Dengue Trajectory – Vector, Weather and Human Behaviour (Policy Brief)

Prepared by Pune Knowledge Cluster

About Pune Knowledge Cluster

The Pune Knowledge Cluster (PKC) is one of the six S&T clusters established by the Office of the Principal Scientific Adviser (O/o PSA) to the Government of India under The City Knowledge and Innovation Cluster Initiative (CKIC). The Cluster was started as a project administered by the Inter-University Center for Astronomy and Astrophysics (IUCAA) in July 2020 and is now incorporated as not-for-profit Section 8 company promoted by IUCAA.

PKC serves as an enabling and knowledge management organization to foster collaborative initiatives that leverage science and technological resources to solve societal problems. PKC has built partnerships with over 70 organizations including academia, R&D institutions, industries, hospitals and local governments in the Pune region. Our areas of focus include Health, Sustainability and Environment, BIG Data & AI and Capacity Building.

PKC's Health initiatives focus on building collaborations to facilitate generation of data critical for public health decisions such as serosurveys, clinical, immunological and environmental surveillance and creating organized platforms with comprehensive health information for the Pune region which includes access to real time data. PKC has enabled a consortium of over 10 organizations to carry out clinical and environmental surveillance of infectious diseases like COVID-19 and vector borne diseases like Dengue over the past three years. This has resulted in gathering of several insights about how diseases are detected, tracked and managed at the city level. This brief summarizes our learnings about disease burden, management, challenges and provides suggestions that could enable building a robust surveillance system for such diseases.

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Abstract

Dengue fever is a global public health threat that is expanding its geographical reach. India bears one of the largest dengue burdens among other endemic regions of the world. Dengue outbreaks in India have been attributed to increasing population, internal migration patterns, and challenges in existing disease management protocols. Changing climate is also a contributing factor. In this policy brief, we examine socioeconomic and environmental components that exacerbate dengue burden and analyze existing procedures of dengue management, regarding data collection and disease surveillance. Emphasizing testing, surveillance, capacity building, awareness, and collaborative policymaking approaches, we propose a potential line of actions to help fill existing gaps in dengue management policies.

Geographic Shift of Dengue

Dengue, a major global threat, is a viral disease borne by a mosquito vector, primarily *Aedes aegypti* and *Aedes albopictus*. Dengue is endemic in tropical and subtropical regions of the world, where the mosquito vector thrives. In recent decades, global warming has expanded the vector's habitat to non-endemic regions. Data from the European Centre for Disease Prevention and Control indicates that the *Aedes albopictus* mosquito was established in 8 European Union countries, affecting 114 regions in 2013, in 13 countries and 337 regions in 2023.

The Burden of Dengue in India

In India, the first confirmed Dengue Fever (DF) epidemic occurred in 1963-64 in Kolkata and adjoining eastern coastal regions, followed by a haemorrhagic fever/dengue shock syndrome (DHF/DSS) epidemic in northern India in 1996[i]. One study[ii] in 2010 found that 34% of clinically apparent dengue cases occurred in India, contributing to a third of the global occurrence of the disease that year. The geographical reach of the disease has expanded from predominantly urban areas to rural areas[iii]. Increased urbanization, population growth, migration, and frequent travel, act in synergy with evolving environmental factors to help the vector thrive in non-endemic environments.

Some dengue infections may not be clinically detectable; however, a subset of infections result in severe forms of the disease, even leading to death[iv]. The dengue virus is an RNA virus with four serotypes (DENV 1-4). Dominant serotypes causing dengue epidemics in India are rapidly changing, as evidenced by a serotype surveillance study from a single centre during the outbreaks of 2012-13 and 2014-15 in southern India[v]. Since acquiring immunity from one serotype of dengue does not provide immunity from other serotypes, concurrent infection with multiple circulating serotypes is possible. While the primary infection may elicit longstanding protection against the infecting serotype, it can only protect for a short term from secondary infection with a different serotype, which would likely cause severe dengue if the gap between the infections is larger. Complexity of dengue vaccine development strategy is in part due to the above-mentioned pathological factors.

Climate's Impact on Dengue Risk

The dengue vector relies on environmental patterns for growth, survival, and breeding. Water is essential for the mosquito larvae to hatch. A temperature of 16-30°C and humidity of 60-80% are ideal for *A. aegypti* to thrive. Studies have shown that increased temperatures and relative humidity can predict dengue transmission patterns, since the vector relies more on human hygienic practices rather than rainfall for its survival[vi]. A study estimated the extrinsic incubation period (EIP) of the virus by associating the disease burden with daily mean temperatures in endemic Indian states[vii]. Results showed that the EIP was lowered when temperatures increase from 26°C to 30°C, coinciding with the rainy season. The study also showed that temperatures lower than 17°C and higher than 35°C negatively impact mosquito survival. A study of Delhi localities showed that high population density areas had higher winter temperatures at night time[viii], creating heat islands conducive for vector proliferation.

High-Risk Communities for Dengue Transmission

A national survey in 2017-2018 found that urban households have higher odds (1.6% adjusted odds ratio) of dengue infection than their rural counterparts[ix]. Urban environments in India are rapidly expanding with increased migration for livelihood from villages and towns. As urban areas expand to accommodate more people, habitats within the urban environment become fragmented by the socioeconomic status of residents, creating pockets of conditions where temperatures, water availability, inadequate sanitation and civic facilities are more conducive for vector growth and spread. As a result of urbanization, the vector increasingly becomes homogenized, which means that a species or serotype that prefers urban environs becomes more resilient after repeated outbreaks and generally thrives better[x].

The previously cited study of Delhi municipal wards showed that lack of access to tap water is a dengue risk factor[8]. Wealthier localities showed increased dengue burden despite lower vector densities in these areas, compared to intermediary income colonies, suggesting that daily human mobility from one area to another could contribute to the spread of disease. Indeed, most cases occurred in colonies with high population densities, regardless of income status.

Dengue Data Management

Disease surveillance and monitoring is managed by the Ministry of Health and Family Welfare (MoHFW)[xi]. The MoHFW monitors and manages dengue incidence through the National Center for Vector Borne Disease Control (NCVBDC)/ National Centre for Disease Control (NCDC) and the Integrated Disease Surveillance Programme (IDSP). Current national policies and initiatives for managing vector-borne disease outbreaks are administered by the NCVBDC[xii], which also conducts dengue surveillance through a network of sentinel hospitals and apex referral laboratories. Although the numbers of sentinel hospitals and apex labs have increased over time, their distribution is disproportionate among states regarding relative state-wise case numbers. Dengue case reporting follows a hierarchical structure starting from Primary Health Care Centres (PHCs), which diagnose dengue severity by clinical examination and laboratory tests, Community Health Care Centres (CHCs), the district-level, and then state-level NCVBDC authorities. Severe dengue cases with signs of circulatory failure are managed at the PHCs. The IDSP operates in a parallel hierarchy with the Central Surveillance Unit (CSU) at national level, State Surveillance Units (SSU) at state level, and District Surveillance Units (DSU) at district level. Its reporting mechanisms differ from the NCVBDC. It offers three channels of reporting – symptomatic diagnosis is reported by nurses and field workers, presumptive diagnosis is confirmed by medical doctors, and laboratory diagnosis is by confirmatory laboratory results.

The Government of India allocates dengue IgM test kits to each state and union territory based on the previous years' epidemiological and geographical pattern of disease incidence[xiii]. The system of testing kit distribution based on previous years' cases is not ideal as dengue incidence does not follow the same pattern every year. Statistical models could help predict the caseload of the approaching dengue season and aid in effective planning of kit distribution and allocation.

Challenges to Surveillance

The complexity of surveillance in India is partly due to non-integrated testing channels and partly due to limited crosstalk between autonomous bodies assigned to manage surveillance. Multiple dengue tests and variability of their acceptance by the government add to the disease reporting complexity. The government recommends ELISA-based antigen detection test for diagnosis from day 1 of symptoms onset, and IgM ELISA from day 5 (Table 1). The government does not accept rapid antigen tests due to low sensitivity, potentially to avoid counting false negative results. Reverse transcription polymerase chain reaction (RT-PCR) results are more accurate and are accepted by the government. Test results data from private diagnostic centers and hospitals are not integrated with government surveillance systems in the current national framework of dengue case reporting.

Type of test	***Testing done between***	***Recognized by the Govt. (YES/NO)***
NS1 Rapid test	Day 1 to Day 5	NO
NS1 ELISA	Day 1 to Day 5	YES
IgM Rapid test	Day 5 to Day 30	NO
IgM Capture ELISA (IgM ELISA)	Day 5 to Day 30	YES
IgG ELISA	Day 7 to Day 30	NO
RT-PCR	Day 1 to Day 5	YES
Viral RNA detection	Day 1 to Day 5	YES

Table 1: *Dengue tests in hospitals and labs (source: discussions with healthcare systems and professionals).*

Since 2007, the government supplies IgM ELISA test kits to identified laboratories through the ICMR - National Institute of Virology (NIV), Pune. IgM kit allocation to states is not proportional to standardized state caseloads. The government also funds states to procure NS1 ELISA test kits and distribute them to the State Sentinel Surveillance hospitals as required.

A study in Hyderabad depicts the complexity of dengue surveillance[xiv]. The NCVBDC, the IDSP, and the local municipal authority's health wing carry out dengue surveillance in the city. There is integration of administrative process and information exchange between the NCVBDC and the IDSP. However, the Greater Hyderabad Municipal Corporation (GHMC) does not integrate administratively with the IDSP or the NCVBDC. While the GHMC is responsible for mosquito control measures, the NCVBDC is responsible for disease surveillance. Furthermore, reporting integration between the NCVBDC and the IDSP is limited to only laboratory-confirmed data. While reports generated by the IDSP are captured by standard forms, both electronically and on paper, reporting at the NCVBDC is via emails. The two reporting channels are not synergised, but data are merged in the district surveillance office. The GHMC maintains its own reporting system via email and is linked to NCVBDC. Thus, it is beneficial to bring all the reporting streams into one central agency or assigning ownership and accountability for all the data streams to a single agency.

Potential Line of Actions

Vector borne diseases have complex disease dynamics that are driven by multiple social and environmental factors. Disease mitigation and management strategies should take all components into account to develop solutions that impact and influence disease outcome through diverse pathways.

Partnerships: Private and public healthcare ecosystems should collaborate for disease management. Two examples of successful public-private partnerships in managing malaria are the Comprehensive Case Management Project (CCMP) in Odisha and the Malaria Elimination Demonstration Project (MEDP) in Mandla district in Madhya Pradesh[xv]. The former was a collaboration between the Government of Odisha, the ICMR-National Institute of Malaria Research, and the Medicines for Malaria Venture (MMV) (a not-for-profit public-private partnership established as a foundation in Switzerland in 1999 with the aim to reduce malaria burden in endemic countries). The latter is a partnership between the ICMR, the MoHFW, Madhya Pradesh State Government, and the Foundation for Disease Elimination and Control of India (a not-for-profit entity created by Sun Pharmaceutical Industries Limited for conducting public health programmes). The CCMP has shown to enhance early detection and treatment of malaria by improving networks of malaria services, which helped reduce incidence in three endemic districts[xvi]. The MEDP employs active surveillance and case management, vector control, information, and capacity-building strategies to eliminate malaria[xvii]. A recent study surveying the beneficiaries of MEDP found that most of them associated MEDP with regular and prompt service delivery, availability of diagnostics and drugs, and effective community mobilization to enhance treatment-seeking behaviour[xviii].

In recent years, dengue infections have spread by increased and continuous human traffic within and between endemic regions, as for example, shown by a study of spatiotemporal dynamics of DHF in Thailand indicating periodic waves of infection emanating from Bangkok[xix]. Mechanisms to establish and facilitate regional cooperation in disease surveillance would benefit all stakeholders in this increasingly dynamic environment of human mobility. A case in point is establishing the Regional Emerging Disease Intervention Centre (REDI) in Singapore as a joint United States–Singapore collaboration on defence against emerging infectious diseases. Along with widening the international network for research, it translates research findings into improved public health[xx]. While its focus may not be dengue, it is an example of a collaborative approach toward epidemic prevention and management.

Multi-faceted approach to dengue monitoring: Research groups should focus on developing early warning systems to identify specific disease hotspots within a city and locale. Integrated, real-time data tracking of positive dengue tests, long-term retrospective data including from private hospitals and clinics, would help researchers and government surveillance systems to form reliable predictive models of disease incidence. Climate and socioeconomic factors, such as urbanization, population growth and migration, tourism, etc., should also be factored into predictive models. Additionally, integrating dengue research into the public health ecosystem would help establish synergy in efforts and work toward more efficient information exchange. Overall, collaborative interdisciplinary studies factoring in ecology, vector biology, epidemiology, and sociology are needed to address adequate predictive capacity.

Consolidation of reporting through innovative means: To avoid reporting delays during an outbreak, syndromic reporting by medical doctors may be practiced instead of laboratory confirmations during outbreak in endemic regions. This approach was taken in a case study from 1999-2001 in Kottayam, Kerala[xxi] and disease cluster detection using this method was critical in effective early management. However, this is not recommended for regular reporting, as there may be false positive cases. A case study in Delhi[xxii] used the GIS system to tie reporting data with spatiotemporal occurrence parameters. The analysis gave an overview of regions of possible underreporting to develop a more targeted approach toward addressing reporting needs. GIS systems might be useful in understanding a broad landscape of dengue reporting across endemic regions.

An innovative study has used Google Trends-based prediction system to highlight how outbreaks may be identified in advance of case reporting. Trends in Google search phrases for dengue and chikungunya and correlation with IDSP reporting data were conducted for the states of Haryana and Chandigarh[xxiii]. The study showed that detecting increased search patterns of certain phrases in Google, which may occur in response to a disease outbreak within a community or from information gathered in social media, or both, can be a potential indication of an outbreak. The use of technology and other methods to monitor disease trends can capture pre-clinical disease phase and undetected/home diagnosed cases.

The combination of traditional testing methods while leveraging newer disease monitoring tools can provide a robust picture of the disease situation.

Synergy in data collection: The bulk of dengue detection occurs outside of the government surveillance systems; they occur in private laboratories and through rapid antigen testing, leading to undercounting of cases in the overall population. Data reporting should be mandated for all entities within public health. This would help map the true disease burden and help build robust disease prediction systems. Correlations between presumptive, suspected, and confirmed cases should be mandated to track disease progression in patients with symptoms. The approach may be complicated by the fact that early symptoms of dengue overlap with symptoms of other prevalent diseases in endemic areas, and therefore, reporting based on clinical manifestations alone is not foolproof. Per an estimation, more than half the number of dengue-affected persons have mild to no symptoms and are not likely to be tested[xxiv].

Capacity building: Shortage in knowledgeable and trained staff during an outbreak is one of the most critical aspects of lacunae in epidemic management. Shortage of staff necessitates multitasking and an increased burden for staff. The responsible departments should prioritise capacity building of personnel to ensure quick identification and pre-emptive measures targeting disease incidence reduction and management. The seasonal nature of the disease positions it to be leveraged to identify staffing needs in advance of an outbreak by taking cues from past years. Because, in large part, dengue can be reduced by the host behaviour, planned outreach programs in endemic communities could sensitize local populations to take necessary precautions. Implementing dengue awareness campaigns and providing at-risk populations with accurate information and prevention strategies would help the attainment of this measure.

To tackle and manage the disease, below are some recommendations through, Immediate, Mid-term and Long-Term Goals.

Immediate goals

- Piloting synchronized data collection within the government and private sectors and ensuring representation of all data streams.
- Correlation of dengue testing data with hospitalization data to understand the rate at which dengue infections turn severe.
- Building awareness through public campaigns in collaboration with local municipalities to address specific issues that concern that geography.

Mid-term goals

- Framing policies to include multiple testing methods to account for all cases and collection channels into the official data count.
- Consolidating dengue data surveillance with social, behavioural, and environmental data, such as climate, urbanization, human activities, etc., to help build into predictive models of dengue incidence and severity.
- Building an early warning system based on retrospective and real-time disease data.

Long term goals

- Building an adaptable, structured, and interoperable data collection system that may be implemented across India.
- Building a self-operating and real-time disease surveillance system.
- Enabling Local governments through capacity building to identify and target correlations between disease and non-disease factors such as climate, mobility, and urbanisation, that impact the spread of dengue.
- Integrating dengue research into the public health ecosystem by enabling crosstalk of academic, policymaking, public health, and governance bodies.

Given recurrent dengue outbreaks and accompanying pressure on the health infrastructure, it is imperative to have policies and early warning systems in place to adequately predict an outbreak and establish guidelines to curb the spread. A shift in focus is needed by local municipalities and governments toward developing systems that actively capture disease and vector dynamics through contributing factors, such as urbanisation, water availability and storage patterns, heat zones, and mobility patterns within the city, amongst others.

Credits and Acknowledgements

This document was prepared in consultation with several experts. Profiles of key contributors are detailed below. We are grateful to The Rockefeller Foundation for their support in enabling this brief.

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Prof. Shashidhara is currently the Director at the National Centre of Biological Science (NCBS). Prof. Shashidhara has served as Vice-President of the Indian National Science Academy and Secretary-General of the International Union of Biological Sciences. He served as President of IUBS, the first Indian to be elected in its 100 years of history. He has been awarded the prestigious Shanti Swarup Bhatnagar Prize for Science and Technology, and the JC Bose National Fellowship and has been elected as a member of European Molecular Biology Organisation (EMBO).

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Prof. Juvekar has a PhD in Anthropology and has spent the last 20 years in public health and specifically worked towards empowering public health at a rural level. He is a researcher, mentor, teacher (Guide to over 500 national and international scholars, including Undergraduates, Masters, PhD, and Post-Doctoral students). His experience spans more than 30 years in community health research. He Established the Indian Health and Demographic Surveillance Systems Network (IHN).He has over 200 publications in the public health research in TB, non-communicable diseases (COPD, Asthma, Hypertension) , maternal & child health, adolescent health, Deworming, PSBI, nutrition, HDSS, air pollution, household energy, and implementation research of national relevance.

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Priyanki Shah has over 15 years of experience within the health eco-system, transversing through private and public. She has a Master's in Molecular Medicine and Microbiology and is a qualified project manager. She specializes in driving collaborations between government, academics and philanthropies to generate evidence and knowledge that drives public health work. She specialises in the implementation and management of large-scale public health programs.

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Dr. Narayan has a PhD in Physics. She has over 10 years of research experience and 12 published papers in reputed journals. She works on data analysis of disease data collected from various government bodies and draw actionable insights.

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