

Research Article

Seasonal Trends & Short-Term Fluctuations of Aedes Larval Indices and Their Climatic Correlates Across Locality Types in South Zone, Delhi, India

Amar Nath Pandey¹, Arun Chauhan², Rohit Sagar³, Neera Kapoor⁴, Sukhvir Singh⁵, S K Sagar⁶

¹Research Scholar, IGNOU, Maidan Garhi, Delhi, India

²Entomologist, National Centre for Vector Borne Disease Control, Delhi, India

³Shri Ram Murti Gupta Govt P G College, Chharra, Aligarh, Uttar Pradesh, India

⁴Professor, School of Life Sciences, IGNOU, Maidan Garhi, Delhi, India

⁵Ex-Join Director, National Centre for Vector Borne, Diseases Control, Delhi, India

⁶Department of Zoology, Swami Shraddhanand College, University of Delhi, India

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I N F O

Corresponding Author:

S K Sagar, Department of Zoology, Swami Shraddhanand College, University of Delhi, India

E-mail Id:

ssagar.du@yahoo.com

Orcid Id:

<https://orcid.org/0000-0003-4256-5475>

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A B S T R A C T

Introduction: Dengue infects an estimated 390 million people annually, though underreporting is widespread due to asymptomatic cases. It is endemic in 129 countries, including nearly all of India, causing 20,000 deaths and 264 disability adjusted life years (DALYs) per million population yearly. Its vectors, *Aedes aegypti* and *Aedes albopictus*, differ in habitat and behaviour.

Method: Breeding habitats across eight localities (slum settlements, urban villages, high-income colonies, and government institutions) in five wards of South Zone, Delhi, were surveyed from January 2024 to December 2025. Monthly door-to-door surveys of 360 households and two institutions, examined water holding containers across nine categories for Aedes immatures.

Results: All localities showed larval indices lowest in Winter, peaking in Monsoon, and declining post- Monsoon. In 2024, HI rose from 2.5%–13.6% (Slums), 1.1%–12.2% (Urban Villages), and 0.6%–11.4% (High-Income Areas). In 2025, HI, CI and BI increased during Monsoon and post-Monsoon (HI +75% to +115%), coinciding with rainfall rising from 200.5–257.2 mm (Monsoon) and 70.8–99.3 mm (post- Monsoon), and humidity from 72%–81%. Positive containers rose from 418 to 587 (40.4%).

Conclusion: This two-year survey reveals a repeatable seasonal cycle peaking in Monsoon, tracking rainfall and humidity more than temperature. Locality ranking (Slums greater than(>) Urban Village greater than(>) High-Income greater than(>) Govt. Institutions) suggests housing density and water-storage habits as key drivers. Locality-specific, container-targeted interventions during Winter and Pre-Monsoon are likely more effective than uniform measures, though findings need validation with adult mosquito and case data.

Keywords: *Aedes aegypti*, *Aedes albopictus*, larval indices and entomological surveillance

Introduction

Dengue is one of the most serious re-emerging viral diseases transmitted by arthropods and caused by arboviruses, with nearly 390 million new dengue cases reported globally in a single year, according to recent estimates.¹ It is caused by the dengue virus (DENV, 1-4 serotypes) and is regarded as one of the most important arboviruses in the tropics and subtropics.² Epidemic dengue and dengue haemorrhagic fever: a global public health problem in the 21st century by *Aedes aegypti*.³ Most of these cases are, unfortunately, asymptomatic and present few, or even no, obvious clinical signs.⁴ Thus, the officially recorded rate of dengue cases is likely to significantly under-report the true incidence.

Dengue's prevalence has surged dramatically, and the disease is now endemic in 129 countries across Africa, the Americas, the Eastern Mediterranean, South-East Asia, and the Western Pacific regions. In the South-East Asia Region, every country except the Democratic People's Republic of Korea, including India, are dengue endemic.⁵ Cases and deaths have been reported across all Indian states and union territories except Ladakh and Lakshadweep.⁶ Hundreds of thousands of severe cases occur each year, resulting in roughly 20,000 deaths and a loss of about 264 disability adjusted life years (DALYs) per million population.⁷

The absence of distributional data on the *Aedes* vector and its potential breeding sources hampers effective vector surveillance and control.⁸ This makes a careful entomological survey essential for understanding vector bionomics and distribution, which in turn can guide proper vector control strategies and disease prevention. Two species drive dengue transmission viz. *Aedes aegypti*, the primary vector, and *Aedes albopictus*, the secondary vector. Earlier studies show their behaviour differs substantially. *Aedes aegypti* favours human made confined containers in densely built neighbourhoods and tends to be endophilic, whereas *Aedes albopictus* breeds preferentially in containers surrounded by vegetation and is exophilic.⁹ *Aedes albopictus* is more invasive as compared with *Aedes aegypti*.

Prior research has documented cases where *Aedes albopictus* invasion competitively displaces *Aedes aegypti*.¹⁰ Rising temperatures from global warming now sustain transmission year-round, so the disease is no longer confined to the monsoon season, it circulates continuously in endemic tropical countries.¹¹ Given this, vector control efforts need to begin during the lean period itself, while larval density is still low.

Delhi experiences regular dengue outbreaks because of its dense population, heterogeneous urban environment, and diverse socio-economic conditions. The South Zone of Delhi comprises government institutions, planned residential colonies, urban villages, and densely populated slum settlements, each characterised by distinct environmental conditions and water storage practices that influence mosquito breeding. The present study was therefore undertaken to evaluate the seasonal variation in *Aedes* larval indices and breeding habitats across selected localities of the South Zone, Delhi, during a two-year surveillance period from January 2024 to December 2025. The findings are expected to improve the understanding of seasonal breeding patterns and provide evidence for strengthening locality-specific dengue vector control strategies in urban settings.

Materials & Methods

Study Area

The study was conducted in the South Zone of the Municipal Corporation of Delhi (MCD), one of the largest urban local bodies in the world, providing civic services to more than 11 million residents of the National Capital Territory of Delhi. Administratively, the MCD is divided into 12 zones comprising 250 municipal wards. The South Zone consists of 23 wards with an estimated population of approximately 2.73 million and a population density exceeding 11,000 persons per square kilometre. Rapid urbanization, heterogeneous socio-economic conditions, and high population density create favourable conditions for the breeding of *Aedes* mosquitoes and increase the risk of dengue transmission.

Five municipal wards were selected for the present study, namely Ward No. 148 (Hauz Khas), Ward No. 151 (Munirka), Ward No. 156 (Vasant Kunj), Ward No. 160 (Saidulajab), and Ward No. 172 (Chirag Delhi). Within these wards, eight representative localities were selected based on two criteria: previous dengue occurrence and socio-economic diversity. The selected localities included two government institutions [Indira Gandhi National Open University (IGNOU), Maidan Garhi and Indian Institute of Technology (IIT) Delhi, Hauz Khas], two high-income residential colonies (Asian Games Village Complex, Siri Fort and Vasant Kunj), two urban villages (Munirka and Saidulajab), and two slum settlements (Bengali Camp, Masoodpur and Parvatiya Camp, Sector-4, R.K. Puram). Mapping of these study sites was carried out using QGIS and DIVA-GIS software to ensure accuracy in geographical representation [Fig. 1]. The inclusion of different locality types enabled comparison of *Aedes* breeding patterns under varying environmental and socio-economic conditions.

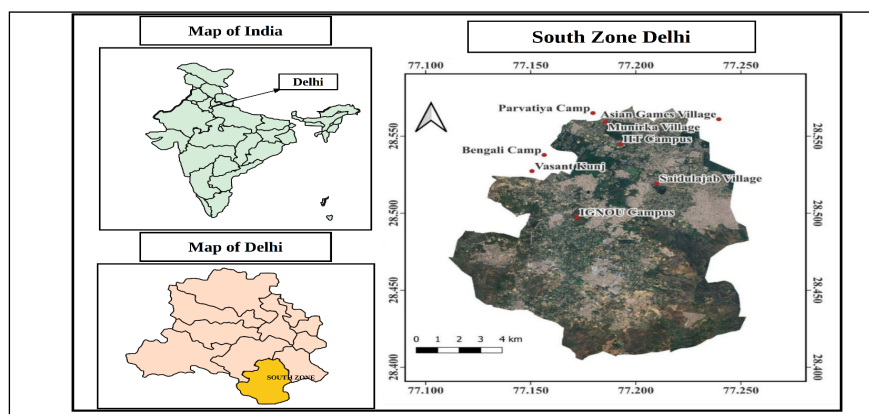


Figure 1. Map showing the study sites in eight selected localities of South Zone, New Delhi

Study Design

A longitudinal entomological surveillance study was conducted over a period of twenty-four months from January 2024 to December 2025. The investigation was designed to assess seasonal variation and short-term fluctuations in *Aedes* larval indices and breeding habitats across different types of localities in the South Zone of Delhi. Field surveys were carried out every month to ensure uniform data collection throughout the study period. Seasonal analysis was performed by grouping the monthly observations into winter, pre-monsoon, monsoon, and post-monsoon seasons.

Entomological Survey

A door-to-door entomological survey was conducted after obtaining consent from household owners. Each household together with its surrounding premises was considered a single sampling unit. In every locality, sixty households were inspected each month throughout the

study period. Consequently, a total of 360 households were surveyed every month across the six selected localities and additionally two government institutions.

All domestic and peri-domestic water holding containers were carefully examined for the presence of immature stages of *Aedes* mosquitoes. The survey included both indoor and outdoor breeding habitats [Fig. 2]. Particular attention was given to artificial water storage containers commonly associated with *Aedes* breeding. Details of each positive breeding site were recorded systematically during every survey. Field data regarding area visited, number of houses checked, number of containers checked, number of houses positive, number of containers positive and types of containers were entered in a Microsoft Excel sheet. During the survey, health education was provided to all participating households. Residents were informed about common breeding sources of *Aedes* species; methods for their elimination and personal protective measures.



Figure 2. *Aedes* mosquito breeding habitats identified during entomological survey within the study area of South Zone, New Delhi, India: (1) Plastic container, (2) Earthen pot, (3) Flower pot, (4) Cooler, (5) Metal container, (6) Tyre, (7) Cement cistern, (8) Water tank, and (9) Others.

Collection and Identification of *Aedes* Larvae

Immature stages of *Aedes* mosquitoes were collected from different water-holding containers, including plastic containers, earthen pots, flower pots, desert coolers, metal containers, discarded tyres, cement cisterns, water storage tanks, and other miscellaneous containers. A flashlight was used to inspect the containers inner walls and rims of containers where larvae frequently remain concealed. Larvae were collected using standard dipping methods, droppers, or pipettes depending on the size & shape of the breeding container and amount of water. The collected specimens were transferred to plastic containers containing water from the original breeding sites and were labelled. Identification of *Aedes* larvae was carried out based on their characteristic oscillatory movement and standard morphological characters of *Aedes* species.

Classification of Breeding Habitats

For uniform analysis, breeding habitats were grouped into nine categories: plastic containers, earthen pots, flower pots, coolers, metal containers, discarded tyres, cement cisterns, water storage tanks, and other miscellaneous containers. Seasonal variation in the distribution of positive breeding habitats was analysed separately for each locality type to identify the most productive breeding containers during different seasons.

Calculation of Larval Indices

Three standard larval indices recommended by the World Health Organization (WHO)¹² were used to assess *Aedes* larval infestation.

The House Index (HI) was calculated as the percentage of houses positive for *Aedes* larvae among the total houses inspected.

The Container Index (CI) was calculated as the percentage of water-holding containers positive for *Aedes* larvae among the total containers examined.

The Breteau Index (BI) was calculated as the number of positive containers per one hundred houses inspected.

These indices were calculated separately for each locality and season to compare the spatial and temporal distribution of *Aedes* breeding.

Seasonal Classification

Monthly observations were grouped into four climatic seasons based on the prevailing weather conditions in Delhi. Winter (December-February) Pre-monsoon (March-May) Monsoon (June-August) and Post-monsoon (September-November). This classification facilitated the evaluation of seasonal changes in larval abundance and breeding habitat distribution over the study period.

Meteorological Data

Meteorological data for 2024-2025 were obtained from the Data Service Portal, India Meteorological Department (IMD), Pune, including monthly values of temperature, relative humidity, and rainfall. These data were compiled and averaged season-wise as four seasons were considered: winter, pre-monsoon, monsoon, and post-monsoon. The seasonal averaged data were used to analyse their association with *Aedes* larval density in the study areas of South Zone of Delhi.

Data Analysis

The data collected during the field surveys were compiled month-wise and locality-wise. Seasonal averages of House Index, Container Index, and Breteau Index were calculated for each locality type. The distribution of positive breeding habitats was expressed as percentages to compare the contribution of different container categories during each season. Comparative analysis was done from January 2024 to December 2025 to assess changes in larval indices and breeding habitat preferences across the study period.

Ethical Considerations

The entomological surveys were conducted after obtaining verbal consent from household owners before inspection of residential premises. Household information was used solely for research purposes, and confidentiality was maintained throughout the study. The research did not involve any endangered or protected species. Collection of mosquito larvae and pupae was carried out using standardized entomological techniques. As the study did not involve human or animal subjects, so no specific ethical approval was required.

Results

Seasonal fluctuations of Larval Indices from January 2024 to December 2025

All four localities showed the same seasonal pattern, the House Index (HI), Container Index (CI), and Breteau Index (BI) were lowest in Winter, rose a bit in pre-monsoon, jumped sharply in Monsoon, and then dropped somewhat in post-monsoon, without ever falling back to Winter levels (Table 1; Fig. 3). In Slum Settlements, HI climbed from 2.5% in Winter, 4.4% in pre-monsoon, 13.6% in Monsoon (more than a fivefold from winter) before dropping to 8.1% in post-monsoon in 2024. Similarly, Urban Village and High-Income areas followed the same trend during winter, pre-monsoon, monsoon and post-monsoon (Urban Village HI: 1.1% → 3.1% → 12.2% → 6.9%; High-Income Areas HI: 0.6% → 2.9 → 11.4% → 6.2%). BI swung the most of the three indices in every locality (for example, Slum Settlements BI went 2.5 → 5.3 → 16.4 → 8.6 in 2024), which makes sense

since BI counts positive containers per 100 houses rather than per house.

The same ranking is held across every season: Slum Settlements > Urban Village > High-Income Areas for all three indices. Govt. Institutions recorded only CI showing any positive numbers, rising from 0.7% in Winter, 3.1% in pre-monsoon, 13.0% in monsoon and 6.7% in post-monsoon in 2024, while 1.0%, 2.9%, 13.5% and 10.3% in 2025 respectively. Govt. Institutions do not record HI & BI, because this just reflects that institutional campuses don't have "houses" in the usual sense.

Year-on-year larval indices comparison (2024 vs. 2025)

All three indices during Monsoon and Post-Monsoon in every locality went up from 2024 to 2025, while Winter

and Pre-Monsoon stayed roughly flat or dipped slightly. The biggest year-on-year jump came in post-monsoon year 2024 Vs, 2025: HI in Slum Settlements went from 8.1% to 14.2% (increased up to 75%), in Urban Village from 6.9% to 11.9% (increased up to 72%), and in High-Income Areas from 6.2% to 13.3% (increased up to 115%). BI moved the same way (Slum Settlements: 8.6 → 16.7; Urban Village: 8.1 → 15.6; High-Income Areas: 6.8 → 16.1). This lined up with a rise in the climate parameters too: Monsoon rainfall went from 200.5 mm to 257.2 mm (increased up to 28%), post-monsoon rainfall from 70.8 mm to 99.3 mm (increased up to 40%), and Monsoon humidity from 72% to 81%, while temperature barely changed between the two years (Figures 3 and 4, right-hand panels).

Table 1. Locality-wise Comparative Seasonal Summary of Aedes larval indices and climatic variables from January 2024 to December 2025

Locality-wise Comparative Seasonal Summary of Aedes Larval Indices from Jan 2024 to Dec 2025													
Year		2024						2025					
Locality Type	Season	Average HI (%)	Average CI (%)	Average BI	Average Mean Temp (°C)	Average Mean Rainfall (mm)	Average Mean Relative Humidity (%)	Average HI (%)	Average CI (%)	Average BI	Average Mean Temp (°C)	Average Mean Rainfall (mm)	Average Mean Relative Humidity (%)
Slum Settlements (Bengali Camp & Parvatiya Camp)	Winter (Dec-Feb)	2.5	2.0	2.5	14.6	17.9	88	1.7	1.4	1.7	16.3	4.6	87
	Pre-Monsoon (Mar-May)	4.4	3.9	5.3	28.6	4.4	47	3.3	2.5	3.3	28.5	31.4	54
	Monsoon (June-Aug)	13.6	10.6	16.4	32.0	200.5	72	20.0	12.7	21.7	30.5	257.2	81
	Post-Monsoon (Sept-Nov)	8.1	6.4	8.6	25.5	70.8	82	14.2	11.8	16.7	24.6	99.3	81
Urban Village (Munirka Village & Saidulajab Village)	Winter (Dec-Feb)	1.1	0.9	1.1	14.6	17.9	88	1.7	1.5	1.7	16.3	4.6	87
	Pre-Monsoon (Mar-May)	3.1	3.4	4.4	28.6	4.4	47	3.9	3.1	3.9	28.5	31.4	54
	Monsoon (June-Aug)	12.2	12.7	18.6	32.0	200.5	72	19.4	15.6	24.7	30.5	257.2	81
	Post-Monsoon (Sept-Nov)	6.9	6.5	8.1	25.5	70.8	82	11.9	11.1	15.6	24.6	99.3	81
High-Income Areas (Asian Games Village Complex & Vasant Kunj)	Winter (Dec-Feb)	0.6	0.5	0.6	14.6	17.9	88	0.6	0.5	0.6	16.3	4.6	87
	Pre-Monsoon (Mar-May)	2.9	2.1	2.9	28.6	4.4	47	2.8	2.3	2.8	28.5	31.4	54
	Monsoon (June-Aug)	11.4	9.1	12.8	32.0	200.5	72	16.9	10.8	17.2	30.5	257.2	81
	Post-Monsoon (Sept-Nov)	6.2	5.3	6.8	25.5	70.8	82	13.3	12.1	16.1	24.6	99.3	81
Govt. Institutions (IGNOU & IIT Delhi)	Winter (Dec-Feb)	0.0	0.7	0.0	14.6	17.9	88	0.0	1.0	0.0	16.3	4.6	87
	Pre-Monsoon (Mar-May)	0.0	3.1	0.0	28.6	4.4	47	0.0	2.9	0.0	28.5	31.4	54
	Monsoon (June-Aug)	0.0	13.0	0.0	32.0	200.5	72	0.0	13.5	0.0	30.5	257.2	81
	Post-Monsoon (Sept-Nov)	0.0	6.7	0.0	25.5	70.8	82	0.0	10.3	0.0	24.6	99.3	81

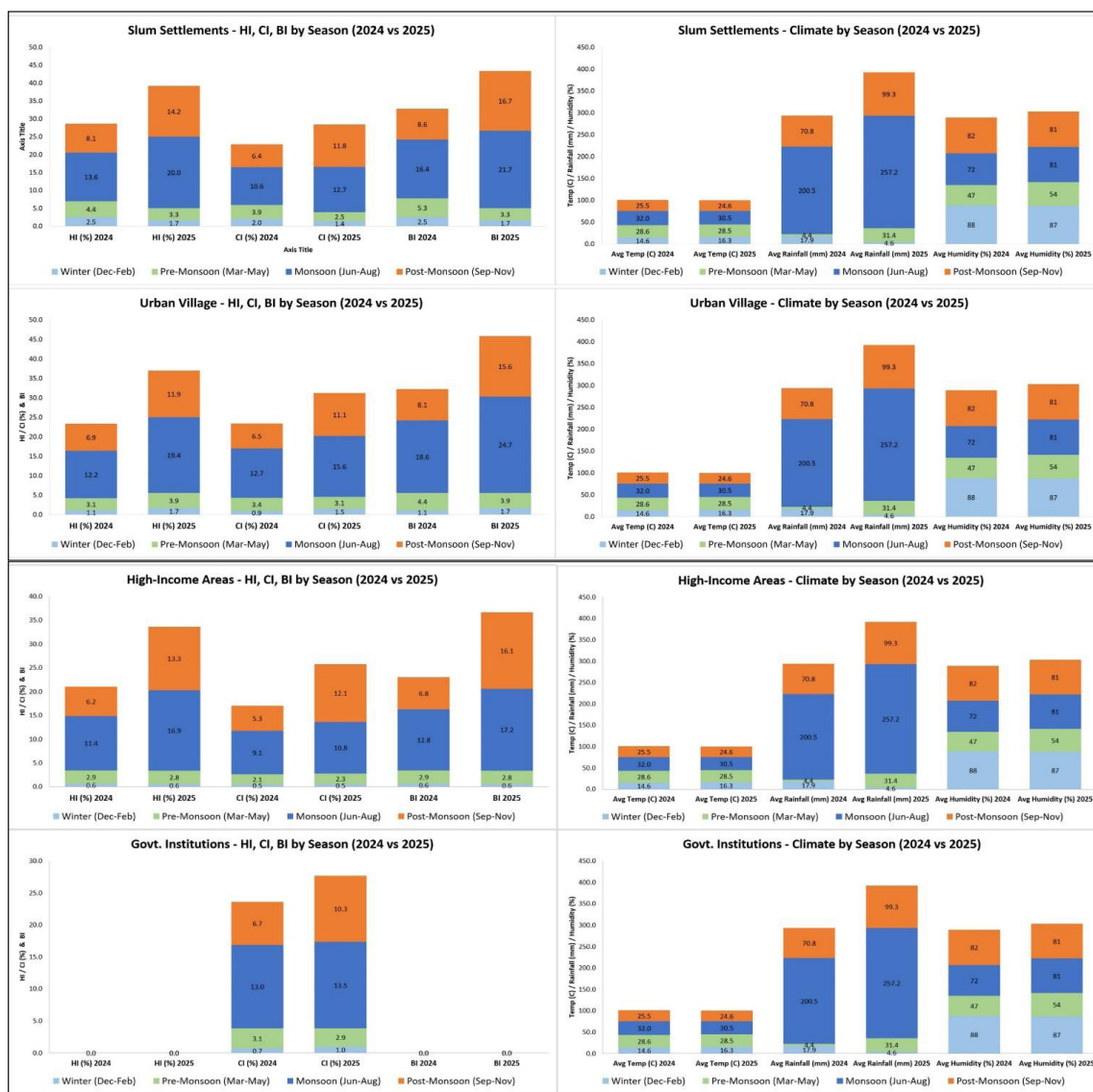


Figure 3. Locality-wise Comparative Seasonal Graph of Aedes larval indices and climatic variables (2024 vs. 2025).

Locality-wise containers positivity during 2024 & 2025

All four localities showed a higher percentage of container positivity in 2025 as compared to 2024. High-Income areas showed the steepest proportional rise (+61.0%) despite recording the lowest absolute totals in both years, followed by Urban Village (+42.2%). Slum Settlements and Government Institutions rose more moderately (+32.2% and +31.4%). In absolute terms, the Higher Income area showed the highest positivity rate (+61.0%) as compared to Urban Village (+42.2%).

Season-wise Mean Meteorological Parameters of South Zone Delhi during 2024 and 2025

Mean temperature, rainfall, and relative humidity followed a broadly similar seasonal cycle in both years, rising from a Winter minimum to a Monsoon maximum before declining

in the post-monsoon period. Rainfall differed more substantially between years than temperature: Monsoon rainfall increased from 200.5 mm in 2024 to 257.2 mm in 2025 (+28.2%), and post-monsoon rainfall increased, from 70.80 mm to 99.3 mm (+40.2%). Conversely, pre-monsoon rainfall rose sharply during 2025 in relative terms, from 4.4 mm to 31.4 mm, while Winter rainfall fell from 17.9 mm to 4.6 mm in 2025. Relative humidity in the pre-monsoon season was marginally higher in 2025 (54.0%) than in 2024 (47.0%), while humidity in the other three seasons remained within a few percentage points across years. Table 3 shows season-wise Mean Meteorological Parameters, South Zone Delhi during 2024 and 2025.

Season wise containers positivity during 2024 and 2025

Table 4 & 5; Figure 4, showed the total number of positive containers 418 recorded in 2024 and 587 in 2025, an

increase of 40.4%. This situation was not uniform across all four seasons: Winter and Pre-Monsoon container counts declined slightly (−11.1% and −10.3% respectively), while Monsoon counts rose from 234 to 305 (+30.3%) and post-monsoon counts nearly doubled, from 108 to 214 (+98.1%), the largest absolute and proportional increase of any

season. Consequently, the monsoon and post-monsoon seasons together accounted for a larger share of the annual container total in 2025 (88.5%) than in 2024 (81.8%), driven primarily by the expansion of the post-monsoon share from 25.8% to 36.5%.

Table 2. Locality-wise containers positivity rate during 2024 and 2025

Locality Type	Number of positive containers in 2024	Number of positive containers in 2025	Difference in % positivity
Slum Settlements	118	156	+32.2%
Urban Village	116	165	+42.2%
High-Income Areas	82	132	+61.0%
Government Institutions	102	134	+31.4%

Table 3. Season-wise Mean Meteorological Parameters, South Zone Delhi, 2024 and 2025

Season	Mean Temp. (°C) in 2024	Mean Temp. (°C) in 2025	Mean Rainfall (mm) in 2024	Mean Rainfall (mm) in 2025	Mean RH (%) in 2024	Mean RH (%) in 2025
Winter (Dec–Feb)	14.6	16.3	17.9	4.6	88	87
Pre-Monsoon (Mar–May)	28.6	28.5	4.4	31.4	47	54
Monsoon (Jun–Aug)	32.0	30.5	200.5	257.2	72	81
Post-Monsoon (Sep–Nov)	25.5	24.6	70.8	99.3	82	81

Table 4. Total positive containers by season (summed across locality categories), 2024 vs 2025

Season	Containers 2024 (n)	Containers 2025 (n)	Change (n)	% Change	Share of Annual Total (2024 -2025)
Winter (Dec-Feb)	18	16	−2	−11.1%	4.3% → 2.7%
Pre-Monsoon (Mar-May)	58	52	−6	−10.3%	13.9% → 8.9%
Monsoon (Jun-Aug)	234	305	+71	+30.3%	56.0% → 52.0%
Post-Monsoon (Sep-Nov)	108	214	+106	+98.1%	25.8% → 36.5%
Annual Total	418	587	+169	+40.4%	100% → 100%

Table 5. Container-wise Comparative Seasonal trends of Aedes larval breeding habitats from January 2024 to December 2025

Container-wise Seasonal trend of Aedes Larval Breeding Habitat from Jan 2024 to Dec 2025																			
Year		2024										2025							
Locality Type	Season	Plastic Container	Earthen Pot	Flower Pot	Cooler	Metal Container	Tyre	Cement Cisterns	Water Tank	Others	Plastic Container	Earthen Pot	Flower Pot	Cooler	Metal Container	Tyre	Cement Cisterns	Water Tank	Others
Slum Settlements (Bengali Camp & Parvatiya Camp)	Winter (Dec-Feb)	4	1	0	0	1	0	0	3	0	3	0	0	1	0	0	0	2	0
	Pre-Monsoon (Mar-May)	6	1	0	8	2	1	0	1	0	3	1	0	6	0	0	0	2	0
	Monsoon (Jun-Aug)	15	9	0	26	4	0	0	2	3	5	27	2	16	15	0	1	1	11
	Post-Monsoon (Sept-Nov)	9	1	0	10	3	2	0	6	0	7	13	2	5	11	8	4	2	8
Urban Village (Munirka Village & Sardulajab Village)	Winter (Dec-Feb)	3	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	3	1
	Pre-Monsoon (Mar-May)	2	1	0	9	3	0	1	0	0	3	1	0	6	0	0	0	4	0
	Monsoon (Jun-Aug)	12	5	0	40	1	0	0	5	4	17	2	1	54	1	0	1	10	3
	Post-Monsoon (Sept-Nov)	11	2	0	9	0	1	1	3	2	11	4	1	29	0	1	1	5	4
High-Income Areas (Asian Games Village Complex & Vasant Kunj)	Winter (Dec-Feb)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Pre-Monsoon (Mar-May)	1	2	2	2	0	0	0	2	1	0	1	2	0	0	0	1	6	0
	Monsoon (Jun-Aug)	5	8	3	7	4	0	0	17	2	7	4	5	3	11	0	3	25	4
	Post-Monsoon (Sept-Nov)	8	7	2	0	3	0	0	4	0	5	5	6	1	2	0	0	37	2
Govt. Institutions (IGNOU & IIT Delhi)	Winter (Dec-Feb)	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2	0
	Pre-Monsoon (Mar-May)	0	2	1	4	1	1	2	1	1	2	3	1	0	0	0	3	6	1
	Monsoon (Jun-Aug)	21	11	4	7	7	1	2	5	4	25	10	2	1	8	3	7	9	11
	Post-Monsoon (Sept-Nov)	8	10	0	1	3	0	0	2	0	14	4	0	0	13	1	1	2	5

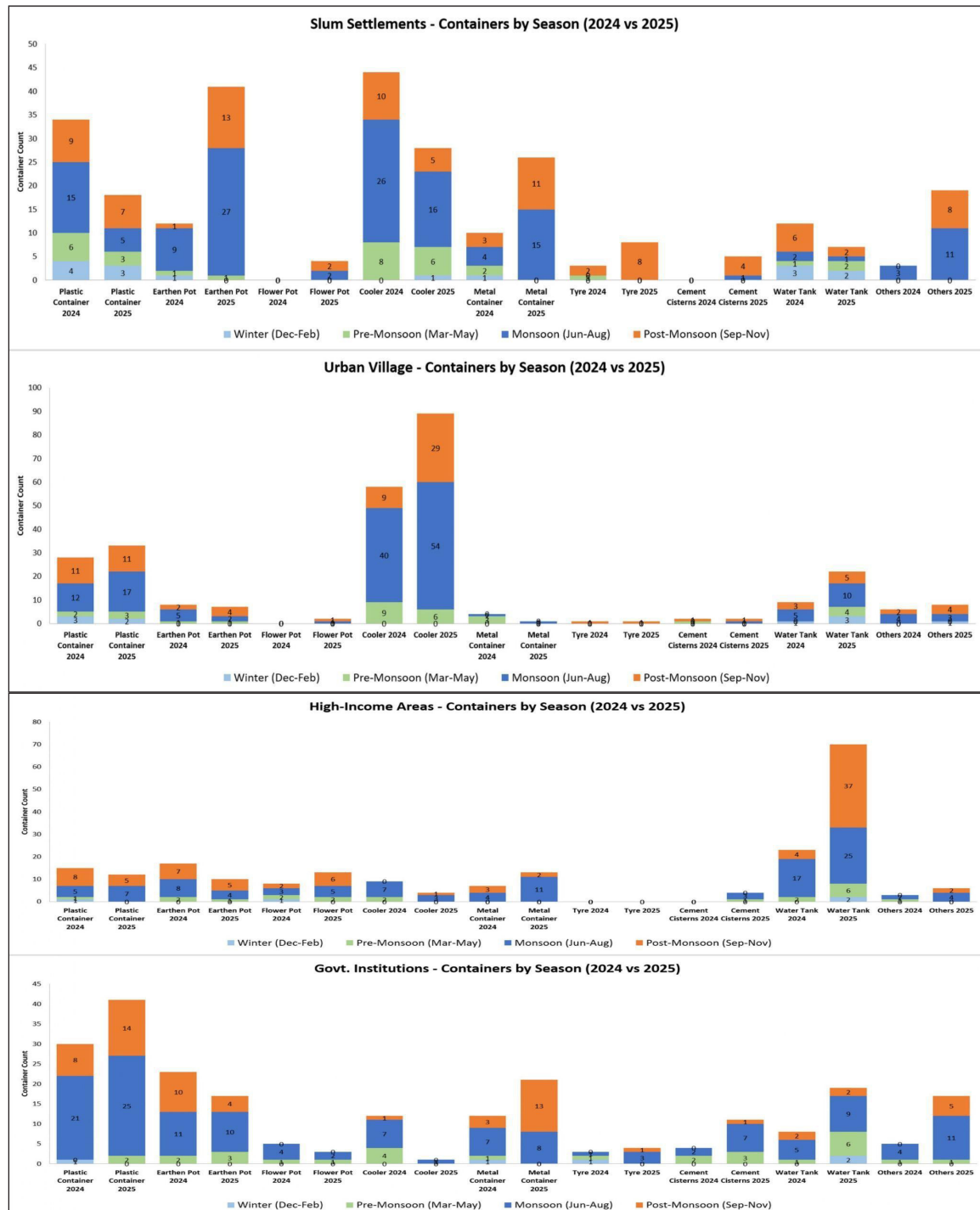


Figure 4. Container-wise Comparative Seasonal Graph of Aedes breeding habitats (2024 vs. 2025)

Container wise seasonal trends in 2024 vs 2025

Two seasonal patterns stand out. First, winter and pre-monsoon counts for metal containers and tyres fell to zero in 2025, from 2 & 6, and 1 & 2 in 2024, respectively, while the same two container types rose sharply in monsoon and post-monsoon of 2025, indicating that the year-on-year increase for these categories was entirely confined to the wetter half of the year. Second, water tanks and cement

cisterns increased in every season without exception, with water tanks showing a particularly steep pre-monsoon rise 4 → 18 (+350.0%) that preceded the monsoon peak, and cement cisterns rising six-fold in both monsoon and post-monsoon (2→12 and 1→6). The “Others” category exhibited the single largest proportional seasonal change in the dataset, rising from 2 to 19 in post-monsoon (+850.0%). Coolers, despite a modest annual decline, showed divergent

within-year movement, a fall in pre-monsoon (23→12, -47.8%) and monsoon (80→74, -7.5%) counter balanced by a rise in post-monsoon (20→35, +75.0%). Container wise and season wise trends for the year 2024 & 2025 are depicted in table number 6.

Table 6. Container wise comparative seasonal trends 2024 vs 2025

Container	Winter 24→25	Pre-monsoon 24→25	Monsoon 24→25	Post-monsoon 24→25
Plastic Container	9 → 5 (-44.4%)	9 → 8 (-11.1%)	53 → 54 (+1.9%)	36 → 37 (+2.8%)
Earthen Pot	1 → 0 (-100%)	6 → 6 (0%)	33 → 43 (+30.3%)	20 → 26 (+30.0%)
Flower Pot	1 → 0 (-100%)	3 → 3 (0%)	7 → 10 (+42.9%)	2 → 9 (+350.0%)
Cooler	0 → 1	23 → 12 (-47.8%)	80 → 74 (-7.5%)	20 → 35 (+75.0%)
Metal Container	2 → 0 (-100%)	6 → 0 (-100%)	16 → 35 (+118.8%)	9 → 26 (+188.9%)
Tyre	1 → 0 (-100%)	2 → 0 (-100%)	1 → 3 (+200.0%)	3 → 10 (+233.3%)
Cement Cisterns	0 → 0	3 → 4 (+33.3%)	2 → 12 (+500.0%)	1 → 6 (+500.0%)
Water Tank	4 → 9 (+125.0%)	4 → 18 (+350.0%)	29 → 45 (+55.2%)	15 → 46 (+206.7%)
Others	0 → 1	2 → 1 (-50.0%)	13 → 29 (+123.1%)	2 → 19 (+850.0%)

Discussion

The two-year entomological surveillance across the eight localities of South Zone, Delhi revealed a consistent, repeatable seasonal cycle in which the House Index (HI), Container Index (CI) and Breteau Index (BI) were lowest during winter, rose modestly in the pre-monsoon period, increased sharply during the monsoon, and then decreased only partially in the post-monsoon months without returning to winter baseline values. This pattern, a rapid monsoon rise followed by a slower, post-monsoon decline is well documented for *Aedes* populations inhabiting monsoon climates and reflects the combined, and somewhat lagged, influence of rainfall, temperature and relative humidity on the vector life cycle.^{13,14} Rainfall creates and replenishes water holding containers, elevated humidity prolongs adult survival and oviposition activity, and the residual water retained in containers after the rains recede sustains breeding well past the point at which rainfall itself has diminished, this explains why the post-monsoon indices recorded in the present study (Slum Settlements HI: 8.1% in 2024, rising to 14.2% in 2025) remained several fold higher than the pre-monsoon values (4.4% and 3.3%, respectively) despite comparable ambient temperatures across the two seasons.

A broadly similar pattern was reported by M. Rajesh Kumar Rao and Rabindra N. Padhy¹⁵ in Angul district, Odisha, where the larval density of *Aedes* species also rose through the monsoon and remained elevated into the immediate post-monsoon months, peaking in October and November (34.3 and 36.2, respectively) before declining in December

and January. An important point of divergence is that the Angul study attributed its highest larval indices explicitly to a period of subnormal rainfall following a comparatively heavy monsoon (cumulative rainfall 266.7 mm from June to September, falling to 25.9 mm from October to December), implying a residual rather than concurrent rainfall effect. In the South Zone Delhi dataset, by contrast, the monsoon season itself carried the single highest indices in both years (e.g., Slum Settlements HI 13.6% in 2024 and 20.0% in 2025), with the post-monsoon representing a decline rather than a continuation of the peak a difference plausibly linked to Delhi's shorter, more concentrated monsoon window compared with the more prolonged, cyclone influenced post-monsoon rainfall documented for coastal Odisha. Seasonal variations study in rural Thiruvavur district, Tamil Nadu, recorded the highest for *Aedes* breeding indices during their "spring" season (August-November, effectively the local post-monsoon), with BI ranging from 16 to 120 and CI from 14.29% to 68.57%, again coinciding with the period of maximum rainfall and moderate temperature. The monsoon–post-monsoon plateau observed in the present study is therefore consistent with the broader South Asian literature, even though the precise month of peak breeding differs regionally according to local monsoon timing.¹⁶

These findings extend a body of Delhi specific surveillance that dates back several decades. Ansari and Razdan (1998) and Katyal et al. (1996).^{17,18} both documented marked seasonal fluctuation of *Aedes aegypti* populations across localities of Delhi, while Sharma et al. (2005)¹⁹ reported that container positivity in Delhi Cantonment declined

in August relative to July and September, a fine-grained fluctuation that the present two-year dataset also captures within-monsoon variability of container-specific. The city's earliest comprehensive *Aedes* survey had found *Aedes aegypti* confined largely to the walled city while *Aedes albopictus* and *Ae. vittatus* dominated the suburbs, and the subsequent detection of *Aedes albopictus* breeding mainly in the wet season while *Aedes aegypti* breeds round of the year²⁰, foreshadows the container type divergence recorded here coolers and earthen pots, favoured largely in Slum Settlements and Urban Village localities and more exposed to seasonal drying, versus water storage tanks, dominant in High-Income areas and retained through the dry season.

A second consistent feature of the results was the locality gradient Slum Settlements > Urban Village > High-Income Areas > Government Institutions, observed across every season and both years for all three indices. This gradient mirrors observation from other Indian urban centres, where informally built, densely housed neighbourhoods with unreliable piped water supply and irregular waste collection sustain higher container and house indices than planned or economically better resourced areas, primarily because residents are compelled to store water in open or poorly covered domestic containers^[21]. The comparatively higher entomological burden recorded in poorer localities is therefore consistent with water storage behaviour rather than climate exposure, since all four locality types experienced an identical meteorological regime. This represents a materially different analytical lens from both comparator studies, Rao and Padhy (2014) reported composite, district wide indices for Angul without disaggregating by socio-economic locality type, while Shukla et al. (2020) compared indices across ten geographically distinct blocks of Thiruvapur district rather than across a socio-economic gradient within a single urban zone. The present dataset therefore offers a complementary, within-city socio-economic perspective that neither comparator study captured, reinforcing the principle that container availability and management practices, and not rainfall alone, mediate the translation of climatic conditions into vector density (WHO Regional Office for South-East Asia, 2011).

The behaviour of the Government Institutions category also merits specific comment, because HI and BI are calculated on a per-house basis, and neither IGNOU nor IIT, Delhi contain "houses" in the residential sense, both indices remained at zero throughout the study, while CI nevertheless rose to 13.0% and 13.5% during the monsoon of 2024 and 2025, respectively. This illustrates a recognised limitation of the classical *Aedes* indices when applied outside conventional residential settings^[22] and indicates that container breeding on institutional campuses is neither

absent nor negligible, even though it is invisible to two of the three standard indices, campus-type premises with laboratories, hostels, gardens and maintenance yards should therefore be assessed principally through container level rather than house-level metrics.

The distribution of positive containers also varied markedly by locality. Coolers were the dominant breeding source in Slum Settlements and Urban Village localities, water storage tanks predominated in High-Income Areas, and plastic containers and earthen pots were the principal sources within Government Institutions. This is consistent with the broader understanding that *Aedes* container preference is governed less by the intrinsic properties of the receptacle than by which containers are locally most abundant, least monitored, and most consistently filled with standing water (Prasad et al., 2023; Ducheyne et al., 2018)^{23&8}. The dominance of desert coolers in the present study aligns with observations from Angul district, where water coolers were recorded as an important artificial breeding habitat for *Aedes aegypti* throughout the year (Rao & Padhy, 2014), and with the Thiruvapur survey, in which open sintex tanks functionally analogous to the water storage tanks recorded here in High-Income areas, contributed substantially to breteau and container indices during the spring season (Shukla et al., 2020). A container type that stood out in the present dataset for its consistency was the combination of plastic containers and earthen pots, which alone among the nine categories sustained low-level positivity through the otherwise near-dry winter and pre-monsoon months in most localities. This "key container" behaviour, which effectively seeds the subsequent monsoon expansion, has previously been highlighted for Delhi by Nagpal et al. (2016)^[24], who demonstrated that targeted removal of a small number of persistently positive container types during the lean season could measurably reduce subsequent vector density; the present findings lend further, locality resolved support to that intervention model, since the specific "key" container differed by locality coolers in Slum Settlements and Urban Village, water tanks and cement cisterns in High-Income areas, and plastic containers and earthen pots in Government Institutions.

The year-on-year comparison provides additional support for rainfall, rather than temperature, as the principal short-term driver of container availability and larval indices in the study area. Between 2024 and 2025, monsoon rainfall rose by 28.2% (200.5 mm to 257.2 mm) and post-monsoon rainfall by 40.2% (70.8 mm to 99.3 mm), while mean temperature in the corresponding seasons changed only marginally (32.0°C to 30.5°C in monsoon; 25.5°C to 24.6°C in post-monsoon). This rainfall increase was accompanied by proportionally larger rises in HI, CI and BI in every locality during precisely those two seasons, most strikingly in the post-monsoon House Index, which

increased by 75% in Slum Settlements, 72% in Urban Village and 115% in High-Income Areas. A comparable climate sensitivity was described by Rao and Padhy (2014), who found the divergence in rainfall and temperature between pre-monsoon, monsoon and post-monsoon periods in Angul to be statistically significant ($p < 0.05$) and identified rainfall, temperature and relative humidity collectively as the major determinants of larval density. The present two-year Delhi dataset extends this observation by showing that even modest inter-annual rainfall variation, without any comparable shift in temperature, is sufficient to produce a substantial shift in vector breeding intensity within the same set of localities. This finding carries a direct operational implication, forecasting or early-warning systems for *Aedes*-borne disease risk in Delhi may derive more predictive value from short-term rainfall anomaly monitoring than from temperature monitoring alone, echoing the emphasis placed on rainfall-linked risk mapping in global dengue prevention strategy documents.²⁵

It is important, however, to interpret these entomological findings cautiously in relation to actual dengue transmission risk. A systematic review by Bowman et al. (2014) found no consistent, quantitatively reliable relationship between conventional larval indices (HI, CI, BI) and confirmed dengue case incidence across the majority of studies examined, a caveat that applies equally to the present dataset, to the Angul findings of Rao and Padhy (2014), and to the Thiruvavur findings of Shukla et al. (2020), all of which infer epidemic risk primarily from larval density rather than from paired case-surveillance data. Underreporting compounds this uncertainty a substantial proportion of dengue infections are asymptomatic or sub-clinical and are consequently never captured by passive case surveillance⁴, meaning that the true burden of transmission risk associated with the elevated monsoon and post-monsoon indices recorded in this study cannot be established from the entomological data alone. The scope of the present study of an immature-stage survey without concurrent adult mosquito collection, viral testing, or species-level confirmation of container-wise breeding further limits the extent to which the observed patterns can be linked mechanistically to the local *Ae. aegypti*/*Ae. albopictus* balance described elsewhere in the literature.^{4&21}

Taken together, the results support three practically relevant conclusions. First, the consistent seasonal rise-and-plateau pattern observed across all eight localities confirms that vector control resources in South Zone Delhi should be pre-positioned before, rather than during, the monsoon, targeting the specific key containers already carrying low-level positivity in winter and pre-monsoon. Second, the persistent locality gradient indicates that a single citywide intervention strategy is unlikely to be equally effective across socio-economic strata; slum settlements and

urban villages, where cooler based breeding predominates, require different messaging and physical intervention (e.g., weekly cooler-emptying drives) from high-income colonies, where periodic water-tank inspection and covering would likely yield greater returns (Nagpal et al., 2016). Third, the sensitivity of larval indices to inter-annual rainfall variation observed here, consistent with the climatic associations reported for Angul (Rao & Padhy, 2014) and Thiruvavur (Shukla et al., 2020), reinforces the case for integrating short-term rainfall forecasts into locality-specific dengue early-warning systems rather than relying on fixed calendar-based vector-control schedules. As recommended in both comparator studies, these entomological observations should nonetheless be corroborated with adult vector surveillance and dengue case data before being used to prioritise or reallocate vector-control resources, a step recommended as a direct extension of the present two-year survey.

The present study measured larval indices rather than adult vector density or confirmed dengue incidence, and the relationship between larval indices and actual transmission risk is known to be inconsistent, Kumar et al., 2014.²⁶

Conclusion

This two-year entomological surveillance of eight localities across five wards of South Zone, Delhi demonstrates a repeatable seasonal cycle in *Aedes* larval indices, rising from a winter low, through a modest pre-monsoon increase, to a sharp monsoon peak that eases only partially through the post-monsoon months rather than falling straight back to baseline.

A second, equally consistent finding was the socio-economic gradient in breeding intensity, Slum Settlements > Urban Village > High-Income Areas > Government Institutions, observed in every season of both years. This locality ranking, together with the marked differences in the dominant breeding container by locality (coolers in Slum Settlements and Urban Village, water storage tanks in High-Income Areas, and plastic containers and earthen pots in Government Institutions), indicates that housing density, water-storage practice and premises type, and not climatic exposure alone, jointly determine where *Aedes* breeding concentrates within a single urban zone.

These findings support a locality-specific, container targeted approach to *Aedes* control in South Zone Delhi, with source reduction and health education activities front-loaded into the winter and pre-monsoon lean period rather than initiated only once the monsoon has already begun. Cooler emptying drives are likely to yield the greatest return in slum settlements and urban villages, whereas periodic inspection and covering of water storage tanks would be more relevant to high-income colonies, and container level

(rather than house level) monitoring is required to capture breeding on institutional campuses, where the House and Breteau Indices are structurally inapplicable. A logical next step, consistent with the recommendations of both comparator studies, would be to corroborate these two years of immature stage surveillance with adult mosquito collection, species-level confirmation of container wise breeding, and locality matched dengue case data, so that the locality and container specific patterns identified here can be translated into a validated, evidence-based vector control prioritisation plan for South Zone Delhi.

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