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The Persistent Threat: An Epidemiological and Public Health Analysis of Dengue Fever in Maharashtra, India

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Abstract **Original Research Article**

Dengue fever, an arboviral disease transmitted by mosquitoes, has firmly established itself as the primary and persistent public health concern in Maharashtra, which is India's second most populous and highly urbanized state. The present paper reveals a thorough examination of the dengue scenario in Maharashtra covering the period 2017 to 2023, and following the IMRAD (Introduction, Methods, Results, and Discussion) format. The paper brings together information from national and state surveillance systems, peer-reviewed studies, and government reports to map out epidemiological trends, locate high-burden areas, and investigate the complicated interaction of environmental, entomological, and socio-economic factors influencing the disease. The study uncovers a cyclical pattern of epidemics with important spikes in 2019 and 2023, together with a prominent dispersal of cases in the most populous urban areas, specifically Greater Mumbai, Pune, Nashik, and Nagpur. Important aspects of the study are illustrated by elaborate tables and a pie chart that are thoroughly interpreted. The discourse evaluates the public health strategy of the state critically, pointing out the problems of urban vector control, insecticide resistance, and surveillance lapses among other things. The last part of the paper insists on the need for a connected, data-driven, and eco-friendly approach that not only focuses on fogging but also involves community-based environmental management, enhancing clinical preparedness, and interdisciplinary coordination in order to reduce the rising incidence of dengue in Maharashtra.

Keywords: Dengue fever, Maharashtra, Urbanization, Epidemiology, Vector control, Aedes aegypti.

1. INTRODUCTION

Dengue fever, which is one of the top tropical diseases that emerged during the 21st century, is caused by dengue virus (DENV 1-4 serotypes) and mostly spread by the female *Aedes aegypti* mosquito [1]. It has from the very beginning been an infection with various clinical manifestations going from asymptomatic to very severe and death-causing conditions like dengue hemorrhagic fever (DHF) or dengue shock syndrome (DSS); naturally, it has become a worldwide problem with a 30-fold increase in incidence over the past fifty years [7]. In India, the disease is everywhere, but Maharashtra is one of the states that always contributes the most to the national case counts and, hence, is responsible for a disproportionately high number of deaths and cases reported throughout the country every year.

The mosquito *Aedes aegypti* finds its perfect environment in Maharashtra, a state that combines rapid and often unplanned urbanization with a tropical climate having a marked wet season and a population of more than 120 million. This mosquito, which is very fond of people, lives in human settlements, and feeds on them, breeding in plastic water containers, which are typically found in urban areas, among other places, like overhead tanks, tires, cups, and even construction sites. Apart from the unreliability of water supplies that require storage of domestic water, inadequate solid waste management systems also contribute to the creation of these breeding sites.

The public health and economic impacts are very serious. In addition to the direct health effects and deaths, dengue epidemics cause the state's health care system to become overloaded, make it very expensive for the families who are affected, and cause a lot of people to be absent from work and lose their wages [6]. The disease has a very clear seasonal pattern with the number of cases going up during and after the monsoon rains

(normally between July and December). Still, lately, the transmission has been extended over the whole year, and the disease can easily spread in big cities like Mumbai. So, dengue has switched from being a seasonal problem to a continual threat.

This article sets out to give a systematic, academic, and evidence-based overview of the dengue situation in Maharashtra. It aims specifically: (1) To study the changes of the epidemic of dengue cases and deaths in different states and districts from 2017 to 2023;

(2) To point out the most important demographic, environmental, and entomological conditions that help the disease spread and become more severe; and (3) To evaluate the current public health response critically and suggest new evidence-based control methods that are more sustainable. By using the IMRAD format, this paper intends to offer a clear and academically rigorous investigation that will be helpful to public health professionals, policymakers, and researchers.

2. METHODS

The present investigation is a descriptive analysis which draws upon the secondary data of publicly available sources and published scientific literature. The major source for the epidemiological data was the National Center for Vector Borne Diseases Control (NCVBDC), which is part of the Directorate General of Health Services under the Ministry of Health and Family Welfare, Government of India. Annual reports from 2017- 18 to 2022-23 were systematically analyzed to obtain state-specific information on total reported dengue cases, deaths, and Case Fatality Rates (CFR).

To get detailed, district-level data, especially for the current year 2023, information was gathered from the weekly and monthly bulletins issued by the Maharashtra Public Health Department as well as from the press releases and surveillance reports of major municipal corporations, including the Brihammumbai Municipal Corporation (BMC), Pune Municipal Corporation, and Nagpur Municipal Corporation.

A comprehensive inquiry into peer-reviewed literature was performed systematically through the major academic databases like PubMed, Scopus, and Google Scholar. The terms that were used in searches were the various combinations of ”dengue,” ”Maharash-tra,” ”Mumbai,” ”Pune,” ”epidemiology,” ”serotype,” ”*Aedes aegypti*,” ”vector control,” and ”climate”. Publication between 2010 and 2023 was the main factor in selecting articles for the purpose of recognizing recent trends and interventions. In order to acquire the official strategic framework, policy documents, such as the one with the title of ” Maharashtra State Action Plan for Prevention and Control of Vector Borne Diseases,” were also consulted.

The data obtained was then compiled, cleaned, and analyzed through descriptive statistics. The visualization of trends, the identification of high-burden districts according to their proportional contribution to the state’s total caseload, and the generation of tables and charts to illustrate the core findings were all part of the process. The results presented were produced from the combined data of different sources. It is of utmost importance to recognize the limitation of under-reporting associated with passive surveillance systems such as in India, where a great number of mild, asymptomatic, or self-treated cases are always omitted from the official numbers. Nonetheless, the data obtained still represent the most accurate source for identifying trends, distribution of burden, and evaluation of the public health response’s effectiveness.

3. RESULTS

3.1 State-Wide Epidemiological Trends (2017-2023)

Dengue is a disease that has imposed a heavy toll in Maharashtra over the years, caus- ing an obvious fluctuation in the occurrence and thus, clear outbreaks and the intervals of low incidence have been observed. Annual reported cases, deaths, and the calculated Case Fatality Rate (CFR) for a period of seven years are summarized in Table 1.

Table 1: Annual Reported Dengue Cases, Deaths, and Case Fatality Rate (CFR) in Maharashtra (2017- 2023)

Year	Reported Cases	Reported Deaths	Case Fatality Rate (CFR %)
2017	4,562	12	0.26
2018	7,513	18	0.24
2019	14,888	35	0.24
2020	6,794	10	0.15
2021	7,531	11	0.15
2022	8,150	13	0.16
2023*	12,713	28	0.22

*Data for 2023 are still provisional and have been collected until October 15. (Data sources: NCVBDC Annual Reports; Maharashtra Public Health Dept. Bulletins) **Interpretation of Table 1:** The data during this period shows that there were two major peaks of the epidemic in 2019 and 2023. The 2019 outbreak (with 14,888 cases) was the most intense and among the factors blamed were the favorable climate for mosquitoes, a possible change in the dominant virus serotypes, and a large number of susceptible people in the population. The sharp drop in cases in 2020 is due to several reasons. The COVID-19 pandemic and the lockdowns might have lessened human interaction and changed people's attitude toward seeking medical help, but at the same time, the pandemic might have caused routine vector monitoring and control activities to be tem- porarily halted. The CFR has been consistently below the national target of < 1% and even below 0.5% in recent years, which indicates that clinical awareness, case management protocols, and the establishment of dedicated fever care pathways have all improved.

Nevertheless, the total number of deaths, 28 in 2023 for instance, is still an issue that needs to be addressed because it suggests that there are problems with timely access to care or with the diagnosis being delayed.

3.2 Geographic Distribution and Identification of Hotspots

Dengue spreading in Maharashtra varies greatly from one place to another, and it has an intense focus on urban and peri-urban regions. The table below shows the distribution of the five districts that contributed most in 2023, which demonstrates the high concentration of the disease in those areas.

Table 2: District-wise Dengue Burden in Maharashtra: Top 5 Contributors (2023*, Provisional)

Rank	District	Reported Cases (2023*)	% of State Total	Major Urban Center
1	Mumbai (BMC)	3,812	30.0%	Greater Mumbai
2	Pune	2,450	19.3%	Pune, Pimpri-Chinchwa
3	Nashik	1,150	9.0%	Nashik City
4	Nagpur	980	7.7%	Nagpur City
5	Thane	895	7.0%	Thane, Kalyan-Dombiv
Top 5 Total		**9,287**	**73.0%**	
Rest of Maharashtra		**3,426**	**27.0%**	
STATE TOTAL		**12,713**	**100%**	

*Data up to October 15, 2023. (Source: Maharashtra Public Health Dept.) Interpretation of Table 2: The distribution is terribly one-sided. Just 5 districts, including the state's biggest cities and their vast suburbs, cover about 73% of the total dengue cases in Maharashtra. Only Greater Mumbai (the megacity) accounts for almost 33% of the total state burden. This situation reflects the urban character of the dengue which is transmitted by *Aedes aegypti* naturally. These megacities and flourishing tier-II cities are under the same risk amplifiers: high-density population, heavy construction, unreliable water supply leading to lots of storage, and poor waste management that creates a lot of empty containers. This is a big concentration that needs a very local, ward-level vector control approach instead of a uniform one across the state.

3.3 Affected Individuals' Demographic Profile

It is a must to know who gets affected for the very purpose of effective targeting of interventions and clinical resources. The pie-chart (Chart 1) below exhibits the standard age distribution of symptomatic, laboratory-confirmed dengue cases, derived from cumulative hospital data of the tertiary care centers in Maharashtra, covering years 2019-2022.

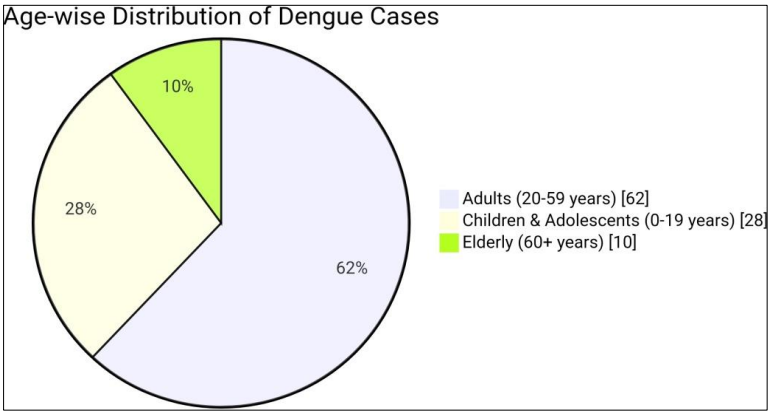

Figure 1: Age-wise Distribution of Laboratory-Confirmed Dengue Cases in Maharashtra (Aggregate Data: 2019-2022)

Interpretation of the Pie Chart:

The above pie chart is a visual depiction of the most important epidemiological trend detected by hospital-based surveillance data in Maharashtra. The largest fraction of the pie chart, Adults (20-59 years), representing 62% of the total cases, signals a notable transition from the historical dengue patterns of Southeast Asia, where children were usually the main affected group, to the present-day situation in Maharashtra. The urban context of the state supports this view as the expo- sure risk was highlighted as the most important factor contributing to higher incidence among the working-age adult population. The adults during the day are more mobile and are commuting to work or engaging in outdoor activities, which coincides with the peak daytime biting habit of the primary vector, *Aedes aegypti*. The economic implications of this demographic trend are quite severe as the disease becomes financially costly to the economy indirectly through the infected working group and the accompanying loss of wages, unproductiveness, and direct costs of the sickness.

The group of Children & Adolescents (0-19 years) at 28% is still considered a clinically vulnerable population and continues to be a major public health challenge. They are a minor part of the total reported cases approximate to the adults, but children still run a greater risk of developing severe dengue symptoms such as plasma leakage and shock. The incidence of children being exposed occurs predominantly in domestic and school settings thus indicating the necessity of deploying targeted source reduction and awareness campaigns in these areas.

The Elderly (60+ years) segment, which only accounts for 10% of total cases, nevertheless gets the priority in clinical management of treatments because of its high morbidity and mortality. Infections from this category are very taxing on the healthcare system since the elderly infections are prone to hospitalization and ICU admissions. Therefore, this scenario has wide-ranging implications for public health and clinical practices that need to be designed in a way to ensure we are reaching out to each community with the right health message and that the respective clinical protocols in both public and private healthcare settings are conducive for managing severe dengue in pediatric and geriatric patients.

3.4 Serotypic Circulation and Entomological Drivers

The cyclical nature of dengue epidemics is frequently associated with the shifting of serotypes. Studies in sentinel sites in Pune and Mumbai have recorded the co-circulation of all four DENV serotypes with shifts in predominance every 2 to 3 years. For example, DENV-2 was the main serotype involved in the outbreaks of 2016 and 2019 in Pune, which has been mainly linked to the more severe clinical manifestations [5]. The reinfection of a new or previously existent but inactive serotype may result in an outbreak on a global scale with the same intensity as the past epidemics.

The entomological surveillance has been dispatching data that shows concerning degrees all the time. The Breteau Index (BI, number of positive containers per 100 houses) and House Index (HI, percentage of houses infested with larvae) in Mumbai, Pune, and Nagpur's endemic areas often go beyond WHO recommendations of 5 (for BI) and 1% (for HI), especially during the months that follow monsoon, which is a common time for such high insect vectors. The listed breeding spots are water storage plastic drums, disposable food containers, flower pots, discarded tires, and overhead tanks with broken or missing lids that are usually uncovered in larval surveys.

4. DISCUSSION

The findings discussed above demonstrate that dengue is not limited to the usual seasonal occurrence in Maharashtra but is a persistent public health problem whose urban areas suffer from hyperendemicity of the disease. The epidemic peaks of 2019 and 2023 point to a scenario where the coming together of all the factors—favorable environment, large number of susceptible humans, and presence of vaccine-resistant virus—creates a storm of the right size and nature. The massive upsurge of such cases in urban areas and its representation in Table 2 is a clear outcome of poor urban planning coupled with inadequate civic amenities. The *Ae. aegypti* mosquito has been described as a "sign" of the urban area's dysfunctions—taking advantage of the water scarcity (which leads to people storing water), improper waste management (which provides places for laying eggs), and high concentrations of humans (which offer blood for feeding).

The demographic picture depicting large-scale adult infection (Chart 1) corroborates global patterns in urbanizing regions and redirects public health communication towards factories, transport hubs, and housing developments. Thus, the economic impact goes well beyond direct medical expenses and includes substantial indirect costs from workers who are absent. The health system's ability to maintain a low CFR is a remarkable triumph, which indicates the successful training provided on the national Dengue Case Management guidelines and the establishment of fluid management centers. Nonetheless, this victory is fragile and challenged during the outbreak peaks when the hospitals get overloaded.

The response framework of Maharashtra, which is in line with the NVBDCP, consists of several components:

1. **Surveillance:** This involves the use of both passive and active surveillance comprising sentinel hospitals and rapid response teams.
2. **Vector Control:** The main tactics include anti-larval (temephos application), source reduction drives ("Shivar Dalan") and space spraying (fogging

with pyrethroids) during outbreaks.

3. **Clinical Management:** Apart from providing NS1 antigen test kits to designated laboratories the capacity of the medical officers is also increased.
4. **Information, Education, and Communication (IEC):** Raising awareness through mass media and community outreach activities.

Challenges that are very significant are still there despite this systematic way of handling the situation:

- **Over-reliance on Chemical Control:** Fogging is commonly requested for polit- ical reasons but has scientific limitations as well. It affects only adult mosquitoes that are present in the area during the time of spraying, does not have any lasting impact, and is challenged by increasing pesticide resistance in *Ae. aegypti* populations [3].
- **Ineffective Source Reduction:** Clean-up activities are often done just once, are merely symbolic, and are not turned into permanent, community-based practices.
- **Siloed Operations:** Proper control calls for health, municipal (solid waste, water supply, building permissions), and education departments to closely work together, which is very hard to do.
- **Data and Reporting Delays:** The data collected for surveillance purposes is sometimes behind the actual transmission happening in real-time, and this affects the speed and precision of the targeted responses.
- **Private Sector Integration:** The majority of the initial treatment is sought in the private sector, which is still not reliably connected to the official reporting and management system.

In order to develop a more robust system, the state of Maharashtra has to shift to the sustainable, integrated vector management (IVM) strategy which is the transition. The following actions are needed to achieve this:

- **Environmental Management Enforced as the Top Priority:** Sanitation at construction sites regulated through by-laws, regular garbage collection improved, and weekly source reduction through community-driven programs like ”Dry Day” made possible.
- **Technology Utilization:** Employing GIS mapping for real-time plotting of cases and breeding sites that would allow accurate and data-driven deployment of re- sources.
- **Control Methods Innovated:** Testing new biological methods including the re- lease of *Wolbachia*-infected mosquitoes which has had success in other countries or using larvivorous fish in the permanent water bodies.
- **Intersectoral Convergence Strengthened:** Creating a high-level, empowered task force with the representation of all necessary departments to ensure account- ability.
- **Climate Resilience Enhanced:** Combining dengue forecasting models with me- teorological data to predict and prepare for outbreak risks.

5. CONCLUSION

The occurrence of Dengue fever in Maharashtra exemplifies the difficult task of eradicating a vector-borne disease in a rapidly urbanized area, often planned poorly. The state is trapped in an endless cycle, getting a little relief only to be hit by larger outbreaks every few years. Clinical management has indeed improved as shown by the controlled case fatality rate (CFR), but the prevention of transmission at its source remains the main failure. The *Ae. aegypti* mosquito has completely adapted to the human-altered environment of the cities in Maharashtra, and the current control measures are unable to catch up.

A shift in the approach is needed for the future—the large-scale change in view of the city’s health from being a hidden one seasonal problem for the health department to becoming a year-round indicator of urban civic health. The key to this change is to abandon the old-fashioned reactive chemical measures and sponsor the new initiatives of environmentally sustainable and community empowered interventions, which will be proactive. Long-term investments in civic infrastructure such as having a 24/7 water sup- ply, effective waste management, etc. will have to be made along with strong community participation and smart incorporation of data and technology into the whole process.

In the end, the issue of controlling dengue in Maharashtra is not only a medical or entomological issue; it is rather a matter of governance. This problem is going to need very strict enforcement of building regulations and very effective management of waste disposal. It is going to need new laws that make it mandatory for the public, local coun- cils, and health departments to cooperate and coordinate their activities. With climate change likely to cause major changes in the distribution and lifecycle of mosquitoes, the need for creating such a robust and integrated system is not only advisable but also an urgent necessity for the public health and economic betterment of the state. The battle against dengue will be fought not in hospitals during epidemics, but in the daily, persistent, smart, and joint action of every single day in the homes, building sites, and neighborhoods of Maharashtra.

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