

Evolving landscape of viral infections in Pakistan: A comprehensive review of current surveillance, emerging threats and changing epidemiological patterns

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ABSTRACT

Objective: Pakistan faces several challenges from endemic and emerging viral threats owing to its unique geographical location. Several factors including climatic conditions, socioeconomic challenges, urban overcrowding and travel, overwhelm the already fragile national healthcare system of the country.

Material and Methods: The authors conducted a comprehensive analysis of peer-reviewed literature published in PubMed-indexed journals, along with review of WHO reports and official surveillance data from Pakistan's National Institute of Health between 2020-2024. Endemic and emerging viral threats and their transmission routes, epidemiological trends and surveillance system performance was critically reviewed to formulate an objective report on the current evolving landscape of viral diseases in the country.

Results: Viral infections have exhibited dramatic shifts in past 5 years in Pakistan. Surge in vector-borne infections was observed, with dengue cases increasing from 3,442 in 2020 to more than 20,000 in 2024, and chikungunya was recorded as an emerging threat with 28 cases in 2024. Polio surveillance reported an alarming resurgence with 74 cases in 2024 against 6 in 2023. Respiratory viral infections showed changing trends with influenza A H1N1pdm09 remaining the leading cause accounting for 42.6% of respiratory viral infections, but with decreasing overall positivity rates. Hepatitis B and C remain significant public health concerns with Pakistan being the second country in the world in terms of the burden of hepatitis C.

Conclusion: The viral disease landscape in Pakistan is dynamic, marked by endemic persistence and emergent threats. This review highlights critical shifts in epidemiology and underscores that strengthening integrated surveillance, laboratory capacity, and climate-adaptive public health measures is imperative for effective control and future pandemic preparedness.

Keywords: Viral infections, Surveillance, Epidemiology, Emerging diseases, Climate change, Pakistan

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INTRODUCTION

Pakistan, exhibiting a population of about 245 million people, is among the most challenging epidemiological settings in the world [1]. The geographical positioning of the country at the intersection of South Asia, Central Asia and the Middle East, and the very high diversity of climatic conditions from arid deserts to snow-clad mountains creates a favorable setting for the transmission of wide range of viral pathogens. The widely reported risk of infectious diseases in the country is compounded by socioeconomic determinants such as poverty, inadequate healthcare facilities and poor access to preventive health care services [2].

The epidemiological background of viral infections in Pakistan has been fundamentally altered through a variety of processes including climate change, urbanization, population mobility, and advances in surveillance technology in the last decade [3]. Familiarity with these developments is necessary in order to make appropriate public health policy and to prepare in the event of novel viral threats.

Pakistan's infectious disease surveillance system, though improving, also continues to struggle with detection, reporting and management of viral outbreaks. The Integrated Disease Surveillance and Response (IDSR) system, which was put in place for the reporting of priority diseases, has varying levels of effectiveness across the provinces with 55% to 100% compliance [4]. The difference in the strength of surveillance directly explains the country's inability to put forth a correct estimate of the true incidence of viral infections and apply prompt interventions.

The emergence of new viral threats such as Zika virus (ZIKV) in Pakistan, and the persistence of endemic diseases such as hepatitis B and C, polio

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and dengue, present a multifaceted public health challenge [5]. Climate change has also been a key determinant of changing disease patterns, with rising temperatures and altering precipitation patterns affecting the epidemiology of vector-borne diseases. This review attempts to give a comprehensive overview of the current viral infection scenario in Pakistan, with special reference to epidemiology trends, effectiveness of surveillance systems and the appearance of new viral threats. By integrating evidence from a range of sources, such as peer-reviewed articles published in PubMed-listed journals, official surveillance reports and assessments carried out by global health agencies, we present evidence-based views on the viral disease burden dynamics in Pakistan and point out areas of urgent concern.

MATERIAL AND METHODS

This study is a comprehensive narrative review. A systematic literature search was conducted in PubMed for articles published between January 2020 and December 2024. Search terms included: 'viral infections' or 'epidemiology' or 'surveillance' and 'Pakistan' combined with specific disease names (e.g., dengue, polio, hepatitis). Official surveillance data, outbreak reports, and strategic documents from the WHO and Pakistan's NIH for the same period were concurrently reviewed. Data were extracted, thematically synthesized, and analyzed to provide an integrated overview of the evolving viral infection landscape.

Studies were included if they: (1) reported epidemiological data on viral infections in Pakistan, (2) evaluated surveillance system performance, or (3) discussed emerging viral threats. Exclusion criteria comprised: (1) studies not focused on Pakistan, (2) non-viral infectious diseases, (3) editorials, commentaries, or non-peer-reviewed sources without original data, and (4) articles not available in English. Data were extracted using a standardized form capturing: study design, population, viral pathogen, key findings, and surveillance indicators. Quality and validity of included studies were assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools, appropriate for varied study designs (e.g., cross-sectional, surveillance reports). Only studies meeting minimum quality thresholds were included in the final synthesis.

Vector-Borne Viral Infections: A Shifting Paradigm:

Dengue Fever: An Escalating Public Health Crisis:

Dengue fever has emerged as the most prevalent vector-borne viral disease in Pakistan with a significant increase in incidence and geographical spread in the last decade [6]. The epidemiological patterns of dengue in Pakistan are reflective of foreboding trends that are suggestive of the role of environmental factors as well as improved surveillance measures.

Statistics from the National Institute of Health (NIH) show a variable year-wise pattern of dengue fever, with an increase to over 20,000 cases in 2024, compared to 3,442 cases in 2020. This represents an approximate six-fold increase, with the largest number of cases reported in the Balochistan province (6,958), followed by Punjab (5,405), Khyber Pakhtunkhwa (KPK) (3,649) and Islamabad (3,754) [7]. The geographical pattern of cases reflects correlation with the spread of *Aedes aegypti* breeding sites, and this can be explained by the effects of urbanization and climate change.

Historical analysis indicates that Pakistan has faced several large dengue epidemics, the largest being the 2011 Punjab epidemic with 21,685 cases and over 350 deaths [8]. Furthermore, the 2017 KPK epidemic infected over 18,000 people and caused 86 deaths, whereas the 2019 epidemic had 52,485 cases and 91 deaths in the province [9]. Such outbreaks are characteristic of the cyclical patterns of dengue transmission and the inability to maintain effective vector control interventions.

The spatiotemporal pattern of dengue virus (DENV) serotypes in Pakistan has been extremely heterogeneous, where DENV2 and DENV3 have been the most common in early years; however, recent studies report the circulation of all four serotypes [10]. The heterogeneity in serotype prevalence across the country raises the risk of severe dengue owing to antibody-dependent enhancement, especially in the context of recurrent outbreaks.

Chikungunya: An Emerging Threat: Chikungunya virus (CHIKV) has become an emerging public health concern in Pakistan since its first large-scale outbreak was reported in December 2016. This outbreak was reported by the World Health Organization (WHO), affecting over 30,000 individuals in which infections were confirmed by RT-PCR [11]. CHIKV has now been established in Pakistan's disease landscape as

an annual concern, with 28 cases reported in 2024 predominantly from KPK province [12].

The climate and topography of Pakistan supports the transmission of CHIKV through the *Aedes* mosquito. Unregulated urbanization with inadequate sanitary facilities has provided conducive breeding sites for the mosquito vectors resulting in widespread outbreaks in large metropolitan cities such as Karachi. The tendency of CHIKV infection for inducing chronic arthralgia along with similarity with dengue fever poses severe challenges in diagnosis, especially in low-resource settings [13].

Crimean-Congo Hemorrhagic Fever: A Persistent Threat: Crimean-Congo Hemorrhagic Fever (CCHF) is a major public health concern in Pakistan, and the country has become the fourth highest globally in terms of reported disease. The virus is endemic in the country, with seasonal outbreaks of approximately 60 cases, indicating a worrisome trend from seasonal to year-round transmission [14].

Epidemiological pattern of CCHF in Pakistan is directly associated with occupational and cultural practices. Outbreak peaks usually coincide with Eid-ul-Adha, indicating higher animal contact during this season and at the time of animal slaughter creating opportunity for viral transmission [15]. Seroprevalence surveys indicate 7.59% prevalence in Faisalabad, indicating high population exposure to the CCHF virus [16].

Zika Virus: A New Concern: Recent studies have also established the presence of ZIKV in Pakistan, with retrospective studies reporting cases initially classified as "unknown febrile illness" in Karachi to have been caused by ZIKV infection [5,17]. This is the first reported ZIKV outbreak in Pakistan raising alarms over the predisposition of the population to emerging arboviral infections [5].

The Centers for Disease Control and Prevention (CDC) has already categorized Pakistan as one of 12 Asian high-risk countries for ZIKV transmission, in light of the presence of competent vectors and incoming air traffic from Zika-endemic countries [17]. The local transmission of the virus emphasizes the necessity of enhanced arboviral surveillance and vector control interventions.

RESPIRATORY VIRAL INFECTIONS: EVOLVING PATTERNS AND PANDEMIC IMPACT

Influenza Surveillance: Trends and Challenges: Pakistan's influenza surveillance system, in place since 2008 and supported by CDC, has yielded valuable information on patterns of circulation of

respiratory viruses. The surveillance system has five geographically representative sites where influenza-like illness (ILI) and severe acute respiratory illness (SARI) surveillance are conducted [18,19].

Current surveillance data indicate dramatic changes in virus circulation patterns. In 2008-2024, influenza A H1N1pdm09 was the most dominant strain, making up 42.6% of positive cases, followed by influenza B (26.6%). The overall positivity rate has decreased in recent years, with only 3.5% positivity in 2020, which may be due to control measures during the COVID-19 pandemic [20].

The seasonal spread of influenza is most active in January and February, with A/H1N1pdm09 as the most common subtype [20]. This pattern holds significant value in selecting vaccine strains and timing vaccination campaigns.

Respiratory Syncytial Virus And Human Metapneumovirus: Respiratory Syncytial Virus (RSV) and Human Metapneumovirus (HMPV) are also significant etiologic agents of pneumonia among children in Pakistan, with the incidence of RSV peaking in July and that of HMPV in February. Incidence of RSV in children from retrospective surveillance data is 17.8% to 24%, while reported incidence of HMPV is 14.2 % [21].

Recent surveillance in 2022-2023 indicates continued transmission of these viruses, with 10% RSV and 26.4% influenza A prevalence among the population tested [22]. This evidence indicates the continued burden of respiratory viral infections among the pediatric population of Pakistan.

Hepatitis Viruses: A Persistent Public Health Challenge

Hepatitis B and C – A Global Burden: Pakistan bears one of the highest burdens of viral hepatitis in the world. It stands second in the world in terms of hepatitis C infection with a prevalence of about 9.8 million chronic hepatitis C cases [23]. The prevalence of hepatitis B surface antigen (HBsAg) is estimated at 2.5%, while hepatitis C prevalence is 3.8% to 4.8% among different provinces [24].

Epidemiological trend of viral hepatitis in Pakistan is highly variable geographically. The prevalence is 6.7% in the province of Punjab and 5% in Sindh [24]. This variation is because of differences in healthcare practices, socioeconomic status and transmission risk factors.

The WHO 2024 Global Hepatitis Report is an indication of advancement in the control of viral hepatitis in Pakistan with particular appreciation for

the national mobilization of resources of the Prime Minister's initiative for viral hepatitis treatment and testing [25]. Yet, obstacles in universal coverage of screening and treatment remain.

Hepatitis E: A Neglected Threat: Hepatitis E virus (HEV) is an important yet under-diagnosed viral infection in Pakistan among pregnant women and children. The virus is highly endemic among pregnant women with jaundice (57-91%) with a 40% risk of vertical transmission [26]. HEV infection among children contributes to 50-60% of acute viral hepatitis infection with high disease burden [27,28].

The mode of transmission of HEV in Pakistan is contaminated water supply and it occurs in outbreaks in the form of waterborne transmission. The initial outbreak was seen in 1972, where 250 people were infected through contaminated water supply [29].

Polio: A Resurgent Challenge: Pakistan remains one of only two countries in the whole world where polio transmission persists, in addition to Afghanistan [30]. The country has experienced a surprising resurgence of polio cases, with a total of 74 cases in 2024 compared to 6 cases in 2023 [31]. This is a dramatic leap that has raised global concerns and demands for emergency measures.

Geographical distribution of polio cases during 2024 indicates Balochistan as the most affected province with 27 cases, followed by KPK and Sindh with 19 cases each, and one case each in Punjab and Islamabad [31]. The pattern is indicative of the difficulty in sustaining vaccination coverage in security-compromised and hard-to-reach areas.

The rise in polio cases has been attributed to several factors, most significantly the re-emergence of the wild poliovirus type 1 (WPV1) YB3A genetic lineage from Afghanistan in 2023, which in turn spread to 90 districts [32]. The repatriation of unvaccinated Afghan refugees also played a key role in spreading the disease within the country.

Pakistan's acute flaccid paralysis (AFP) surveillance system is one of the largest in the world, with over 12,500 AFP reporting sites, 127 environmental surveillance sites, and 81 primary immunodeficiency disorder surveillance sites [32]. Despite this extensive surveillance system, it is estimated that 500,000 children were not vaccinated in the October 2024 campaign, indicating serious operational obstacles [33].

COVID-19 Impact on Surveillance Systems: The COVID-19 pandemic significantly impacted viral disease surveillance frameworks in Pakistan. The response of the country's healthcare systems

exhibited a combination of advantages and shortcomings regarding surveillance capabilities, as evidenced by the National Institute of Health's (NIH) swift establishment of testing facilities and its processing of more than 36,500 samples during the preliminary phase [34].

However, the pandemic significantly disrupted the surveillance of several endemic viral infections. Studies indicate that efforts launched to curtail the spread of COVID-19, reduced the surveillance of acute upper respiratory tract infections, viral hepatitis, pneumonia and other infectious diseases [35,36]. This disruption has led to gaps in understanding the actual prevalence of endemic viral infections during the pandemic era.

The beneficial outcomes of the COVID-19 pandemic response included a radical increase in polymerase chain reaction (PCR) testing capacity, setting up electronic reporting channels for health and improving coordination between the provincial and federal governments. These developments have provided a stepping stone for improving ongoing and future surveillance.

Emerging Viral Threats and Climate Change Impact

Climate Change and Vector-Borne Diseases:

Climate change has been a major impetus for shifting viral disease patterns in Pakistan. Climate change in the country involves rising temperature, shifted precipitation patterns and heightened frequencies of extreme weather events. These alterations have direct effects on the transmission of vector-borne diseases through the expansion of vector habitats and altered disease seasonality.

The devastating 2022 Pakistan floods resulted in additional 6.6 million malaria cases over a period of three years (2022-2024), showing the direct influence of climate events on the transmission of disease [37]. Though malaria is parasitic and not viral, the above example shows how climate change can drastically alter vector-borne disease dynamics.

DENV, CHIKV and other arboviral infections are spreading to previously non-endemic areas of Pakistan because of climate change [38]. Regions previously too cold to harbor *Aedes* mosquitoes now have vector populations, raising the risk of arboviral disease transmission.

Surveillance System Challenges: Pakistan's viral disease surveillance system is faced with a number of challenges that limit its performance in detecting and responding to emerging health threats. The IDSR system performs unevenly across the provinces,

ranging from 55% in KPK to 100% in Gilgit Baltistan and Azad Jammu Kashmir [4].

The main constraints are lack of adequate laboratory facilities, poor human capacity, inadequate quality data, and poor linkage between surveillance systems. Moreover, the lack of a national antimicrobial resistance and emerging pathogens surveillance system exacerbates the issue.

The COVID-19 pandemic highlighted the strength and the vulnerability of Pakistan's surveillance system. While the country was able to scale up testing capacity and set up laboratory networks, the diversion of funds away from routine surveillance activity resulted in gaps in the surveillance of endemic diseases.

Laboratory Capacity and Diagnostic Challenges:

The diagnostic capability of Pakistan for viral diseases has grown immensely over the last decade, especially molecular diagnostics. NIH is the national reference laboratory, while the provincial public health laboratories are the decentralized testing capacity.

The COVID-19 pandemic led to a tremendous surge in PCR testing capacity, as evidenced by the development of 134 COVID-19 testing laboratories [39]. Although the expansion has opened up chances to ramp up diagnostic capacity for other viral infections, the sustainability factor remains a concern. Nevertheless, there are diagnostic challenges, particularly for arboviral diseases, whose serological cross-reactivity between DENV, CHIKV and ZIKV may hinder accurate diagnosis [40]. Moreover, the lack of proper viral isolation and characterization methods hinders Pakistan's ability to detect and characterize new viral strains and emerging viral pathogens.

Public Health Response and Control Measures

Vaccination Programs and Coverage: Pakistani immunization programs are a central component for prevention of viral diseases, although coverage is less than ideal for most important vaccines. Measles vaccination plateaued at around 81% for the first and 74% for the second dose, far below the 95% needed for herd immunity [41].

The country conducted one of the world's biggest immunization campaigns in 2021 when it immunized 90 million children between the ages of 9 months and 15 years against measles and rubella. Even with such efforts, measles is still reported, with more than 20,000 cases and 800 deaths in 2021 [42].

Hepatitis B coverage within the Expanded Programme on Immunization (EPI) has improved.

Although, 74% of routine immunization has been reported, just 3% of newborns are receiving the all-important birth dose [43]. This gap in birth dose is a large lost opportunity for the prevention of mother-to-child transmission.

Vector Control Strategies: Vector control is still the pillar for arboviral disease prevention in Pakistan. Pakistan has adopted a number of measures in the form of integrated vector management, community-based surveillance, and third-party validation of control activities.

Punjab province has established new dengue control methods, such as the implementation of electronic surveillance systems, third-party validation and community mobilization. The Anti-dengue Third Party Validation program successfully lowered dengue incidence by using systematic larval surveillance and control [44]. Nonetheless, vector control is challenged by severe issues such as limited resources, low community involvement and the development of vector breeding sites as a result of uncontrolled urbanization. Climate change further makes vector control more difficult by increasing the geographic and seasonal range of the vector population.

Surveillance System Strengthening Initiatives

IDSR Roadmap 2024-2028: Pakistan has also formed a detailed roadmap for improving its IDSR system from 2024-2028. The roadmap focuses on eight main goals such as governance improvement, core surveillance functions, laboratory and information technology infrastructure [45].

The strategic framework calls for inter-sectoral cooperation, coordination of hierarchical surveillance networks and reinforcing human resource capacities at various levels. Its implementation should greatly enhance Pakistan's capacity to detect, report and respond to viral disease outbreaks.

International Partnerships and Support: Pakistan's surveillance system is supplemented by widespread international support, including collaboration with WHO, CDC and other agencies. CDC has been in support of influenza surveillance in Pakistan since 2004 and has instituted five surveillance sites for influenza-like illness surveillance [18]. WHO support includes technical support for capacity building of surveillance systems, laboratory capacity and outbreak response. The new Pandemic Fund initiative, with Asian Development Bank, the Food and Agriculture Organization and the WHO as implementing partners, offers further funds for pandemic readiness capacity building [46].

Table-I: Major Viral Disease Burden and Trends in Pakistan (2020-2024).

Disease	2020 Data	2023 Data	2024 Data	Epidemiology
Dengue Fever	3,442 cases	Not specified	20,000+ cases	Balochistan (n=6,958), Punjab (n=5,405), KPK (n=3,649), Islamabad (n=3,754)
Chikungunya	Not reported	Not specified	28 cases	Primarily in KPK
Polio (Wild Poliovirus)	Not specified	6 cases	74 cases	Balochistan (n=27), KPK (n=19), Sindh (n=19), Punjab (n=1), Islamabad (n=1)
Hepatitis B (HBsAg prevalence)	2.5% prevalence	2.5% prevalence	2.5% prevalence	National prevalence
Hepatitis C (prevalence)	3.8-4.8% prevalence	3.8-4.8% prevalence	3.8-4.8% prevalence	Punjab 4.8%, Sindh 3.8%
Influenza A H1N1pdm09	42.6% of positive cases	42.6% of positive cases	42.6% of positive cases	Predominant influenza strain
Respiratory Syncytial Virus (RSV)	17.8-24% prevalence	10% prevalence	10% prevalence	Pediatric populations, peak in July
Human Metapneumovirus (HMPV)	14.2% prevalence	Not specified	Not specified	Pediatric populations, peak in February
Crimean-Congo Hemorrhagic Fever	~60 cases annually	~60 cases annually	~60 cases annually	Year-round transmission, spikes during Eid-ul-Adha

Table-II: Surveillance system performance and public health response indicators.

Surveillance Component	Performance Metric	Status	Priority Action Required
IDSR Compliance Rate - KPK	55%	Lowest compliance among provinces	Strengthen surveillance in KPK
IDSR Compliance Rate - Gilgit Baltistan	100%	Highest compliance	Maintain current performance
IDSR Compliance Rate - Azad Jammu Kashmir	100%	Highest compliance	Maintain current performance
Polio Surveillance - AFP Reporting Sites	12,500+ sites	Comprehensive network established	Continue comprehensive monitoring
Polio Surveillance - Environmental Sites	127 sites	Environmental surveillance active	Expand coverage if needed
Influenza Surveillance Sites	5 sites	Established since 2008 with CDC support	Enhance laboratory capacity
COVID-19 Testing Laboratories	134 laboratories	Rapid expansion during pandemic	Maintain expanded capacity post-pandemic
Influenza Positivity Rate (2020)	3.5%	Declined possibly due to COVID-19 interventions	Monitor for rebound effects
Measles Vaccination Coverage (1st dose)	81%	Below 95% herd immunity threshold	Improve vaccination coverage
Measles Vaccination Coverage (2nd dose)	74%	Below 95% herd immunity threshold	Improve vaccination coverage
Hepatitis B Birth Dose Coverage	3%	Critical gap in preventing mother-to-child transmission	Urgent intervention needed
Children Missed in Oct 2024 Polio Campaign	500,000 children	Significant operational challenge	Improve campaign reach and acceptance

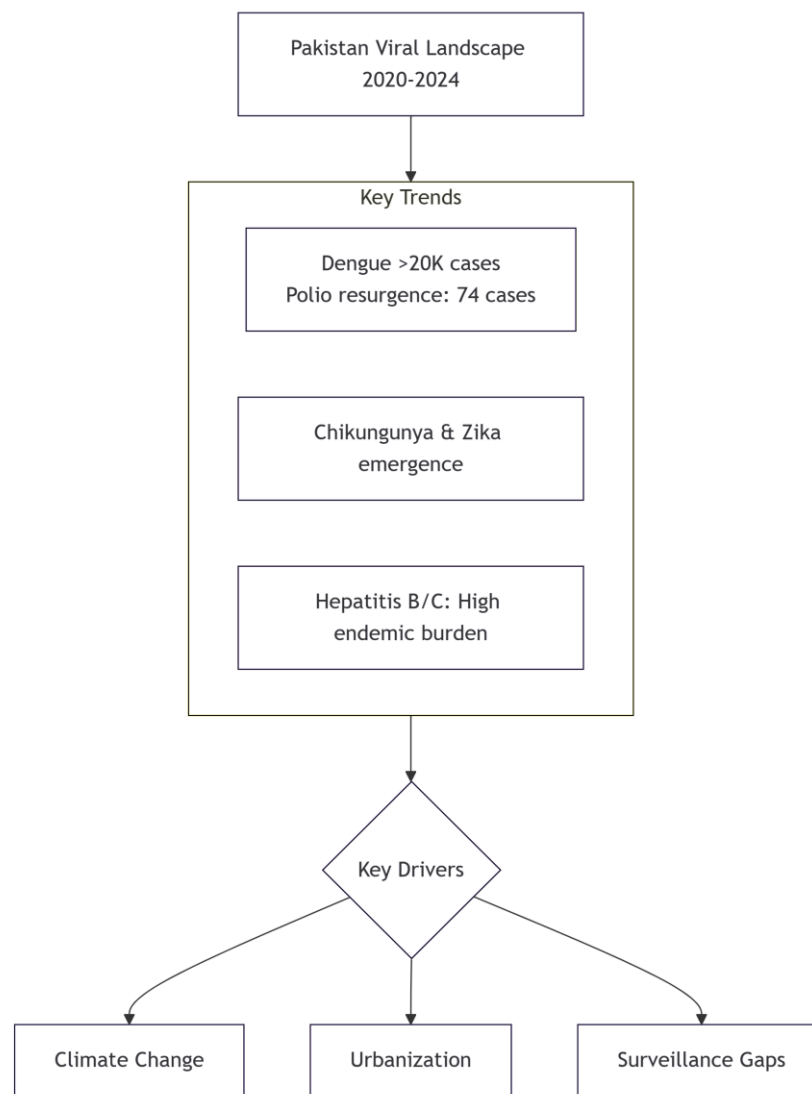


Figure-I: Graphical summary of major viral disease trends and key drivers in Pakistan (2020–2024).

IMPLICATIONS, LIMITATIONS, AND FUTURE DIRECTIONS

The findings underscore an urgent need for a climate-resilient, integrated health security framework in Pakistan (Figure-I). Strengthening real-time surveillance, ensuring equitable vaccine access, and implementing sustainable vector control are critical for mitigating the dual burden of endemic and emerging viral threats.

This review is subject to the inherent limitations of a narrative synthesis. The reliance on published literature and official reports may not capture subnational or unreported outbreaks. Furthermore, surveillance data variability across provinces can affect the precision of national trends.

Future research should employ mixed-methods designs to evaluate socioeconomic and environmental drivers of outbreaks. Operational research is needed to assess the cost-effectiveness

of new surveillance technologies and community-based interventions. Longitudinal studies on zoonotic and arboviral emergence in the context of climate change are also recommended.

CONCLUSION AND RECOMMENDATIONS

Pakistan's viral disease landscape is ever-changing and dynamic with endemic and emergent viral threats exhibiting typical spatial and temporal patterns. Pakistan has achieved impressive growth in the development of surveillance systems and laboratory networks but important gaps still exist in the accomplishment of integrated viral disease surveillance and control.

Based on the findings of this review, several key recommendations are proposed. First, it is imperative to strengthen the Integrated Disease Surveillance and Response system by fully implementing the 2024-2028 roadmap, ensuring uniform reporting

compliance across all provinces, and establishing a dedicated national system for monitoring antimicrobial resistance and emerging pathogens. Second, the molecular diagnostic capacity expanded during the COVID-19 pandemic must be sustained and leveraged for broader pathogen detection, with parallel investments in advanced viral characterization techniques. Third, vaccination programs require urgent attention to overcome operational barriers; goals must include achieving >95% coverage for routine antigens such as measles and polio, and guaranteeing universal access to the hepatitis B birth dose to prevent mother-to-child transmission. Fourth, vector control strategies need to be scaled and adapted to climate realities through integrated management informed by robust entomological surveillance, particularly in urban centers and flood-prone regions. Finally, a holistic One Health approach must be operationalized by fostering stronger intersectoral collaboration between public health, environmental, disaster management, and veterinary authorities to address zoonotic and emerging disease threats comprehensively.

CONFLICT OF INTEREST

Authors declare no conflict of interest

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AUTHORS CONTRIBUTION

Moiz Ahmed Khan: Substantial contributions to study design, acquisition of data, manuscript drafting and reviewing it critically for important intellectual content, final approval, accountable for all aspects of publication

Victor Basheer, Margaret Palous & Nassim Sheraz: Reviewing manuscript critically for important intellectual content, final approval, accountable for all aspects of publication

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