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Original Research Article

Report of dengue outbreak investigation in Jothinagar village, Thiruvallur district, Tamil Nadu, India, 2017: epidemiological, entomological, and geospatial investigations

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ABSTRACT

Background: During July 2017 to August 2017, five cases of laboratory-confirmed dengue cases were reported from Jothinagar village, Tamil Nadu, India. The episode was investigated to confirm the existence of an outbreak and formulate appropriate recommendations for containment.
Methods: The monthly occurrence of dengue cases from 2014 to 2017 was compared to confirm the outbreak. Additional blood specimens from 22 patients were sent for laboratory confirmation. We conducted active case search, eco-entomological survey, and geo-mapping of cases and *Aedes* breeding spots.
Results: The occurrence of 36 cases of dengue in the village, previously free from the disease for the past 3.5 years, confirmed the outbreak. Twelve were laboratory-confirmed while the remaining 24 were probable cases. The attack rate was highest amongst females in the age group 11-15 years (10.8/100 population). Case fatality was zero. The house index, Breteau index, container index (CI) and pupal index was 37.7% (23/61), 54.1% (33/61), 16.7% (33/198) and 32.8% (20/61) respectively. Discarded tyres were the key productive containers (CI=28.36%). Geo-analysis suggested clustering of cases within 70 m of the *Aedes* breeding spots particularly within the central part of the village.
Conclusions: Based on high entomological indices, an intensive vector elimination campaign was implemented with a special focus on managing discarded tyres. Geo-analysis can be incorporated in surveillance to identify clusters early for control measures.

Keywords: Dengue, Geo-analysis, India, Outbreak, Pupal index

INTRODUCTION

Dengue is an arboviral disease transmitted by the bite of infected female mosquitoes, mainly *Aedes aegypti* and, to a lesser extent by *Aedes albopictus*. It causes a wide spectrum of illness from mild asymptomatic to severe fatal dengue hemorrhagic fever/dengue shock syndrome (DHF/DSS).[1] It is estimated that globally 3.97 billion people in 128 countries are at risk for dengue infection.[2] Modeling estimates 96 million apparent dengue infections globally, 70% of which was borne by Asia wherein India alone contributed 34% of the global burden.[3]

Dengue outbreaks can cause major public health, social and economic impacts. It also competes with other diseases for the limited resources available especially in dengue-endemic countries. It is estimated that during epidemics, dengue may affect 80% to 90% of the susceptible individuals and lethality may exceed 5%.[4] As a matter of fact, among the six World Health Organization (WHO) regions, the largest number of outbreaks occurred in the Southeast Asia region, followed by the Western Pacific region and the American region, accounting for more than 83.6% of all reported outbreaks during 1990-2015.[5] Furthermore, the highest number of outbreaks was observed in India.[5] Dengue outbreaks were reported from Rio de Janeiro (2002), Bolivia (2009), Oceania (2019), Philippines (2019), Bangladesh (2000), Singapore (2013), Sri Lanka (2017), and India (Kerala, 2017).[6]

In India, the first epidemic of clinical dengue-like illness was recorded in Chennai (erstwhile Madras) in 1780 and the first virologically proved epidemic of DF in India occurred in Kolkata (erstwhile Calcutta) and the eastern coast of India in 1963-1964.[1] The first major epidemic of DHF/DSS occurred in India during 1996 involving the areas around Delhi with subsequent spread all over the country.[1] Outbreaks were reported from Kanpur (1968-1969), Vellore (1966), Gujarat (1988-1989), Rajasthan (1969-1985), Madhya Pradesh (1966), Kolkata (1990), Gwalior (2003), and Tamil Nadu (2010).[1]

During July 2017 to August 2017, Rajiv Gandhi Government Hospital, Chennai notified five cases of dengue from Jothinagar village to the district surveillance office, Thiruvallur, Tamil Nadu. The thick blood smears of these patients were negative for malaria. District Deputy Director deployed a team of epidemiologists to assess the situation and to provide useful evidence for decision-making to the benefit of public health. The investigation was conducted from 28 July 2017, to 24 September 2017, to confirm the existence of an outbreak and describe its epidemiological and entomological situation; and to recommend appropriate vector control measures for containment of the disease.

METHODS

Study site and settings

The study area, Jothinagar village in Thiruvallur district, Tamil Nadu is bound by 13°12'17.2"N latitude and 80°10'43.4"E longitude comprising an area of 0.12 sq km (Figure 1). The study area consisted of 221 houses and a settled human population of about 966 without any change in its structure during the study period. The annual mean minimum and maximum temperatures of the district were 24.3 and 32.9 °C, respectively.[8] The area receives rainfall under the influence of both southwest (i.e. June-September) and northeast monsoons (October-December).[8] The average annual rainfall of the district is reported to be 1,291 mm.[8]

Data collection

Confirmation of the existence of an outbreak

We used data from the district surveillance unit to compare the monthly occurrence of dengue cases from 2014 to 2017 to confirm the outbreak.

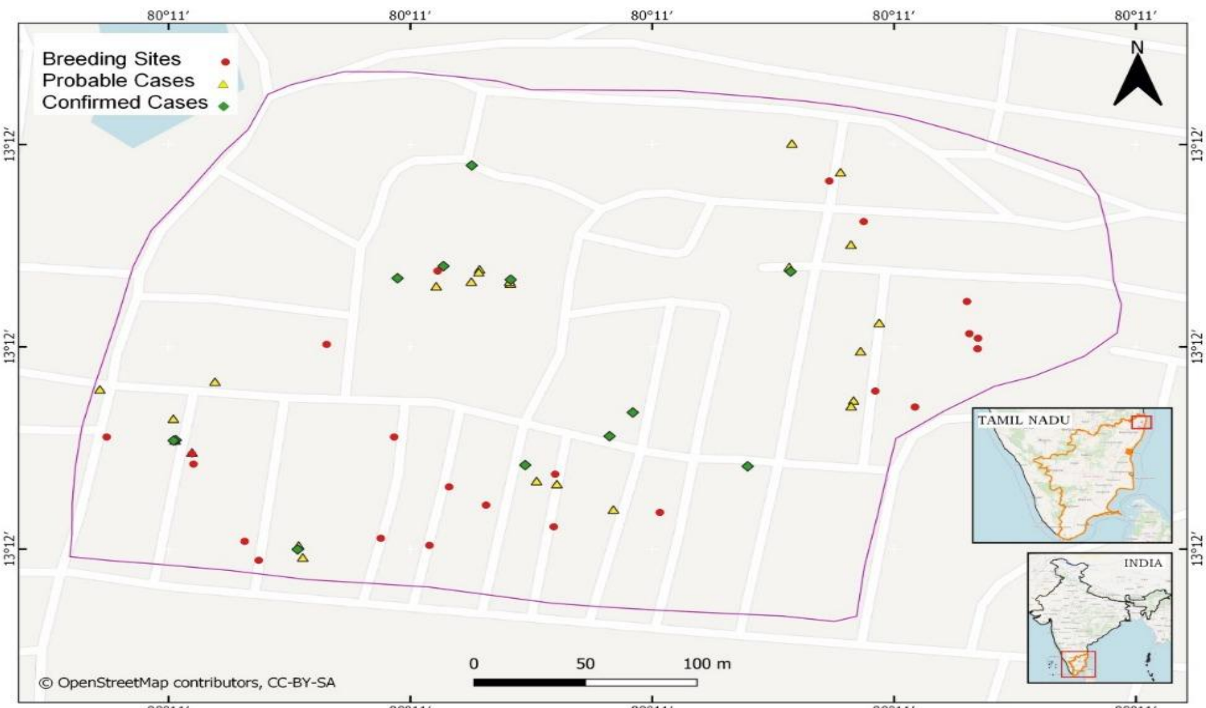

Figure 1: Map indicating location of the study area (inset maps highlight areas zoomed in the subsequent frames).

Case finding and definitions

We conducted a cross-sectional survey in the entire village for additional case search and collected data on age, gender, date of onset of fever, associated symptoms, and outcome from June 2017 to September 2017 in pre-tested format. A probable case of dengue fever was defined as the occurrence of fever of 2-7 days' duration with two or more of the following clinical manifestations: headache, retro-orbital pain, myalgia, arthralgia, rash, hemorrhagic manifestations.[9] A case compatible with the above clinical description, along with the demonstration of either IgM antibody or dengue virus antigen nonstructural protein 1 (NS1) or both by enzyme-linked immunosorbent assay (ELISA) was considered as a confirmed case.[9]

Trigger levels are important to initiate response activities.[10] Trigger-1 is defined as the clustering of two similar cases of probable dengue fever. Trigger-2 is defined as more than 4 cases of dengue fever in a village/geographical area of 1000 population.[10]

Laboratory diagnosis

5 ml of blood was collected under aseptic precautions from febrile patients and transported to the ICMR-National Institute of Epidemiology, Chennai for dengue-specific NS1 and IgM ELISA testing.

Geospatial data

We used a global positioning system (GPS) enabled android phone to locate geographic coordinates for: spots with standing water containing *Aedes aegypti* immature forms; and houses with probable and confirmed dengue cases. These coordinates were imported into a Microsoft excel spreadsheet and saved as comma separated values (CSV) file.

Entomological and environmental investigation

We estimated the infestation level of immature forms of the dengue vector, *Aedes aegypti* in the locality by entomological survey using sampling strategy.[11] We expected a house index of approximately 10% for the village, 95% confidence interval, and precision of 5-18% to get the sample size of houses.[11] We estimated 67 houses to be surveyed for entomological investigation. We did linear systematic sampling and inspected every third house for larval infestation.

The survey was conducted by well-trained technicians from the ICMR-National Institute of Malaria Research, Chennai from 7 August to 9 August 2017 between 9:00 AM to 12:30 PM. Water storage containers used for domestic purposes such as plastic barrels, buckets, synthetic tanks, plastic pots (usually for cooking purposes), wells, and other water-holding habitats such as tap water pits, discarded tyres, refrigerator trays, steel vessels were examined for the presence of immature forms. Later were identified based on their morphological features. The number and type of containers, their location (outside/inside of the house), and immature forms (pupa or larva) found within them were recorded in the pre-tested data collection form. We calculated the house index (HI), container index (CI), the Breteau index (BI), pupal index (PI), and pupal productivity percentage for different container types. Value of HI greater than 10% and/or of BI greater than 50% in the locality, was considered as high risk of transmission.[12]

We sampled the immature forms from various water-holding containers using ladles with a volume of 250 ml and larval collection nets and then transported them to the laboratory at the ICMR-National Institute of Malaria Research, Chennai. The immature forms were reared under controlled laboratory settings till the emergence into adult mosquitoes. The emerged adults were identified to the species level based on morphology.

We collected mean temperature (°C), relative humidity (%), and precipitation (rainfall in mm) for the Thiruvallur district from available sources.[13,14] Seasons were defined as the winter period from January-February; summer from March-May; the South-west monsoon from June–September, and the northeast period from October–December.

Data analysis

Data were entered into Epi Info version 3.5.4 software. Age was summarized as median with inter-quartile range (IQR). Age and gender-specific attack rates were calculated per 100 population.

The incubation period of dengue is 3-14 days, commonly 5-7 days.[10] To include the maximum number of cases, we considered an incubation period of 14 days. We collected the date of onset of fever for double the incubation period (28 days) retrospectively from the date of onset of fever of the index case. We then plotted this to generate an epi-curve. Week interval was based on the integrated disease surveillance program calendar. We continued the survey for three weeks after the last case was identified.

We calculated the proportions of houses using different types of containers. We plotted proportions of different types of containers used for water storage and container-specific index.

A statistical software R was used to analyze spatial data. Moreover, QGIS software was used to prepare maps. The female *Aedes* mosquito can fly up to 400 m in search of an aquatic habitat and blood meals to lay eggs.[15] We, therefore, assessed the distance of the nearest dengue case from a breeding site using rgeos package (version 0.5-5) in the R statistical programming language. We attempted to decipher the pattern of the spatial distribution of cases viz. clustering, random or regular using the K-Ripley function test in the spatstat package.[16,17]

Further, the statistical significance test was carried out by a simulation experiment that generates maximum and minimum values which are plotted to create a significance envelope. If the observed pattern goes above the high confidence envelope, spatial clustering is statistically significant. While, if the observed pattern is below the low confidence envelope, distribution is more dispersed than random.[17] We carried out 99 such simulations. We assessed the location of clusters using kernel density estimation (KDE).

Ethical approval

This investigation was undertaken as an emergency public health response to the acute event and hence approval from institutional ethics committee was not sought. Information obtained during the survey was kept confidential,

RESULTS

Confirmation of an outbreak

Surveillance data review suggested the absence of dengue in the village from January 2014 to June 2017. Hence, a sudden occurrence of five confirmed cases during July 2017 to August 2017, clearly indicated the existence of an outbreak in the village. The timeline for major events and decisions during an outbreak is listed in Table 1.

Laboratory confirmation

A total of 36 cases were reported in this outbreak. Blood specimens from 22 (62.9%) patients were tested for laboratory confirmation by the ELISA method. Twelve (54.5%) patients were confirmed positive: 10 for dengue IgM and 2 for NS1 antigen.

Distribution of cases and clinical profile

Fifteen cases (41.7%) of dengue were observed in the age group of 15-30 years compared to other age groups. The median age of the affected person was 22 years (IQR: 15-35) with a male: female ratio of 1:2. The attack rate was highest amongst females in the age group 11-15 years (10.8/100 population) (Table 2).

We observed that the laboratory-confirmed index case was 20 years old male patient with a history of travel to the neighboring Kanchipuram district for study purpose. He developed fever on 09 July 2017 (Figure 2). The case was notified on 14 July 2017 to the district health authority under passive surveillance. Preventive measures such as entomological surveys, fever clinics, and concurrent vector control measures were initiated on the same day by the district health authority.

However, a week later, we observed trigger 1 (Figure 2). With the onset of trigger 2, an intensified vector elimination campaign was executed from 10 August 2017 to 16 August 2017. The peak occurred between 14 August and 20 August 2017 followed by subsequent tapering. No new cases were noted for three consecutive weeks after the last case on 07 September 2017. This marked the end of the transmission. The epi-curve was a typical propagated type with a step ladder pattern (Figure 2).

All 36 patients had fever while 35 (97.2%) had myalgia, 32 (88.9%) had headache and 30 (82.9%) had arthralgia. None of the patients were presented with hemorrhagic manifestation. All patients had recovered without any fatality.

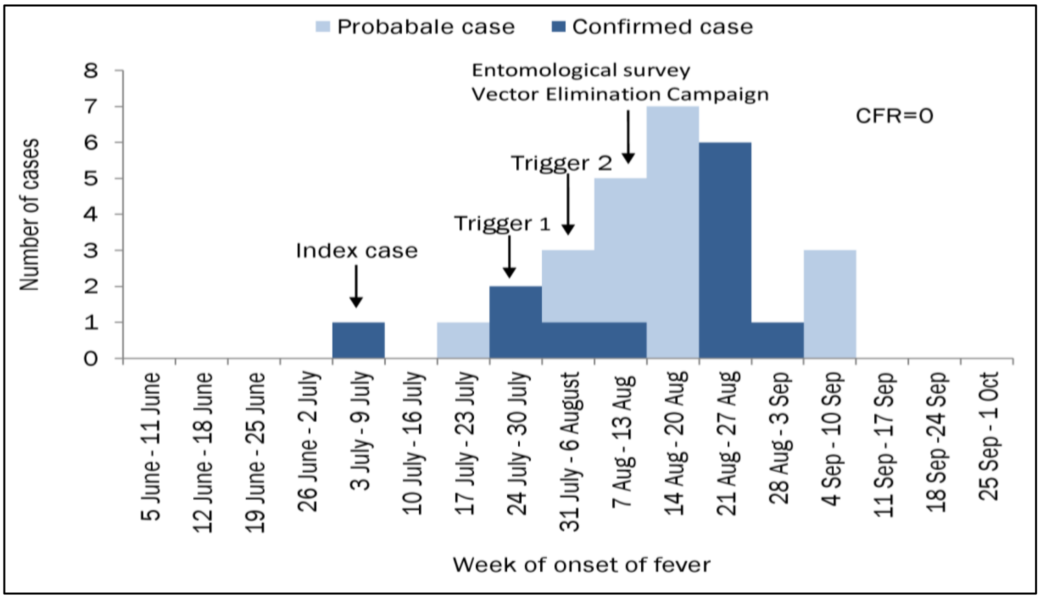

Figure 2: Epicurve of dengue fever outbreak in Jothinagar village, Tamil Nadu, India, 2017.

Geo-spatial findings

Distance analysis revealed that all of the cases were distributed within the distance of 70 m from *Aedes* breeding spots while 90% of the cases were within the 50 m range (Figure 3). The K-Ripley test of cases revealed that dengue cases were more clustered than expected as the observed pattern was over the confidence envelope from a distance of zero to 75 m (Figure 4). KDE reveals that the highest density of cases was located in the central part of the village (Figure 5). We found seven houses with more than one dengue case: two houses with two probable cases, two houses with one probable and one confirmed case, two houses with two probable and one confirmed case and one house with one probable and two confirmed cases.

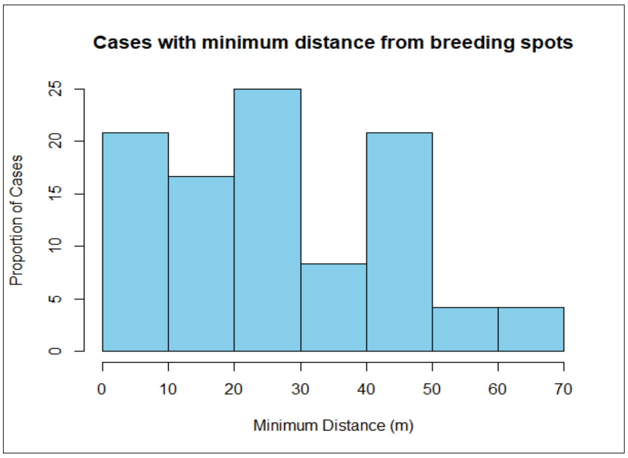

Figure 3: Analysis for the location of dengue cases within d_{min} (Minimum distance upto which cases are found around breeding spots).

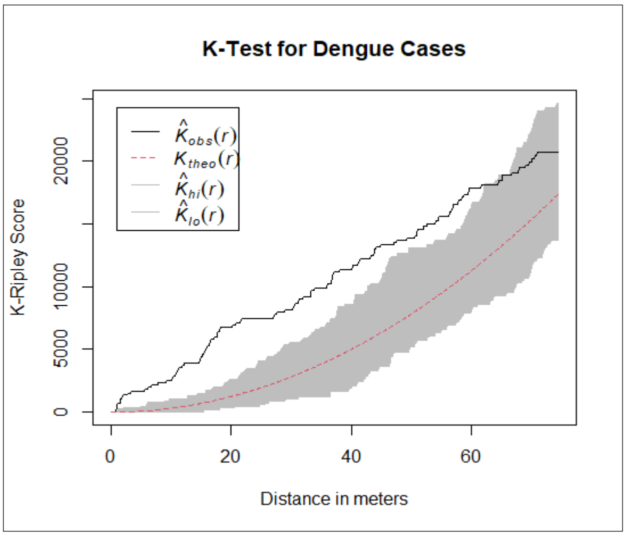

Figure 4: K-Ripley score for dengue cases with higher and upper confidence envelope for number of cases expected under random distribution. The observed curve lies above the upper bound suggesting clustering of cases.

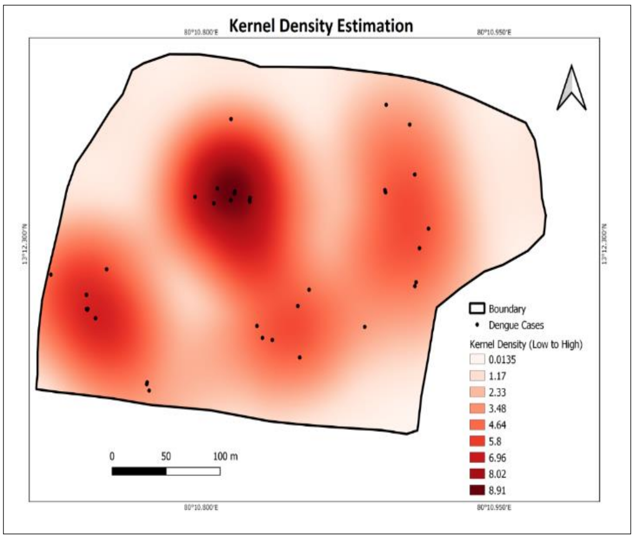

Figure 5: Kernal density estimation of dengue cases during an outbreak in Jothinagar Village, Tamil Nadu, India during July-September 2017. Cases tend to cluster in central part of the village.

Eco-entomological findings

The water supply in the village was through a pipeline by the local panchayat, the governing body of the village. However, people used to store water in different types of containers such as synthetic tanks, barrels, plastic pots, and buckets for domestic purposes. We examined 149 such water-storing containers in 61 (100%) houses: 22 (36.1%) of these houses had barrels, 5 (8.2%) had tanks, 3 (4.9%) had buckets and 31 (50.8%) had a combination of these containers with water. Four houses had one well each in their backyard. Eleven houses had plastic pots in the kitchen mainly for cooking purposes. Out of these 149 containers, 71 (47.7%) were open or loosely covered with wooden planks or clothes. We also examined 49 lesser examined potential receptacles such as refrigerator trays in twelve houses, flower pots in seven houses, discarded tyres outside five houses, and tap-pits near three houses. Overall, the median number of wet containers checked per house was 3 (IQR: 2-4). We also observed three spots in the village where household solid waste such as polythene bags, plastic bottles, plastic teacups, plastic jars, and coconut shells was dumped. Out of 198 containers, 174 (87.9%) containers were found outdoors in yards.

We were able to collect 39 immature forms (20 pupae and 17 larvae). Out of 20 pupae, nine were collected from discarded tyres, four from barrels, three from plastic pots, two from tanks, and one each from refrigerator tray and bucket. Pupal productivity percentage was 45% (9/20) for tyres which was the highest amongst these containers. The larvae and pupae collected from the field survey were visibly healthy and active. Out of 39 immature forms collected from these containers, 36 (92.3%) emerged into *Aedes aegypti* adult while only three died. Immature forms collected from one well emerged into *Aedes aegypti* and *Anopheles stephensi* adult.

A total of 23 houses and 33 containers were positive for *Aedes aegypti* immature forms. Thus, the HI, BI, CI, and PI were 37.7% (23/61), 54.1% (33/61), 16.7% (33/198), and 32.8% (20/61) respectively. Besides other lesser examined sites such as one solid waste spot, one well and one tap pit was also positive for *Aedes aegypti* immature forms. CI was highest for discarded tyres (28.6%) and least for buckets (6.3%) while flower-pots were non-productive (Figure 6). Climatic parameters affecting vector ecology are given in Table 3. With the onset of the southwest monsoon, there was a drop in average temperature from 32°C in June to 29°C in September and a rise in humidity from 64% to 78%. Average rainfall observed during winter, summer, southwest, and northeast monsoon was 33.5 mm, 65.7 mm, 449.5 mm, and 604.1 mm respectively.

Table 1: Timeline of major events and decisions during the outbreak.

Date	Events/activities
9 July 2017	-Onset of fever in an index case
14 July 2017	-Index case notified to district health authority
	-Fever and vector surveillance carried out by local health authority
	-One medical team was deployed
	-Anti-larval measures and fogging initiated
10 July-16 July 2017	No new cases identified
28 July 2017	Two cases of laboratory confirmed dengue cases were notified that marked trigger 1
	Intensification of surveillance and control measures by local health authority
	Decision to conduct detailed investigation of the event by a team of experts
28 July 2017 onwards	Training of field staff
	Active case search by intensive house to house survey using case definition
	Fever clinic started
31 July-6 August 2017	Four cases of dengue identified that marked the trigger 2
7 August-9 August 2017	Initiation of an intensive entomological survey by the expert team
10 August 2017	Sharing the results with the authority
	High entomological indices noted
	Decision and initiation of vector elimination campaign
16 August 2017	Vector elimination campaign ends
7 September 2017	Last case of dengue identified

Table 2: Age and gender stratified attack rate per 100 population in dengue outbreak, Jothinagar village, Tamil Nadu, India, 2017.

Age group	Population at risk	No. of probable cases	No. of confirmed cases	Total cases	Attack rate for probable cases	Attack rate for confirmed cases	Overall attack rate
Male							
0-5	35	0	0	0	0	0	0
6-10	27	0	1	1	0	3.7	3.7
11-15	32	1	1	2	3.1	3.1	6.3
16-30	138	2	4	6	1.4	2.9	4.3
31-45	108	3	0	3	2.8	0.0	2.8
46-60	75	0	0	0	0.0	0.0	0.0
61-100	44	0	0	0	0.0	0.0	0.0
Total	459	6	6	12	1.3	1.3	2.6
Female							
0-5	39	0	1	1	0	2.6	2.6
6-10	37	1	0	1	2.7	0.0	2.7
11-15	37	3	1	4	8.1	2.7	10.8
16-30	135	7	2	9	5.2	1.5	6.7
31-45	129	4	0	4	3.1	0.0	3.1
46-60	93	1	2	3	1.1	2.2	3.2
61-100	37	2	0	2	5.4	0.0	5.4
Total	507	18	6	24	3.6	1.2	4.7
Total	966	24	12	36	2.5	1.2	3.7

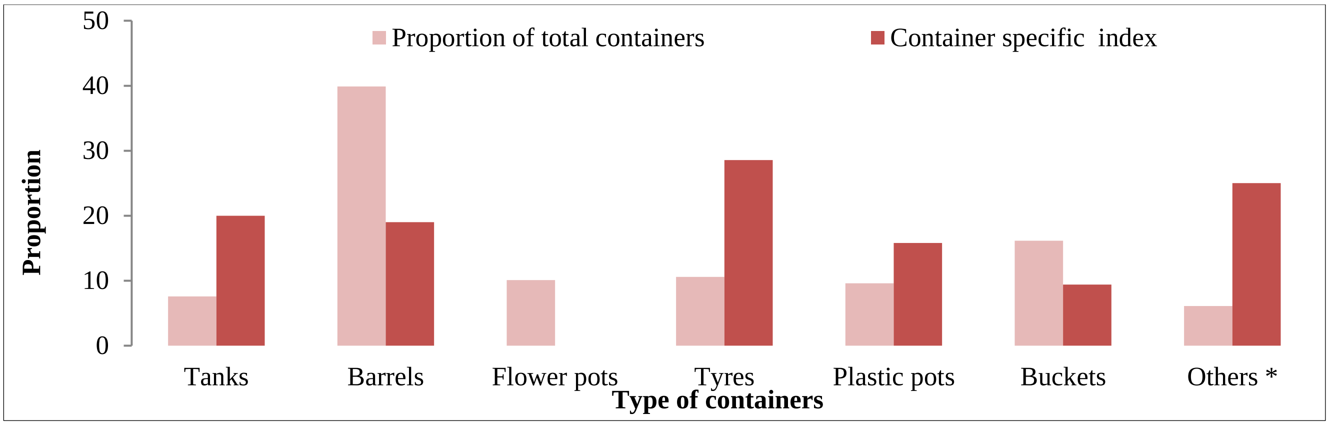

Figure 6: Total 198 containers of all types were examined during entomological survey.

Barrels were most commonly used containers in houses; However, discarded tyres were the most infested containers, *others include wells, tap-pits and refrigerator trays.

Table 3: Climatic characteristic of Thiruvallur District, Tamil Nadu, India, 2017.

Month	Temperature (°C)	Humidity (%)	Rainfall (mm)	Season
January	26	70	33.5	Winter
February	26	67		
March	29	71	65.7	Summer
April	31	73		
May	33	64		
June	32	64	449.5	South West monsoon
July	31	68		
August	29	76		
September	29	78		
October	28	82	604.1	North East Monsoon
November	27	84		
December	26	76		

Enhanced fever surveillance and vector elimination campaign

Consequent to the outbreak, a fever clinic was established in the community. An intensified case investigation was made during a house-to-house survey using the case definition. A total of 46 fever cases were identified, all of whom were referred to the fever clinic for further management. During the intensified vector elimination campaign from 10-16 August, (7 days), all 221 households were visited by two teams of surveillance workers. Each team inspected 15 houses per day between 9:00-12:30 PM for different water-holding containers. Various vector control measures were undertaken such as source reduction, cleaning, and scrubbing of containers with active community participation, application of conventional larvicide- temephos @ 1 ppm if needed, and house-to-house advocacy for adopting mosquito-proof lids to prevent mosquito breeding and use of personal protection measures. With intensive search efforts, 21 water-holding discarded tyres were found abandoned in the village. Water was removed, discarded tyres were scrubbed and larvicide was applied. These were then either relocated in the shade or stacked together with the top tire covered with a polythene sheet.

DISCUSSION

In the present paper, we report the laboratory-confirmed dengue outbreak transmitted by *Aedes aegypti* in Jothinagar village based on the epidemiological characteristics and *Aedes aegypti* breeding dynamics. The disease predominantly affected young females. Geographical clustering of cases was observed. The entomological indices were high. Although the barrels were the most commonly available containers in the village, discarded tyres were the most productive containers. Our observation that young females in the age group between 11-30 years were most affected is consistent with findings from other studies.[18,19] The vector mosquitoes, *Aedes aegypti* are domestic and peri-domestic in nature and females/ housewives who are at home have a greater chance of exposure to mosquito bites.[18] In the present outbreak, we observed that all the cases were distributed within 70 m of *Aedes* breeding spots which suggests that the vector mosquitoes emerging from these breeding spots did not fly long and could get blood meals nearby, putting the population within this flight range at high risk of contracting the disease. Although this seems to be biologically plausible, inconsistent results of the association between adult vector abundance and spatial distribution of cases between different studies limits the usefulness of entomological data for spatial analysis of dengue risk.[20,21] Nevertheless, mapping is essential for dengue control programs as demonstrated in a study from Malaysia.[22] The present study highlights the importance of using geo-spatial technologies to decipher the patterns of a disease outbreak, a guide for control measures, and the urgent need for more confluence of epidemiology and GIS data.[16,23-26] Application of such analysis is the essential guide to formulate recommendations for more focused control measures thereby allowing judicious use of scarce resources.

In the present outbreak, HI and BI were 37.7% and 54.1 % respectively. This was higher than the defined threshold putting the village at high risk of transmission.[12] Higher indices could be explained by water-storing practices amongst residents and favorable climatic conditions. Water supply in the village was through a piped network by the local panchayat (the governing body of the village) for fixed hours in a day and sometimes irregular. Consequently, residents were accustomed to storing water for domestic purposes in various containers, 88% of which were found outdoors in peri-domestic areas. Almost 51% of houses used a combination of barrels, buckets, and tanks to store water. Amongst these containers, barrels were most used followed by buckets. 48% of these containers were loosely covered. Besides, other containers that are not used for water storing but act as a potential source of breeding such as tyres, flowerpots, and solid waste dumping sites became active with rainwater accumulation. Furthermore, the overall mean temperature of the district dropped down from 32° C in June to 29 °C in September during the southwest monsoon. This drop prevents the evaporation of water in aquatic habitats. Thus, there was an environment suitable for vector ecology.[27,28]

It should be noted that identification of the most productive categories of container habitats is essential to prioritize control actions with a consequent reduction in labor and costs because the most frequent container categories are not necessarily those producing the greatest number of adult mosquitoes.[29] The present study confirmed that barrels represented 45.5% of total positive containers but produced 20% of collected pupae. Conversely, discarded tyres represented only 18.2% of total positive containers and produced 45% of collected pupae. CI (28.6%) of discarded tyres was highest amongst other containers- a finding consistent with a study from Dhaka.[30] Discarded tyres were thus identified as key productive containers and required urgent attention. These were found abandoned outside the houses and collected rainwater during the monsoon that provided aquatic habitats for *Aedes* breeding. We recommended the appropriate management of tyres during the vector elimination campaign.

Our outbreak investigation had various strengths. First, our sample size estimation and selection of houses for the initial entomological survey were based on the standard guidelines.[11] Second, the entomological survey was carried out by a well-trained research team. Third, larvae were confirmed as *Aedes aegypti* by their emergence under controlled laboratory settings. Fourth, we attempted to explore the potential role of geo-spatial analysis in an outbreak investigation.

The present findings should be interpreted within the context of certain limitations too. First, although the active case search was carried out by trained local health staff, some contingencies are expected to occur during interviews as with any surveillance system. Second, we could not undergo laboratory testing for all probable cases, and hence attack rate may be under-estimated. Third, identification of viral strain in blood samples and mosquitoes that emerged would have added value to the investigation.

CONCLUSION

In conclusion, there was an environment conducive to vector breeding. Additionally, the absence of disease in the community for past years could have weakened herd immunity with the building up of susceptible population. The event might have been triggered by the introduction of the virus in the community through the index case who had a history of travel to a neighbouring district, Kanchipuram.

Recommendations

We communicated our findings with the district health authority to propose recommendations. For the immediate containment of the outbreak, an intensive vector elimination campaign must be carried out. Geo-mapping of dengue cases and positive breeding spots can be incorporated into the surveillance system to identify clusters and targeted control measures. Vector elimination drives may be carried out routinely with a focus on key productive containers to keep the vector indices below the threshold.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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