Multi-Hazard Management in Public Health Emergencies: A Case Study of Earthquake-Induced Dengue Outbreak in Bihar, India

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ABSTRACT

On June 14, 2024, a 6.2 magnitude earthquake struck northeastern Bihar, India, followed by a dengue outbreak 20 days later, exacerbating public health challenges. This case study analyzes the multi-hazard scenario across four districts (A, B, C, D), which reported 56 earthquake-related deaths, over 420 injuries, 1,740 suspected dengue cases, 314 confirmed cases, and 7 dengue deaths. Key vulnerabilities included damaged infrastructure, water stag- nation, and strained health systems. Utilizing data from the Public Health Emergency and Disaster Management (PHEDM) Tier-III training, this paper examines risk assessment, preparedness, response, and recovery strategies. Findings highlight the need for integrated disaster and vector control plans, robust surveillance, and multi-sectoral coordination to mitigate secondary health crises post-disaster. Recommendations include resilient infrastructure, community engagement, and real-time data systems to enhance multi- hazard resilience.

INTRODUCTION

India, particularly the state of Bihar, is highly susceptible to a range of natural hazards due to its geophysical and climatic conditions. Bihar lies in seis- mic zones IV and V, positioned near the boundary of the Indo-Australian and Eurasian tectonic plates, making it prone to earthquakes. Historical records underscore this vulnerability; for instance, the devastating 1934 Bihar-Nepal earth- quake, measuring 8.0 on the Richter scale, resulted in over 10,700 deaths and widespread destruction across northern Bihar and Nepal (1). This event, one of the deadliest in Indian history, highlighted the region's seismic risks, with ground shaking, landslides, and liquefaction causing massive infrastructure col- lapse (5). More recent seismic activities, such as the 2015 Nepal earthquake that affected Bihar, further emphasize the recurring threat (6).

Compounding these geophysical risks are climate-sensitive public health threats, notably vector-borne diseases like dengue. Dengue, transmitted by *Aedes* mosquitoes, thrives in tropical and subtropical climates with high humidity and rainfall, conditions prevalent during Bihar's monsoon season. In recent years, Bihar has witnessed a surge in dengue cases; in 2023 alone, the state reported 6,712 confirmed cases, contributing significantly to India's national tally of over 289,235 cases (2).

By 2024, partial data indicated continued escalation, with Bihar recording thou- sands of cases amid urbanization, poor sanitation, and climate change effects (7). The interplay between natural disasters and vector-borne diseases is well- documented; earthquakes disrupt water supply, sanitation, and housing, creating stagnant water pools that serve as ideal breeding grounds for mosquitoes, thereby amplifying dengue transmission (4; 1).

Global case studies highlight similar patterns. The 2010 Haiti earthquake led to 6 reported dengue cases alongside malaria and filariasis, driven by overcrowding in temporary shelters and water stagnation

(14). Similarly, the 2016 Ecuador earthquake triggered a surge in Zika virus cases, rising from 89 to 2,103, due to damaged infrastructure creating mosquito breeding sites (15). In India, post- disaster outbreaks are not uncommon; for example, flooding in Kerala (2018) led to a spike in leptospirosis and dengue, underscoring environmental triggers (21). These examples emphasize the need for integrated disaster and health response frameworks in multi-hazard contexts.

The simulated scenario of June 14, 2024, a 6.2 magnitude earthquake in north- eastern Bihar, exemplifies this multi-hazard dynamic. The epicenter near District A triggered tremors across Districts B, C, and D, causing 56 deaths, over 420 injuries, and displacing hundreds of families in vulnerable rural and low-income areas (2). Structural damages to buildings, primary health centers (PHCs), and roads impeded immediate response efforts. Subsequently, broken pipelines, clogged drains, and monsoon rains led to water stagnation, fostering a dengue outbreak after 20 days. This resulted in 1,740 suspected cases, 314 confirmed positives, and 7 deaths, straining already overburdened health services (2).

This multi-hazard event was analyzed during the PHEDM Tier-III training (Batch 3, Group D) in Bihar, involving mentors and mentees from health and disaster management sectors. The training simulated real-world challenges to evaluate vulnerabilities, preparedness gaps, and response mechanisms. This paper synthesizes these insights, drawing on frameworks like the National Vector Borne Disease Control Programme (NVBDCP) and the District Action Plan on Climate Change and Human Health (DAPCCHH) Jehanabad 2025-30 (1; 2; 3). It aims to underscore the complex interplay between natural disasters and public health crises, providing evidence-based recommendations for integrated multi-hazard management in resource-constrained settings like Bihar. By examining risk assessment, prevention, preparedness, impact, response, and recovery, the study contributes to broader discussions on disaster resilience in India, where multi- hazards pose escalating threats amid climate change and urbanization.

METHODS

This study employs a qualitative synthesis of data from a simulated case scenario developed and discussed during the PHEDM Tier-III training program in Bihar. The training, part of a national initiative to build capacity in public health emergency and disaster management, was conducted for Batch 3, Group D, un- der the guidance of mentors Dr. Balmukund Kumar (Medical Officer, JNKTMCH, Madhepura), Dr. Sazid Hussain (Professor and Head, Department of Community Medicine, Madhubani Medical College), and Er. Alok Ranjan (Disaster Management Expert). Mentees included professionals from health departments, such as district epidemiologists and medical officers, representing diverse expertise in vector control, surveillance, and emergency response.

The scenario was based on a hypothetical yet plausible multi-hazard event: a 6.2 magnitude earthquake on June 14, 2024, followed by a dengue outbreak. Group discussions, lasting over several sessions, incorporated injects and questions on risk assessment, preparedness, activation of Emergency Operations Centers (EOCs), search and rescue, public health response, logistics, communication, and recovery. Participants analyzed district-specific impacts, vulnerabilities, and capacities using tools like hazard identification, vulnerability mapping, and capacity gap analysis.

Data synthesis involved thematic analysis of discussion notes, supplemented by secondary sources from similar case studies. References included the DAPC- CHH Jehanabad 2025-30 for climate-health linkages, NVBDCP portal for dengue surveillance data, and Integrated Health Information Platform (IHIP) for real- time health monitoring (1; 2; 3). Additional insights were drawn from global literature on disaster-induced outbreaks, including reviews of post-earthquake vector-borne diseases and regional studies on flood-related outbreaks (4; 20; 14; 15; 21). The analysis focused on key themes: hazards, vulnerabilities, exposures, capacities, and decision-making for interventions. Ethical considerations ensured anonymity of participants, and the study adhered to principles of evidence-based public health research. Limitations include the simulated nature of the scenario, which may not fully capture real-time complexities, though it was grounded in Bihar’s historical disaster profile and comparable global cases.

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Event Description

The earthquake struck at 4:42 AM on June 14, 2024, with the epicenter in District A, registering 6.2 on the Richter scale. Tremors extended to Districts B, C, and D, causing immediate chaos. In District A, the most affected, 27 deaths and 180 injuries occurred due to collapsed government buildings, homes, and PHCs. Cracked roads and debris blocked access to remote villages, delaying relief. District B, with a history of dengue, reported no earthquake fatalities but suffered lab damage at Sadar Hospital, halting local testing. District C saw 18 deaths and over 140 injuries from debris in low-income neighborhoods, leading to displacement into shelters with poor drainage. District D, moderately impacted, had 1 death and 19 injuries but benefited from prior preparedness.

Post-event, infrastructure damage—broken pipelines and clogged drains—combined with monsoon onset created stagnant water, ideal for *Aedes* mosquito breeding.

Dengue cases emerged around July 4, 2024, totaling 1,740 suspected (314 con- firmed, 7 deaths): District A (112 cases, 2 deaths), B (96 cases, 1 death), C (79 cases, 3 deaths), D (27 cases, 1 death) (2). This dual hazard strained resources, with the State EOC activating Level 2 protocols under Unified Command.

Risk Assessment

Primary hazards from the earthquake included ground shaking, causing structural failures; landslides in hilly areas; and liquefaction in saturated soils, leading to sinking buildings (8). Secondary hazards encompassed flooding from dam breaches, fires from gas leaks, and chemical spills. For dengue, hazards arose from *Aedes* vectors, influenced by environmental factors like rainfall (increasing breeding sites) and temperature (optimal 25–30°C for virus development) (7).

Vulnerabilities were multifaceted: infrastructure/health systems collapsed in Districts A and C, with District B's lab damage delaying diagnostics; vector-borne risks intensified in waterlogged areas; socio-economic factors affected low-income groups in District C, including elderly and children; climatic context amplified risks in Bihar's Gangetic plains (1). Exposure included 420+ injured and 56 deaths from earthquake, plus 314 dengue cases. Capacities like NVBDCP surveillance and NDRF/SDRF deployments existed, but gaps in real-time tools persisted. Decision- making prioritized resilient infrastructure, WASH preparedness, and multi-sectoral coordination.

Prevention and Mitigation (Pre-Event)

Pre-event measures were inconsistent. Public education on dengue involved limited campaigns promoting bed nets and repellents. Environmental management focused on eliminating standing water but suffered from poor waste disposal in urban areas. Vector control included annual larvicide and fogging in District D, using biological methods like mosquito predators, but was sporadic elsewhere (4). Health infrastructure strengthening entailed stocking diagnostics and training workers, though shortages prevailed. Community engagement through local leaders and clean-up drives was minimal.

Mitigation challenges stemmed from weak building codes, inadequate disaster laws, and limited ecosystem-based solutions like natural buffers. Intersectoral investments were low, hindering coordination between health, urban planning, and disaster management

Preparedness Measures

District D exemplified effective preparedness with annual campaigns, surveil- lance, and inter-sectoral coordination. However, gaps included limited early warning systems under NVBDCP, insufficient stockpiles of insecticides and satellite phones, and localized NDRF/SDRF. Challenges: resource shortages, low aware- ness leading to apathy, coordination delays among agencies, environmental barriers like debris, human resource deficits, cultural misconceptions, financial constraint, and unpredictable disaster dynamics (3).

Learnings from past events stressed early surveillance for containment, com- munity engagement for participation, multi-sectoral coordination for efficiency, and stockpiling to counter infrastructure damage (11).

Impact and Response

Impacts: Earthquake caused 56 deaths, 420+ injuries, displacement, and environmental degradation; dengue added 1,740 suspected cases, worsened by shelters and stagnation, leading to psychological stress and economic losses (4; 10).

Response in first 24–72 hours: Evacuation, on-site treatment, EOC activation, supply delivery, sanitation setup. Key responders (health, DM, NGOs) used Unified Command. Challenges like access blocks were addressed with mobile clinics and external labs (2).

Emergency Management Principles

Utilized NVBDCP/DAPCCHH plans; all-hazards approach integrated responses; IRS and SEOC Level 2 ensured command; joint planning with veterinary sec- tors; EOCs for surveillance; backup communication and NGO-led awareness; psychosocial support addressed fear. Limitations: outages and constraints (3; 13).

DISCUSSION

The Bihar scenario illustrates how earthquakes exacerbate vector-borne diseases, aligning with global patterns where disasters create breeding sites and disrupt services (4; 1). District D's success via proactive fogging contrasts with others' failures due to damage (2). Gaps in surveillance and resources mirror India's broader challenges, where 2023 dengue cases exceeded 289,000 (2). Community engagement proved vital, as seen in post-1934 recoveries (9).

Previous studies provide critical parallels. The 2010 Haiti earthquake reported 6 dengue cases alongside malaria and filariasis, driven by overcrowding in shelters (14). The 2016 Ecuador earthquake caused a Zika virus surge (89 to 2,103 cases), linked to debris and stagnant water, similar to Bihar's *Aedes*-driven dengue outbreak (15; 16). In Iran, the 2003 Bam earthquake led to cutaneous leishmaniasis outbreaks, with incidence rising from 58.6 to 864 per 100,000, due to rubble creating sandfly habitats (17; 18). Post-1991 Costa Rica earthquake, malaria cases surged by 1600–4700%, driven by altered river flows (19). In India, the 2018 Ker- ala floods triggered dengue and leptospirosis spikes, highlighting environmental triggers like waterlogging (21). These cases underscore common mechanisms: infrastructure damage, displacement, and environmental changes amplifying vector-borne disease risks (20).

These global insights reinforce the need for pre-emptive vector control in seismic zones, as seen in Bihar. Effective measures in Ecuador included rapid fumigation and community clean-ups, which District D mirrored (15). However, Bihar's resource constraints and coordination gaps, unlike Ecuador's international aid, highlight context-specific challenges. Comparatively, the 2010 Haiti cholera out- break underscores the broader risk of post-disaster epidemics (10). In India, flood-related dengue spikes emphasize multi-hazard frameworks like NDMA's (12). Implications include policy shifts toward resilient health systems, climate- integrated planning, and GIS-based predictive analytics for future preparedness. Recommendations

Short-Term

For earthquakes: Immediate evacuation of affected populations and livestock to safe zones, provision of on-site and off-site medical treatment including trauma care, activation of district and state EOCs for centralized coordination, establishment of robust supply chains for food, water, and essential commodities, prioritization of sanitation to prevent secondary infections, setup of relief camps with adequate shelters focusing on vulnerable groups like children and elderly, and proper disposal of human and animal bodies to avoid health risks.

For dengue: Rapid restoration of clean water supply to reduce stagnation, clearance of drains and debris to eliminate breeding sites, widespread screening for vector-borne diseases using mobile teams, implementation of integrated vector management including larvicide and fogging, public awareness campaigns via radio and community meetings, and deployment of ambulances for quick case transportation.

Long-Term

Earthquake: Strict enforcement of building by-laws incorporating seismic standards, promotion of earthquake-resistant construction techniques in new and retrofitted structures, mass education through IEC and BCC on disaster prepared- ness, identification and mapping of high-risk groups and areas, designation and maintenance of permanent shelters, and development of detailed SOPs for response and recovery.

Dengue: Enhancement of water sanitation and hygiene (WASH) infrastructure, improvement of drainage systems in urban and rural areas, regular removal of stagnant water through community drives, scheduled fogging and spraying operations pre-monsoon, establishment of field and hospital-level case management protocols, and promotion of IEC/BCC for sustained behavioral change (1; 12). Additional strategies: Integrate multi-hazard perspectives in health plans, conduct regular drills, invest in technology like GIS for monitoring, foster partnership with NGOs, and secure funding for capacity building.

CONCLUSION

This case study on the 2024 Bihar earthquake-dengue outbreak highlights the imperative for integrated multi-hazard management. By prioritizing surveillance, engagement, and stockpiling in preparedness, alongside swift response and resilient recovery, such dual threats can be mitigated. Bihar, with its historical vulnerabilities, must adopt forward-looking strategies emphasizing infrastructure, data systems, and coordination to build enduring resilience against evolving disasters and health crises.

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