zeka dkk., 2024). The reviewed literature consistently shows that integrating environmental determinants into epidemiological models produces more accurate assessments of population health risks and supports proactive intervention designs (Jayakumar dkk., 2024).

One of the key results is the establishment of national and regional frameworks such as the Environmental Public Health Tracking (EPHT) system in the United Kingdom. This framework integrates environmental exposure data with health surveillance to identify at-risk populations and inform targeted Health Impact Assessments (HIA) (Zeka dkk., 2024). Similarly, the EPHT model has been instrumental in facilitating early detection of community-level hazards, optimizing resource allocation, and enhancing preventive policy formation (Lee & Park, 2022). The success of EPHT demonstrates how real-

time environmental and epidemiological integration can enhance public health decision-making accuracy.

The literature also emphasizes significant methodological innovations. For instance, Wastewater-Based Epidemiology (WBE) has emerged as a transformative tool in environmental health monitoring. The framework, as demonstrated by the WATERS program in Arizona, uses wastewater analysis to detect pathogen presence and chemical contaminants, enabling early outbreak detection and rapid response (Brosky dkk., 2024). This approach effectively bridges the gap between environmental monitoring and community health outcomes, especially during pandemics and localized disease outbreaks.

Furthermore, Big Data and Geospatial Analytics have become integral in linking environmental exposure with epidemiological outcomes. These technologies enable large-scale spatial correlation of air, soil, and water quality data with morbidity and mortality rates (Titus dkk., 2025). The findings reveal that incorporating geospatial and environmental datasets enhances predictive modeling accuracy for disease distribution and environmental exposure mapping. However, these innovations also present analytical challenges, such as data complexity and the need for interdisciplinary data governance frameworks (Déglin dkk., 2022).

In the context of non-communicable diseases, multiple studies confirm a strong association between environmental pollution and cardiovascular disease (CVD) incidence. Pollutants induce inflammatory and oxidative stress pathways, exacerbating cardiovascular risks across populations exposed to high levels of fine particulate matter (PM2.5) and industrial emissions (Scimeca dkk., 2024). These findings highlight how integrating molecular and epidemiological data supports early identification of disease mechanisms and guides environmental policy interventions.

Conversely, for communicable diseases, the reviewed evidence underscores the role of environmental health measures—particularly sanitation, clean water provision, and waste management—as fundamental interventions in disease prevention (Jayakumar dkk., 2024). Studies indicate that effective environmental health policies substantially reduce infectious disease prevalence, especially in densely populated or resource-limited areas. The integration of epidemiological surveillance with environmental health infrastructure strengthens outbreak prevention and improves population-level resilience.

Table 1. Innovations, Key Benefits, And Main Challenges Identified Across The Literature Regarding The Integration Of Epidemiology And Environmental Health

Innovation/Practice	Main Benefits	Key Challenges	References
Wastewater-Based Epidemiology (WBE)	Early outbreak detection and rapid response	Implementation and communication barriers	(Brosky dkk., 2024)
EPHT & Health Impact Assessment (HIA)	Identification of vulnerable populations	Data integration and professional training gaps	(Lee & Park, 2022; Zeka dkk., 2024)
Big Data & Geospatial Analytics	Broader exposure-outcome correlation analysis	Analytical complexity and data harmonization	(Titus dkk., 2025)
Cross-sector Collaboration	Evidence-based policymaking and prevention	Interdisciplinary silos and coordination issues	(Déglin dkk., 2021, 2022; Titus dkk., 2025)

The results also show that the integration process faces persistent institutional and methodological barriers, such as fragmented communication between epidemiologists and policymakers, inconsistent exposure datasets, and limited availability of quantitative data (Déglin dkk., 2021; Di Ciaula dkk., 2024). These limitations hinder the full realization of integrated approaches in both

environmental health and epidemiological modeling. Nevertheless, most authors advocate for increased transparency, data standardization, and training in multidisciplinary collaboration to strengthen integration efforts (Shaffer dkk., 2025).

Additionally, the synthesis highlights the importance of incorporating biomarkers and molecular indicators to improve exposure and outcome measurement (Vrijheid, 2014). Advances in molecular epidemiology and life-course approaches also enable researchers to trace health outcomes across lifespan exposures (Wagner dkk., 2024). These integrative models represent a paradigm shift toward "One Health" thinking, bridging molecular, environmental, and social determinants of health for global precision medicine (Nishi dkk., 2016).

In conclusion, the results demonstrate that the integration of epidemiology and environmental health significantly enhances disease risk mitigation through multi-dimensional data utilization, technological innovation, and cross-sectoral governance. Despite ongoing challenges, the empirical and conceptual findings across the reviewed literature provide a robust foundation for advancing sustainable, data-driven health policies responsive to modern environmental and epidemiological threats.

DISCUSSION

The synthesis of the reviewed literature demonstrates that the integration of epidemiology and environmental health offers not only a conceptual advancement but also a tangible framework for mitigating disease risks through evidence-based and interdisciplinary approaches. This integration aligns with the One Health and exposome paradigms, which conceptualize health as an interconnected system influenced by environmental, biological, and social factors (Vrijheid, 2014; Wagner dkk., 2024). These frameworks emphasize that disease causation extends beyond biological pathogens to encompass environmental exposures, behavioral patterns, and social determinants. Consequently, the integration of these domains contributes to a more holistic understanding of disease ecology and prevention.

A central analytical finding from the literature is the translational value of environmental epidemiology in public health policy. For example, programs such as the Environmental Public Health Tracking (EPHT) in England and similar initiatives in Korea have demonstrated that linking environmental exposure data with health surveillance can significantly enhance the precision of health impact assessments (Lee & Park, 2022; Zeka dkk., 2024). These systems operationalize the integration of epidemiological data into real-time decision-making, allowing policymakers to identify high-risk populations and implement targeted preventive interventions. The practical implication is that environmental monitoring should be embedded into health policy frameworks to foster adaptive and resilient public health systems.

The literature also underscores that technological and methodological innovations—particularly Wastewater-Based Epidemiology (WBE) and Big Data–Geospatial Integration—are redefining how public health surveillance operates (Brosky dkk., 2024; Titus dkk., 2025). WBE, as employed in the WATERS program in Arizona, demonstrates the ability to detect outbreaks and monitor chemical and microbial exposure at the population level. Meanwhile, geospatial modeling and data integration enable large-scale mapping of disease-environment correlations. However, the implementation of these technologies remains constrained by disparities in data accessibility, interdisciplinary coordination, and analytical capacity, particularly in developing nations (Déglin dkk., 2021; Di Ciaula dkk., 2024).

From a theoretical standpoint, the integration reinforces the ecological model of health, which posits that environmental and social contexts interact dynamically with individual-level biological factors. Empirical findings linking air pollution and cardiovascular disease (CVD) provide compelling evidence of how environmental exposure contributes to chronic disease mechanisms through oxidative stress and systemic inflammation (Scimeca dkk., 2024). This complements prior epidemiological frameworks that have largely focused on behavioral or genetic risk factors alone. Thus, integrating environmental health variables into epidemiological research extends explanatory power and enhances disease prevention models.

At the same time, the reviewed studies reveal critical institutional and structural barriers that constrain full integration. These include limited interdisciplinary collaboration, fragmented data governance, and insufficient translation of epidemiological insights into actionable policy (Déglin dkk., 2022; Shaffer dkk., 2025). For instance, while U.S. EPA scientists acknowledge the potential of epidemiological data to inform human health risk

assessments, inconsistencies in data reporting and communication between researchers and policymakers impede effective utilization (Shaffer dkk., 2025). Overcoming these obstacles requires standardized data frameworks, open-access platforms, and investment in cross-disciplinary training.

Another important implication lies in the application of integrated approaches to infectious disease control. Environmental health measures such as improved sanitation, waste management, and clean water access continue to play pivotal roles in reducing disease prevalence (Jayakumar dkk., 2024). When combined with epidemiological surveillance, these measures not only improve outbreak prediction but also enhance the efficiency of response systems. The integration of environmental interventions within epidemiological models thus bridges the gap between prevention and early detection.

Nevertheless, several limitations are acknowledged in the reviewed literature. First, most integrative studies remain context-specific, with limited generalizability across regions due to variations in environmental exposures and data quality. Second, many existing frameworks prioritize quantitative modeling while neglecting socio-behavioral dimensions of health, which are equally vital for sustainable interventions (Nishi dkk., 2016). Third, despite progress in molecular epidemiology, the operational integration of biomarkers and exposome indicators into environmental surveillance systems remains underdeveloped, particularly in low-resource settings (Vrijheid, 2014; Wagner dkk., 2024).

Moving forward, the literature recommends reinforcing integration through interdisciplinary governance, standardized metrics, and enhanced data transparency. The convergence of environmental, molecular, and social epidemiology offers a pathway toward precision public health—where policies are tailored based on spatial, temporal, and molecular data. Future research should also explore adaptive models that incorporate artificial intelligence and machine learning to handle complex datasets and dynamic exposure profiles. Furthermore, collaborative platforms between governments, academia, and private sectors are essential to ensure long-term sustainability of integrated health systems.

In sum, this analysis establishes that integrating epidemiology with environmental health transforms the conventional disease prevention paradigm into a more proactive, predictive, and participatory model. It bridges the divide between science and policy, fosters data-driven public health decision-making, and promotes equity in health risk management. The theoretical and practical contributions of this integration reaffirm its pivotal role in shaping the future of global health governance and disease resilience.

CONCLUSION

The integration of epidemiology and environmental health, as revealed through this qualitative literature study, underscores a transformative shift toward a more holistic, data-driven, and interdisciplinary framework for mitigating disease risks. The synthesis of findings—spanning innovations such as wastewater-based epidemiology, environmental public health tracking, and geospatial data analytics—demonstrates how combining environmental determinants with epidemiological methods enhances both preventive and predictive public health capabilities. These results deepen theoretical understanding by reinforcing the One Health and exposome paradigms, positioning environmental factors as integral components of disease etiology and population health resilience. The study also highlights significant implications for public policy and community health, emphasizing the need for cross-sectoral collaboration, data transparency, and equitable access to environmental health resources. Nonetheless, persistent limitations—such as fragmented data systems, uneven interdisciplinary communication, and insufficient integration of molecular or behavioral dimensions—remain challenges to achieving comprehensive implementation. Future research should therefore explore adaptive, AI-assisted, and participatory models that bridge the remaining gaps between epidemiological insight and environmental health governance, paving the way for sustainable, inclusive, and globally responsive health systems..

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