Emergence of Dengue Problem in India – A Public Health Challenge

R. S. Sharma[*], Roop Kumari[*], P. K. Srivastava[*], Kalpna Barua[**], L. S. Chauhan[*]

Abstract

India contains approximately half of the 205 billion people worldwide who are at risk of dengue fever. The virus causing Dengue/ DHF is believed to have established in almost all parts of India and has emerged as a major public health concern. Dengue is found in tropical and sub- tropical regions around the world, predominantly in urban and semi- urban areas. It is the most common mosquito-borne viral disease of humans. Globally, 2.5 billion people live in areas where dengue viruses can be transmitted. *Aedes aegypti* is the main vector playing a major role in the transmission of dengue/ DHF. Dengue fever and its severe complication i.e. DHF are caused by one of four types of distinct, but closely related, viruses namely DEN1, DEN2, DEN3 and DEN4 of genus flavivirus. By the last decade of the 20th century, *Aedes aegypti* and the four dengue viruses had spread to nearly all the countries of the tropical world. Some 2 billion persons live in dengue- endemic areas with tens of millions infected annually. Dengue pandemics were also documented in the 18th and 19th centuries; they were contained by organized anti- *Aedes aegypti* campaigns and urban improvements. The 20th century dengue pandemic has brought with it the simultaneous circulation of multiple serotypes and in its aftermath, endemic dengue haemorrhagic fever/ dengue shock syndrome (DHF/ DSS).

At the national level, dengue control is coordinated by the National Vector Borne Diseases Control Programme (NVBDCP). NVBDCP is the agency responsible for framing national dengue guidelines and policies for guiding the implementations of programme strategies at the state level.

In the absence of a vaccine, vector control is the main strategy to prevent dengue outbreaks. The country paradigm for dengue control is largely passive surveillance and early case detection coupled with rapid mobilization in the case of an outbreak. The first outbreak of DHF occurred in Calcutta in 1963. After that disease outbreaks reported from different states. The first major outbreak of dengue fever (DF) was reported in Calcutta in 1963. Since then, more than 60 outbreaks have been reported in India from different states. During recent years, it has become a major public health problem in the urban areas of India and is gradually spreading to the rural areas. The problem of dengue is increasingly becoming important in most tropical countries due to the expanding urban areas, limited piped water supply, constant influx of people from rural to urban areas, creation of slums, and high rise buildings with increased use of water coolers during the summer season.

[*] National Centre for Disease Control, 22 Sham Nath Marg –Delhi110054

[**] National Vector Borne Disease Control Programme, 22Sham Nath Marg-Delhi

Correspondence to: Dr. R. S. Sharma, National Centre for Disease Control, 22 Sham Nath Marg –Delhi110054.
E- mail: ranjandersharma@gmail.com

An epidemic of dengue was also reported in Rajasthan in 1985. A severe outbreak of dengue was reported in 1996 in Delhi with more than 400 deaths. Gurgaon town of Haryana state faced similar outbreak of dengue with 1137 cases and 9 deaths in 2008. During 2009, Pune Corporation in Maharashtra state reported an outbreak of dengue. The state reported 2255 cases and 20 deaths. The maximum dengue deaths were reported from Haryana, Kerala, and Punjab state.

***Aedes aegypti* was the only vector in all these outbreaks. The epidemic, which occurred during 2005- 06 in certain islands of Indian Ocean and in Kerala strongly suggests that *Aedes albopictus* played an alternate role. *Ae. albopictus* invaded the peridomestic settings, hitherto the exclusive domain of *Ae. aegypti*. The aggressive nature of *Aedes albopictus,* when compared that of to *Ae. Aegypti,* may help them to out compete the latter and could play a crucial role in the disease transmission due to aggressive bites in Kerala state. *Ae. albopictus,* a secondary vector for dengue, is likely a significant factor in the persistence of dengue in the environment through vertical transmission and may be replacing *Ae. aegypti* in semi- urban areas.**

The diverse breeding habitats of the dengue vector, *Aedes* spp. mosquitoes, demand community education and mobilization for effective control. However, community involvement for dengue control has mixed results in the country. Improper water management, lack of public awareness, inadequate solid waste disposal mechanisms, urbanization, lack of communication and integration between governing agencies, all contribute to increased number of dengue cases. This article highlights the state of dengue control in India, explores vector control mechanisms that have worked elsewhere, to strengthen dengue control activities by policy and practice.

Keywords: **Dengue, NVBVDCP, India, *Aedes aegypti, Aedes albopictus.***

Introduction

Dengue fever is a disease of the public health importance caused by arbovirus and transmitted by *Aedes* mosquitoes in both urban and rural areas. The dengue viruses consists of an antigenic sub- group of closely related, yet antigenically distinct virus, serotype DENV1-4, within the genus Flavivirus, Family Flaviviridae.[1] Serotypes produce disease ranging from the relatively mild dengue fever, a self– limiting febrile illness to the severe DHF characterized by haemorrhaging with or without fatal shock syndrome.[2]

The annual incidence of dengue is estimated at 50 million cases globally.[3] In the 1950s, nine countries reported dengue; today over 100 countries are endemic for DF. Dengue has been known to exist in the country for over a century and two stains of dengue virus were first isolated by Sabin in 1945.[4] The first outbreak of dengue was reported from Calcutta in 1963 and later on the outbreaks were reported from Vizag, Madras, Vellore and Pondicherry as well as few other areas in south India in 1964, and from Nagpur in 1965.Another severe outbreak of dengue was reported in Ajmer District of Rajasthan in September- October, 1969.[5] After that, the disease has been reported from other states also.

The geographic distribution of dengue has increased over decades. The first major outbreak of dengue in India occurred in Delhi in 1996.[6]It is now estimated that India has become hyper- endemic for dengue. All four viral serotypes in circulation during an outbreak in 2006 were reported from Delhi. In recent years, the epidemiology of the virus has changed dramatically and it is recommended to monitor

Aedes indices for effective planning of control strategies for dengue/ DHF outbreaks.[8, 9]The present communication attempts to review the DF/ DHF situation in the country and its prevention and control.

Methods

A systematic review was done to identify eligible articles. Relevant findings of all published articles were compiled together and discussed in here. The NVBDCP web sites were also searched to get valuable information on dengue and its control programme. The entomological survey was conducted for dengue vectors in different states as well as air ports/ sea ports.

Results

History of Dengue and disease burden

The pandemic of dengue during 19th and early 20th century were reported from Pondicherry and the Gangetic valley up to Banaras. Carey and Kemp [9]believed that the chikungunya virus was responsible for the 1824- 1825 outbreaks from Calcutta, Madras and Gujrat.[10,] Dengue pandemics were again reported in Calcutta and Kanpur in 1848.[11]Again, the disease was reported in 1872 and 1873 from Bombay, Pune, Calcutta, and Kerala coast from Calicut to Qulin, Madras. The dengue appeared in Calcutta in 1901 and in Meerut, North India in 1912. It was reported that Dengue Fever and its complications, dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) was caused by a mosquito– borne flavivirus. Dengue manifests clinically as a severe but rarely fatal influenza- like illness with high attack rate and low mortality. By contrast, DHF/ DSS is characterized by haemorrhagic disease with a case fatality rate that can approach 44% for untreated DSS. In an epidemic, the dengue attack rate is often 40-50%, [12] and can exceed up to 80% [13]. Case fatality in India has remained above 1% during epidemics. [14] Mortality in specific outbreaks has been much higher, reaching 4.5% in 1996. In the Delhi outbreak, a mortality rate of 2.7% was reported. [15]

The country experiences seasonal outbreaks of dengue coinciding with end of monsoon rains.[16] A major dengue outbreak with more than 10,000 cases and 425 deaths occurred in Delhi in 1996. In 2008, 12,351 cases of DF were reported from 17 states.[17] Similarly, Gurgaon town of Haryana state adjoining Delhi, faced similar outbreak of dengue in 2008. During 2009, Pune Municipal Corporation in Maharashtra state reported an outbreak of dengue. The state reported 2,255 cases and 20 deaths. The maximum dengue deaths were reported from Haryana (20), Kerala (17) and Punjab state (15). Dengue long followed a pattern of urban prevalence, but recently has spread even to semi- arid rural areas, due to the introduction of piped water and the abandonment of traditional water sources, which now harbour *Aedes* mosquitoes. The age distribution of dengue has changed from a predominantly paediatric disease to one that affects all age groups. Since *Aedes* are daytime biters and those people who spend time outdoors or in unprotected dwellings are at high risk of exposure, making the poor a preferential target. Low- income is a risk factor of dengue in multiple regions. Although the total number of dengue cases has consistently remained above 12,000 since 2003 (fig. 1), the annual case fatality rate has been decreasing due to improvements in case detection and management of severe cases (fig. 2). The history of dengue, recrudescence, and appearance of DHF was also reviewed at the global level. [12]

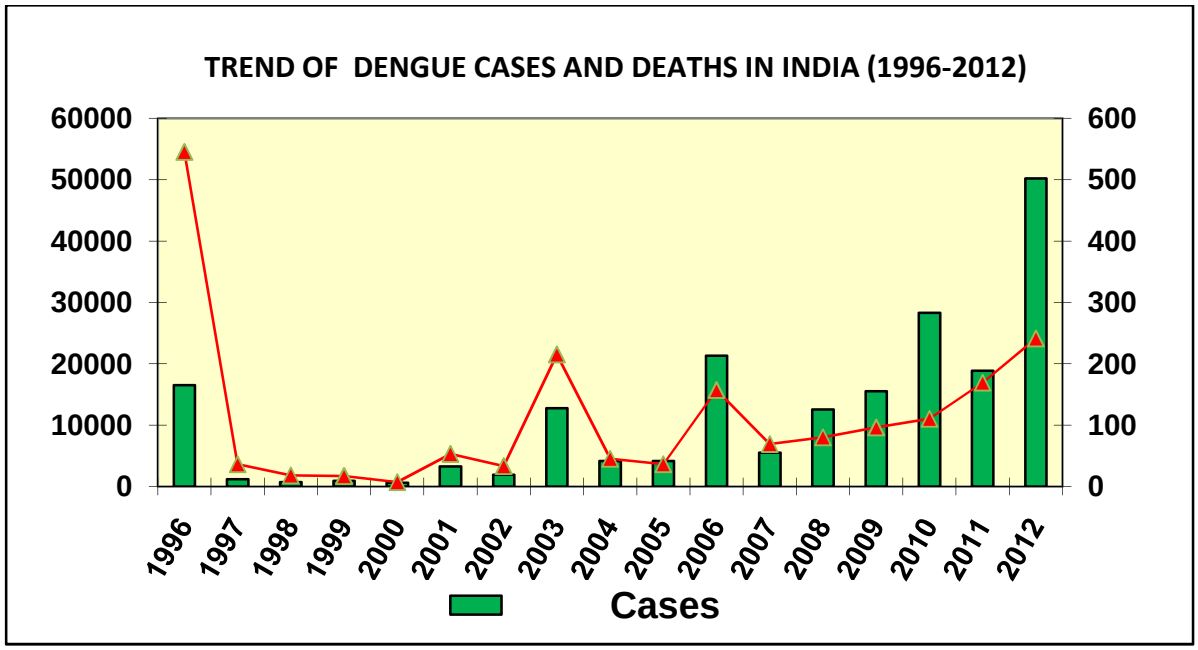

Figure 1.Trend of dengue cases in the country

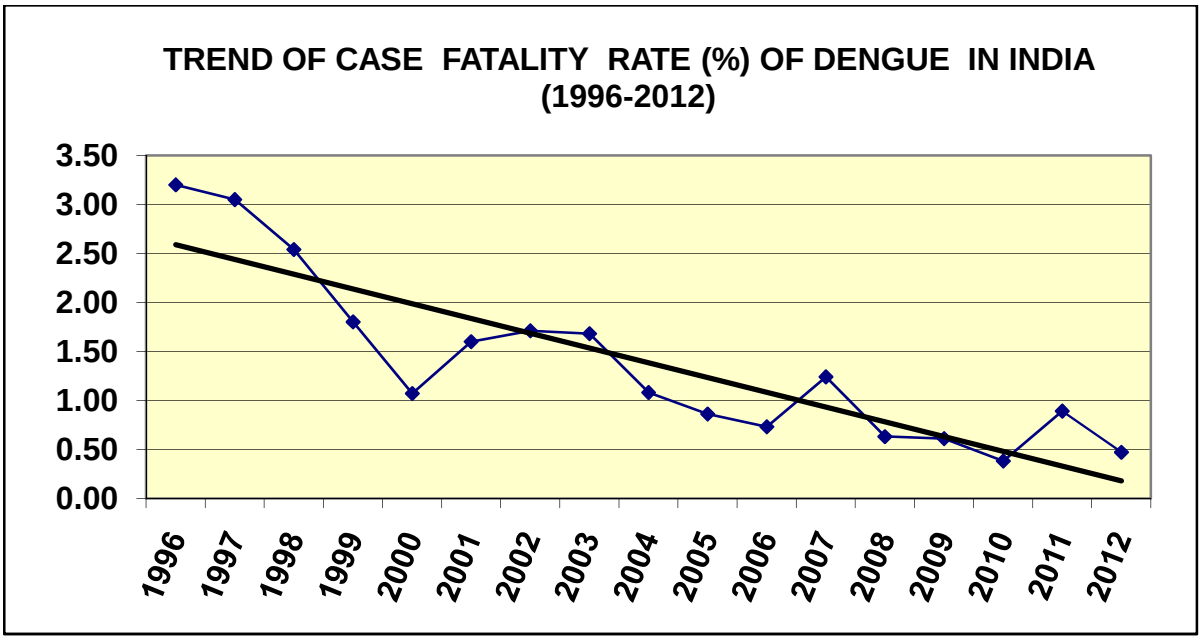

Figure 2.Diagnostic Facilities at State & District Level for Dengue & Chikungunya

Geographical Distribution

An attempt has been made to review and link the dengue episodes in India since 1950s with regard to its epidemiological profile and geographical distribution. Though, the first recorded outbreak of dengue fever in India was in 1812, serological surveys were first carried out in 1954 and later it was indicated that DENV-1 and DENV-2 are causing dengue fever/ DHF. The first isolations of DEN – 2 were made in 1956 by Virus Research Centre from human sera at Vellore. During 1956, DEN-4 virus was also isolated for the first time in Vellore (Tamil Nadu).

During 1962, serological studies showed a high endemicity of dengue in Calcutta with more than

80% of the population with antibodies to group B arboviruses.[17] During 1963, Calcutta reported epidemic of haemorrhagic fever while a febrile illness in Nagpur in Maharashtra was reported during 1965.[18] Major outbreaks have been reported during 1964 (Vishakapatnam), 1968 (Kanpur), 1969 (Ajmer), 1985 (Vellore), 1988 (Delhi), 1993 (Satara, Bankura).[19, 20, 21] The nature of the outbreaks occurred during 1963- 65 was more severe during the first two years while mortality declined in 1965. During 1968, an epidemic of febrile illness occurred in Kanpur in which morbidity rate was high while mortality was low. An outbreak of dengue was reported in Ajmer (Rajasthan) in 1969.[6] A total of 33.8% of the city's population was affected with an incidence of 47.8%. In 1967, 1968 and 1969, outbreaks of dengue occurred in Delhi when a number of strains of DEN-2 were isolated from humans. In 1970, DEN-1 and DEN-3 were the causative agents during the outbreak in Delhi and all the four serotypes were found to be co- circulating in 2006 outbreak with DENV-3 being the predominant serotype.[22]

After the 1963- 64 outbreaks of DHF in Calcutta, there were only sporadic cases of DHF in India during 1970- 80. A total of 40% of the population was affected by dengue outbreak in the town of Amalner in Maharashtra and DENV 2 was isolated from that outbreak.[23] A survey was carried out during 1976 outbreak of febrile illness in the town of Beawar in Ajmer district of Rajasthan and 23% of the population was found suffering from the disease.[24] Confirmed report of dengue activity was reported in Jammu in 1974 when 64% of the population was affected with febrile illness.[25]

An epidemic took place during 1985 in Jalore city of Western Rajasthan, which occurred in the summer (April-May).[26] The shortage of water during the summer led to increased storing of water and led to the increased breeding of *Ae. Aegypti*. This was the first reported outbreak of dengue in the arid zone in western Rajasthan that occurred in summer in contrast to other parts of India, where such outbreaks are commonly reported after the rains. An outbreak of dengue fever occurred in Maharashtra in the villages due to water storing habit of people.[27] An outbreak of dengue fever occurred during 1992 in Malikpur village on the outskirts of Delhi.[28] Detailed entomological, epidemiological and serological investigations of an outbreak that occurred in Shajahanpur, Uttar Pradesh, were carried out.[29]

Pathogen (Virus)

There are four dengue serotypes. Recovery from infection with single serotype produces lifelong immunity to that serotype, but only partial immunity to other serotypes. Sequential infection with different serotypes may lead to immune cross-reactivity and enhancement and progression to DHF/ DSS.[30, 31]Hyper- endemicity with multiple circulating serotypes of dengue increases the probability of cross- reaction and progression to severe forms of the disease. The co- circulation of all four serotypes, which increases the future risk of DHF/ DSS, has been documented in Delhi and Mumbai in 2005,.[32] Each serotype contains various genotypes, and the virulence of different genotypes can vary significantly over the range of their circulation. In India, the prevalence and virulence of different serotypes has shifted dramatically in recent years. In the 1996 Delhi epidemic, DEN-2 was primarily responsible, with DENV-1 circulating after the outbreak.[31] In 2003, all the four serotypes were found circulating in Delhi, but in 2005, DENV-3 was the main serotype in circulation and appeared to have established dominance in Delhi.[22]

Multiple lineage of a single genotype of Den-1 (genotype111) was reported during 1956 to 2007 in the country [33, 34] and independent lineage of dengue virus type 1(Dengue-1) and its co- circulation with predominant DEN-3 during the 2006 dengue outbreak in Delhi was also observed. Dash[34] studied the emergence and continued circulation of Dengue 2 (genotype IV) virus strains in Northern India. Single genotype of Dengue virus Type- 3 (DENV-3) reported in Delhi since its re- emergence over the last decade. Molecular subtype of the dengue-3 was identified during 2003 outbreak in Delhi.[36] Kukreti[35]reported the active circulation of DENV-3 genotype III over the last decade in Delhi, which has been implicated in several outbreaks in South East Asia and other parts of the world.

The micro- evolution of virus is as mentioned below, with 16 genotypes: [37]

1. DENV-1 - 5 genotypes
2. DENV-2 - 5 genotypes
3. DENV-3 - 4 genotypes
4. DENV-4 - 2 genotypes

16 genotypes

All the four serotypes circulating in humans have been isolated in India. The isolation of DEN 2 serotype was done during 1956 from the serum of a child from Vellore. Subsequently, the other three serotypes namely DEN 1, 3 & 4 were isolated from different parts of the country. The details of the major outbreaks reported in India since 1956 are given in table 1.

Table 1.State wise reporting of different dengue serotypes during outbreaks

Year	Place/States	Virus isolation
1956-60	Vellore	DEN -1, 2
1961	Vellore	DEN - 4
1962	Calcutta	DEN - 2
1964	Vishakhapatnam	DEN - 2
1965	Nagpur	DEN - 4
1965	Madras	DEN – 1, 3
1966	Vellore	DEN - 3
1966	Jabalpur	DEN - 3
1966	Surat	DEN - 1
1967	Madras	DEN - 2
1967	Delhi	DEN - 2
1967	Asansol	DEN – 2, 4
1968	Vellore	DEN – 1, 2,3 & 4
1968	Kanpur	DEN – 4
1969	Kanpur	DEN – 2, 4
1969	Ajmer	DEN – 1, 3
1970	Delhi	DEN –1, 3
1970	Gwalior	DEN – 3
1970	Hardoi	DEN – 2
1970	Bangalore	DEN – 1, 2
1971	Jaipur	DEN – 1, 2
1975	Amalner (Maharashtra)	DEN – 2
1976	Beawar (Rajasthan)	DEN – 2
1977	Jammu	DEN – 2
1982	Delhi	DEN – 1, DEN – 2
1985	Jalore (Rajasthan)	DEN – 3
1986	Miraj	DEN 2 & 3
1987	Calcutta	DEN - 4
1988	Delhi	DEN - 2
1988	Parbhani	DEN –1, 2
1989	Chennai	DEN - 2
1990	Vellore	DEN 1, 2
1996	Delhi Hisar (Haryana)	DEN - 2
2003	Delhi	DEN - 3
2004	Delhi	DEN - 3
2003	Delhi	All four dengue virus subtypes
2005	Delhi	predominance of DEN-3
2002-06	Delhi	DV-1, 2, 3
2003 -04	Gwalior	DEN - 3
2007	Andhra Pradesh	DV-1 & 4 (Genotype I)
2008	Ernakulam, Kerala	DEN-2
2007-09	Delhi	DV 1, 2, 3 & 4
2009-10	Pune	DEN – 4 (Genotype I)
2010	Tirupur, Tamil Nadu	DEN - 3

An epidemic of febrile illness in Mangalore city, Karnataka, India during 1993 indicated that five strains of dengue (DEN-2) virus were recovered from the acute- phase sera. Dengue virus- specific IgM type of antibodies were detected in 29/116 (25%) sera. Outbreaks of dengue (DEN) fever reported from 22 villages in five districts in the state of Maharashtra during 1991 reported DENV types 2 and 3 among the 16 strains isolated[37] Epidemiological and entomological investigations conducted in seven affected villages of Sanand and Viramgam Talukas of Ahmedabad district revealed that all age groups and both the genders were affected. Co- related evidences indicated the possible role of dengue 2 virus in the outbreak.[38] During 1988, dengue (DEN) virus activity was demonstrated in large cities such as Surat and Rajkot as well as in several villages in Sabarkantha district. Two strains of dengue type- 2 each were isolated from human sera from Surat city and a village in Sabarkantha district.[40] In Chirimiri colliery area of Madhya Pradesh, during 1992 outbreak, 25 patients' sera were tested, of which 13 showed seropositivity to dengue (DEN) by MAC- ELISA test; DEN-2 was isolated from *Aedes aegypti* collected from two of the eight settlements of the area.[41] In an outbreak of febrile illness during 2001 in Gwalior, Madhya Pradesh, the serological analysis indicated 65 per cent positivity of which 21 per cent are of recent infection as indicated by the presence of IgM antibody and 78 per cent are found to be secondary in nature by showing the presence of IgG and/ or IgM antibodies. Of these 9 samples, 80% were confirmed positive for virus isolation as identified by RT-PCR, thus confirming the outbreak attributed to dengue virus type- 2.[42] The rural areas of Hissar district of Haryana state experienced an outbreak of febrile illness in 1996 affecting 13 villages. The aetiological agent of this outbreak, the DEN-2 virus, was isolated from 12 acute- phase sera specimens.[43]

The epidemic of 1996 in Lucknow indicated that the age group affected most was 11 to 30 years and 21% of the patients were less than 10 years old.[44] The male to female ratio was 1.9:1. Among the patients with profound shock, the mortality was 47% while the overall fatality rate was 3.8%. During 1997, Dengue virus type 1 was demonstrated by culture in 8 (21.6%) of 37 serum samples and IgM antibody could be detected in 42 (29.4%) of the 143 serum samples by the serological methods. The prevalent serotype during September and December 1997 was DEN1. Since previous epidemic of DHF was due to DEN2 type, isolation of DEN1 serotype indicates changes of another epidemic of DHF due to DEN1 serotype.

In an attempt to determine the prevalence of certain arthropod- borne viruses amongst the human population of the Andaman and Nicobar Islands of India, the highest prevalence of HI antibodies was detected against KFD virus (22.4%), followed by Langat (20.2%), JE (5.9%), DEN-2 (3.1%), CHIK (2.9%) and WN (0.8%) viruses. Cross- reactions to the viral antigens were also noted. The results mm indicated a high prevalence of DEN-2 (25.4%) virus, followed by Langat (17.5%), CHIK (15.3%), KFD (12%), JE (2.19%), and WN (1.8%).[45]

These results are discussed in relation to important epidemiological parameters like age, sex, and geographical location. To our knowledge, this is the first report of an extensive serosurvey of arthropod-borne viruses on these islands. An outbreak of dengue haemorrhagic fever/ dengue shock syndrome (DHS/ DSS) occurred in 1996 in and near Delhi, which was confirmed to be due to dengue virus type 2, and resulted in the largest outbreak reported from India. Similar outbreak was reported from Ludhiana during 1996.[46] Serological evidence of DEN-2 activity in Assam and Nagaland has been also demonstrated. An epidemic of febrile illness with haemorrhagic manifestations occurred in certain parts of Mangalore city, Karnataka, India, from the last week of July 1993. Five strains of dengue (DEN-2) virus were recovered from the acute- phase sera. Following the epidemics of febrile illness from Gujarat state in 1988, two strains of dengue type-2 each were isolated from human sera from Surat city and a village in Sabarkantha district. An outbreak of Dengue Haemorrhagic Fever (DHF) occurred in Calcutta between September and December 1990. It was for the first time, that DEN-3 was considered to be the aetiologic agent for DHF in Calcutta.

Outbreak of dengue fever in Chikalthana, Pimpalgaon and Waloor villages in Parbhani district of Maharashtra (India) indicated dengue virus type 2 and 1. An epidemic of acute febrile illness that occurred in Jalore town of Rajasthan during 1985 showed that dengue type 3 virus was the main

aetiological agent. An epidemic of dengue fever that broke out in Calcutta during 1983 confirmed the virus isolated as dengue type 3 (DEN-3), the first isolation of DEN-3 virus in Calcutta. Similar outbreaks of dengue have been reported in Jabalpur (1966), Kanpur (1968), Vellore (1968), Ajmer (1969), Jaipur (1971), Jammu (1974), Amalner (1975), and Delhi (1982).

Molecular Aspects

In a study, quantitative comparison of 406 nucleotide long sequence from the capsid-premembrane junction region (C-PrM) of nine dengue virus type 2 (DEN-2) isolates from Delhi with 10 DEN-2 isolates from diverse geographic areas provided sufficient information for estimating genetic relationships. The data indicated that the 1996 epidemic of DHF in Delhi was caused by genotype IV strains of DEN-2. This genotype, perhaps, displaced genotype V strains of DEN-2, which was a circulating genotype in 1967. In another study, sequence analysis revealed that most of the mutations in this region remained silent, except a few at the carboxy- terminal of the capsid. Reported phylogenetic analysis classifies DEN-2 viruses into five distinct genotypes. The Gwalior DEN-2 viruses, included in the present study were classified into genotype-IV, and were found to be the most closely related to Delhi 1996 DEN-2 viruses and FJ 10/11 strains prevalent in the Fujian state of China. However, two earlier Indian isolates of DEN-2 were classified into genotype-V. The present study indicates that genotype V of DEN-2 has been replaced by genotype IV during the past decade, which continues to circulate silently in north India, and has the potential to re- emerge and cause major epidemics of DF and DHF.

The epidemic strains of 1996 in Delhi had a divergence of 10%- 11% from the 1967 strains, but were quite similar to DEN-2 isolates from Seychelles, Somalia, and Torres Strait. The phylogenetic analysis by the Molecular Evolutionary Genetics Analysis program suggests that the 1996 Delhi isolates of DEN-2 were genotype IV. The 1967 isolate was similar to a 1957 isolate of DEN-2, P9-122, from India, and was classified as genotype V. This study indicates that earlier DEN-2 strains of genotype V have been replaced by genotype IV. According to one study, the nucleic acid sequences of the pre- membrane/ membrane and envelope protein genes of 23 geographically and temporally distinct dengue (DEN)-3 viruses were determined. The DEN-3 viruses were separated into four genetically distinct subtypes. Subtype I consists of viruses from Indonesia, Malaysia, the Philippines and the South Pacific islands; subtype II consists of viruses from Thailand; subtype III consists of viruses from Sri Lanka, India, Africa and Samoa; subtype IV consists of viruses from Puerto Rico and the 1965 Tahiti virus. Phylogenetic analysis has also contributed to our understanding of the molecular epidemiology and worldwide distribution of DEN-3 viruses.

Disease vector

The primary dengue vector, *Ae. aegypti*, is a highly domesticated, day- feeding arthropod with a preference for manmade storage containers. *Ae. aegypti* was only vector in all these outbreaks. The epidemic which occurred during 2005- 06 in certain islands of Indian Ocean and in Kerala strongly suggests that *Ae. albopictus* played an alternate role. *Ae. albopictus* has invaded the peridomestic settings, hitherto the exclusive domain of *Ae. aegypti*. The aggressive nature of *Ae. Albopictus*, when compared to that of *Ae. Aegypti*, may help them to out compete the latter and could play a crucial role in disease transmission. *Ae. aegypti* prevalence in different parts of the country including western, northern, Indo- Gangetic and eastern plains, Assam valley and the coastal areas of Orissa state in India was surveyed. The species was non- existent in the Himalaya region. In north- central highlands, the species showed low- to- moderate prevalence, while in south, in south–central highlands, the mountainous areas were largely free but high populations of the vector were encountered in the valleys. Similarly, the eastern plateau, including the Eastern Ghats was comparatively free of the vector except large towns in the Mahanadi basin. The Satpura ranges of north Deccan were also found to be free of *Ae. aegypti*. Water coolers and tyres were found to be the preferred breeding habitats of Aedes mosquitoes in the city. *Aedes aegypti*, being hygroscopic, showed a phenomenon of annual pulsation. It tends to move to mother foci in the central areas of the city, which are humid in the dry season, and spread out during the wet season.

Primarily an urban problem, dengue has spread to semi- urban, rural, and semi- arid regions of the country due to spread of the vector species, *Ae.*

aegypti and Ae. albopictus. There have been more than eighty dengue outbreaks in 31 states/ UTs in India (table 2). As per Internal Health Regulations (IHR) directives, Aedes sp. surveillance was carried out at different airport/ seaport and the results are given in table- 3.

Table 2.Apex Referral labs for dengue in different states

1	Andhra Prd*	32
2	A&N Islands	3
3	Arunachal Pradesh	1
4	Assam*	9
5	Bihar	5
6	Chandigarh*	1
7	Chhattisgarh	2
8	Daman & Diu	1
9	D&N Haveli	1
10	Delhi**	33
11	Goa	3
12	Gujarat*	16
13	Haryana	14
14	Himachal Prd	2
15	J & K	7
16	Jharkhand	4
17	Kerala*	20

*Locations of 14
Apex Referral Laboratories

18	Karnataka*	22
19	Lakshadweep	1
20	Maharashtra*	23
21	Madhya Prd**	17
22	Manipur	2
23	Meghalaya	3
24	Mizoram	1
25	Nagaland	2
26	Orissa	8
27	Pondicherry	4
28	Punjab	15
29	Rajasthan	20
30	Sikkim	2
31	Tamil Nadu*	30
32	Tripura	1
33	Uttar Pradesh*	22
34	Uttarakhand	7
35	West Bengal*	13

Table 3.Vector surveillance at different ports

Locality	Year	House index	Container index	Breteau index
Airport Health Organization ,Campus, Tuticorin	2007	6.2	15	18.8
Old Airport Chennai	2007	35.7	46.4	185.7
Central Govt. Office Complex Rajaji	2007	17.6	20.6	41.1
Circuit house &surrounding area,	2007	6.6	22.7	33.3
Airport, Thiruchirapalli.	2007	3.1	37.8	53.1
Port Turst ,Kandla, Gujarat				
Engineering .workshop	2008	-	44.4	-
Water Workshop	2008	-	11.1	-
PHO staff Colony –I	2008	28.6	37.5	42.9
IFFCO,Govt. Bldg	2008	-	21.4	-
Seaport Bldg.Out Side	2008	-	11.1	-
Port Turst Hospital	2008	-	12.5	-
Custum Building	2008	-	22.5	-
PHO Staff Clolony-II	2008	21.4	14.3	28.6
Fisherman Colony	2008	39.6	37	70.8
Port Turst Building in- side	2008	-	35.6	-
Kandla port Trust (Jattly Office)	2008	-	50	-

Cochin Seaport	2009			
Port container yard	2009		30.2	
FACT Godwan Seaport	2009		23.4	
Mattanchey Warf Seaport	2009		30.7	
Tiruchirappalli Airport	2013			
		18.1	48.4	290
Kozhikode Airport	2013			
		18.7	26	54.5
Cochin Airport	2013			
			6.6	
Cochin seaport			20	
Cochin -Angamali municipal area		9	5	13
Thirvuvananpuram Airport	2013		10.67	
Thirvuvananpuram Corp area		2	0.9	2
Tuticorin seaport	2013	7.69	1.69	7.69
Residential area , Tutikorin sea port		38.71	21.77	58.06
Bengaluru Air port	2013			
		17.4	4,46	30.64

Vector control measures for *Ae. aegypti* mosquitoes have a collateral benefit for the control of another emerging disease. Like dengue, chikungunya is also spread by *Ae. aegypti* and *Ae.albopictus* mosquitoes. Chikungunya has been resurging at an alarming rate throughout India. In 2006, chikungunya infected over 1.42 million people, with an attack rate approaching 45%.[47] Similar to dengue, domestic water containers serve as breeding sites, with small, peri- domestic containers serving to amplify mosquito population. Although this article will focus on dengue, the control measures outlined have direct implication for the containment of chikungunya also.

The elevation, type of relief, terrain, density of population, water storage practices in drought- prone regions and high rainfall leading to formation of secondary foci had direct relationship with the prevalence of the species. Altitudes above 1000 meters were found to be unfavourable for the species.

Being hygroscopic, they depicted a phenomenon of 'annual pulsation'. They tend move to 'mother foci' in the central parts of cities, which are humid during the dry season and spread out during the wet season. *Ae. albopictus* was encountered in the peripheral areas of towns where it replaced the *Ae. aegypti* populations. However, in the eastern plateau, the species penetrated up to the central parts, probably due to lack of intra- species competition from *Ae. aegypti* which is very scanty in the region. *Ae. albopictus*, a secondary vector for dengue, is likely a significant factor in the persistence of dengue in the environment through vertical transmission[48] and may be replacing *Ae. Aegypti.* In semi- urban areas, populations of *Aedes* spp. mosquitoes tend to fluctuate during the monsoon season. In urban areas like Delhi, overhead tanks and cement serve as the main pre- monsoon breeding foci, with spread to other breeding habitats such as tyres and coolers during the monsoon.[49] Smaller, secondary sites tend to amplify the mosquito populations during the monsoon and post- monsoon periods.

Ae. aegypti and *Ae. albopictus* remain restricted to limited breeding sites during the dry season but spread extensively to PD and outdoor sites during the wet season.[50] In Delhi, *Aedes aegypti* is the most prevalent Aedes mosquitoes which prefers to breed in man- made containers. Recent report shows that *Aedes albopictus* and *Ae. vittatus* are also adapting to breed in man- made containers in the urban areas of Delhi in addition to their natural habitats of bamboo bushes and rock pits.[50] *Ae. albopictus* was found in 9.52% of surveyed localities including the central urban part of Delhi.

Ae. aegypti is prevalent throughout India so the entire country is at risk for dengue transmission.[51] Chikungunya is also spread by *Ae. aegypti* and *Ae. albopictus*, and thus follows the same patterns of transmission and spread. Unplanned urbanization and informal settlements create ideal breeding

habitats for *Aedes*. India's rapid population growth and increased rural– urban movement has augmented the spread of dengue and resurgence of chikungunya.

National level dengue control is coordinated by the NVBDCP, an umbrella program for the prevention and control of the vector borne diseases like malaria, dengue, lymphatic filariasis, Kala- azar, Japanese encephalitis, and chikungunya. The NVBDCP is also responsible for guiding state- level program strategy, and developing policies and guidelines.

Dengue Virus in Vector Mosquitoes

Detection of viruses in human sera particularly in endemic areas is cumbersome, difficult, and also not desirable. Therefore, as an alternative approach, detection of the dengue virus antigen in mosquitoes has provided a reliable tool to- (i) comprehend the types of viruses circulating in nature; and (ii) help in designing vector- specific control strategies. Various techniques available in detection and isolation of dengue viruses in mosquitoes have been reviewed and it has been suggested that ELISA can be used in dengue surveillance.[52, 53] The best method for diagnosis is considered to be the one that is rapid, specific, and inexpensive. An antigen capture ELISA recently developed for detecting dengue viral antigen in desiccated mosquitoes would be much useful in dengue surveillance for quickly screening large number of samples.[54]This could be considered as an essential component to establish a Dengue Surveillance Network for collection, compilation and documentation of data to develop a model for forecasting DF/ DHF outbreaks. In order to develop dengue- specific ELISA, dengue serotype- specific monoclonal antibody, MABs can be used as an inexpensive way to screen large number of mosquito specimens with relatively little effort. [55, 56, 57]

Methods selected for virus isolation depend much upon the laboratory facilities available. Reverse transcriptase polymerase chain reaction (RT-PCR) is a recent molecular diagnostic technology used for detecting virus infections in mosquitoes, which gives rapid results but is expensive and prone to contamination. Obviously there is no one 'best' method for all arboviruses, therefore, a melange of approaches fulfils the requirement.

In India, dengue virus isolations in mosquitoes have been made in wild- caught mosquitoes as early as 1960s. [58, 59]In southern India, dengue was mainly an urban disease in the 1960s and 1970s, associated with the container breeding vector *Ae. aegypti*. Many isolations of all the four serotypes of dengue virus (DENV) were made from pools of *Ae. aegypti*; for the first time, DEN1 and DEN4 (five isolates) in 1961, DEN2 (two isolates) in 1966[60] and 36 isolates of all the four serotypes in 1968[61].

The role of *Ae. Aegypti* as a principal vector had already been well documented in India, [62, 63] but the role of *Ae. albopictus* was not defined, although *Ae. albopictus* has been considered a potential vector of dengue and several virus isolations have been made in southeast Asia.[64, 65] In India many reports are now available from South India where *Ae. albopictus* has also been incriminated with dengue virus. However, isolation of DENV serotype-4,from *Ae. albopictus* had been documented once in the east from Asansol in West Bengal.[66]In Tamil Nadu, a 2-year (1997–1999) longitudinal, entomological, and virological study was carried out in Vellore district. From 271 pools of adult females, eight dengue virus (DENV) isolates were obtained, of which 7 were from *Ae. aegypti* and one from *Ae. albopictus*. ELISA and indirect immuno fluorescent assay (IFA) using dengue virus- specific Monoclonal antibody (MAbs) were used for virus isolation. They isolated all the four serotypes from mosquito samples indicating that the serotypes, which were demonstrated during the 1960s are well established in this area. More than 85% of the total confirmed DENV isolates were from *Ae. aegypti*, indicating that this species was the primary vector of dengue in villages in Vellore. The infection rate appears to be lower than that reported by others.

Although the dengue virus had been earlier reported from *Ae. albopictus* in India, but the finding of *Ae. albopictus* carrying dengue virus, that too in the absence of *Ae. aegypti*, was reported for the first

time in Kerala. [67] In 2007, *Ae. albopictus* has been incriminated as the vector in Kerala by isolating dengue type 2 virus, even in the *Ae. aegypti* which carries enormous epidemiological significances. It has been reported that *Ae. albopictus* has adapted to breed in man- made containers in urban environment and found infected with dengue virus.

Many publications are available mostly from South India, however, few are available from North India. Recently from urban areas of Delhi, dengue virus (DENV) was detected using using enzyme- linked immunosorbent assay with dengue- specific monoclonal antibodies in Ae. *aegypti* and *Ae. albopictus* . In North India, dengue virus was detected in *Aedes albopictus* mosquito in urban areas of Delhi. Further it was reported that 10.5% pools of *Ae. aegypti* were found positive for DENV while 11.8% pools of *Ae. albopictus* were found infected in Delhi. However, in earlier studies, 12.5% pools of *Ae. albopictus* were reported with DENV infection from Vellore district of Tamil Nadu, and 6.1% pools were reported from Kerala.[48] Vertical transmission may be an additional mechanism for the maintenance of DENV in nature. Although several studies have demonstrated the vertical transmission of dengue virus in the laboratory, few studies have reported the vertical transmission in nature, and still fewer have reported vertical transmission involving *Ae. albopictus*. Jodhpur, Rajasthan, western India, confirmed the transovarial cycle of dengue virus in *Ae. Albopictus.*[68, 69]Recently, occurrence of natural vertical transmission of dengue virus was reported in urban areas of Delhi.

Prevention and Control

Vector surveillance

The vector surveillance was carried out during outbreak in various areas including different ports. The container index was more than 22% during 1st outbreak of dengue in Calcutta city. Similarly, in Visakhapatnam, the container index for *Ae. aegypti* was very high in worst affected zone III. The shortage of water and high storage practice in Jalore city during April- May 1985 increased the *Ae. aegypti* population and outbreak of dengue. Normally, epidemics of dengue occurred between August and November in North India. The Chennai city reported 33% container index in 1989 outbreak. NCT Delhi reported 423 deaths due to dengue in 1996 with 72% container index. Ludhiana city, Punjab faced first outbreak of dengue and reported a very high container index (54.17%) even from Christian Medical College. The entomological indices and dengue outbreaks since 1963 to 2010 are given in table 4. The vector surveillance was also carried out in different ports and entomological data is given in table 3. Kozhikode and Triuchirappali showed very high indices for vector species.

Table 4.Entomological indices and Dengue outbreaks in India

Year of outbreak	Place of outbreak	Area of entomological and epidemiological survey	Entomological parameters, container index	Epidemiological Status (Attack rate)
1963	Calcutta city West Bengal	Calcutta city	22.0 26.0	Severe outbreaks with 200 deaths in the city
1964	Visakhapatnam Andhra Pradesh	Municipal Zone III Municipal Zone II Municipal Zone I Naval Base	48.1 17.5 11.5 0.0	More affected Less affected Less affected Nil
1966	Jabalpur Madhya Pradesh	Central City area Peripheral area Urbanized rural Outer most Rural area Cantt. area Civil /Military	20.2 6.5 19.0 0.0 11.0 0.0	33.3 9.4 20.0 14.6 3.3 0.0
1969	Ajmer City Rajasthan	Central Zone	43.7	47.8
1970	Gwalior City Madhya Pradesh	CENTRAL Ganesh Colony Danili PeripheraKhalasipura Morar Sikanara Camp Gunda Birpur Horkota	 65.2 40.5 0.0 0.0 4.0 0.0 0.0 0.0	 53.3 43.0 8.5 7.8 13.2 3.4 1.5 1.2
1976	Bewar town Rajasthan	Central Zone North Zone South Zone East Zone West Zone	60.32 54.63 57.69 53.32 26.42	All the zones More or less Equally affected with Dengue
1989	Madras City	City	33.0	Badly affected with 21 deaths.
1992	Shahjahanpur (U.P)	7 affected localities in the heart of city peripheral area	40.0 10.0	80.0 Few cases
1992	Malikpur village Delhi	Village	50.0	42.6
1996	Delhi	City and its neighbouring states	72.0	423 deaths

2001	Rajasthan	Jaipur Alwar Dausa		32 deaths
2001	Chennai	City		8 deaths
2005	Delhi	All Zones	52.5	1011cases 9 deaths
2005	Kolkata	Haldia Dock –Kolkata Port	24.0	4003 cases 14 deaths
2007	Haryana	Jacubpura Gurgaon	29.3	365 cases 11 deaths
2007	Kerala	Not Available		603 cases 11 deaths
2007	Maharashtra			614 cases 21 deaths
2008	Maharashtra			743 cases 22 deaths
2008	Rajasthan	Kendriya Vidyalaya, Moti Dungari, Alwar Raj Rishi College, Alwar Nursing Colony, Kehedali Alwar Shiv Colony, Alwar Shanti Kunj Res. Area CMH Officer Campus, Alwar Shyam Nagar Bharatpur Maharaja Badan Singh Sr.Sec. School Pusp Vatika, Bharatpur Nadbai Near CHs	29.2 22.2 54.5 37.3 31.3 4.8 25 8.3 21.6 51.2	
2008	Haryana	Jacubpura Gurgaon	76.8	1137 cases 9 deaths
2008	Kerala	District Kasargod	19.3	
2008	Punjab	New Sabji Mandi DMC Hospital Co-ed Sr. School SAD Haebowal Khurd Basti Jodewal SPO Haebowal khyrd	14.4 25 6.6 4.4 8.9	4349 cases 21 deaths

		R. C. Haebowal Kalan Shiv Puri Guru Nanak pura R.C. Kandanpuri Tutiawals Mandir Shivpur Technocare Nursery Punjab Agriculture University Staff Qtrs Co-ed .School SAD Haebowal Khurd Railway Colony State Govt. Office Complex, Civil Line Punjab Roadways Workshop Club Road, Civil Line	6.3 3.2 1.4 4 9.4 5.2 7.8 4.5 17.5 8.6 40.4 2.7	
2009	Andhra Pradesh	N.A.		1190 cases 11 deaths
2009	Gujarat	District Anand	56.0	2461 cases 2 deaths
2009	Karnataka	N.A.		1764 cases 8 deaths
2009	Maharashtra	N.A.		2255 cases 20 deaths
2009	Rajasthan	N.A.		1389 cases 18 deaths
2009	Kolkata	Swasthya Bhawan, Salt Lake Netaji Subhash Docks, PHO Netaji Subhash Chandra Bose International	46.4 65.3 27.9	
2009	Mumbai	Chamdawari, Bandra, Mumbai Lower parel, N.M. Joshi Marg Govt. Bldg.,	6.4 2.7	

2009	Kerala	Guest House Road Kannur Railway Colony Kannur Azhikode, Kannur Govindankutty Nair Kozhikod Pokkiyyil Vadakara Mappyil place, Vadakara Kunnukuzhy, Trivandrum Kannamoola, Trivandrum Vanchiyoor, Trivandrum Anayara, Trivandrum Karamana, Trivandrum Venkra, Trivandrum Manacaud, Trivandrum Vizhinijiam Kottapuram, Fisherman Cly Rajaji Nagar, Trivandrum Valiaveli ,Trivandrum Pangappra, Trivandrum Ullor, Trivandrum District Kottayam	33.3 6.6 3 3.4 27.1 28 5.6 4.7 4.7 7.1 13.1 4.1 11.1 25.2 5.6 4.7 27.6	
2010	Haryana	Office Municipal Corporation Commissioner, F-Block	8.6	866 cases 20 deaths
2010	Karnataka	N.A.		2285 cases 7 deaths
2010	Kerala	District Kollam	7.6	2597 cases 17 deaths
2010	Punjab	N.A.		4012 cases 15 deaths
2010	Gujarat	District Bhavnagar	35.7	

Rajasthan -2008	HI	CI	BI
Kendriya Vidyalaya, Motta Denair, Alwar	-	29.2	-
Raj Rishi College, Alwar	-	22.2	-

Nursing Colony, Khedali Alwar	61.1	54.5	100
Shiv Colony, Alwar	52.6	37.3	75.4
Shanty Kunj Res. Area	36.4	31.3	63.6
CMH office Campus, Alwar	-	4.8	-
Shyam Nagar Bharatpur	30.8	25	46.1
Maharaja Badan Singh Sr. Sec. School	-	8.3	-
Pusp Vatika, Bharatpur	35.7	21.6	38.1
Nadbai Near CHS	73	51.2	80.7
Ludhiana- 2008			
New Sbji Mandi	10.2	14.4	17.6
DMC Hospital	-	25	-
Co- ed Sr. School SAD Haebowal Khurd	-	6.6	-
Basti Jodewal	3.7	4.4	5.5
SPO Hawbowal Khurd	6.3	8.9	12.6
R.C Heabowal Kalan	8.7	6.3	8.7
Shiv puri	3.7	3.2	3.7
Guru Nanak Pura	1.8	1.4	1.8
R. C. Kundanpuri	5.3	4	5.3
Tutiawals Mandir Shivpur	8.1	9.5	11.4
Technocare Nursery	-	5.2	-
Punjab Agriculture University Staff Qtrs	9.6	7.8	9.6
Co-ed Sr. School SAD Haebowal Kurd	-	4.5	-
Railway Colony	23.2	17.5	23.2
State Govt. Office Complex ,Civil Line	-	8.6	-
Punjab Roadways Workshop	-	40.4	-
Club Road, Civil Line	3.7	2.7	3.7
Kolkata- 2009		CI	

Swasthya Bhawan, Salt Lake		46.4	
Netaji Subhash Docks, PHO		65.3	
Netaji Subhash Chandra Bose International		27.9	
Mumbai City- 2009			
Chandwari, Bandra	9.3	6.4	9.3
Lower Parel, N.M. Joshi Marg, Govt.Bldg	-	2.7	-
Kerala State-2009			
Guest House Road Kannur	8.3	33.3	41.6
Railway Colony Kannur	8.6	6.6	8.6
Azhikode, Kannur	3.3	3	3.3
Govindan Kitty Nair Kozhikod	7.6	3.4	7.6
Pokkiyyil Vadakara	18.4	27.1	67.1
Mappyil Place, Vadakara	20	28	68
Kunnukuzhy, Trivandrum	4.2	5.6	6.3
Kannamoola, Trivandrum	2.7	4.7	5.4
Vanchiyoor, Trivandrum	5.5	4.7	5.5
Anayara, Trivandrum	6.8	7.1	9
Karamana, Trivandrum	9.2	13.1	18.5
Venkara, Trivandrum	6	4.1	6.
Manacaud ,Trivandrum	10.8	11.1	15.2
Vizhinijam Kottapuram, Fisherman Cly	20	25.2	45
Rajaji Nagar, Trivandrum	6.3	5.6	6.3
Valiaveli, Trivandrum	5.3	4.7	5.3
Pangappara, Trivandrum	1.6	1.3	1.6
Ullor, Tricandrum	2.1	2	2.1
Distt. Jalpaiuri, West Bengal-2004			
Ashwani Nagar	16.6	13.3	16.6

Uttalbadi Tea Garden	22.7	21.8	31.8
Gazal Daba No.10	6.6	4.5	6.6
Gaza Daba No.7	18.7	13.7	18.7
Jaigaon 1, Bhutan Bdr.	20	36.1	52
Jaigaon –II, Bhutan Bdr.	90.9	74.4	186.3
Distt. Darjeeling ,West Bengal- September-2004			
Malvitta Tea Garden	28.5	35	50
Simalbadi Tea Garden	22.2	55.5	83.3
Golma Railway City	26.6	31.8	46.8
Punding Village	33.3	26.6	33.3
Khairani Basti Village	11.1	7.6	11.1
Ghaziabad- 2010 UP			
MMG Hospital	-	4	-
Shyam park Sahibabad	-	-	-
Shaded Pyare Lal colony- 1, Shahibabad	1.449	1.4	1.4
Police station Sahibabad	-	1.4	-
MMG Civil Hospital Ghaziabad	48	40.0	48.0
Narender Mohan Hospital staff qrt., Mohan Nagar	19.6	21.1	23.5
Narender Mohan Hospital, Mohan Nagar	-	46.4	-
Police station Sahibabad	-	21.1	-
Noida -2010			
Dr. Bhim Ambedkar Hospital Sect.-39	-	-	-
Noida Authority complex sect.- 6, Noida	-	-	-
Industrial Area Sect.-6, Nioda	-	-	-
Aravali Apartment B-3,sect.- 34	-	-	-
Noida Authority workshop sect.-39	-	25.0	-
Dr.Bhim Ambedkar Hospital sect.-39	-	23.9	-

Gram Vikash Khand –II, sect.-39	-	20.6	-
Residential Area A-Block, sect,-52	12.5	12.2	18.8
S. P. City Office sector -6 Noida	-	11.1	-
Indira Gandhi Kala Kendra sect.-6	-	701	-
Industrial Area sect.6, Noida	6.3	8.9	10.9
Noida Entrepreneurs Association sect-6	-	24.0	-
Industrial Area sect.63, Noida	12.8	13.5	17.9
Gurgaon-2010			
Civil Hospital Gurgaon	-	-	-
Shivaji Nagar	6.3	5.2	6.3
Prem Nagar huts	3.7	2.9	3.7
Police station colony Gurgaon	15.5	18.4	40.5
Sect.-5, Gurgaon	17.4	10.4	21.7
Huda Gust house Gurgaon	-	13.6	-
Patel Nagar Gurgaon	30.2	29.5	53.5
General Hospital Gurgaon	-	17.1	-
Faridabad-2010			
Escourt Hospital Fortis Faridabad	-	20.4	-
B.K .Hospital Faridabad	-	4.8	-
Railway colony	2.5	2.0	2.5
Maharishi Hospital Near Rahul Colony	-	16.7	-
Rahul Colony Ward No.-3	22.2	16.8	22.2
Police Residential colony NIT No.5	13.6	11.5	13.6
Red cross Bhawan sect.-12 Faridabad	-	10.0	-
Central store Faridabad Complex	-	6.0	-

Larval and pupae surveys: The NVBDCP conducts larval surveys to predict vector density in the pre-monsoon season. The guidelines for vector surveys vary from location to location and contain specific measures for households and institutions.[70]Vector surveillance is the responsibility of state and city level governments, to be conducted with the cooperation of community and civic organizations and individual households. In December 2006, Pupae surveillance was added to better estimate the adult population.[71]Since many larvae do not mature into adult mosquitoes, pupae are thought to give a more accurate estimation of the quantities of vector in the environment.[41]

Vector control

In the absence of a vaccine, vector control is the primary means of controlling dengue. Aedes spp. mosquitoes provide challenges to traditional vector measures. Unlike *Anopheles spp.,* the primary vector for malaria, *Aedes* feed during the day, making insecticide- treated bed nets (ITN)/ LLIN an ineffective instrument to reduce the number of bites. The breeding places differ due to climatic variables, social cultural socio economic, avenues generation by new technological advances. Maximum breeding of *Ae. aegypti* was reported from desert water coolers and discarded tyres in Delhi. The cement tanks in Maharashtra state were preferential breeding source for *Ae. aegypti*. Coconut shells and Latex cup reported maximum breeding in southern states viz. Kerala and Lakshadweep Island. Epidemic containment has focused on insecticide spraying for adult mosquitoes, but this is usually unproductive.[72] *Aedes* often hide within homes during the day, so normal fogging efforts do not effectively kill adult mosquitoes. All the international airports/ seaports in the country must take effective control measures for interruption of dengue transmission as per IHR.

Guidelines: The NVBDCP published extensive national vector control guidelines recommending activities for vector control and surveillance at the household, community, and intuitional level. These guidelines include activities to control vector sites and personal protective measures. Promotion of NGO involvement in special education campaigns has been recommended as crucial to prevent outbreaks.[70] Guidelines are disseminated via states and focus on inter- sectoral vector and disease surveillance, vector control, and emergency preparedness.[39]

Municipal fines for individual households: The NVBDCP urges enactment of civil bylaws to penalize property owners who are found to have uncontrolled larval breeding sites. Implementation and enforcement of bylaws and regulations are left at the discretion of the states and Municipal Corporations. There has been an increased interest in using legal notices and fines to control mosquito breeding sites in private residences and businesses.[73]

Control of vector proliferation: Official vector control guidelines focus on large water storage containers and household sources such as flower pots and air conditioners. However, small discards such as water bottles, tyres, and plastic bags have been highly correlated with household dengue infection[74] and are utilized by both *Ae. aegypti* and *Ae. albopictus* for proliferation and amplification. These vector sources have received less policy attention. Inadequate public sanitation, a boom of new construction, and unplanned settlements have created infinite breeding sites for *Aedes* in discarded refuse. The widespread nature of such sites across India makes community participation essential to reduce vector proliferation. India is faced with the enormous public health challenge of controlling solid waste created by rapid population and economic growth and urbanization without improved waste management systems.

Passive case reporting: Passive case reporting is the primary method of outbreak surveillance. Monthly dengue cases are reported to the Directorate of the NVBDCP. During dengue outbreaks, a daily report is sent to NVBDCP. A sudden increase in dengue cases or deaths is reported to the district health officer. Surveillance measures are based on standard case definitions, reported cases, and fever incidences. During an outbreak, 5% of clinically diagnosed cases are sent for laboratory confirmation.[44]

Active case detection: The country has conducted limited active surveillance for dengue since 1996. 137 dengue sentinel surveillance centres have been established in all the affected states. A network of surveillance hospitals and referral laboratories is maintained to monitor and confirm suspected dengue cases. In Delhi alone, 33 dengue sentinel surveillance centres are functioning. 13 Apex laboratories for dengue have also been established. The NCDC (National Centre for Disease Control) is also an apex laboratory for dengue and operates a program of continuous sero- surveillance of blood sample supplies from several Delhi hospitals, with good correlation between serum antibody levels and case reports .[75]

Monitoring and warning system for outbreaks: In the pre– monsoon period, the Government of India's (GoI) Ministry of Health and Family Welfare

provides advisories and guidelines to all endemic states, and reviews contingency plans with states for inter- sect-oral mosquito control and surveillance. Emphasis is on emergency control of outbreaks. The GoI provides support to states, including provision of insecticides and pesticides; and cash assistance for information/ education/ communication (IEC) activities and capacity building.[70] When early signs of an epidemic are observed, meetings are held between the state government, municipal corporations and the Indian medical associations focusing on public health measures such as IEC for community action; hospital, laboratory and blood supply preparedness; and monitoring and reporting. The GoI's health minister reviews the situation with state health ministers, installs a control centre for monitoring, and provides material logistics support. In the case of outbreaks, emergency action committees are instituted at the district or municipal level to provide resources and guidance for the standardized management of severe cases and to institute emergency vector control measures.

Information, education, and communication (IEC) for community involvement and epidemic containment: Multi- media IEC are emphasized for behaviour change, community action, and inter-sect-oral collaboration with non- government and community- based organizations.[76]NVBDCP provides IEC resources including posters, pamphlets, stickers, banners, press releases, audio-visual spots, flyers, and public service announcements in several dialects. During an epidemic, IEC is focused on informing the public about healthcare provisions and avoiding panic.

Knowledge, Attitudes and Practices (KAP) of Indians regarding dengue: Community participation is necessary to manage prolific Aedes breeding sites; yet public awareness of mosquito habits and control remains limited in both urban and rural areas. The results of KAP surveys on dengue transmission and vector have yielded mixed results. In a survey conducted in Karnataka, less than 50% of the respondents knew of measures to reduce mosquitoes in the environment, and less than 1% of the respondents were aware that dengue is transmitted by mosquitoes. A hospital- based survey of highly educated participants in Delhi showed a better knowledge of dengue transmission and prevention, but poor practice of control measures.[76] Studies in other dengue- endemic regions of the world have demonstrated a similar gap between knowledge and practice, even in areas where awareness of dengue is high.[77] Community education interventions in India have shown that the KAP of dengue transmission and vector can be substantially increased with community education and mobilization measures.[73]

Community mobilization: Dengue fever guidelines focus on mobilizing schools, communities, and individuals emphasizing on NGO involvement. [70] The NVBDCP (formerly as the NAMP) undertook a massive health education campaign in Delhi, beginning in the late 1990s, which included both advertising media and community interaction by health staff. Health education was combined with increasing legal action taken against property owners found to harbour mosquito breeding sites. This massive community action resulted in the reduction of dengue incidence from 10,252 dengue cases and 423 deaths in 1996 to 180 cases and 2 deaths in 2000. This remarkable reduction in cases illustrates the potential for community– based action in India to have an immediate and lasting effect on vector control. However, it will be difficult to sustain long- term control of small Aedes breeding sites.

Capacity building and vector control research: Capacity building and vector control research are two of the global strategies for prevention and control of dengue, [78] in which India is building a strong base. India has a well-developed system of secondary education and a strong network of research facilities across the country. India has 72 entomological zones and multiple research organizations working on the biology and control of *Ae. aegypti* and *Ae. albopictus*. The NVBDCP provides funding and support, to many of these organizations for various vector control studies throughout the country.

In response to increasing frequency of outbreaks, states are undertaking more comprehensive larval and breeding control measures. Previously, anti-larval measures were carried out by states in urban areas only. However, in response to outbreaks of dengue and chikungunya in rural areas, Tempos 50EC larvicide is being utilized in rural areas. Every year, more than 3000 Municipal Corporation of

Delhi (MCD) workers are employed for breeding detection in addition to regular vector control staff for the detection and elimination of *Aedes* breeding sites. Vector surveillance and control measures are cross- checked by NVBDCP.

Personal protection guidelines: Some dengue guidelines do not appear to be entirely practical for the Indian setting. India's hot climate and traditional clothing is not conducive to personal protective measures such as wearing long-sleeve garments, but this measure is stipulated in most public guidelines. Use of insect repellents may be appropriate for middle and high income groups, but the poor may not find such products accessible. A survey of personal protection KAP conducted in Pondicherry revealed extremely varied use and opinion of personal protective measure.[79]While use of mosquito coils, electric fans, and mats was noted in rural and urban areas, only 40% of rural participants used any measure daily. Nearly half of urban participants felt that personal protective measures were harmful to their health, and rural participants spent significantly less money on such measures than those in urban areas. Protective creams and sprays were not widely used or available for purchase. An effective insect repellent for the Indian setting must be cheap, effective, pleasant to use, widely available and accepted.

Limitations of passive case reporting: There are limitations to relying on passive case reporting for dengue surveillance. Relying on physicians to distinguish dengue from other febrile illnesses may result in underreporting of cases. Case surveillance will mostly catch severe forms of dengue, leaving mild and asymptomatic episodes undetected. Opportunities to contain early epidemics and avert outbreaks of DHF/ DSS may be lost if greater active surveillance is not utilized.

Initiatives

1) As per policy of Planning Commission, all the vector borne diseases were kept under NVBDCP. Previously there was as a national programme for prevention and control, only for malaria. Establishment of a national dengue initiative is overseen by the Ministry Health and Family welfare. The unique features of *Aedes* spp. demand specialized vector control programs, which are distinct from the control of Anopheles mosquitoes. Creating a specific dengue/ chikungunya initiative would respond to the unique challenges of the vector, attract research interest in dengue and will ensure that funding is allocated for dengue control and surveillance. The initiative should employ a multi- sectoral approach to control and employ entomologists, civil engineers, public health, and social marketing specialists who could create sustainable, creative solutions to vector control and sustain effective mobilization of community members.
2) **Improve disease surveillance-** Expand active blood supply and vector surveillance to better understand the dynamics of dengue transmission and to identify epidemics. With additional funding, active surveillance could be integrated into existing primary care facilities.
3) **Enforce vector control-** Increase penalties for individuals and businesses who do not take adequate steps to reduce vector proliferation. This will give incentive for individual and community involvement .Shifting policy measures from top- down to community– based prevention methods will increase capacity to prevent dengue/ chikungunya transmission.
4) **Establish dengue as a research priority** for the Indian Council of Medical Research and increase funding opportunities and recognition for advances in dengue research. Much is still unknown about the epidemiology, transmission patterns, and pathogenesis of disease progression. Research is required to better prepare and plan for future trends in incidence and severity.
5) **Prioritize solid waste collection and water management** to reduce abundant vector breeding sites. Without improved waste management and sanitation systems, vector-borne diseases will be difficult, if not impossible to control.
6) **Create incentives for community education and vector monitoring:** The NVBDCP already has a wide array of excellent IEC for community mobilization and education about Aedes- borne disease

and vector control. KAP surveys have revealed that much of the public remains naïve about vector control and disease transmission. Incentives to encourage enhanced IEC may help to mobilize the public against *Aedes*.

New Challenges – As the construction activities viz. highways and rain water harvesting projects are going on in big way in the country, the mosquito vector potential is increasing in the absence of Health Impact Assessment (HIA). Recently there was an outbreak of dengue in Kolkata due to heavy breeding of *Aedes aegypti* in peripheral areas due to construction of high way. The rainwater harvesting activities are also mosquito vectors friendly in some cities like Chennai and Delhi and contribute high potential for future outbreaks of Vector Borne Diseases.

Discussion

Ae. aegypti was the most predominant species, which preferred to breed in man- made containers. In contrast, to earlier *Aedes* survey conducted in 1965 and 1998 from Delhi and from urban city, Ajmer, Rajasthan, an outbreak in 1969 revealed that *Ae. aegypti* populations were mostly restricted to the central part/ urbanized areas of Delhi.[80, 81,82]No *Ae. aegypti* was encountered in colonies on the periphery of Delhi. Due to development at the periphery of the city, increased construction activities as a part of urbanization over the years have led to inadequate water supply, leading to storage of waters. These factors have contributed the distribution pattern of different species of Aedes mosquitoes. *Ae. albopictus* and *Ae. vittatus* also adapted to breed in manmade containers in the central urban areas of Delhi in addition to their natural habitats. The aggressive nature of *Aedes albopictus* when compared to *Aedes aegypti* may help them to out compete the latter and could play a crucial role in disease transmission due to aggressive bites. In India, military areas of cantonment where dry day was observed did not reveal any incidence of dengue cases or presence of *Aedes* mosquitoes.[83] Recently, Mumbai reported dengue and malaria outbreaks due to construction activities. In 1928, Sir Gordon Covell, recommended legislative measures for vector breeding in Mumbai viz. overhead tanks and ground water tanks to be built as per "Approved specification" and ladder to be fixed in concrete for cross checking. No water connections were to be provided till the above requirements were met. Building bye- laws were framed and builder had to deposit a specified advance with the MCGM to undertake anti- larval works at the cost of the builder. Similarly, monsoon deposit for any person stacking goods (used tyres, scraps etc.) were made for anti- larval works by MCGM. The wells were to be sealed and water was to be drawn by hand pump. Larvivorus fish were to be released in Mill ponds/ tanks, ornamental ponds, temple ponds and other permanent water bodies. As a result, malaria was totally controlled and collateral benefit was achieved in the city for another container species *Ae. aegypti*, vector of dengue. During Indo Pak war in 1965, all the wells were opened to meet fire exigencies during any air- raid. Malaria showed resurging trend. In 1970, all wells were again sealed and again the disease declined. Till a couple years back, Mumbai did not report any malaria or dengue outbreak. Resurgence of malaria in Mumbai since 2001 has been shown increasing trend since 2007. During 2010 and 2011, 145 and 69 deaths reported from Mumbai Corporation. Slacking of implementation of legislative measures, poor disease surveillance, and ineffective anti- larval measures at construction sites are the main reasons for resurgence of malaria and introduction of dengue in the city. The contributory factors for resurgence were non- compliance of monsoon building deposit, closure of textile mills and high rise residential apartment on land vacated by textile mills without Health Impact Assessment (HIA)., inclusion of seven lakes for water supply as an integral part of the city with high potential of *An. culicifacies* were also involved in malaria transmission., high rate of migration to urban Mumbai, construction of developmental projects, water scarcity leading to high domestic practice, flower pots in each apartment in high rise buildings increased the breeding potential of malaria and dengue vectors. The HT,S were also not mosquito

proof. During the outbreak on Indian Ocean islands, a large number of travellers from industrialized countries with temperate climates became infected with CHIKV. Afterwards local transmission was reported from in Emilia- Romanga, Italy during 2007. The presumed index case was a man from India who developed fever and joint pain two days after his arrival in Italy.[84] The World Health Assembly has declared any DF outbreak a 'potential public emergency of international concern'.[85] Globalization, warming trends, and increasingly mobile populations all contribute to the proliferation of dengue vector mosquito populations. Although dengue mortality remains low, the rapid spread of multiple serotypes increases the risk of fatality from DHF/ DSS. As control measures continue to focus on emergency epidemic containment and personal protections, the urban and rural poor, who are at the most risk of transmission, will bear the brunt of the disease. The mobility of modern populations and goods means that no country is safe if neighbouring countries still harbour dengue. The country must take action to curb the transmission and spread of Aedes- borne diseases.

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