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Water quality index of *Aedes aegypti* (L) breeding sites in southern coastal areas of India

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Abstract

Background/Objectives: Breeding habitat can influence the biological features of the mosquitoes and can be utilized to improve the implementation of the vector control. The major objective of this study was to evaluate the Water Quality Index of various breeding sites. **Methods/Statistical analysis:** Community Development Blocks (n=9) of the Kanyakumari district were selected as the main research site to study the water quality characteristics of *Ae. aegypti* mosquitoes' breeding sites. The physicochemical parameters in the mosquito breeding containers were analyzed. **Findings:** Sixteen types of breeding sites were analyzed, among them nine breeding sites had good quality of water and remaining seven breeding sites contained slightly polluted water. **Novelty/Applications:** The awareness of water quality parameters of mosquito breeding sites can be used in the adoption of preventive methods.

Keywords: Community development blocks; Physico-chemical parameters; *Aedes aegypti*; Breeding sites

1 Introduction

Aedes aegypti mosquitoes are competent vectors of several pathogens of human health importance such as chikungunya, dengue, yellow fever, and Zika viruses that causes dangerous diseases like dengue, yellow fever, and chikungunya⁽¹⁾. Among them, dengue fever has become an important public health problem as the number of reported cases continues to increase, especially with more severe forms of the disease such as dengue haemorrhagic fever, dengue shock syndrome and unusual symptoms in central nervous system⁽²⁾.

The selection of suitable breeding sites to lay eggs is basic to the distribution and establishment of *Ae. aegypti* population. The activities like reproduction, aggregation and offspring production are controlled by chemical methods. They are attracted towards the odour depending on the nature of the stimulus. Females use their olfactory sense to select a place with the nutrients necessary for the development of the larvae. This factor is essential, not just to enhance the chances of survival, also in guaranteeing

the emergence of many *Ae. aegypti* adults⁽³⁾. *Ae. aegypti* may prefer containers as a favorable breeding source because of conducive water quality characteristics. These mosquitoes primarily breed in artificial water containers and its life cycles are closely related to human activities. The abundance of mosquitoes has a negative effect on the quality of life of humans and their environment⁽⁴⁾. In urban areas, mosquitoes are prone to utilize water-filled containers in the development of immature life stages. Most of the mosquito species prefer to ovipositor in shaded areas⁽⁵⁾. Water conditions, location, presence of larval nutrient and shade are the factors in the selection of breeding sites⁽⁴⁾. Study on the dengue vector distribution along with the water quality can provide an insight to the complexity of the dengue outbreak.

The types of containers, physicochemical parameters of water, and conditions of water containers are essential for the breeding of *Ae. aegypti*. Embryonic development of mosquitoes is influenced by water temperature. *Ae. aegypti* can tolerate both acidic and basic conditions of water. The mechanisms used to regulate body pH in acidic and alkaline conditions are not mutually exclusive, maybe physically by acid-base secreting intercalated cells of the mammalian nephron. Aquatic insects fully depend on epithelial transport across renal systems for acid-base homeostasis. Most of the studies revealed that a tough relationship exists between the water acidity and the composition of the macro invertebrate community⁽⁶⁾.

The physicochemical analysis of water is the most important aspect to determine the quality of lotic water for its best uses, certain water quality indicators must be monitored and controlled. In physicochemical parameters, temperature controls the rate of metabolic and reproductive activities of aquatic organisms. P^H is an indicator of the acidic or alkaline condition of the water. The aquatic life tends to be very sensitive towards P^H . The measure of water capacity to convey an electric current is the electrical conductivity. It brings to the measurement of total dissolved solids in water. Total dissolved solids (TDS) indicate the number of ions present in the water and an analysis of the quality of water. High TDS in water reduces clarity in water and decreases photosynthesis in aquatic plants. Dissolved oxygen indicates the ability of water to support aquatic life. Biological oxygen demand measures the amount of food for bacteria in water. Total hardness mainly depends on the calcium and magnesium salts. The increase of nitrate, calcium, and magnesium causes eutrophication which affects the water quality.

Water quality index (WQI) helps to calculate a large amount of data into simple terms such as excellent, good and bad. Based on many water quality parameters, a water quality index provides a single number that expresses the overall water quality at a certain location and time. WQI can be used as a tool in comparing the water quality of different sources and a general idea of the possible problems with water in a particular location. These indices are among the most effective ways to communicate the information on water quality trends for quality management⁽⁷⁾.

WQI can assist in the establishment of priorities by providing numerical data on overall water quality in regular water samples instead of evaluating the breeding site in specific water quality parameters⁽⁸⁾. It provides overall idea about the nature of aquatic habitats of *Ae. Aegypti*, this includes Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Total Dissolve Solids (TDS), Total Hardness, Nitrate, Chloride, Calcium and Magnesium presence in the water in a single and understandable number. The method to identify, label and classify organisms is largely built around morphological characteristics. Therefore, the present study investigated and identified *Ae. aegypti* mosquitoes' breeding performance in natural and artificial water containers that serve in the potential dengue fever (DF) transmission in Kanyakumari district. The results would enable to provide awareness about *Ae. aegypti* mosquitoes' aquatic habitats and preventive measures necessary.

2 Materials and methods

2.1 Study Area

Community Development Blocks (n=9) of the Kanyakumari district were selected as the main research sites to study the water quality characteristics of *Ae. aegypti* mosquitoes' breeding sites. The selected landscape characteristics of this area include the developing urban areas and rural areas. The major land-use in this area is residential and commercial. The map in [Figure 1](#) shows the locations of the study area included for the study.

2.2 Mosquito Sampling

The selection of the localities was based on the constant occurrence of dengue fever cases for two years (2017-2019). The water-holding containers were visually inspected for the presence of water with *Ae. aegypti* immature mosquitoes such as larvae and pupae. All the water-holding containers detected during the survey were counted and classified into 16 categories based on the breeding site identity (BSID). The factors for the categories of BSID were based on observed at the sampling sites were, they are BS1: Plastic tubs; BS2: Flower vases; BS3: Buckets; BS 4: Drums; BS5: Earthen pots; BS6: Vehicle Tires; BS7: Coconut shells; BS8: Plastic sheets; BS9: Glass materials; BS10: Water Reservoirs; BS11: Discarded shoes; BS12: Dust carriers; BS13: Ant guards;

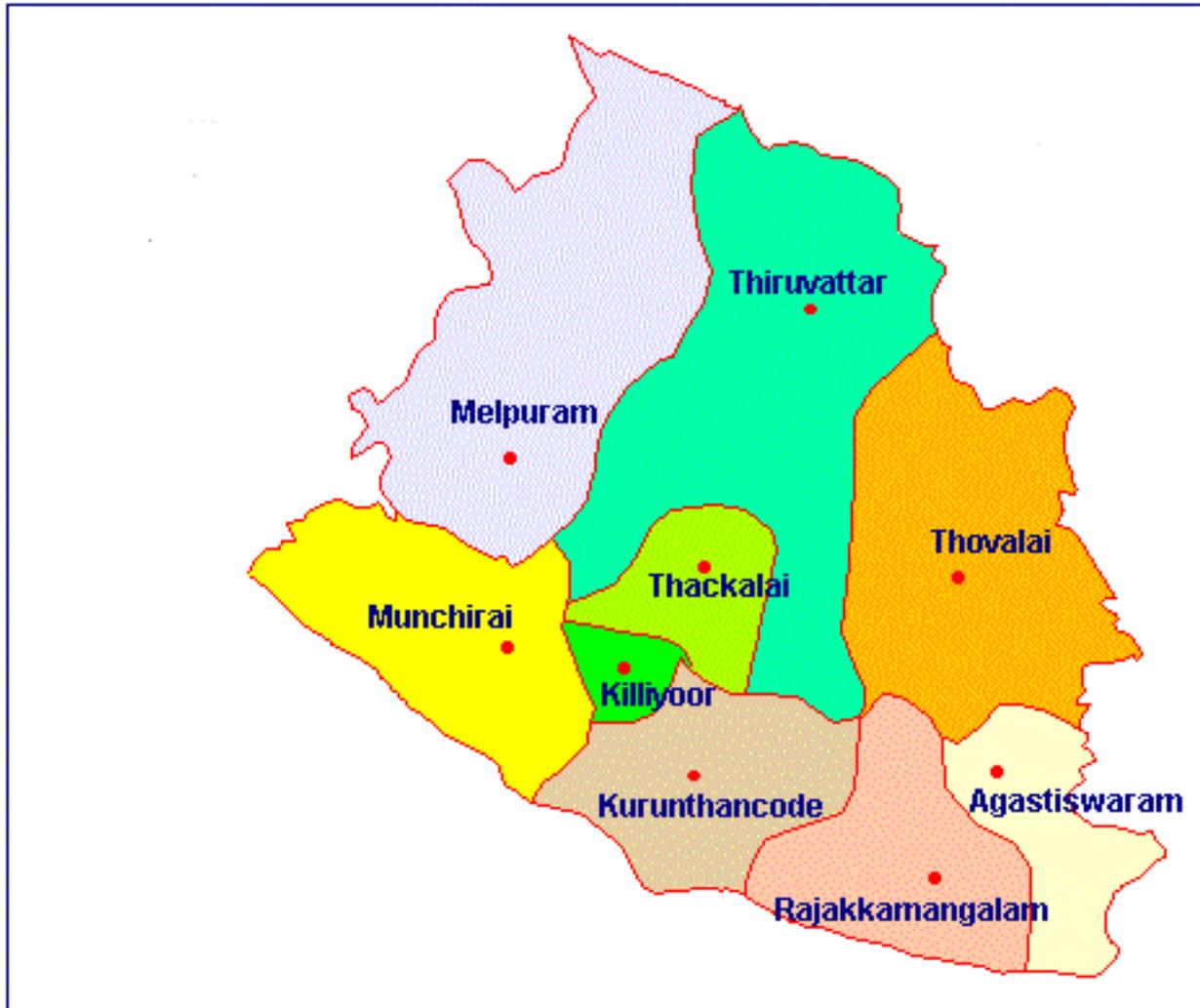


Fig 1. Map showing the location of the study area

BS14: pile of metals; BS15: Waste water from refrigerators and BS16: Tree holes and leaves.

2.3 Measurement of Water Quality Parameters

Eleven parameters were considered to assess the water quality characteristics of *Ae. aegypti* breeding sites, which included physicochemical parameters. A physical analysis of water in the breeding habitat was performed in-situ. Temperature (°C) of water before sampling, were tested on-site at the time of collection with the help of a thermometer. The physicochemical parameters like Electrical Conductivity, pH, Calcium, and Magnesium were analyzed according to standard methods prescribed by the Government of India⁽⁹⁾. Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Solids, Total Hardness, Nitrate, and Chloride were analyzed according to standard methods as per American Society for Testing and Materials International⁽¹⁰⁾.

2.4 Calculation of the Water Quality Index (WQI)

The calculation of the WQI was done using a weighted arithmetic water quality index, which was suggested by Brown et al.⁽¹¹⁾. Weighted arithmetic water quality index (WQI) was calculated by using the following equation,

$$WQI = \frac{\sum N_1 R_1}{\sum N_1} \tag{1}$$

Where,

R_1 = Quality rating for the nth water quality parameter,

N_1 = Unit weight for nth water quality parameter.

The unit weight (N_1) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters. The value of R_1 is calculated using the following equation:

$$R_1 = 100 (OV_n - OV_{10}) / (OS_n - OV_{10}) \tag{2}$$

Where,

R_1 = Quality rating for the nth water quality parameter,

OV_n = Estimated value of the nth water quality parameters of the collected sample,

OS_n = Standarded permissible value of the nth water quality parameter,

OV_{10} = Ideal value of the nth water quality parameter in pure water.

(i.e. 0 for all other parameters except the parameter for PH and DO (7 and 14.6 mg/l respectively). For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH was calculated from the following equation:

$$R_{pH} = 100 (OV_{pH} - 7.0) / (8.5 - 7.0) \tag{3}$$

Where,

OV_{pH} = observed value of pH.

For dissolved oxygen, the ideal value is 14.6 mg/l and the standard permissible value for drinking water is 5 mg/l. Therefore, its quality rating is calculated from the following equation:

$$RDO = 100 (OV_{DO} - 14.6) / (5.0 - 14.6) \tag{4}$$

Where,

OV_{DO} = observed value of dissolved oxygen.

The unit weight (W_n) for each water quality parameter is calculated by the following formula

$$N_1 = K/OS_n \tag{5}$$

Where,

K = proportionality constant

Table 1. Water quality index level with water quality status

Sl. No.	water quality index level	water quality status
1	0-25	Excellent
2	26-50	Good
3	51-75	Poor
4	76-100	Very poor
5	Above 100	contaminated water

3 Results and Discussion

Sixteen types of breeding sites were analyzed, among them nine breeding sites had good quality of water and remaining seven breeding sites contained slightly polluted water. The water had become polluted due to the storage of the water in the container for long period with ambient relative humidity and temperature, which favor the mosquitoes to breed. The results found here implies that *Ae. aegypti* can thrive in a variety of habitat with clear, turbid or polluted, which are used for drinking or washing. *Ae. aegypti* more commonly prefer outside areas such as open spaces with shaded vegetation, car tyres, plastic sheets and coconut shells.

In the present study the calculated water quality index of BS1, BS2, BS3, BS4, BS5, BS6, BS7, BS8, BS9, BS10, BS11, BS12, BS13, BS14, BS15 and BS16 were 46.15, 48.74, 50.50, 52.19, 45.113, 46.053, 50.877, 50.448, 40.133, 52.711, 50.225, 48.199, 54.184, 47.408, 43.385 and 49.058 respectively. The physico-chemical parameters in the mosquito breeding containers were found to be

ranging from, 38.41 ± 0.05 to 50.6 ± 0.02 , 7.2 ± 0.01 to 7.8 ± 0.1 , 4.67 ± 0.01 to 8.5 ± 0.07 , 3.42 ± 0.2 to 5.23 ± 0.05 , 35.2 ± 0.07 to 58.6 ± 0.01 , 4.9 ± 0.05 to 8.23 ± 0.05 , 0.31 ± 0.1 to 0.82 ± 0.07 , 3.7 ± 0.01 to 5.7 ± 0.1 , 1.02 ± 0.01 to 1.49 ± 0.07 and 0.72 ± 0.05 to 1.07 ± 0.2 for Conductivity, pH, DO (mg/L), BOD (mg/L), TDS (mg/L), Total Hardness (mg/L), Nitrate (mg/L), Calcium (mg/L), Magnesium (mg/L) and Chloride (mg/L) respectively (Table 2).

Table 2. Water Quality Index (WQI) in *Ae. aegypti* Breeding Sites

Sl. No.	BSID	Types of breeding sites	WQI= $\frac{\sum W_n Q_n}{\sum W_n}$
1	BS1	Plastic tubs	46.152
2	BS2	Flower vases	48.741
3	BS3	Buckets	50.504
4	BS4	Drums	52.190
5	BS5	Earthen pots	45.113
6	BS6	Vehicle tyres	46.053
7	BS7	Coconut shells	50.877
8	BS8	Plastic sheets	50.448
9	BS9	Glass materials	40.133
10	BS10	Water Reservoirs	52.711
11	BS11	Discarded shoes	50.225
12	BS12	Dust carriers	48.199
13	BS13	Ant guards	54.184
14	BS14	Group of metals	47.408
15	BS15	Waste water from refrigerators	43.385
16	BS16	Tree holes and leaves	49.058

The results of the present study correlates with the study of Tiimub et al.⁽¹²⁾ reported that the levels of physico-chemical parameters in the mosquito breeding waters which were found to be ranging from $17.03 \pm 0.18^\circ\text{C}$ - $24.06 \pm 0.18^\circ\text{C}$, $17.03 \pm 4.04\text{mg/L}$ - $96.67 \pm 4.04\text{mg/L}$, $1.09 \pm 3.23\text{mg/L}$ - $35.67 \pm 3.23\text{mg/L}$, $3.97 \pm 0.13\text{mg/L}$ - $7.43 \pm 0.13\text{mg/L}$, 17.00 ± 1.30 - 83.00 ± 1.30 and 7.77 ± 0.0 - 10.70 ± 0.01 for Temperature, TSS, TDS, DO, EC and pH respectively.

The graph in the Figure 2 shows the Water Quality Index of various breeding sites with *Ae. aegypti*. The results were relatively much lower when compared to their corresponding EPA Maximum Permissible Limits of $< 3^\circ\text{C}$, 1000 mg/l, 50 mg/l, 50 mg/l, 1500 mg/l and 6–9 for water that are likely to be polluted. The mean differences between all the physicochemical parameters were generally statistically significant at approximately $P < 0.005$ between the two control sites. In the rest of the ordinary sampling sites, even though between the two control sites, there were no significant differences observed.

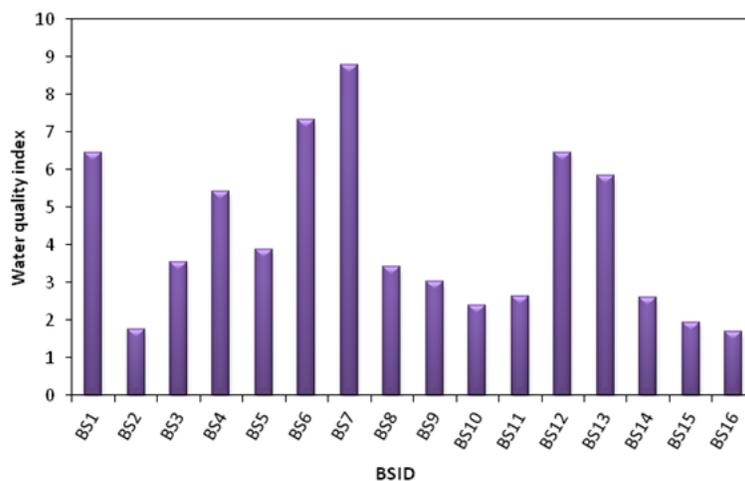


Fig 2. Water Quality Index of various breeding sites with *Ae. aegypti*

Temperature and pH were both associated with an increase or decrease in larval density. In the present study across all breeding sites, water mean pH ranged from 7.2 to 7.8 and temperature ranged from 25°C to 27°C. Sanford⁽¹³⁾ reported that pond water temperature affects both spawning and growth of mosquito larvae and pupae. The mean temperatures of the water sites ranged between $17.03 \pm 0.18^\circ\text{C}$ to $24.06 \pm 0.18^\circ\text{C}$.

Breeding sites with high pH range are not ideal for mosquito breeding and survival due to free ammonia, which tends to increase with rising pH. The neutral pH range from 6.8 to 7.2 was a preferred breeding site by mosquitoes. Therefore, outside this range mosquito eggs, larvae and pupae growth were reduced and at the pH range below 4.5 or above 10, mortality occurs. *Ae. aegypti* have inability to survive and develop in waters with pH ranging from 4 to 11. They regulate hemolymph pH over this pH range. Even more notable is their ability to tolerate abrupt transfer from one extreme of this pH range of the other. The results of this study found that the *Ae. aegypti* mosquitoes prefer to oviposit in slightly alkaline water. Earlier studies reported that Aedes species had an inclination for a narrow pH range (6 - 8), while Culex and Armigeres occurred in the broader range of pH 6-10⁽¹⁴⁾.

Adebote et al.⁽¹⁵⁾ reported that mosquitoes breeding in rock pools on Inselbergs around Zaria, Northern Nigeria determined the pH level of pools that supported Aedes vittatus breeding to be ranging from 5.97 to 9.85. From this result, it can be observed that *Ae. vittatus* has wider pH level tolerance compared to other mosquito species such as Anopheles ardensis, Anopheles distinctus, Anopheles wilsoni, and Culex ingrami. Filter feeding mosquitoes require fresher, transparent and more oxygenated waters to complete its life cycle. Therefore more suitable Dissolved Oxygen (DO) requirement is essential for the development of *Ae. aegypti*. Low level DO of aquatic habitat indirectly reduced the TSS and TDS concentrations. Higher concentrations of TSS and TDS may reduce transparency and increase oxygen deficiency. High concentrations of these parameters can be harmful to some species of mosquitoes.

3. Conclusion

Ae. aegypti is the vital species found in rubber estates because coconut shells are used to collect rubber milk. Kanyakumari district has lots of rubber plantation areas. Commonly used discarded materials also act as the favorable breeding places of these dengue vectors. The knowledge of water quality parameters of mosquito breeding sites can be used to for the adoption of preventive methods during the pre-monsoon season. It is one of the source reduction activities which are area specific, but can be implicative for control of mosquito borne diseases all over the globe.

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