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A review on pathogenic *Aedes aegypti* and dengue cases in India

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ABSTRACT

Dengue is one of the most significant mosquito-borne viral diseases affecting human populations worldwide and represents a major public health concern in tropical and subtropical countries, including India. The principal vector responsible for transmission of dengue virus is *Aedes aegypti*, a highly adaptive mosquito species commonly found in urban and peri-urban environments. Rapid urbanization, population growth, climate variability, poor sanitation, and increased human mobility have contributed substantially to the expansion of mosquito populations and increased dengue incidence in India. *Aedes aegypti* possesses several biological and behavioral characteristics including anthropophilic feeding habits, daytime biting activity, and adaptation to artificial water containers, which facilitate efficient disease transmission. The increasing burden of dengue cases in India has generated major challenges for healthcare systems and disease control programs. The present review summarizes available information regarding the biology and pathogenic significance of *Aedes aegypti*, mechanisms of dengue transmission, epidemiological trends of dengue in India, and major environmental factors associated with disease spread. The review further discusses current prevention strategies and future perspectives for effective vector management and disease control.

Introduction

Dengue fever is one of the most rapidly spreading mosquito-borne viral diseases affecting human populations worldwide and has become a major public health concern in tropical and subtropical countries (Gubler, 2012; WHO, 2024). During recent decades, substantial increases in dengue incidence have been observed because of urbanization, globalization, climate variability, population growth, and environmental changes. The disease has expanded geographically and now affects millions of individuals annually across different regions of the world (Bhatt *et al*., 2013). Approximately half of the global population currently lives in areas considered at risk of dengue transmission (WHO, 2024). Dengue is caused by dengue virus (DENV), an RNA virus belonging to the genus Flavivirus and family Flaviviridae. Four antigenically distinct serotypes of dengue virus have been identified, namely DENV-1, DENV-2, DENV-3, and DENV-4 (Guzman *et al*., 2010). Infection with one serotype generally produces long-term immunity against that specific serotype but does not provide complete protection against the remaining serotypes. Consequently, secondary infections with different serotypes may increase the risk of severe disease manifestations including dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Halstead, 2007). Transmission of dengue virus occurs primarily through the bite of infected female *Aedes aegypti* mosquitoes, which represent the principal vector responsible for disease spread. *Aedes aegypti* exhibits several biological and behavioral characteristics that contribute to efficient transmission of dengue virus. These mosquitoes are highly anthropophilic, demonstrating strong preference for human blood meals, and exhibit daytime biting behavior with peak feeding activity commonly observed during early morning and late afternoon periods (Gubler, 2012). Additionally, the species has adapted successfully to urban environments where numerous artificial breeding habitats are available.

The mosquito life cycle consists of egg, larval, pupal, and adult stages. Female mosquitoes commonly deposit eggs in artificial water-holding containers including discarded tires, water storage tanks, flower pots, plastic containers, and domestic water reservoirs (WHO, 2024). Rapid urbanization and poor sanitation practices frequently increase the availability of such breeding sites and consequently facilitate vector proliferation.

India represents one of the countries experiencing a substantial burden of dengue infections because of favorable environmental conditions for vector survival and disease transmission. The country possesses tropical and subtropical climatic conditions characterized by high temperature and humidity, which support mosquito development and reproduction (Gupta *et al*., 2012). During recent decades, dengue cases in India have increased considerably, affecting both urban and rural populations.

Multiple factors contribute to the increasing incidence of dengue in India. Rapid population growth and urban expansion have resulted in unplanned settlements and inadequate waste management systems that frequently create mosquito breeding habitats (Murray *et al*., 2013). Increased human migration and international travel have additionally contributed to dissemination of viral strains and expansion of disease distribution. Environmental and climatic factors also play significant roles in vector ecology and dengue epidemiology. Temperature, rainfall, humidity, and seasonal variation strongly influence mosquito survival, development, and transmission efficiency (Morin *et al*., 2013). Elevated temperatures may shorten the developmental period of mosquitoes and accelerate viral replication within vector populations, thereby increasing transmission potential. Rainfall patterns may similarly affect availability of breeding habitats by creating temporary water collections suitable for larval development.

Climate change has emerged as an important factor influencing vector-borne disease dynamics globally. Rising temperatures and changing precipitation patterns may alter the geographical distribution and seasonal abundance of mosquito vectors (Messina *et al*., 2019). Such environmental changes may facilitate expansion of dengue transmission into regions previously considered unsuitable for vector survival.

In addition to environmental factors, socioeconomic conditions substantially influence dengue occurrence. Poor housing conditions, inadequate sanitation facilities, limited access to healthcare services, and low public awareness regarding disease prevention frequently increase vulnerability among populations (Gupta *et al*., 2012). Lack of effective vector control programs may further contribute to persistent transmission within endemic regions.

Clinical manifestations of dengue infection range from asymptomatic infection and mild fever to severe life-threatening complications. Common symptoms include:

- High fever
- Headache
- Retro-orbital pain
- Muscle and joint pain
- Skin rash
- Nausea and vomiting

Severe disease conditions may involve plasma leakage, hemorrhage, organ dysfunction, and circulatory failure (Guzman *et al*., 2010). Despite considerable advancements in diagnostic approaches and public health programs, dengue continues to impose substantial healthcare and economic burdens. Effective disease prevention requires integrated approaches involving vector surveillance, environmental management, public education, and early diagnosis. Therefore, understanding the biological characteristics of *Aedes aegypti*, disease transmission mechanisms, and epidemiological patterns of dengue in India is essential for development of effective control strategies and reduction of disease burden. This review aims to summarize current knowledge regarding vector biology, pathogenic significance of *Aedes aegypti*, epidemiological trends of dengue cases in India, and major factors influencing disease transmission.

Review of Literature

Several researchers have investigated the biology of *Aedes aegypti*, dengue transmission dynamics, and epidemiological trends associated with dengue infection. Previous investigations indicate that interactions among vector biology, environmental conditions, viral characteristics, and human behavior collectively influence disease transmission patterns. Early studies by Duane J. Gubler highlighted the global emergence and re-emergence of dengue as a major public health problem and emphasized the importance of *Aedes aegypti* in disease transmission (Gubler, 1998). The study reported that increasing urbanization, population growth, and international travel substantially contributed to expansion of dengue incidence. Halstead (2007) investigated immunopathological mechanisms associated with dengue infection and reported that secondary infection with different dengue serotypes may increase the risk of severe disease manifestations including dengue hemorrhagic fever and dengue shock syndrome. The study further suggested that antibody-dependent enhancement contributes significantly to disease severity. Guzman *et al*. (2010) reviewed epidemiological and clinical characteristics of dengue virus infections and documented increasing incidence worldwide. Their study reported that interactions among viral serotypes, host immune responses, and environmental factors influence disease outcomes. Gupta *et al*. (2012) evaluated dengue epidemiology in India and demonstrated increasing incidence rates associated with urbanization, inadequate sanitation, and environmental changes. Their findings suggested that rapid population growth and water storage practices contribute to mosquito breeding and disease transmission. Bhatt *et al*. (2013) estimated the global burden of dengue using geographical and epidemiological modeling approaches. Their investigation indicated that actual disease burden may be substantially greater than previously estimated and highlighted the importance of improved surveillance systems. Murray *et al*. (2013) reviewed epidemiological patterns of dengue and reported that climatic variables including rainfall, temperature, and humidity strongly influence vector abundance and disease transmission dynamics. Morin *et al*. (2013) examined relationships between climate variability and dengue transmission and observed that increasing temperatures may accelerate mosquito development and viral replication processes. Environmental conditions were reported to affect vector competence and transmission efficiency. Messina *et al*. (2019) analyzed global environmental suitability for *Aedes aegypti* and reported that climate change may alter geographical distribution of vector populations and increase risks associated with mosquito-borne diseases. Recent reports from the World Health Organization emphasized that dengue cases have increased substantially during recent decades and identified vector control and disease surveillance as important public health priorities (WHO, 2024). Gould *et al*. (2021) reported that environmental changes and increasing urbanization contribute significantly to the spread of vector-borne diseases in developing countries. Their findings suggested that integrated management approaches involving environmental monitoring and public health interventions are essential for effective disease control. Overall, previous studies indicate that dengue transmission in India is influenced by multiple interacting factors including mosquito ecology, environmental conditions, viral diversity, urbanization, population density, and climate variability.

Table 1. Summary of Previous Studies Related to *Aedes aegypti* and Dengue

Author	Major Findings
Gubler (1998)	Urbanization increased dengue spread
Halstead (2007)	Secondary infection linked with severe dengue
Guzman *et al.* (2010)	Multiple serotypes influence disease severity
Gupta *et al.* (2012)	Environmental conditions affect transmission
Bhatt *et al.* (2013)	Global dengue burden underestimated
Messina *et al.* (2019)	Climate change affects vector distribution

3. Taxonomy, Biology and Life Cycle of *Aedes aegypti*

The mosquito *Aedes aegypti* is one of the most important vectors of human diseases worldwide and serves as the principal vector for dengue virus transmission. In addition to dengue, *Aedes aegypti* is involved in transmission of several other arboviral diseases including Zika virus disease, Chikungunya, and Yellow fever (Gubler, 2012; WHO, 2024). Its remarkable adaptation to urban environments and close association with human populations make it one of the most medically important mosquito species.

Taxonomic Classification

Taxonomic Rank	Classification
Kingdom	Animalia
Phylum	Arthropoda
Class	Insecta
Order	Diptera
Family	Culicidae
Genus	*Aedes*
Species	*Aedes aegypti*

Aedes aegypti possesses several distinctive morphological characteristics that facilitate identification. Adult mosquitoes are generally small to medium-sized with black coloration and characteristic white markings on the legs and thorax. The thoracic region frequently exhibits lyre-shaped silvery-white patterns that distinguish the species from other mosquitoes (Rueda, 2004).

Biological Characteristics of *Aedes aegypti*- The biological success of *Aedes aegypti* as a disease vector is associated with several important characteristics:

Anthropophilic feeding behavior-The species shows a strong preference for feeding on human blood. Female mosquitoes require blood meals for egg development and frequently bite multiple individuals during a single reproductive cycle, increasing opportunities for disease transmission (Scott *et al*., 2000).

Daytime biting activity-Unlike many mosquito species that feed primarily during nighttime, *Aedes aegypti* exhibits daytime biting behavior with feeding peaks generally observed during:

- Early morning
- Late afternoon

This characteristic increases contact between humans and mosquitoes (WHO, 2024).

Adaptation to urban environments-The species has adapted effectively to urban habitats and commonly breeds in artificial containers including:

- Water tanks
- Plastic containers
- Discarded tires
- Flower pots
- Buckets
- Domestic water storage systems

Urbanization and poor waste management therefore frequently contribute to increased vector abundance (Gupta *et al*., 2012).

Life Cycle of *Aedes aegypti*

The life cycle of *Aedes aegypti* consists of complete metamorphosis involving four developmental stages:

- Egg
- Larva
- Pupa
- Adult

Environmental variables such as temperature, humidity, rainfall, and nutrient availability influence developmental rates and survival (Morin *et al*., 2013).

Egg Stage-Female mosquitoes deposit eggs individually on moist surfaces near water containers. Eggs possess substantial resistance to desiccation and may remain viable for several months under suitable environmental conditions (Christophers, 1960).

Important characteristics of eggs include:

- Elongated shape
- Dark coloration
- Ability to survive dry conditions
- Larval Stage

After contact with water, eggs hatch and release larvae. Mosquito larvae are commonly called “wrigglers” because of their characteristic movement patterns.

The larval stage consists of four developmental instars. Larvae feed primarily on:

- Organic debris
- Microorganisms
- Algae
- Bacterial populations

Temperature strongly influences larval growth and developmental duration (Rueda, 2004).

Pupal Stage-Following completion of larval development, mosquitoes enter the pupal stage. Pupae do not feed and primarily undergo transformation into adult forms.

Pupal characteristics include:

- Comma-shaped body
- High mobility in water
- Short developmental duration
- Adult Stage

Adults emerge from pupae and rest on the water surface until wings become fully developed. Male mosquitoes generally feed on plant sugars and nectar, whereas females require blood meals for egg production (Scott *et al*., 2000). Adult female mosquitoes play the primary role in transmission of dengue virus and other pathogens.

Pathogenic Role and Vector Competence of *Aedes aegypti*- *Aedes aegypti* is regarded as one of the most medically important mosquito species because of its remarkable ability to transmit multiple viral pathogens affecting human populations. Unlike pathogens themselves, mosquitoes function as biological vectors that acquire infectious agents from infected hosts and subsequently transmit them to susceptible individuals (Gubler, 2012). The species possesses several biological, physiological, and behavioral characteristics that make it an efficient vector for disease transmission. The pathogenic significance of *Aedes aegypti* primarily arises from its role in transmitting arboviruses, particularly dengue virus. The mosquito is also involved in transmission of several additional pathogens including:

- Dengue fever
- Zika virus disease
- Chikungunya
- Yellow fever

(Gould & Solomon, 2008; WHO, 2024)

Mechanism of Dengue Virus Transmission- Transmission of dengue virus generally begins when a female *Aedes aegypti* mosquito feeds on blood from an infected individual during the viremic phase.

The transmission process involves the following steps:

Step 1: Acquisition of virus

The mosquito acquires dengue virus during blood feeding on an infected host.

Step 2: Viral replication within mosquito

Following ingestion, viral particles enter the mosquito midgut and undergo replication. The virus subsequently spreads through internal tissues and reaches salivary glands (Salazar *et al*., 2007).

Step 3: Transmission to healthy host

During subsequent feeding events, infected saliva containing viral particles enters a new human host, initiating infection.

This internal developmental period occurring within mosquitoes is commonly referred to as the extrinsic incubation period (EIP) and may vary according to environmental temperature and viral strain (Morin *et al*., 2013).

Factors Influencing Vector Competence-Vector competence refers to the capacity of mosquitoes to acquire, maintain, and transmit pathogens effectively (Lambrechts *et al*., 2010).

Several factors influence transmission efficiency:

- Environmental factors
- Environmental variables strongly affect mosquito biology and pathogen development.

Important variables include:

- Temperature
- Relative humidity
- Rainfall
- Seasonal variation

Elevated temperatures may accelerate viral replication and shorten incubation periods, thereby increasing transmission efficiency (Morin *et al*., 2013).

Genetic factors- Genetic variability among mosquito populations may influence susceptibility to viral infection and transmission potential (Lambrechts *et al*., 2010).

Feeding behavior-The anthropophilic feeding behavior of *Aedes aegypti* significantly enhances transmission probability because the mosquito preferentially feeds on human hosts.

Multiple feeding events within a single reproductive cycle further increase disease spread (Scott *et al*., 2000).

Mosquito longevity-Longer survival duration increases the probability that mosquitoes complete the viral incubation period and subsequently transmit pathogens.

Public Health Significance in India-India has experienced increasing dengue incidence during recent decades, making vector management an important public health priority.

Several factors contribute to disease spread in India:

- Rapid urbanization
- Increased population density
- Water storage practices
- Poor sanitation systems
- Climate variability
- Insecticide resistance

Studies suggest that increasing adaptation of *Aedes aegypti* to urban environments has facilitated persistent transmission in numerous Indian states (Gupta *et al*., 2012).

Table 2. Major Diseases Transmitted by *Aedes aegypti*

Disease	Causative Agent	Major Symptoms
Dengue fever	Dengue virus	Fever, headache, rash
Zika virus disease	Zika virus	Fever, joint pain
Chikungunya	Chikungunya virus	Joint pain, fever

Yellow fever	Yellow fever virus	Fever, jaundice

Epidemiological Trends of Dengue Cases in India-Dengue fever has emerged as one of the most important vector-borne diseases in India and represents a major challenge for public health systems. During recent decades, India has experienced a substantial increase in dengue incidence due to rapid urbanization, population growth, environmental changes, climate variability, and expansion of vector habitats (Gupta *et al*., 2012; WHO, 2024). The epidemiological pattern of dengue in India demonstrates considerable spatial and temporal variation among different states and regions. Early reports suggested that dengue outbreaks in India occurred sporadically; however, recent investigations indicate that the disease has become endemic in many regions with recurrent seasonal outbreaks (Murray *et al*., 2013). Increasing transmission has been observed particularly in densely populated urban and peri-urban areas where environmental conditions support mosquito breeding. Several studies indicate that changes in environmental conditions and human activities have significantly influenced dengue epidemiology. Increased availability of artificial water storage containers and improper waste disposal practices frequently create suitable breeding habitats for *Aedes aegypti* mosquitoes (Gupta *et al*., 2012).

Distribution of Dengue Cases in India-Dengue cases have been reported from almost all states and union territories of India, although disease burden varies considerably across regions.

High-incidence states commonly include: Delhi, Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka, Kerala, West Bengal

Urban areas generally report greater disease incidence because of:

- High human population density
- Increased breeding habitats
- Water storage practices
- Human movement patterns

Seasonal Trends of Dengue Transmission- Seasonal variation strongly influences dengue transmission patterns.

Peak dengue incidence generally occurs during:

- Monsoon season
- Post-monsoon season

Rainfall creates temporary water collections that serve as breeding habitats for mosquito larvae (Morin *et al*., 2013).

Temperature and humidity also affect:

- Mosquito development
- Adult survival
- Feeding activity
- Viral replication

Factors Associated with Increasing Dengue Cases

Multiple interacting factors contribute to increasing disease burden in India:

Urbanization-Rapid urban development frequently produces environmental conditions favorable for mosquito breeding.

Climate variability-Temperature and rainfall changes influence vector abundance and transmission efficiency.

Population movement-Migration and travel may facilitate dissemination of viral strains.

Insecticide resistance- Increasing resistance among mosquito populations may reduce effectiveness of control programs.

Public awareness and sanitation-Inadequate awareness regarding mosquito control practices frequently contributes to persistent transmission.

Table 3. Major Factors Influencing Dengue Incidence in India

Factor	Potential Impact
Urbanization	Increased breeding habitats
Temperature increase	Enhanced mosquito development
Rainfall	Increased larval habitats
Population growth	Greater transmission opportunities
Insecticide resistance	Reduced vector control efficiency

Several epidemiological investigations suggest that interactions among environmental conditions, vector biology, and human behavior collectively determine disease occurrence and transmission patterns (Bhatt *et al*., 2013).

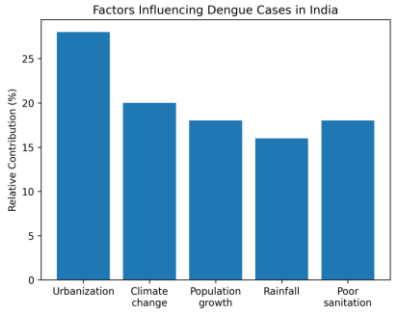

Figure 1 – Factors Influencing Dengue Cases in India

Fig. 1. Major environmental and socioeconomic factors influencing dengue cases in India including urbanization, climate change, population growth, rainfall, and poor sanitation.

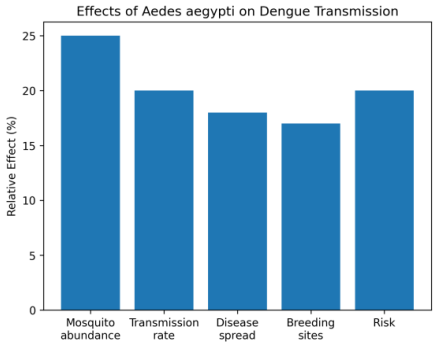

Figure 2 – Effects of *Aedes aegypti* on Dengue Transmission

Fig. 2. Major effects of *Aedes aegypti* abundance on dengue transmission including disease spread, breeding sites, and transmission risk.

Discussion

The present review demonstrates that *Aedes aegypti* is one of the most important vectors responsible for transmission of dengue virus and other arboviral diseases affecting human populations. The increasing incidence of dengue cases in India represents a significant public health challenge and highlights the complex interactions among vector biology, environmental conditions, socioeconomic factors, and human behavior. The biological characteristics of *Aedes aegypti* contribute substantially to its effectiveness as a disease vector. The mosquito demonstrates strong anthropophilic feeding behavior and preferentially feeds on human blood. Multiple feeding activities during a single reproductive cycle increase opportunities for viral transmission (Scott *et al*., 2000). Furthermore, adaptation of the species to urban habitats has facilitated persistence of mosquito populations in highly populated regions. Urbanization has been identified as one of the major factors influencing dengue epidemiology in India. Rapid expansion of urban settlements often occurs without adequate sanitation and environmental management systems. Improper waste disposal and water storage practices create favorable breeding habitats for mosquito development (Gupta *et al*., 2012). Artificial containers such as tires, buckets, water tanks, and discarded plastic materials commonly accumulate stagnant water and support larval growth. Environmental and climatic variables also play significant roles in vector abundance and disease transmission. Temperature strongly influences mosquito development, survival, feeding behavior, and viral replication within vectors (Morin *et al*., 2013). Elevated temperatures may reduce the duration of the extrinsic incubation period and consequently increase transmission efficiency. Rainfall patterns represent another important factor affecting dengue occurrence. Moderate rainfall frequently creates suitable breeding habitats, whereas excessive rainfall may sometimes remove larvae from breeding sites. Seasonal increases in dengue cases during monsoon and post-monsoon periods have been reported from several regions of India. Climate change has additionally emerged as an important determinant of vector-borne disease dynamics. Changes in environmental conditions may alter geographical distribution of mosquito populations and facilitate expansion of disease transmission into previously unaffected regions (Messina *et*

al., 2019). Increasing temperatures may extend seasonal activity periods of vectors and increase disease risk. The interaction between mosquito vectors and pathogens is also influenced by genetic and ecological factors. Vector competence varies among mosquito populations and may determine efficiency of pathogen transmission (Lambrechts *et al*., 2010). Genetic diversity within mosquito populations may therefore influence epidemiological patterns. Public health management strategies have traditionally focused on vector control through insecticide application and environmental sanitation measures. However, increasing insecticide resistance among mosquito populations has become a major concern affecting effectiveness of disease control programs (WHO, 2024). Integrated vector management approaches involving environmental management, community participation, surveillance systems, biological control, and public awareness programs may provide more sustainable solutions for disease prevention.

Conclusion

The present review demonstrates that *Aedes aegypti* serves as an important vector responsible for transmission of dengue virus and represents a major contributor to increasing dengue cases in India. Biological characteristics including anthropophilic feeding behavior, adaptation to urban habitats, and daytime biting activity contribute substantially to transmission efficiency.

Increasing dengue incidence in India is associated with multiple interacting factors including:

- Rapid urbanization
- Climate variability
- Population growth
- Environmental conditions
- Insecticide resistance
- Poor sanitation practices

Effective management of dengue requires integrated approaches involving:

- Vector surveillance
- Environmental management
- Public awareness programs
- Community participation
- Sustainable vector control strategies

Future research integrating molecular techniques, artificial intelligence-based surveillance, and ecological monitoring may improve understanding of vector biology and support development of effective disease prevention programs.

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