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Ecological Risk Factors Contributing to Dengue Fever Prevalence: Rawalpindi Experience

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Abstract

The recent floods in different regions of Pakistan caused massive disaster and deaths. The present study is based on the post-flood relief activities done by Rawalpindi Medical University, Rawalpindi, Pakistan. The 2025 floods in District Buner, Khyber Pakhtunkhwa, Pakistan, have caused extensive collateral damage in terms of deaths, individual displacement, and disruption of healthcare facilities. The current report highlights clinical data related to airborne communicable diseases, including acute respiratory infections, malaria, diarrhea, and skin infections. This case report highlights clinical presentations, healthcare challenges, and climate-related drivers behind the disaster. A total of 500 patients (265 male, 235 female) were assessed in relief camps, with acute respiratory infections, diarrheal diseases, malaria, and skin infections being the most frequent. The current study emphasizes the climate change extremities in Buner district, which are life-threatening weather events, and health vulnerabilities faced in such effected area having a very low resource settings and a lack of basic health care facilities.

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Introduction

In infectious disease epidemiology, the classic triad of host, agent, and environment highlights that outbreaks depend not just on the presence of the pathogen and vector, but also on ecological and environmental conditions. Dengue fever, including its severe form, dengue hemorrhagic fever (DHF), is a major mosquito-borne viral disease, especially in tropical and subtropical areas.

Globally, approximately 390 million infections occur annually across more than 125 countries, and dengue incidence has increased by an estimated 30-fold over the past half-century. [i]The disease's range has expanded into previously temperate regions[2] Dengue viruses (serotypes 1–4) are transmitted by *Aedes aegypti* (primary vector) and *Aedes albopictus* (secondary vector). The ecology of dengue transmission involves a complex interplay of climatic, environmental, socio-demographic, infrastructural, and human behavior variables.[3–6]

Dengue outbreaks are becoming more common in Pakistan, especially in Punjab, Khyber Pakhtunkhwa, and Sindh. Rawalpindi, a crowded city near areas with climates that help mosquitoes thrive, is a useful example for studying ecological risks. In this city, factors like monsoon rains, changes in temperature and humidity, and urban challenges have often been linked to dengue outbreaks.

This review examines the literature specific to Rawalpindi and nearby settings to identify ecological risk factors, supporting evidence, gaps, and proposes recommendations tailored to the Rawalpindi environment.

Ecological Risk Factor in Rawalpindi and Their Evidence Meteorological Factors (Rainfall, Temperature, Humidity)

A study on vector indices and meteorological factors across Lahore, Faisalabad, and Rawalpindi (2017–2018) found that rainfall (62.5–106.5 mm), temperature between ~22.1–30.25 °C, and relative humidity ~ 53.5–73.5% were significantly associated with dengue incidence; both Container Index (CI) and Breteau Index (BI) showed strong positive correlations with dengue cases.[8]

In the broader Pakistan context, Epidemiological Trends and Risk Factors analysis indicates that the seasonal monsoon pattern (July–September) with elevated temperature and humidity creates conducive habitat conditions for *Aedes* breeding. [9]

In a multi-city study (Islamabad, Rawalpindi, Lahore, Karachi), minimum temperature, rainfall, population density, and travel were significant predictors of dengue transmission based on regression and neural network modeling.[10]

In Rawalpindi specifically, a case-control study of the 2017 dengue outbreak identified open water storage in containers at homes as a risk factor (OR ~2.04), while continuous piped water supply (i.e., reducing need for storing water) had a protective effect (OR ~0.03).[11]

These studies show that weather conditions like rainfall, temperature, and humidity are key factors. They affect how mosquitoes survive, breed, feed, and spread the virus, as well as where they can lay eggs.

Vector Indices and Breeding Site Ecology

In the Rawalpindi / Punjab vector study, Container Index (CI) and Breteau Index (BI) were statistically significantly correlated with dengue case counts (BI: r ~0.824; CI: r ~0.706).[8]

Dengue cases often cluster in crowded neighborhoods with poor infrastructure. Small habitats like water containers, old tires, and broken drains help mosquitoes breed in large numbers.

A case-control investigation in Rawalpindi found that all 5 water samples taken in affected areas had *Aedes* larvae present, reinforcing entomological evidence of local breeding.[11]

Water Storage, Waste Management & Urban Infrastructure

In the Rawalpindi outbreak study, stored water containers left uncovered were significant risk factors, indicating that household practices directly mediate vector breeding.[11] Across Pakistan, an association of dengue case load with environmental factors highlighted factors like inadequate solid waste management, irregular water supply, high population density, and socio-economic status as key variables.[12] Urbanization pressure, poor drainage, open garbage disposal, and blocked stormwater channels create standing water pockets, thereby expanding vector niches.[10]

Flooding events and heavy rainfall exacerbate these risks, as residual water pools in low-lying urban depressions become breeding grounds.

Human Mobility, Travel, and Introduction Risk

Travel to dengue outbreak areas was a significant risk factor in Rawalpindi's 2017 case-control study (OR ~2.88).[11]

Broader analyses in Pakistan implicate human movement (intercity travel, migration) and globalization in introducing new dengue serotypes or strains into regions, accelerating epidemic emergence.[9]

Genetic and phylogeographic studies show repeated introduction of dengue virus genotypes (e.g., DENV-2 genotype IV) from neighboring regions, leading to transition from hypoendemic to hyperendemic transmission.[10]

Virus Evolution & Serotype Dynamics

Pakistan has witnessed shifts in circulating dengue serotypes and genotypes.[10] This evolving viral ecology may influence transmissibility, virulence, and outbreak potential.

Genomic characterization studies indicate that subsequent infection with heterologous serotypes is a potent risk for severe dengue manifestations.[13]

Case Study: Rawalpindi (2017 Outbreak Insights)

The 2017 Rawalpindi outbreak was extensively studied using a case-control design in urban areas. Among ~373 confirmed cases and matched controls: Males made up ~75% of cases; predominant age group 21–30 years.[11]

Core risk factors: contact with confirmed dengue case, water storage in open containers, and recent travel to outbreak zones. Protective behaviors included the use of repellents and regular piped water supply.

All five water samples tested in households in affected zones contained *Aedes* larvae. This local study shows that even small mistakes in managing water at home or being exposed to mosquitoes can lead to outbreaks when the climate is suitable.

Discussion & Synthesis

The evidence from Rawalpindi is similar to what has been found in other places where dengue is common. It confirms that ecological risks are a main cause of outbreaks. In Rawalpindi:

Rainfall and ambient temperature act as triggers for seasonal vector proliferation. Household and community water storage practices are critical micro-determinants of breeding opportunities. Urban infrastructure deficits, waste accumulation, inadequate drainage, and open garbage disposal amplify risk. Human mobility and virus importation contribute to seeding new outbreaks. Vector indices such as BI/CI provide operational surveillance metrics and early warning potentials. However, gaps remain: Limited longitudinal data are available to assess how ecological risk variables change over time relative to dengue incidence. Few studies integrate high-resolution spatial mapping or GIS overlays to pinpoint micro-hotspots in Rawalpindi. Interactions between climate change, land-use change, urban expansion, and vector ecology are not fully quantified. Sociocultural behavior (how people manage water, waste, and vector prevention practices) is understudied in parallel with ecological data.

Ultrasound can detect early complications of dengue, such as acalculous cholecystitis and fluid accumulation, supporting prompt diagnosis and management

Recommendations

Strengthen Meteorological-Entomological Surveillance

- Integrate weather data (rainfall, temperature, humidity) with entomological indices to forecast epidemic risk zones in Rawalpindi.
- Develop early warning triggers (e.g., BI/CI crossing thresholds after rains) to prompt preemptive vector control.

Improve Urban Infrastructure & Drainage

- Ensure maintenance and cleaning of storm drains, gutters, and sewage channels to prevent stagnant water buildup.
- Design urban planning strategies that minimize water stagnation zones, especially in new housing expansions.

Household Water Management Interventions

- Promote use of covered water storage containers, periodic cleaning, larvicidal treatment (e.g., Temephos) in domestic containers.
- Ensure a reliable piped water supply so that residents are not compelled to store water.

Waste Management & Environmental Clean-Up

- Enforce municipal solid waste collection, discourage illegal dumping, recycle or remove discarded containers, tires, and waste materials.
- Community clean-up campaigns synchronized with pre-monsoon periods.

Community Participation & Behavior Change

- Launch targeted awareness campaigns about ecological risk, breeding sites, and preventive practices.
- Engage local communities in vector reduction (source removal, larviciding) as part of integrated vector management (IVM).

Mobility Control & Surveillance at Entry Points

- Monitor travel and movement during epidemics; provide health advisories to passengers arriving from outbreak zones.
- Strengthen virus surveillance, genotyping, and monitoring to detect introductions of new serotypes.

Research & Spatial Modeling

- Conduct GIS-based hotspot mapping in Rawalpindi to guide micro-targeting of vector control.
- Perform longitudinal studies to correlate climate trends, land-use change, and dengue incidence over the years.

Policy Integration & Intersectional Collaboration

- Align municipal, environmental, health, and urban planning sectors to manage ecological determinants.
- Institutionalize regular audits of vector habitats in development zones, enforcement of building codes to prevent water pooling.

Conclusions

Rawalpindi's experience demonstrates that ecological factors, especially weather patterns, mosquito breeding, urban infrastructure, and human practices, play an important role in dengue outbreaks. In Rawalpindi and similar cities, reducing dengue risk requires a holistic approach including ecological, infrastructural, and community strategies. Effective surveillance, environmental improvements, and public involvement should work together with scientific modelling to anticipate and prevent future outbreaks.

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