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Research Article

Prevalence of *Aedes* Mosquitoes During the Dengue Transmission Season in Haridwar City of Uttarakhand State, India

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A B S T R A C T

Introduction: Dengue is an acute viral illness caused by RNA virus of the family Flaviviridae and spread by *Aedes* mosquitoes. Common presenting features may range from asymptomatic fever to dreaded complications such as hemorrhagic fever and shock. So that an entomological investigation was conducted in the dengue-affected regions of Haridwar city, Uttarakhand, during the dengue transmission season. The purpose of the study was to determine the prevalence and distribution of *Aedes* mosquitoes and identify high-risk areas in Haridwar city for the control of dengue disease.

Methods: Adult mosquito were collected from all selected areas of city with the help of standard collection methods. A total of 1922 mosquito were collected.

Results: Out of 1922 residential premises, commercial establishments, and public places, only 244 localities were found positive for *Aedes* breeding. The House Index (HI), Container Index (CI), and Breteau Index (BI) in residential areas were 12.40, 8.08, and 20.68, respectively, while the CI in commercial and public places was 33.50. *Aedes* aegypti followed by A*e. albopictus* and *Ae. vittatus* was the most dominating species and found in peri-domestic habitats. Larvae of *Ae. aegypti* were collected from junk materials, cemented tanks, pots, water tanks, mud pots, discarded tyres, tree holes, desert coolers, mani plant pots, plastic containers, trays of domestic refrigerators, and flower pots. The average Man Hour Density (MHD) of *Ae. aegypti, Ae. albopictus*, and *Ae. vittatus* in residential areas were 10.77, 6.81, and 0.52, while in commercial/ official areas, they were 4.75, 7.95, and 1.68.

Conclusion: During the study, most of the areas showing high larval indices, may be the probable reason for the persistence of dengue in the city. Five species of *Aedes* mosquitoes, namely *Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus,* and *Ae. thomsoni,* were recorded Therefore there is a urgent need of more surveillance in dengye afftected areas as well as their surroundings.The vector control and all the preventive measures need to be directed to eliminate the *Aedes* mosquito breeding

Keywords: Dengue Fever, *Aedes* Mosquito, Breeding, Entomological, Transmission Season

Introduction

Dengue disease is one of the most common arthropod-borne viral diseases across the world and majorly occurs in tropical and sub-tropical areas.[1] Dengue virus has four serotypes (DEN-1, DEN-2, DEN-3 and DEN-4) that cause infection in humans.[2,3] All four serotypes can activate a broad range of illnesses, ranging from apparent or mild febrile dengue fever (DF) to severe and fatal haemorrhagic disease.[1,4,5] The transmission of the disease is primarily attributed to *Aedes aegypti* and *Ae. albopictus* mosquitoes.[4] Many studies stated that dengue fever has been identified as a significant disease burden in endemic countries.[6] In 1943, Dengue Virus (DENV) was first isolated from inoculated patient's serum samples in suckling mice from Japan[7] and Calcutta (now Kolkata) in 1944 from serum samples of US soldiers.[8] Epidemically, the first case of clinical dengue-like illness was documented in Madras (now Chennai) in 1780, while the initial virologically confirmed epidemic of DF occurred in Calcutta and the Eastern Coast of India during 1963-1964.[9–12] The first widespread epidemics of DHF occurred in India in 1996, specifically in areas surrounding Delhi and Lucknow,[13,14] and dengue shock syndrome (DSS) followed in 2004 in Mumbai and other areas[15]. Subsequently, the disease spread throughout the entire country, infiltrating new regions and populations, and its magnitude as an epidemic continues to increase. The challenge posed by dengue viral infection is multifaceted, as the pathogenesis of severe dengue disease remains unknown, there is currently no available vaccine for protection, and the existing vector control measures are inadequate and insufficient.[16,17] More than half of the world's population is at risk of dengue viral infection. Each year, an estimated 390 million dengue infections occur around the world, resulting in up to 36,000 deaths.[18] Delhi is also endemic to DF/ Dengue haemorrhagic fever (DHF) and has experienced several outbreaks.[19–22] Presently, DF/ DHF has been reported as a re-emerging disease in India[23–29] and in 2021 DF cases were reported from all over the country and all the states by the National Center for Vector Borne Diseases Control (NCVBDC)[30]. During the COVID-19 pandemic situation, the total number of DF cases seemingly decreased during the years 2020 and 2021 including deaths as reported.[31,32] In India in 2021, a total of 193245 DF/ DHF cases with 306 deaths were reported while in Uttarakhand state, 738 DF/ DHF cases with 2 deaths were also reported (NCVBDC 2022).[30] Overall, the rising graph of DF/ DHF, imposes a serious concern on the health of the country, including the state of Uttarakhand and in the past, a few entomological studies were carried out on dengue surveillance in Uttarakhand state.[27,33,34]

Dengue fever cases were regularly reported during the last decade, as 738 DF/ DHF confirmed cases and 2 deaths were reported in 2021 and a few unreported DF/ DHF cases also occurred during the study from the Uttarakhand state. The District Health Authority (DHA) made significant efforts to control the small dengue epidemic. National Institute Malaria Research (NIMR) field unit, Haridwar on request of the Chief Medical Officer (CMO) and District Malaria Officer (DMO) of Haridwar, to conduct an entomological investigation during the dengue transmission season. A study was conducted to gain insight into the breeding of *Aedes* mosquitoes, the distribution of adult mosquitoes, and the stratification of areas with *Aedes* mosquitoes. The study also aimed to identify high-risk areas in Haridwar city that are susceptible to dengue outbreaks. The results of this study are presented in this research article and a detailed report of the entomological survey was sent to the CMO and DMO, Haridwar for further follow-up and necessary action.

Materials & Method

Study Site and Topography

Haridwar district, which came into existence on December 28, 1988, was formed by separating it from the Saharanpur district of Uttar Pradesh state. It is surrounded by Saharanpur district in the west, Dehradun district in the north, Pauri Garhwal district in the east, and Muzaffar Nagar and Bijnor districts of Uttar Pradesh in the south. The district's population, according to the 2011 census, is 18,90,422.[35] Haridwar is located on the banks of the holy River Ganga and boasts abundant water resources. It is known for its agricultural productivity, with a wide variety of food grains being cultivated here. The weather in Haridwar is characterized by a temperature of 34 °C, a wind wave of 13 km/h, and a humidity level of 33%.[35] This district holds great significance as a Hindu pilgrimage site and is an ancient city in Uttarakhand state, North India. It is where the River Ganges emerges from the Himalayan foothills, making it one of the first towns where the sacred river touches the plains. Haridwar district spans an area of approximately 2360 km^2 and is situated in the western part of Uttarakhand state, India. Its geographical coordinates are 29.58 degrees north latitude and 78.13 degrees east longitude. The district's elevation from sea level is 249.7 meters. We have collaboration with BHEL, Haridwar for regular surveillance during transmission seasons and provide control strategies for disease control programmes. So that no need of regular permission for surveillance.

Entomological Surveys

The study site was selected based on the confirmed dengue cases reported over the past three years (2018–2020). From June 8, 2021, to December 23, 2021, an entomological study was conducted in 24 localities within Haridwar city and the BHEL complex area. In each selected site, a comprehensive

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survey was conducted in approximately 59-451 houses to collect larvae, employing the single larval technique simultaneously.[36] Both residential and commercial/ official premises within the chosen localities were randomly screened to identify *Aedes* breeding sites in various types of containers found in and around the houses. A total of 1917 residential and 12 commercial/ official premises were thoroughly screened in the dengue-affected areas of Haridwar to detect *Aedes* breeding within the houses and their surroundings. A door-to-door entomological survey was conducted to identify *Ae. aegypti* breeding habitats, including desert coolers, cemented tubs, cemented tanks, overhead tanks, iron/ metal drums, junk materials, discarded tyres, etc., in domestic and peridomestic areas of all selected localities, following the standard procedure outlined by the World Health Organization (WHO) for entomological techniques.[37] Larvae were collected from each locality using dipping and pipetting methods, and subsequent emergence was observed in the laboratory. Larger containers were searched using a 300 ml capacity dipper. The reared adult mosquitoes were identified using standard keys.[37–39] Additionally, the House Index (HI), Breteau Index (BI), Container Index (CI), and Pupal Index (PI) were recorded for these localities. The data collected on the types and locations of breeding habitats were properly documented and analyzed, and various indices were calculated using larval techniques and the standard WHO procedure.[2,40] Containers found to have *Aedes* breeding during the survey were further examined, and the Breeding Preference Ratio (BPR) was calculated to determine the percentage of species composition of Aedes mosquitoes.

Adult Mosquito Collection and Sampling

Adult mosquitoes were collected from both indoor and outdoor areas of the houses using a mouth aspirator and a torch (flashlight). This was done to determine the mosquito biting activity and identify the species up to the species level. The identification was carried out using standard identification keys.[37–39] The collection of adult mosquitoes took place during the early morning hours (0600–0900) by two insect collectors. These collectors visited two human dwellings, including cattle sheds, in dengue-affected localities. The same field team was responsible for capturing the Aedes mosquitoes in each study locality. Once collected from all selected localities, the mosquitoes were placed in test tubes and separated based on the locality name, date, and time of collection. Subsequently, the adult mosquitoes were identified up to the species level and screened for infectivity.

For each locality, container-wise data were pooled to calculate indices like container index, house index, breteau index and man-hour density (MHD) using the following formulae:

Container Index (CI): percentage of water-holding containers infested with larvae or pupae

CI = Number of Aedes larvae-positive containers x 100/ Number of containers with water inspected

House Index (HI): percentage of houses infested with larvae and/ or pupae

HI = Number of houses positive for *Aedes* larvae x 100/ Number of houses inspected

Breteau Index (BI): number of positive containers per 100 houses inspected.

BI = Number of positive containers x 100/Number of houses inspected

Man Hour Density (MHD): Number of mosquitoes collected x 60/Time spent in minutes x Number of persons involved in collections

Results

Entomological surveys were carried out by the NIMR Field team in both residential and commercial (office) premises of Haridwar during the month of June 2021 to December 2021 to find out the breeding sites where mosquitoes breed and infect the people. During the surveys, a total of 1922 house premises were surveyed, out of which 1910 houses were screened from residential areas and 12 from commercial areas. In residential areas, out of 1910 houses, 237 houses were found to be positive with *Aedes* breeding while out of 12 commercial areas, only 7 were found to be positive with *Aedes* breeding. Inside both premises, a total of 5081 water containers were screened for larval presence and out of 5081 water containers, 4884 water containers were found positive from residential areas and 197 water containers from commercial areas with Aedes breeding (Tables 1 and 2).

During the survey, in residential areas (4884 water containers), only 395 water containers were found positive for the breeding of *Aedes* mosquitoes. When calculating its overall House Index (HI), Container Index (CI), and Breteau Index (BI), it was observed that the HI (12.40), CI (8.08) and BI (20.68) of water containers were observed (Table 1). While in commercial areas (197 water containers), only 66 water containers were witnessed with *Aedes* breeding and their CI (33.50) was calculated during the survey (Table 2). During the investigation in both study areas (Haridwar city and BHEL complex), different stages of larvae and adult *Aedes* mosquitoes were detected and their stages vary locality-wise in dengue-affected areas. We also recorded the positivity rate of *Aedes* larvae irrespective of the number of dengue cases recorded in these localities.

The distribution of *Aedes* larvae and Breeding Preference Ratio (BPR) in different types of breeding habitats was also

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recorded, and their results are depicted in Table 3. Among all the *Aedes* mosquito breeding habitats, the highest positivity of *Ae. aegypti* larvae were found in junk materials (4.46) followed by cemented tanks, pots & water tanks (3.96), mud pots (3.58), discarded tyres (3.72), tree holes (2.95), desert coolers (1.97), money plant pots (1.86), plastic containers (1.02), tray of the domestic refrigerator (0.72) and flower pots (0.22) (Table 3). During the entomological survey, a few localities were found to be positive, with the breeding of Ae. albopictus and *Ae. vittatus* breeding, observed in outdoor open spaces of houses. *Aedes* mosquito breeding was also found in intra-domestic water storage containers from the same areas where dengue cases were also reported.

During indoor mosquito collections, only 3 *Aedes* mosquito species were collected, out of which, *Ae. aegypti* and *Ae. albopictus* were found to be the most abundant species and other *Ae. vittatus* species were found in small numbers (Tables 4 and 5). The Average Man Hour Density (MHD) of the dengue vector was calculated and found to vary from locality to locality from the dengue-affected localities (Tables 4 and 5).

During the surveillance, area-wise adult mosquito were collected from different breeding sites. In each locality, the range of collected mosquito species, *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* were varies. From residential area the range between 18–86, 11–91 and 0–12 and 5–32, 22–44 while in commercial area 0-14 only. The average MHD of *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* in residential areas were 10.77, 6.81 and 0.52 (Table 4) and in commercial/ official areas, the values were 4.75, 7.95 and 1.68 (Table 5).

The percent species composition of *Aedes* mosquito larvae was isolated and collected from different localities of Haridwar City and the BHEL complex (Table 6). A total of 637 larvae emerged into adults in the insectary/ laboratory condition and among all five species of Aedes mosquitoes i.e. *Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus* and Ae. thomsoni were properly identified. In Haridwar city, *Ae. aegypti* was widespread mostly and the percentage species composition was 89.1% while in BHEL complex *Ae. albopictus* was most prevalent and its percentage species composition was 73.3% and very low breeding of *Ae. aegypti* 23.9% was recorded. High prevalence of *Ae. aegypti* was recorded in Haridwar city which was designated as a dengue-affected area. Overall, the percent species composition of *Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus* and *Ae. thomsoni* were 56.5, 41.45, 1.05, 0.4 and 0.6, respectively.

Table 1.Prevalence of *Aedes* Mosquito Larvae in Different Localities of Residential Areas in Haridwar City during Dengue Transmission Season

S. No.	Name of the Study Area	No. of House Surveyed	No. of House Positive	No. of Water Containers Surveyed	No. of Positive Containers	HI (%)	CI (%)	BI (%)
1	Hajari Bagh, Kankhal	188	8	156	11	4.25	7.05	5.85
2	Bhagwant Vatika, Kankhal	91	5	76	6	5.49	7.89	6.59
3	Indira Basti, Kankhal	88	9	196	16	10.20	8.16	18.20
4	Phari Bazaar, Kankhal	229	7	526	9	3.05	1.71	3.93
5	Miyan Mohalla, Kankhal	114	6	241	11	5.26	4.56	9.64
6	Sector-1, 2, 3 & 5 BHEL	221	64	1144	116	29.00	10.10	52.50
7	Bairagi Camp Bajariwala, Kankhal	451	28	1044	62	6.20	5.93	13.70
8	Devpura, Project Bairaj Colony & Vichitra Vatika	188	39	398	59	20.70	14.80	31.40
9	Canal Colony Mayapur	74	27	360	46	36.50	12.80	62.20
10	Shiv Murti Chowak	133	10	469	15	7.51	3.19	11.30
11	Bairaj Colony	74	31	241	41	41.90	17.00	55.40
12	Kashipura, Mansa Devi Area	59	3	33	3	5.08	9.09	5.08
Total		1910	237	4884	395	12.40	8.08	20.70

HI: House Index, CI: Container Index, BI: Breteau Index

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Table 2.Prevalence of *Aedes* Mosquito Larvae in Different Localities of Commercial Areas in Haridwar City during Dengue Transmission Season

S. No.	Name of the Study Area	No. of House Surveyed	No. of House Positive	No. of Water Containers Surveyed	No. of Positive Containers	CI (%)
1	Civil Maintenance Office, Sec-3, BHEL	1	1	23	13	56.52
2	Civil Maintenance Office Sec-5, BHEL	1	1	28	5	17.85
3	Civil Maintenance Office Sec-12, BHEL	1	1	23	5	21.73
4	CIVIL Maintenance Main Building, BHEL	1	0	9	0	0.00
5	Vidhut Sub Station Sec-3, BHEL	1	1	3	1	33.33
6	Vidhut Sub Station Sec-5, BHEL	1	0	3	0	0.00
7	Vidhut Sub Station Sec-1, BHEL	1	1	11	1	9.09
8	Jal Sansthan Sec-3, BHEL	1	0	19	0	0.00
9	Kotwali Police Station Ranipur Sec-5, BHEL	1	0	11	0	0.00
10	SOG, Office Police Station Sec-5, BHEL	1	0	4	0	0.00
11	State Office, BHEL	1	1	12	12	100.00
12	Trishul Guest House, BHEL	1	1	51	29	56.86
Total		12	7	197	66	33.50

CI: Container Index

Table 3.Breeding Preference Ratio (BPR) of *Aedes* Larvae in Haridwar City during Dengue Transmission Season

S. No.	Type of Breeding Habitats	Number of Containers with Water				Breeding Preference Ratio
		Examined	(X%)	With Larvae	(Y%)	BPR (Y/X)
1	Flower pots	2750	54.12	55	11.93	0.22
2	Desert coolers	1155	22.73	207	44.9	1.97
3	Plastic containers (tubs, bowls, tanks, buckets, drums, kens)	793	15.60	74	16.05	1.02
4	Refrigerator trays	15	0.29	1	0.21	0.72
5	Mud pots/ pitchers	71	1.39	23	4.98	3.58
6	Discarded tyres	55	1.08	15	3.25	3.00
7	Air conditioner's trays	11	0.21	0	0.00	0.00
8	Cemented tanks, pots and seepage water tanks	67	1.31	24	5.20	3.96
9	Tree holes	11	0.22	3	0.65	2.95
10	Mani plants	12	0.23	2	0.43	1.86

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11	Junk materials (iron drums, containers, steel pots, steel wastes, lids, drums, aluminium sodium light fitting covers, discarded toilet seat, cistern lid, discarded helmet, waste crockery)	141	2.77	57	12.36	4.46
Total		5081	-	461	-	-

BPR: Breeding Preference Ratio

Table 4.Man Hour Density (MHD) of *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* Mosquito Species in Commercial Areas of Haridwar City during Dengue Transmission Season

S. No.	Name of the Study Area	No. of *Ae. aegypti*	MHD of *Ae. aegypti*	No. of *Ae. albopictus*	MHD of *Ae. albopictus*	No. of *Ae. vittatus*	MHD of *Ae. vittatus*	Ratio of *Ae. aegypti, Ae. albopictus* and *Ae. vittatus*
1	Hajari Bagh, Kankhal	37	9.25	21	5.25	0	0.00	1.8:1
2	Bhagwant Vatika, Kankhal	21	5.25	11	2.75	0	0.00	1.9:1
3	Indira Basti, Kankhal	30	7.50	18	4.50	2	0.50	15:09:01
4	Phari Bazaar, Kankhal	34	8.50	26	6.50	0	0.00	1.4:1
5	Miyan Mohalla, Kankhal	18	4.50	10	2.50	0	0.00	1.8:1
6	Sector-1,2,3&5, BHEL	56	14.00	91	22.75	12	3.00	4.7:7.6:1
7	Bairagi Camp Bajariwala, Kankhal	35	8.75	40	10.00	8	2.00	4.4:5:1
8	Devpura, Project Bairaj Colony & Vichitra Vatika	86	21.50	18	4.50	0	0.00	4.8:1
9	Canal Colony Mayapur	44	11.00	23	5.75	0	0.00	1.9:1
10	Shiv Murti Chowak	31	7.75	13	3.25	0	0.00	2.4:1
11	Bairaj Colony	83	20.75	34	8.50	3	0.75	27.7:11.3:1
12	Kashipura, Mansa Devi Area	42	10.50	22	5.50	0	0.00	1.91:1
Average MHD		-	10.77	-	6.81	-	0.52	-

MHD: Man Hour Density

Table 5.Man Hour Density (MHD) of *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* Mosquito Species in Residential Area of Haridwar City during Dengue Transmission Season

S. No.	Name of the Study Area	No. of *Ae. Aegypti*	MHD of *Ae. aegypti*	No. of *Ae. albopictus*	MHD of *Ae. albopictus*	No. of *Ae. vittatus*	MHD of *Ae. vittatus*	Ratio of *Ae. aegypti, Ae. albopictus* and *Ae. vittatus*
1	Civil Maintenance Office, Sec-3, BHEL	16	4.00	23	5.75	8	2.00	02:09.9
2	Civil Maintenance Office Sec-5, BHEL	12	3.00	22	5.50	4	1.00	06:05.5
3	Civil Maintenance Office Sec-12, BHEL	11	2.75	27	6.75	4	1.00	2.8:6.8:1
4	CIVIL Maintenance Main Building, BHEL	28	7.00	35	8.75	13	3.25	2.2:2.7:1

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5	Vidhut Sub Station Sec-3, BHEL	32	8.00	44	11.00	9	2.25	3.6:4.9:1
6	Vidhut Sub Station Sec-5, BHEL	26	6.50	35	8.75	10	2.50	2.7:3.5:1
7	Vidhut Sub Station Sec-1, BHEL	20	5.00	29	7.25	6	1.50	3.3:4.8:1
8	Jal Sansthan Sec-3, BHEL	22	5.50	40	10.00	6	1.50	3.7:6.7:1
9	Kotwali Police Station Ranipur Sec-5, BHEL	5	1.25	24	6.00	0	0.00	01:04.8
10	SOG, Office Police Station Sec-5, BHEL	8	2.00	31	7.75	0	0.00	01:03.9
11	State Office, BHEL	28	7.00	33	8.25	7	1.75	05:11.7
12	Trishul Guest House, BHEL	20	5.00	39	9.75	14	3.50	1.4:2.8:1
Average MHD		-	4.75	-	7.95	-	1.68	-

MHD: Man Hour Density

Table 6.Percent Species Composition of *Aedes* Mosquitoes from Haridwar City and BHEL Complex during Dengue Transmission Season

S. No.	Area	No. of Emerged Adults Identified	Species Composition				
			Ae. aegypti	*Ae. albopictus*	*Ae. vittatus*	*Ae. pseudotaeniatus*	*Ae. thomsoni*
1	Haridwar city	380	89.1	9.6	0.5	0.8	0.0
2	BHEL complex	257	23.9	73.3	1.6	0.0	1.2
Total		637	56.5	41.45	1.05	0.4	0.6

Adult mosquitoes were identified from larvae

Discussion

Since the MHD depicts more than one critical level, it necessitates adequate vector control measures to eliminate mosquito breeding habitats in the houses and surroundings to avoid contamination of the disease in the localities. Vector Control (VC) is the only way to disease control and can be achieved by the enhanced Integrated Vector Management (IVM) for early detection of mosquito breeding, so that, VC measures can be taken into action to eliminate mosquito breeding.[40] Environment Management Methods (EMM) are used to control *Aedes* mosquito larvae and adults. In our study, the overall percent species composition of *Ae. aegypti*, and their high entomological indices were recorded in Haridwar city; water storing habits in the water holding containers were also observed in some of the localities due to scarcity of tap water, and the householders were not aware of the factors exacerbating the breeding of mosquitogenic conditions, the larval indices have been also observed above the critical levels by the earlier workers from the state.[28,34] Additional steps can be taken to eliminate the potential mosquito breeding habitats in the houses and in localities by covering all water-holding containers to prevent fresh egg laying by the dengue vector.[40] The control of Vector Borne Diseases (VBDs) and their prevention depends on the reduction of mosquito density through breeding sources and contact between mosquitoes and people, this ultimately enhanced the surveillance of the Integrated Disease Surveillance Programme (IDSP) at the community level in dengue case detection and keeping a watch on people returning from dengue affected areas and suffering from febrile illness.[22,31]

To know the percentage of species composition of *Aedes* mosquitoes, larvae were collected from different localities of Haridwar City and the BHEL complex (Table 4). After the emergence of larvae into adults, they were properly examined and five species were recorded. *Ae. aegypti, Ae. albopictus, Ae. vittatus, Ae. pseudotaeniatus* and *Ae. thomsoni* mosquito species were recorded during the study. *Aedes aegypti* was found as the dominant and most prevailing species in residential areas, which were inhabitants of domestic and peri-domestic water holding containers and this data was recorded earlier also.[3,20,22–24,27]

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Most of *Ae. aegypti* was found as the dominant species inside the houses in dengue-affected areas during the dengue epidemic in most areas showing larval indices may be the most probable reason for the persistence of dengue. *Ae. albopictus* species was found in the wet containers, mostly outside the house which were left in the open space around the house premises.[21,34] Similarly, previous researchers recorded these types of water-holding containers, left outside the houses that were rarely cleaned, and mostly remain undisturbed for a long time, which further became the site for *Aedes* mosquito breeding. Water storing habits were determined as one of the reasons responsible for Aedes mosquito breeding.[25] *Ae. albopictus* and Ae. aegypti were also found to co-breed in the same type of mosquito breeding habitats in several localities. In addition, mixed breeding of *Ae. aegypti*, Ae. albopictus and *Ae. vittatus* were also recorded in some manmade breeding habitats.[41] This may be due to fast urbanization in the last three to four decades and the destruction of natural breeding habitat conditions, these conditions forced *Ae. albopictus* and *Ae. vittatus* to acquire and adapt to breed in manmade habitats besides the restriction of natural habitats. Similar observations were recorded by the previous researchers on the adaptation of both mosquito species in Malaysia.[42] There may be intra-species competition for food and existence, which increases its epidemiological potential and risk to the population. Pant et al. recorded that "*Ae. albopictus* mosquitoes are fed outdoors as compared with *Ae. aegypti. Aedes* albopictus mosquitoes may play the role in amplifying dengue transmission".[43] Both the *Aedes* species should be checked before the transmission season in Haridwar City as observed by Joshi et al., which may play an important role in the maintenance of the urban cycle of dengue in Jodhpur and more attention should be paid to clarify the involvement and transmission dynamics of dengue of *Ae. albopictus* in Haridwar City.[44]

In an earlier study, high entomological indices were observed in some of the villages of Haridwar due to water storage habits in the domestic containers. The highest positivity number of *Ae. aegypti* larvae was found in the domestic refrigerator tray (4.55), most of the people/ villagers were not aware of these factors exacerbating mosquito breeding conditions, suggesting its potential for future outbreaks (unpublished data).[45] Similar observations were observed by the previous researchers on the environment and highlighted these factors.[46] The present situation of mosquito breeding indices might be attributed to changes in the ecology and social behaviour of residents/ householders, changes in the living lifestyle, and non-availability of tap water supply properly enforcing water storage practices.[47] Therefore, continuous entomological surveillance should be undertaken in the Haridwar City area to control the repeated occurrence of dengue outbreaks and the information should be utilized to forecast future dengue outbreaks, so that necessary VC efforts could be taken before possible dengue outbreaks by the DHA to cease the epidemic and stop resurgence in future.

Special efforts can be used to empty and dry water-holding containers, desert coolers, bird baths, flower pots etc. at least once a week. *Gambusia* larvivorous fishes can be introduced in ornamental water tanks, similarly, *Bacillus thuringiensis* (BTi) and Temephos larvicides can be applied in stagnant water for more than one week. Temephos larvicides, which is not dangerous to humans and non-targeted organisms, or the environment when used as per the WHO/ National guidelines.[30,40] Synthetic Pyrethroids (SP) insecticide can used for Indoor Residual Spray (IRS) in areas where dengue cases are reported.[28] Pyrethrum spray/ malathion fogging can be applied for the control of adult Aedes mosquitoes. Personal protective prevention (PPP) measures can be used as insect repellents and wearing light-coloured clothes for the coverage of the body; closing the doors and windows properly, and using mosquito bed nets/ insecticide-treated bed nets for sleeping to protect from mosquito bites.[28] Legislative measures and by-laws should be implemented to avoid situations which favour mosquito breeding. Health education for community mobilisation and community participation to eliminate *Aedes* mosquito breeding with the involvement of other sectors/ departments should be encouraged as per national guidelines for dengue prevention (NCVBDC).

Conclusion

The field study showed that *Aedes* mosquito breeding was detected in all the dengue-affected areas during transmission season in Haridwar city. Most of the areas showing high larval indices may be the probable reason for the persistence of dengue in the city. A focal and small outbreak of dengue was reported in the Hardwar district of Uttrakhand state in 2021. Dengue infection was also observed in the rural area of the district Haridwar but the infection was low. The vector control and all the preventive measures need to be directed to eliminate the *Aedes* mosquito breeding by adopting a bottom-up vector-borne disease control programme, the water management practice by the householders along with the implementation of IEC activities are suggested to contain dengue epidemics in the future, which was hitherto free, for further containment.

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References

1. Gubler DJ. The global pandemic of dengue/dengue hemorrhagic fever: current status and prospects for the future. Ann Acad Med Singap. 1998;27(2):227-34. [PubMed] [Google Scholar]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202458

2. World Health Organization. Prevention and control of fever and dengue haemorrhagic fever: comprehensive guidelines. WHO Regional Publication SEARO No. 29, New Delhi: WHO-SEARO; 1999.
3. Nandi J, Sharma RS, Datta PK, Dhillon GP. Dengue in the National Capital Territory (NCT) of Delhi (India): epidemiological and entomological profile for the period 2003 to 2008. Dengue Bull. 2008;32:156-61. [Google Scholar]
4. Whitehorn J, Farrar J. Dengue. Br Med Bull. 2010;95:161-73. [PubMed] [Google Scholar]
5. Innis BL. Dengue and dengue hemorrhagic fever. In: Porterfield JS, editor. Exotic viral infections. London: Chapman Hall; 1995. p. 103-46.
6. Gubler DJ, Meltzer M. Impact of dengue/dengue hemorrhagic fever on the developing world. Adv Virus Res. 1999;53:35-70. [PubMed] [Google Scholar]
7. Kimura R, Hotta S. Experimental inoculation of dengue virus into mice. Nippon Igaku. 1943;3344:1378-9. [Google Scholar]
8. Sabin AB, Schlesinger RW. Production of immunity to dengue with virus modified by propagation in mice. Science. 1945;101(2634):640-2. [PubMed] [Google Scholar]
9. Ramakrishnan SP, Gelfand HM, Bose PN, Sehgal PN, Mukerjee RN. The epidemic of acute hemorrhagic fever, Calcutta, 1963: epidemiological inquiry. Indian J Med Res. 1964;52:633-50. [PubMed] [Google Scholar]
10. Sarkar JK, Chatterjee SN, Chakravarty SK. Haemorrhagic fever in Calcutta: some epidemiological observations. Indian J Med Res. 1964;52:651-9. [PubMed] [Google Scholar]
11. Chatterjee SN, Chakravarti SK, Mitra AC, Sarkar JK. Virological investigation of cases with neurological complications during the outbreak of haemorrhagic fever in Calcutta. J Indian Med Assoc. 1965;45(6):314-6. [PubMed] [Google Scholar]
12. Carey DE, Myers RM, Reuben R, Rodrigues FM. Studies on dengue in Vellore, South India. Bull World Health Organ. 1966;35(1):61. [PubMed] [Google Scholar]
13. Dar L, Broor S, Sengupta S, Xess I, Seth P. The first major outbreak of dengue hemorrhagic fever in Delhi, India. Emerg Infect Dis. 1999;5(4):589-90. [PubMed] [Google Scholar]
14. Agarwal R, Kapoor S, Nagar R, Misra A, Tandon R, Mathur A, Misra AK, Srivastava KL, Chaturvedi UC. A clinical study of the patients with dengue hemorrhagic fever during the epidemic of 1996 at Lucknow, India. Southeast Asian J Trop Med Public Health. 1999;30(4):735-40. [PubMed] [Google Scholar]
15. Shah I, Deshpande GC, Tardeja PN. Outbreak of dengue in Mumbai and predictive markers for dengue shock syndrome. J Trop Pediatr. 2004;50(5):301. [PubMed] [Google Scholar]
16. Gupta E, Dar L, Kapoor G, Broor S. The changing epidemiology of dengue in Delhi, India. Virol J. 2006;3:92. [PubMed] [Google Scholar]
17. Gupta N, Srivastava S, Jain A, Chaturvedi UC. Dengue in India. Indian J Med Res. 2012;136(3):373-90. [PubMed] [Google Scholar]
18. World Mosquito Programme [Internet]. Dengue Fact Sheet; 2022 [cited 2023 Feb 21]. Available from: https://www.worldmosquitoprogram.org/en/learn/mosquito-borne-diseases/dengue
19. Kalra NL, Kaul SM, Rastogi RM. Prevalence of *Aedes aegypti* and *Aedes albopictus*- vectors of dengue and dengue haemorrhagic fever in North, North-east and Central India. Dengue Bull. 1997;21:84-92. [Google Scholar]
20. Kaul SM, Sharma RS, Sharma SN, Panigrahi N, Phukan PK, Lal S. Preventing dengue/dengue haemorrhagic fever outbreaks in the National Capital Territory of Delhi--the role of entomological surveillance. J Commun Dis. 1998;30(3):187-92. [PubMed] [Google Scholar]
21. Singh RK, Mittal PK, Yadav NK, Gehlot OP, Dhiman RC. *Aedes aegypti* indices and KAP study in Sangam Vihar, south Delhi, during the XIX Commonwealth Games, New Delhi, 2010. Dengue Bull. 2010;35:131-40. [Google Scholar]
22. Singh RK, Mittal PK, Kumar G, Dhiman RC. Prevalence of Aedes mosquitoes in various localities of Delhi during dengue transmission season. Entomol Appl Sci Lett. 2014;1(4):16-21. [Google Scholar]
23. Sharma SN, Raina VK, Kumar A. Dengue/DHF: an emerging disease in India. J Commun Dis. 2000;32(3):175-9. [PubMed] [Google Scholar]
24. Sharma RS, Kaul SM, Sokhay J. Seasonal fluctuation of dengue fever vector, *Aedes aegypti* (Diptera: Culicidae) in Delhi, India. Southeast Asian J Trop Med Public Health. 2005;36(1):186-90. [PubMed] [Google Scholar]
25. Balakrishnan N, Venkatesh S, Lal S. An entomological study on the dengue vectors during outbreak of dengue in Tiruppur town and its surrounding, Tamil Nadu, India. J Commun Dis. 2006;38(2):164-8. [PubMed] [Google Scholar]
26. Singh RK, Das MK, Dhiman RC, Mittal PK, Sinha AT. Preliminary investigation of dengue vectors in Ranchi, India. J Vector Borne Dis. 2008;45(2):171-3. [PubMed] [Google Scholar]
27. Singh RK, Dhiman RC, Dua VK. Prevalence of Aedes aegypti Linnaeus and *Aedes albopitus* Skuse in Koderma, Jharkhand. J Commun Dis. 2011;43(3):223-8. [PubMed] [Google Scholar]
28. Singh RK, Dhiman RC, Dua VK, Joshi BC. Entomological investigations during an outbreak of dengue fever in Lal Kuan town, Nainital district of Uttarakhand, India.

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202458

J Vector Borne Dis. 2010;47(3):189-92. [PubMed] [Google Scholar]
29. Singh RK, Mittal PK, Kumar G, Karlekar RR, Dhole RB, Dhiman RC. Prevalence of *Aedes* mosquitoes in various localities of Gadchiroli district of Maharashtra state, India. Int J Mosq Res. 2015;2(2):38-41. [Google Scholar]
30. National Centre for Vector Borne Diseases Control, Ministry of Health and Family Welfare [Internet]; [cited 2023 Feb 2]. Available from: https://ncvbdc.mohfw.gov.in/index4.php?lang=1&level=0&linkid=431&lid=3715.
31. Tuli NR, Singh K, Singh P, Bisht B, Singh H. Impact of COVID-19 pandemic on prevention and control of dengue in Delhi, India. Dengue Bull. 2020;41:166-93. [Google Scholar]
32. Sharma H, Ilyas A, Chowdhury A, Poddar NK, Chaudhary AA, Shilbayeh SA, Ibrahim AA, Khan S. Does COVID-19 lockdowns have impacted on global dengue burden? A special focus to India. BMC Public Health. 2022;22(1):1402. [PubMed] [Google Scholar]
33. Kumar A, Sharma SK, Padbidri VS, Takare JP, Jain DC, Datta KK. An outbreak of dengue fever in rural areas of northern India. J Commun Dis. 2001;33(4):274-81. [PubMed] [Google Scholar]
34. Kumar S, Singh US, Katyal R. Preliminary observation on *Aedes aegypti* survey during lean transmission season in sub-Himalayan town of India. J Commun Dis. 2008;40(2):167-8. [PubMed] [Google Scholar]
35. Government of Uttarakhand [Internet]. Haridwar: about district; [cited 2023 Feb 2]. Available from: https://haridwar.nic.in/about-district/
36. Sheppard PM, Macdonald WW, Tonn RJ. A new method of measuring the relative prevalence of Aedes aegytpti. Bull World Health Organ. 1969;40(3):467. [PubMed] [Google Scholar]
37. World Health Organization. Manual on practical entomology in malaria. Geneva, Switzerland: WHO; 1975. 160 p.
38. Das BP, Kaul SM. Pictorial key to the common Indian species of *Aedes* (Stegomyia) mosquitoes. J Commun Dis. 1998;30(2):123-7. [PubMed] [Google Scholar]
39. Barraud P. The fauna of British India, including Ceylon and Burma, Diptera. Vol. 5, Family-Culielale. Tribes Megarhinini and Culicine; 1934. p. 28, 463. [Google Scholar]
40. World Health Organization. Dengue: guidelines for diagnosis, treatment, prevention and control. Geneva: World Health Organization; 2009. p. 1-147. [Google Scholar]
41. Kumari R, Kumar K, Chauhan LS. First dengue virus detection in *Aedes* albopictus from Delhi, India: its breeding ecology and role in dengue transmission. Trop Med Int Health. 2011;16(8):949-54. [PubMed] [Google Scholar]
42. Lee HL. A nationwide resurvey of the factors affecting the breeding of *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse) (Diptera: Culicidae) in urban towns of peninsular Malaysia, 1988-1989. Trop Biomed. 1991;8(2):157-60. [Google Scholar]
43. Pant CP, Jatanasen S, Yasuno M. Prevalence of *Aedes aegypti* and *Aedes albopictus* and observations on the ecology of dengue haemorrhagic fever in several areas of Thailand. Southeast Asian J Trop Med Public Health. 1973;4(1):113-21. [PubMed]
44. Joshi V, Singhi M, Mourya DT. Studies on determination of possible role of *Aedes albopictus* mosquitoes in maintenance of urban cycle of dengue. Desert Medicine Research Centre (Indian Council of Medical Research) Jodhpur, Annual Report. 2003;3:58-65.
45. Singh RK, Nasreen A, Pooja P, Singh G, Singh H. An entomological investigation in dengue affected areas during transmission season in district Haridwar, Uttarakhand, India. communicated in Jour Vec Born Dis 2023.
46. Tewari SC, Thenmozhi V, Katholi CR, Manavalan R, Munirathinam A, Gajanana A. Dengue vector prevalence and virus infection in a rural area in South India. Trop Med Int Health. 2004;9(4):499-507. [PubMed] [Google Scholar]
47. Joshi V, Sharma RC, Sharma Y, Adha S, Sharma K, Singh H, Purohit A, Singhi M. Importance of socioeconomic status and tree holes in distribution of *Aedes* mosquitoes (Diptera: Culicidae) in Jodhpur, Rajasthan, India. J Med Entomol. 2006;43(2):330-3. [PubMed] [Google Scholar]

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