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STUDIES FROM BITE TO BATTLE (ASSESSMENT OF HEALTH SYSTEM READINESS IN PAKISTAN'S DENGUE OUTBREAK STRUGGLE 2025

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Abstract

In late 2025, Sindh (Karachi, Hyderabad, and adjacent districts) is experiencing particularly sharp increases in cases and rising mortality from a dengue outbreak that has resurfaced and is fast spreading over heavily populated urban areas devastated by flooding. This article summarizes national warnings, operational guidelines, and current surveillance and news reporting to: (1) outline the current state of the epidemic; (2) evaluate the preparedness of health-system operations, including surveillance, laboratory, clinical care, vector control, logistics, risk communications, and governance; and (3) offer a framework for immediate, medium, and long-term action that is actionable and prioritized. The essay is intended for district health managers, hospital administrators, NGO partners, and public health planners who must translate strategic recommendations into practical actions during a serious post-monsoon outbreak.

INTRODUCTION

In South Asia, dengue fever an acute, mosquito-borne virus caused by four closely related dengue virus (DENV) serotypes has grown in frequency and severity as a hazard to public health. Pakistan saw a sharp increase in dengue cases following the monsoon in 2025, which was accompanied by extensive flooding and widespread relocation. This created the ideal environment for increased transmission and revealed enduring weaknesses in the preparedness of the health system. High-risk circumstances for *Aedes* mosquito reproduction and person-to-mosquito transmission were created by the ecological driver's widespread standing water, poor sanitation, and warm, humid post-monsoon conditions combined with congested relief camps and densely populated urban populations [1] and [2]. From a systems perspective, the effectiveness of several interrelated health-system functions such as surveillance and early warning, diagnostic and laboratory capacity (including serotype/genotype monitoring), clinical triage

and inpatient surge management, targeted vector control and environmental management, logistics and supply-chain resilience, risk communication, and community engagement determines dengue outcomes more than any one clinical intervention. Weaknesses in these areas have been exacerbated by the 2025 emergency: unreliable platelet and IV fluid supply visibility, inadequate district-level PCR/serotyping capacity, unequal surveillance reporting (especially from commercial providers), and disjointed municipal cooperation for environmental control [3].

The stakes are significant for public health. Rapid circulatory collapse and organ failure can result from severe dengue; case fatality is significantly decreased by prompt diagnosis, systematic fluid management, and availability to supportive treatment. Effective transmission management necessitates both ongoing community involvement and quick, locally focused reductions in mosquito reproduction (larval source reduction, larviciding, and focal adult control), which depend on coordinated municipal, provincial, and health authorities. Flood-related delays to shelter and WASH services in 2025 have increased clinical demand and made it more challenging to achieve long-term vector-control results [4].

Beyond the immediate operational response, the 2025 surge reveals structural factors that determine long-term vulnerability: rapid urbanization with insufficient drainage and solid-waste systems, gaps in integrated data systems that impede quick hotspot detection, and climate variability and extreme rainfall events that prolong and expand *Aedes* breeding seasons. Expanded molecular surveillance, predictive models that integrate climate and epidemiologic data, and creative vector-control strategies like Wolbachia deployments are examples of new tools that provide pathways to resilience, but they need to be incorporated into year-round preparedness planning and stronger governance architecture.

In Pakistan and throughout South Asia, dengue fever, an arboviral disease mostly spread by *Aedes aegypti*, has grown to be a persistent concern to public health. Over the past ten years, dengue prevalence has increased dramatically worldwide, and as outbreaks became bigger and less predictable, more emphasis has been paid to environmental factors and their effects on the health system [5].

The dengue burden in Pakistan is highly seasonal, although in recent years, it has expanded both geographically and temporally. Urbanization and extreme weather events, such as large-scale floods and heavier-than-expected monsoon rainfall, have increased the risk of transmission and produced an abundance of breeding habitats, leading to subsequent high-case seasons and localized epidemics. Throughout 2024–2025, national and international agencies have issued operational guidelines and alerts to provinces and districts, signaling an increased danger of dengue [6].

Numerous health-system domains, including surveillance sensitivity and timeliness, laboratory capacity, clinical surge capacity (beds, trained personnel, and essential supplies), vector control operations, risk communication, and logistical/financial surge mechanisms, are necessary for a nation to effectively respond to early warning. Evaluations from Pakistan's districts show mixed results: while some provinces have improved dengue monitoring units and reporting systems, there are still gaps in case detection, quick reporting, entomological capacity, and public health and primary/secondary care coordination. These flaws are particularly problematic in areas affected by flooding and displaced populations, where overcrowding in shelters and poor sanitation raise vector exposure and put a strain on services [7].

There is an urgent need for a thorough evaluation of health-system preparedness for the 2025 dengue challenge due to the increasing epidemiologic risk. The study "From Bite to Battle" presents readiness as a multifaceted concept that includes risk communication, clinical surge capacity, vector control responsiveness, surveillance and laboratory readiness, and preparedness planning. The study intends to identify actionable gaps and prioritize

solutions that will lower morbidity and death in the current and upcoming dengue seasons by combining surveillance data, facility readiness assessments, policy papers, and field observations [8].

Literature Review:

DengueEpidemiologyWorldwide

With an estimated 100–400 million cases each year, dengue fever has emerged as one of the viral diseases conveyed by mosquitoes that spreads the fastest in the globe [9] Due to urban demographic pressures, globalization, and climate variability, the WHO reports growing geographic spread and hyperendemicity in Asia, Latin America, and Africa. Dengue seasons between 2019 and 2024 broke previous records due to increased vector survival and extrinsic incubation brought on by global warming [10] [11] [12], [13]. According to recent worldwide analyses, half of the world's population would reside in dengue-suitable areas by 2050 [14] [15].

DengueinSouthAsia

Nearly 70% of dengue cases worldwide occur in South Asia, with recurrent outbreaks occurring in Bangladesh, India, and Pakistan. Seasonal spikes and persistent clusters are caused by rapid urbanization, inadequate sanitation, and inconsistent vector control initiatives [16], [17]. *Aedes* growth is facilitated by monsoon anomalies, extended wet seasons, and cyclonic patterns, according to regional climate research [18], [19]. The severity of the outbreak has increased due to cross-border viral circulation and serotype changes, especially the appearance of DENV-2 and DENV-3lineages [11], [20]. Additionally, historical data show that larger epidemic waves are driven by serotype interactions [21], [22].

Contemporary and Historical Burden of Dengue in Pakistan

The first substantial dengue outbreak in Pakistan was in 1994, and there were several major outbreaks in 2005–06, 2011, 2019, 2021, and 2022 [23], [24] Rising hospital admissions, quickly changing serotype dominance, and overcrowded metropolitan healthcare facilities were characteristics of this. Because of their dense populations and favorable breeding conditions, Lahore (2011), Karachi (2019), and Khyber Pakhtunkhwa (2021–2022) continue to be hotspots. [25], [26].

Studies in Lahore and Karachi show persistent breeding in peri-domestic containers, limited community vector-control compliance, and inadequate environmental management. Post-monsoon flooding in 2022–2024 further heightened dengue risk as stagnant water and displacement camps intensified exposure [27], [28].

Environmental Drivers, Climate Change and Flooding

Rapid mosquito multiplication has been linked to Pakistan's susceptibility to climate extremes, such as the historic 2022 floods that drowned one-third of the country. According to studies, dengue case spikes four to six weeks later are predicted by increasing minimum temperatures, humidity, and changed rainfall patterns [22], [29]. *Aedes* reproduction is increased by flood-related ecological changes (water stagnation, debris accumulation), [30] while public health response is slowed by damaged infrastructure [31], [32].

Health-System Readiness: Conceptual Foundations

The ability of a system to mobilize resources, coordinate operations, identify cases early, and maintain an efficient outbreak response is referred to as health-system readiness. Frameworks for WHO operational readiness highlight:

- **Surveillance sensitivity & early warning systems**
- **Laboratory diagnostic capacity**
- **Clinical surge capabilities** (beds, triage, supplies, trained staff)
- **Vector control operations** (larviciding, fogging, entomological surveillance)

Any domain gap can increase the severity of an outbreak. Because vector alterations and serotype shifts necessitate quick reaction scaling, preparedness is particularly important for dengue [9], [33].

Pakistan's Early Warning and Surveillance Systems

DHIS-2 reporting, provincial dengue monitoring units, and restricted entomological surveillance make up Pakistan's dengue surveillance. However, predictive potential is diminished by case reporting delays, a lack of district-level entomologists, fragmented data sharing, and a lack of integration of climate indicators. Due to limitations in data quality, machine-learning early warning models used in Punjab have shown promise but are still underutilized [28], [34].

Preparedness for Laboratory and Diagnostic Work

RT-PCR, IgM/IgG serology, and NS1 antigen tests are necessary for early dengue confirmation. Geographical disparities (more facilities in Punjab than in Baluchistan or rural Sindh) [35], [16], [36] low PCR capacity, and reagent shortages are common problems for public-sector labs. Turnaround times surpass guideline limits for big epidemics, impeding prompt vector and clinical action.

Surge Capacity and Clinical Readiness

During peak outbreak seasons, tertiary institutions report packed ERs, a lack of skilled dengue teams, a paucity of high-dependency beds, and depletion of IV fluids and platelet concentrates [37] Standardized triage procedures are frequently absent from district hospitals, which results in unnecessary admissions and avoidable deaths. Research indicates that when followed consistently, enhanced therapeutic pathways considerably minimize case fatality (<0.1%).

Operational Restrictions and Vector-Control Systems

Reactive fogging is a major component of Pakistan's vector-control measures rather than proactive, evidence-based methods. Systemic flaws include:

- Irregular larviciding cycles
- Insufficient entomological mapping
- Lack of community-level source reduction
- Limited accountability mechanisms [16], [33].

Gaps in Policy and Issues with Governance

Policy delays result from the division of authority between municipal authorities, health departments, environmental agencies, and disaster management units. Mosquito habitats are further reinforced by poor waste management, water-storage practices, and poor urban planning. Despite the existence of dengue legislation and goods in certain areas, intersect oral coordination and enforcement are still inconsistent [17], [21].

The Context of the 2025 Outbreak

Early in 2025, forecasts of above-average humidity and extended rains sparked worries of a significant dengue season. Positivity rates are rising in KP, Punjab, and Sindh, according to early trends. A thorough readiness evaluation is both necessary and timely due to health-system weaknesses, which are already exacerbated by the ongoing post-flood recovery. [19]

Materials & Methods:

Study Design: This was a mixed methodology, surveying and cross-sectional study evaluating the health system readiness in Pakistan during dengue outbreaks with a focused on provincial wise comparison. The quantitative factor observed epidemiological investigation and health service data, while the qualitative factors explored health system response mechanisms, strength, and breaches. The study covered major provinces of Pakistan such as Punjab, Sindh, Khyber Pakhtunkhwa (KPK) and Balochistan depending on availability of data In Present study it was examined dengue on peak outbreak years during the year 2025 to observed incidences, health system responses and size. Province wise epidemiological and surveillance was collected from World Health Organization (WHO) disease information on dengue outbreaks in Pakistan including confirmed cases, case fatality ratios (CFR), and provincial breakdowns [1] National Dengue Control Program (NDCP) Provincial Disease Surveillance Units (PDSUs) District Health Information System (DHIS-2) Publicly

available weekly outbreak monitoring bulletins. The data includes number of confirmed cases of dengue and mortality, number of suspected cases and geographical distribution of reported collections periodic epidemic arcs and for data health facility readiness and organized tool was used to evaluate health facility readiness crossways sampled from public sector hospitals. The data on health facilities level data covered bed capacity for dengue management over-all and high reliance, intensive care units, trained medical staff, availability of vital diagnostic services, stock levels of health materials such as IV fluids, platelet units, antipyretics and vector control resources at district level. The health facilities were selected through stratified purposive sampling, ensuring from tertiary, secondary, and district-level hospitals. The data on qualitative factor collected through informant interviews provincial district, hospital administrator's dengue control health officers District surveillance coordinators and vector control unit staff. The participants were informed through consent before enrolment. The data were collected and evaluated using standardized form to avoid duplication. Health facility readiness checklists were completed through information and direct observations hospital logs, and verification of supply inventories. The data on qualitative factors recorded by using digital audio recordings and field study proceedings were maintained. The data on outcome indicators was recorded by using methodology dengue cases in population size, case casualty ratio (CCR), provincial wise health readiness and vector surveillance activity index based on World Health Organization (WHO) recommendations,

Statistical Analysis of data: The data was evaluated especially quantitative Excel 2016 and SPSS latest version and presented in table and graphs latest version.

Ethical Deliberations: The secondary data was recorded from World Health Organization (WHO) and National Institute for Health (NIH) literatures. For qualitative interviews data obtained informed consent from all participants ensured.

Results:

In present study a total number of dengue cases were 18441 reported from four provinces. The distribution of reported case varied from province to province which indicated significant heterogenicity in disease burden.

Provincial Distribution of Cases:

From Sindh province it was reported the highest number of 11763 (63.8%) cases followed by Khyber Pakhtunkhwa (KPK) with 5435 (29.5%). Punjab contributed 1,000 cases (5.4%), while from Baluchistan province reported the lowest number, with 243 cases (1.3%) out of total number of reported cases (Table X). The large variance among Sindh province and other provinces indicated noticeable clusters of dengue activity in the southern and northern area of the country, while Punjab and Baluchistan exhibited relatively lower incidences of dengue cases.

Table.1. Showing Provincial Distribution and Dimensional Clusters and Hotspot cities

Province	Cases reported	Hardest hit cities
Sindh	**11,763**	**Hyderabad, Karachi**

PUNJAB	1,000	Lahore, Rawalpindi, Ghaziabad
BALOCHISTAN	243	Kech District
Kkhyber Pakhtunkhwa	5435	Peshawar, Mardan, Noshera

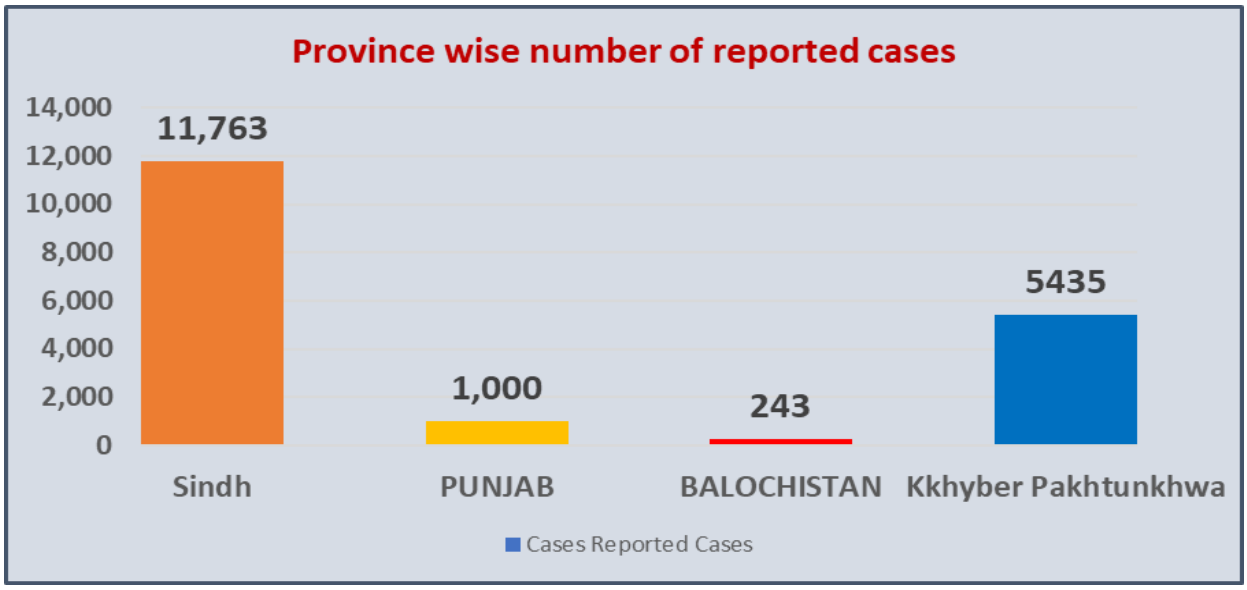


Fig.1. Showing Provincial wise number of dengue reported cases

Intra provincial diseases pattern

Sindh Province

In Sindh province the major cities such as **Karachi** and **Hyderabad** occurred as the hardest-hit areas. Karachi is the metropolitan city in the province contributed majority of dengue cases. Whereas Hyderabad city also presented a significant number of cases, indicating active transmission in densely populated areas of the district. Together, these two major cities signified the essential hotspots within province, showed consistent clustering of dengue cases.

Punjab Province

While the total provincial dengue reported cases, remained relatively low as compared with other province of the country such as Sindh and KPK, the cases were profoundly found in major cities like Lahore, reported the highest number of dengue cases within the province, followed by **Rawalpindi** and **Ghaziabad**. These cities showed contained outbreaks indicated high exposure risk connected with dense population areas, where intercity, mobility, and socioeconomic activities carried out.

Balochistan Province

In this province reported overall dengue cases were the with **243 cases**, mostly intense in the **Kech District**. No prevalent spreading of dengue cases transversely numerous districts was observed. This indicated a restricted and localized outbreak contained within one demographic area.

Khyber Pakhtunkhwa (KP):

KPK province showed the second highest provincial burden with **5 435 reported dengue cases**. The **Peshawar**, **Mardan**, and **Noshera** observed as hardest hit cities together recorded for the mainstream of provincial dengue cases. Peshawar city exhibited the significant clusters followed by Mardan and Noshera reported moderate number of dengue cases, whereas, prominent caseloads founded a contiguous district within the province.

Comparative Burden Across Provinces

When compared within provinces, in Sindh province reported cases was **(11.7 times)** more than Balochistan and **(11 times)** than Punjab province. Whereas in KPK reported dengue cases recorded **(5.4 times)** more as compared with the Punjab. Province. The unambiguous dissimilarity between Sindh/KPK provinces and Punjab/Balochistan provinces reflected as the major dissimilarities in disease transmissions and its dynamics and exposure risk.

Overall Pattern of Disease Spread

The dimensional investigations suggested a south-to-north incline in cases burden, within Sindh and KPK province exhibited as the most affected provinces. The Punjab displayed isolated but slightly milder outbreak and in the Balochistan province the most demographically was observed a limited pattern. The burden of dengue reported cases in urban and semi urban areas indicated the credible role of demographic density, travelling pattern and socioeconomic connections in determining disease transmissions.

Discussions:

In present study, observed reported dengue cases distributions revealed significant provincial inequalities, most notable varian of cases in Sindh and Khyber Pakhtunkhwa provinces. In Sindh province leading number of cases were reported from dense urban populations, high mobility, and higher intercity connectivity and travelling, particularly in Karachi and Hyderabad cities. The urban area's environments usually enable faster transmissions due to population clusters, were found the hardest-hit areas line up with the epidemiological manners. This was previously reported studies with an estimated 100–400 million cases each year, dengue fever has emerged as one of the viral diseases conveyed by mosquitoes that spreads the fastest in the globe [9] Due to urban demographic pressures, globalization, and climate variability, the (WHO) reports growing geographic spread and hyperendemicity in Asia, Latin America, and Africa. Dengue seasons between 2019 and 2024 broke previous records due to increased vector survival and extrinsic incubation brought on by global warming [10] [11] [12], [13]. According to recent worldwide analyses, half of the world's population would reside in dengue-suitable areas by 2050 [14] [15]. The examination revealed a significant provincial variance in disease transmissions and distributions among Sindh and Khyber Pakhtunkhwa provinces as the most affected areas among provinces. In KP, Peshawar, Mardan, and Noshera represented the principal hotspots, while in Balochistan, the majority of cases were clustered in the Kech District. The transmission pattern of elevated cases across Mardan and Noshera suggested consistent local transmission mediated shared community networks. KPK recorded as the second highest province in reported cases nearly one third of the total national wise reported cases. Nearly 70% of dengue cases worldwide occur in South Asia, with recurrent outbreaks occurring in Bangladesh, India, and Pakistan. Seasonal spikes and persistent clusters are caused by rapid urbanization, inadequate sanitation, and inconsistent vector control initiatives [16], [17]. Aedes growth is facilitated by monsoon

anomalies, extended wet seasons, and cyclonic patterns, according to regional climate research. [18], [19]. The severity of the outbreak has increased due to cross-border viral circulation and serotype changes, especially the appearance of DENV-2 and DENV-3lineages. [11], [20]. Additionally, historical data show that larger epidemic waves are driven by serotype interactions. [21], [22]. In present study, Punjab province had the most populous, this was recorded a significant lower number of dengue cases as compared with the Sindh and KPK provinces. The number of cases mainly reported from the Lahore city followed by Rawalpindi and Ghaziabad indicated that clusters were largely found in to urban areas rather than transmitted that provincewide. This pattern reflected variances in outbreak response strategies to disease, well organized surveillance in urban areas, or early and latent diagnosis different semi urban and rural areas. In Punjab province comparatively, reported cases were at moderate levels may also be related with earlier suppression efforts or less penetrating early seeding of the outbreak. The first substantial dengue outbreak in Pakistan was in 1994, and there were several major outbreaks in 2005–06, 2011, 2019, 2021, and 2022. [23], [24] Rising hospital admissions, quickly changing serotype dominance, and overcrowded metropolitan healthcare facilities were characteristics of this. Because of their dense populations and favorable breeding conditions, Lahore (2011), Karachi (2019), and Khyber Pakhtunkhwa (2021–2022) continue to be hotspots. [25], [26] Studies in Lahore and Karachi show persistent breeding in peri-domestic containers, limited community vector-control compliance, and inadequate environmental management. Post-monsoon flooding in 2022–2024 further heightened dengue risk as stagnant water and displacement camps intensified exposure. [27], [28]

The Baluchistan province showed the lowest number of dengue cases during this season from with the local areas of the Kech District. This is the lowest dense area with a large demographic area could have played a vital shielding role by interconnected contacts and communication. The marked number of cases in major cities of all provinces highlighted the vital role of urban environments in enabling disease transmission. High density housing and populations, everyday social connections and amplified dependence on public transport in larger and metropolitan areas has created circumstances favorable to speedy transmissions. The appearance of manifold urban hotspots such as in Karachi, Lahore, Rawalpindi, Peshawar further supported the premise that highly populated and larger areas and cities represented as essential drivers of the dengue outbreak during this season. In earlier studies it was reported that, a rapid mosquito multiplication has been linked to Pakistan's susceptibility to climate extremes, such as the historic 2022 floods that drowned one-third of the country. According to studies, dengue case spikes four to six weeks later are predicted by increasing minimum temperatures, humidity, and changed rainfall patterns [22]. [29] *Aedes* reproduction is increased by flood-related ecological changes (water stagnation, debris accumulation), [30] while public health response is slowed by damaged infrastructure. [31], [32]. Reactive fogging is a major component of Pakistan's vector-control measures rather than proactive, evidence-based methods. Systemic flaws include:

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Conclusion

The dengue outbreak in Pakistan in 2025 revealed both enduring weaknesses and significant strengths in the nation's healthcare system. The outbreak's human and financial cost was increased by overburdened hospitals, uneven surveillance, a lack of vector-control capabilities, and unequal access to care; however, quick local reactions, dedicated medical personnel, and flexible community networks showed distinct, scalable points of resilience.

By moving from crisis response to sustained preparedness, Pakistan can significantly lessen the impact of future dengue seasons. This can be achieved by strengthening integrated surveillance and data sharing, professionalizing and expanding vector-control programs, building surge capacity in frontline facilities, investing in diagnostics and case-management training, and prioritizing community engagement and risk communication in prevention strategies.

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