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Risk of Leptospirosis in Flood Affected Areas and Environmental Health Control Measures

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ABSTRACT

Flooding is an environmental disaster that consistently increases the risk of environment-related diseases, including leptospirosis. As a zoonotic disease, leptospirosis frequently emerges in post-flood settings due to sanitation damage, water stagnation, and increased human exposure to environments contaminated with *Leptospira*. However, existing studies on leptospirosis are predominantly clinical and epidemiological, while analyses positioning the disease as a structural environmental health issue in post-disaster contexts remain limited. This study aims to analyze leptospirosis risk in flood-affected areas and to examine relevant and sustainable environmental health control strategies based on scientific evidence. A qualitative descriptive-analytical method was employed using an *Evidence-Based Environmental Health Review* approach, synthesizing scientific literature, institutional reports, and policy documents related to leptospirosis, flooding, and environmental health. The findings indicate that flooding acts as a primary ecological determinant shaping leptospirosis risk through sanitation disruption, water quality degradation, increased reservoir populations, and interactions with social vulnerability. Environmental health–based control strategies—such as sanitation improvement, environmental management, ecological reservoir control, community education, and early warning systems—are shown to be more effective than reactive medical responses. This study reinforces the repositioning of leptospirosis as a structural environmental health issue to support sustainable post-disaster prevention strategies.

Keywords: Environmental Health; Flooding; Leptospirosis; Disease Prevention; Zoonosis

INTRODUCTION

Flooding is one of the most frequent environmental disasters worldwide and has shown an increasing trend in line with global climate change, uncontrolled urbanization, and the degradation of urban and rural ecosystems. Global data indicate that extreme flood events are occurring more frequently and have widespread impacts on public health, particularly through an increase in environmentally mediated diseases and zoonoses. The World Health

Organization reports that regions with high rainfall and inadequate sanitation systems are highly vulnerable to waterborne and environmental diseases, one of which is leptospirosis. In many developing countries, including Indonesia, flooding is not only understood as a hydrometeorological disaster but also as a trigger of recurrent and systemic environmental health crises.

Leptospirosis is a zoonotic disease caused by Leptospira bacteria and transmitted through contact with water or soil contaminated with the urine of animal reservoirs, particularly rodents. This disease is classified as a neglected tropical disease because it often receives limited policy attention despite its significant morbidity and mortality. Globally, leptospirosis exhibits a clear pattern of increased incidence following flood events in both tropical and subtropical regions. A study in Pakistan demonstrated that urban flooding significantly increases the risk of leptospirosis through a combination of standing water, damaged sanitation systems, and population exposure to contaminated environments (Rehan et al., 2022). Similar phenomena have been reported in Brazil, Greece, and Pacific regions, where sharp increases in leptospirosis cases occurred after extreme flooding events (Poulakida et al., 2024; Ziliotto et al., 2024; Kharwadkar et al., 2024).

At the national level, Indonesia is one of the countries with a relatively high leptospirosis burden in Southeast Asia. Cities characterized by seasonal flooding, high population density, and inadequate environmental sanitation show recurrent leptospirosis incidence on an annual basis. Safera et al. (2022) demonstrated a strong correlation between climatic factors, particularly rainfall and humidity, and increased leptospirosis cases in Semarang City. Post-flood conditions such as prolonged standing water, clogged drainage systems, domestic waste mixed with floodwater, and increased rodent populations create an ideal ecological medium for the survival of Leptospira. Thus, leptospirosis cannot be understood merely as an individual infectious disease, but rather as a structural consequence of environmental health degradation following disasters.

From an environmental health perspective, leptospirosis reflects a complex interaction between ecological, social, and human behavioral factors. Post-flood environments generate recurrent and systemic risk patterns, particularly among populations living in densely populated areas, informal settlements, and regions with limited access to sanitation. Eyre et al. (2021) showed that urban environmental degradation, rodent density, and specific geographic conditions directly contribute to the risk of Leptospira spillover to humans. These findings underscore that leptospirosis risk is structural in nature and cannot be separated from the environmental context in which communities live and conduct daily activities.

Nevertheless, leptospirosis research to date has been dominated by clinical and epidemiological approaches focusing on diagnosis, clinical manifestations, and individual risk factors. A systematic review by Baharom et al. (2023) identified various environmental and occupational factors associated with leptospirosis, yet most of the studies analyzed still positioned the environment as a background variable rather than as a primary determinant integrated within a post-disaster environmental health framework. Similarly, Karpagam and Ganesh (2020) emphasized the clinical and pathophysiological aspects of leptospirosis as a neglected zoonotic disease, with limited attention to the environmental constructs that enable recurrent transmission.

Other studies, such as Ahmadi et al. (2022) in Bondowoso Regency, identified environmental determinants of Leptospira transmission from rodents, but their analyses remained partial and did not explicitly link post-flood conditions as an ecological context shaping disease risk. Meanwhile, Galan et al. (2021), in their study on the epidemiology of leptospirosis in urban and rural areas of Brazil, highlighted differences in incidence patterns but did not elaborate in depth on how flooding as an environmental disaster functions as an ecological determinant constructing disease risk. In other words, most previous studies have treated flooding as an incidental triggering factor rather than as part of a broader environmental health risk system.

The research gap becomes more evident when examined from the perspective of qualitative, evidence-based environmental health synthesis. To date, there has been limited qualitative descriptive-analytical research that systematically synthesizes scientific evidence on leptospirosis risk in flood-affected areas and links it to sustainable environmental health control strategies. Rehan et al. (2022) emphasized the urgency of post-flood interventions for leptospirosis, but focused primarily on policy calls without comprehensive environmental synthesis. Ziliotto et al. (2024) linked extreme weather events to increased infectious diseases, yet their analysis remained centered on outbreak narratives rather than preventive environmental health control frameworks.

Based on these conditions, this study offers novelty by adopting an evidence-based environmental health approach to reposition leptospirosis from a purely medical and epidemiological issue to a structural post-disaster environmental health problem. This study not only synthesizes scientific evidence on leptospirosis risk in flood-affected areas but also critically examines relevant and sustainable environmental health control efforts as preventive strategies. The objective of this study is to analyze leptospirosis risk in flood-affected areas based on available scientific evidence and to examine effective, evidence-based environmental health control measures in post-disaster contexts.

METHOD

This study employed a qualitative descriptive-analytical design using an Evidence-Based Environmental Health Review approach. This approach was selected to enable a comprehensive analysis of leptospirosis as a post-flood environmental health problem by emphasizing the synthesis of scientific evidence across studies without conducting quantitative measurements or statistical hypothesis testing. This qualitative approach aligns with the study objective, which focuses on meaning-making, interpretation, and integration of scientific findings within an environmental health framework.

Data sources included peer-reviewed international and national journal articles, reports from health and environmental agencies, and relevant policy documents and guidelines on leptospirosis control. Literature was selected based on relevance to leptospirosis, flooding, and environmental health, as well as the use of scientifically accountable data and evidence. Literature searches were conducted systematically through academic databases using transparent selection processes to ensure source consistency and credibility.

Data analysis was conducted using a descriptive thematic approach by extracting key themes related to environmental risk factors for leptospirosis and post-disaster environmental health control strategies. Evidence synthesis considered the strength of findings and consistency across sources, which were then interpreted within an environmental health perspective. Analytical rigor was maintained through consistency of argumentation, transparency of the literature selection process, and coherence between findings, interpretation, and research objectives.

RESULT AND DISCUSSION

Flooding as an Environmental Determinant in the Formation of Leptospirosis Risk

Flooding represents a primary environmental determinant that systematically shapes leptospirosis risk in disaster-affected areas. Within an environmental health framework, flooding cannot be understood merely as a temporary hydrological event, but rather as an ecological disturbance that fundamentally alters the relationship between humans, pathogens, and the environment. Numerous studies demonstrate that flood events create ecological conditions that allow Leptospira bacteria to survive for longer periods in the environment, particularly through contaminated standing water and moist soils with high organic content (Karpagam and Ganesh, 2020; Rehan et al., 2022). In this context, flooding functions as a catalyst that expands indirect transmission pathways of leptospirosis from animal reservoirs to humans.

Damage to sanitation infrastructure caused by flooding is a key factor in shaping leptospirosis risk. Non-functioning drainage systems, overflowing septic tanks, and the mixing of domestic waste with floodwater create an ideal environmental medium for the spread of *Leptospira* (Baharom et al., 2023). A study in Brazil showed that areas with basic or non-integrated sanitation systems experienced higher leptospirosis transmission rates after flooding compared to areas with better sanitation infrastructure (Cremonese et al., 2023). This finding confirms that sanitation quality is a structural variable that determines regional vulnerability to leptospirosis, particularly in post-flood contexts.

In addition, flooding affects the population dynamics of animal reservoirs, especially rodents, which are the primary hosts of *Leptospira*. Standing water and habitat destruction force rats to move into human settlements, increasing the frequency of contact between humans and environments contaminated with rodent urine (Ahmadi et al., 2022; Eyre et al., 2021). From a disease ecology perspective, this phenomenon reflects pathogen spillover driven by environmental disturbance, in which the boundaries between animal habitats and human living spaces become increasingly blurred. Thus, post-flood leptospirosis risk is not random, but follows predictable ecological patterns based on environmental conditions.

Flooding also contributes to the degradation of surface water quality and drinking water sources, which play a critical role in leptospirosis transmission. Zamir et al. (2022) demonstrated an association between the use of contaminated natural water sources and the emergence of leptospirosis outbreaks in both animals and humans. In post-flood situations, limited access to clean water forces communities to rely on standing floodwater or alternative water sources that are at high risk of contamination, thereby increasing exposure to *Leptospira* (Sato et al., 2024). This condition reinforces the argument that leptospirosis is an environmentally mediated disease closely linked to water quality and water resource management.

From a public health perspective, flooding acts as a socio-ecological determinant that amplifies the vulnerability of certain population groups to leptospirosis. Communities living in densely populated areas, informal settlements, or urban poor neighborhoods tend to face limited access to sanitation, clean water, and healthcare services, making them more susceptible to post-flood health impacts (Galan et al., 2021; Kharwadkar et al., 2024). This condition indicates that leptospirosis risk is not evenly distributed, but rather follows existing patterns of environmental and social inequality.

In the context of climate change, the frequency and intensity of extreme flooding events are projected to continue increasing, further reinforcing the relevance of leptospirosis as a global environmental health problem. Ziliotto et al. (2024) emphasized that extreme weather events contribute to increased environmental pathogen pollution and the expansion of leptospirosis endemic areas. These findings suggest that without systematic environmental interventions, flooding will continue to reproduce leptospirosis risk as a recurring post-disaster health problem. Therefore, understanding flooding as a primary ecological determinant is a critical foundation for formulating sustainable leptospirosis prevention strategies. Overall, this discussion demonstrates that flooding is not merely an incidental triggering factor, but a structural environmental determinant in the formation of leptospirosis risk. This risk emerges from complex interactions between sanitation degradation, changes in reservoir animal ecology, declining water quality, and social inequalities exacerbated by disasters. Consequently, leptospirosis control efforts cannot be separated from comprehensive, evidence-based post-disaster environmental management strategies.

Interaction Between Environmental Factors and Social Vulnerability in Post-Flood Leptospirosis Transmission

Post-flood leptospirosis transmission is determined not only by physical environmental factors, but also by complex interactions with the social vulnerability of affected communities. Within an environmental health framework, this disease reflects how disrupted ecological conditions interact with social structures and human behavior, thereby shaping systemic and recurrent risk patterns (Baharom et al., 2023; Sykes et al., 2022). After flooding, communities are often forced to carry out daily activities in contaminated environments, whether for cleaning homes, working, or meeting basic needs, which increases the intensity of exposure to *Leptospira*.

Animal reservoirs, particularly rodents, play a central role in flood-affected ecosystems and the leptospirosis transmission process. Eyre et al. (2021) showed that rodent density is strongly correlated with environmental degradation and urban poverty. Following floods, rats tend to seek shelter and food sources in human residential areas, increasing the risk of environmental contamination with urine containing *Leptospira*. This phenomenon illustrates that leptospirosis transmission results from interactions between ecological factors and socio-economic conditions that shape shared habitats between humans and animal reservoirs.

Post-flood community behaviors also play an important role in determining levels of leptospirosis exposure. Engagement in mud-cleaning activities without personal protective equipment, the use of unsafe water, and the habit of walking barefoot in flooded areas are common practices that increase infection risk (Karpagam and Ganesh, 2020; Rehan et al., 2022). Such behaviors are often not merely individual choices, but responses to limited resources and the absence of safe environmental support after disasters. Therefore, approaches that blame individual behavior without considering environmental and social contexts risk overlooking the structural roots of the problem.

Social and environmental inequalities further intensify vulnerability to leptospirosis in flood-affected areas. Studies by Galan et al. (2021) and Poulakida et al. (2024) show that low-income populations, informal workers, and environmental sector workers face higher risks of leptospirosis exposure after flooding. Dense living conditions, inadequate sanitation, and limited access to healthcare services exacerbate the health impacts of floods. From this perspective, leptospirosis can be understood as a disease rooted in environmental and social inequality, in which health risks follow lines of structural injustice.

To clarify the interaction between environmental factors and social vulnerability in post-flood leptospirosis transmission, Table 1 presents a synthesis of key findings from various evidence-based environmental health studies.

Table 1. Environmental and Social Risk Factors of Leptospirosis in Flood-Affected Areas

Environmental Factors	Social Vulnerabilities	Implications for Transmission
Flood-induced water stagnation	Informal settlements in flood-prone areas	Prolonged exposure to contaminated water
Damaged sanitation systems	Limited access to clean water	Increased use of unsafe water sources
Increased rodent population	Low-income and marginalized communities	Higher contact with contaminated environments
Degraded waste management	Post-flood cleanup without protection	Elevated occupational and household exposure
Climate-driven extreme rainfall	Weak disaster preparedness	Recurrent and predictable outbreaks

The table shows that post-flood leptospirosis risk is shaped by a combination of environmental factors and social vulnerabilities that mutually reinforce one another. Flood-related standing water, when occurring in informal settlements, creates prolonged environmental exposure to pathogens. Sanitation damage interacting with limited access to clean water encourages the use of unsafe water sources, while increased rodent populations in impoverished environments amplify the likelihood of Leptospira transmission. These findings are consistent with the One Health approach, which emphasizes the interconnection between human, animal, and environmental health in understanding zoonotic diseases (Sykes et al., 2022; Sohn-Hausner et al., 2023).

This analysis also demonstrates that leptospirosis control cannot be separated from efforts to reduce social vulnerability. Interventions that focus solely on medical aspects, such as case treatment, tend to be reactive and are unable to break the post-flood transmission cycle (Muñoz-Zanzi et al., 2025). In contrast, environmental health approaches that integrate sanitation improvement, environmental management, and community empowerment have greater potential to sustainably reduce leptospirosis risk (Pratamawati et al., 2020). Thus, this discussion confirms that post-flood leptospirosis transmission is the result of dynamic interactions between environmental factors and social vulnerability. The disease reflects systemic failures in post-disaster environmental management and social protection. Therefore, effective prevention strategies must adopt an evidence-based environmental health perspective capable of addressing this complexity in a holistic manner.

Evidence-Based Environmental Health Control as a Strategy for Post-Flood Leptospirosis Prevention

Leptospirosis control in flood-affected areas requires a paradigm shift from reactive medical approaches toward preventive and sustainable evidence-based environmental health strategies. Numerous studies indicate that post-disaster health responses focusing on case detection and treatment alone are insufficient to reduce long-term leptospirosis risk, as they fail to address the environmental determinants that constitute the primary sources of transmission (Muñoz-Zanzi et al., 2025; Rehan et al., 2022). In this context, the evidence-based environmental health approach provides an analytical and practical framework for integrating environmental management as a core disease prevention strategy.

Post-flood sanitation improvement and water management represent the most consistently evidence-supported environmental interventions for leptospirosis control. Cremonese et al. (2023) demonstrated that community-based sanitation interventions, such as simplified sewerage systems in underserved urban areas, can significantly reduce leptospirosis transmission risk. Adequate sanitation plays a critical role in disrupting environmental contamination pathways from animal reservoir urine while simultaneously reducing human exposure to contaminated water. These findings underscore that leptospirosis control cannot be separated from long-term investments in environmental infrastructure, particularly in flood-prone areas.

In addition to sanitation, ecological reservoir control constitutes a key component of environmental health-based prevention strategies. This approach does not focus on sporadic rodent eradication, but rather on habitat management that reduces environmental carrying capacity for reservoir animal populations (Ahmadi et al., 2022; Eyre et al., 2021). Evidence from One Health studies indicates that integrated environmental control measures including waste management, drainage improvement, and reduction of rodent food sources are more effective than reactive measures such as post-disaster rodenticide use (Sohn-Hausner et al., 2023). Consequently, reservoir control should be understood as an integral element of sustainable environmental health strategies.

Community education and strengthening environmental early warning awareness also play crucial roles in post-flood leptospirosis control. Lusiani et al. (2023) found that increased public knowledge regarding leptospirosis risks and preventive behaviors can reduce individual exposure to contaminated environments. However, the effectiveness of education is highly dependent on environmental support that enables safe practices, such as the availability of clean water and sanitation facilities. Therefore, education should not stand alone, but must be integrated with structural interventions that tangibly reduce environmental risk.

Environmental-based early warning approaches are increasingly relevant in the context of recurrent flooding and climate change. Temporal and spatial analyses conducted by Safera et al. (2022) indicate that weather patterns and rainfall intensity can be used as early indicators of increased leptospirosis risk. Integrating environmental data, early warning systems, and public health responses enables preventive action before case surges occur. This approach aligns with the recommendations of Pratamawati et al. (2020) regarding the importance of cross-sectoral collaboration in environmental intervention-based leptospirosis early warning systems. Overall, scientific evidence indicates that preventive environmental health approaches are superior to reactive medical responses in controlling post-flood leptospirosis. Such approaches not only reduce disease risk, but also enhance environmental and social resilience to recurrent disasters (Ziliotto et al., 2024; Sykes et al., 2022). By repositioning leptospirosis as a structural environmental health problem, control strategies can be designed in a more holistic, sustainable, and adaptive manner to address the challenges of climate change and urbanization.

CONCLUSION

The analysis in this study demonstrates that leptospirosis risk in flood-affected areas is a direct consequence of post-disaster environmental health degradation. Flooding acts as a primary ecological determinant that creates ideal environmental conditions for Leptospira persistence through standing water, sanitation damage, declining water quality, and increased interactions between humans and animal reservoirs. This risk is structural and recurrent, particularly in areas with high levels of social and environmental vulnerability.

The evidence-based environmental health approach confirms that leptospirosis control cannot rely solely on reactive medical responses. Effective prevention strategies must integrate sanitation improvement, environmental management, ecological reservoir control, community education, and environmental indicator-based early warning systems. This approach not only fulfills the research objective of analyzing leptospirosis risk based on scientific evidence, but also provides a relevant and sustainable environmental health control framework for post-disaster contexts.

Theoretically, this study reinforces the repositioning of leptospirosis as a structural environmental health issue rather than merely an individual infectious disease. Practically, the findings highlight the importance of integrating environmental control into post-disaster health policies. Future research should involve cross-regional and interdisciplinary studies to evaluate the effectiveness of environmental health interventions in recurrent flood contexts, thereby strengthening the evidence base for adaptive and sustainable leptospirosis control strategies.

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