International Journal of Ecology and Environmental Sciences 48: 409-421, 2022
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2022.0409

Physicochemical Characterization of the Breeding Habitats of *Aedes* Mosquito Species in the Southern Districts of West Bengal, India

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ABSTRACT
Aedes sp. are considered to be the primary vector for the transmission of arboviral diseases including Dengue fever. Infections are reported from new areas of the state of West Bengal indicating the dispersal of the vectors. Physicochemical factors of the container habitats influence the oviposition behaviour of the mosquito and the larval density. The information on distribution of the vector is essential for designing and implementing any vector control strategy effectively. Cross sectional random samplings were done from 65 locations of 13 districts in the southern region of the state of West Bengal, India. The potential habitats were located, water sample from those habitats as well as the mosquito life stage were collected for further study. There were more prevalence of *Aedes albopictus* (81.33%) in comparison to *Aedes aegypti* (14.67%) in the region, whereas in a few location we found co-occurrence (4.00%). The mean larval density of the districts shows statistically significant difference ($p<0.05$). A strong positive correlation was found between the larval density and conductivity (Pearson's correlation coefficient, $r = 0.57$), TDS ($r = 0.56$) and Nitrite-Nitrate (NO_2-NO_3) concentration ($r = 0.51$) of the water of the container habitats. Strong negative correlation ($r = -0.59$) was observed between larval density and Cl^- concentration. Principal component analysis revealed a four component solution explaining a total of 64.1% of the variance, with Component 1, 2, 3 and 4 contributing 31.8%, 13.6%, 10.3% and 8.4% respectively. The study revealed the distribution of *Aedes* mosquitoes in the study region, its dispersal, successful thriving and tolerance to a wide range of physicochemical parameters in the region of the southern West Bengal, which certainly have implications to the prevailing vector control measures. Environmental manipulation with respect to certain parameters may be helpful in vector control and preventing the outbreak of dengue in future.

Keywords: Dengue, *Aedes aegypti, Aedes albopictus*, Physicochemical characteristics, Container habitats, Southern West Bengal.

INTRODUCTION

Dengue is recognized as one of the major threat to global health and is a major public health concern with rapidly evolving epidemiology in the tropics and subtropics (WHO 2019). In Indian scenario also, it is emerging as the most common Vector Borne Disease. The disease is endemic for all the 28 states and 8 Union Territories in India (NBVDCP 2020). Dengue fever had a predominant urban distribution even a few decades ago but currently it reported from peri-urban as well as rural areas too (Vong et al. 2010, Chakravarti 2012, Diaz-Nieto et al. 2013, Guagliardo et al. 2014).

Dengue is an arboviral vector borne disease, transmitted by the bite of infected female *Aedes* mosquitoes (WHO 2011). The most important vectors of dengue fever virus are *Aedes aegypti* and *A. albopictus* (Knudsen 1995). Infection with dengue has now extended to new areas where it has not been reported previously (Getachew 2018). The distribution and abundance of arthropod vectors of disease in the newer areas are determined by the very complex interaction of a range of ecological, climatic and environmental variables (Silver 2008).

Aedes mosquitoes find suitable breeding sites due to the population growth, unplanned urbanization and poor water management systems (Kyle 2008). The breeding sites mainly comprised of domestic water storage containers in and around human dwellings (Chareonviriyaphap et al. 2003). *A. aegypti* and *A. albopictus* prefer to lay their eggs in artificial containers (Guillena 2010) generally close to human habitation. The most productive and permanent containers serving as breeding ground for *Aedes* mosquitoes are ground tanks and concrete washbasins for laundry, whereas other non-permanent containers, such as bottles, cans, tires, etc., are only productive during the monsoon and produce low numbers of pupae (Romero 2006, Quintero 2014). Availability of nutrients in the container habitats is critical for mosquito development and may affect mosquito size and survival (Briegel 1990), which in turn may affect the outcome of the vector-borne disease (Sumanochitrapon 1998). A typical skip oviposition behaviour observed in female *A. aegypti* may be regulated by the presence and abundance of conspecifics (Gonzalez 2016). Mosquito oviposition behaviour is known to be influenced by visual, tactile, and olfactory cues, including physico-chemical properties of the water of the container (Bentley 1989). Water characteristics of breeding places play an important role for oviposition and development of mosquitoes (Piyaratne 2005).

Knowledge of the ecological factors affecting mosquito larval biology such as the physicochemical properties of the water of the breeding places and interspecific associations are essential for understanding the survival and spatio-temporal distribution of mosquitoes (Bashar 2016). This background information may serve as the basis for designing and implementation of adequate and effective vector control programs (Mousson et al. 2005) also helps in understanding the vector distribution pattern and mechanism in a specific region (Naoko 2014).

Despite the various existing literature on the distribution of mosquito larvae and physicochemical factors, it seems to be inconclusive in leading to a prediction of the presence of larvae in such a wide variety habitat. Therefore, more studies and systematic reviews in this domain with proper generalization are required.

The region of Gangetic West Bengal possesses diverse demographic and socioeconomic background is recorded to have several incidences of dengue outbreak in the past decade (Majhi 2020) but adequate data is lacking about the distribution of the *Aedes* mosquitoes in this region. The nature and distribution of the habitat types in the study region is least explored except few discrete areas. The present study was conducted to analyse and document the relationship between the physicochemical characteristics of larval habitats and the mosquito distribution in the study region comprising 13 districts.

MATERIALS AND METHODS

Study sites

The study was carried out during April, 2019 to March, 2020 in the area located in 13 districts (namely Murshidabad, Birbhum, Bankura, East- and West - Bardhaman, Nadia, Hooghly, Howrah, Kolkata, North and South 24 Parganas, Purba- and Paschim Medinipur) of the southern region in the State of West Bengal, India designated as the Gangetic West Bengal having tropical savanna, hot and usually dry climate (IMD 2008). The study area comprises of Urban, Suburban and Rural areas having different population structures with inhabitants of varying socioeconomic backgrounds. Cross-sectional random sampling was done from different locations of the above-mentioned districts during different season of the year. Sites were selected on the basis of previous report of infection of dengue available in the IDSP portal of Government of India (IDSP 2019). Five locations for each district were selected for sampling. Periodic surveillances were conducted in the selected sites during different months of the year.

Mosquito Specimen collection and identification

Selected locations were visited and the potential habitats were searched for the presence of any stages of the *Aedes* mosquito. For each site 10-20 houses were selected scattered in the area. The potential container habitats were examined thoroughly for any of the stages of *Aedes* mosquitoes (Eggs, larvae, pupae and adult).

In every site we searched for every possible habitat for *Aedes* sp. like artificial or man-made or natural places that has a chance of water logging. Since there is no fixed recommended size of dippers for collection of larvae of *Aedes* mosquito, dippers of variable sizes were used for larval and pupal collection ranging from 50 ml to 250 ml capacities depending on the water availability in the container habitats. Small pipettes of 3-5 ml capacities or spoon were also used for collection of specimen at sites where water quantity is too low (Srivastava 2016, Service 1993, ECDC 2014, Norbert et al. 2004). A minimum of 10 and maximum of 15 dips were given depending on the water availability in the container habitats. The total number of larvae divided by total number of the dips were calculated for per dip larval density of each habitat. A few of the larvae were collected and brought to the Laboratory for microscopic analysis, identification and documentation. Microscopic slides were prepared from the collected larvae and were identified by their morphological features using appropriate keys (Norbert et al. 2004, Andrew 2013, Leopold 2004). The geographic coordinates of the location were also noted using Google map feature of the smartphone.

Water collection from the container habitats and analysis

Water samples were collected in plastic bottles from each of the container habitats where any of the life history stage was found, and the sample were fixed using standard procedure for further analysis of the physicochemical parameters (APHA 2017). Parameters such as Temperature (Environmental and water), total dissolved solute (TDS), humidity and electrical conductivity (EC) were measured in the spot using digital meters (Divinext make). The previously fixed sample were analyzed in the laboratory for the following parameters- pH, alkalinity, hardness, concentration of Potassium (K^+), Sodium (Na^+), Nitrite-Nitrate (NO_2-NO_3), Sulphate (SO_4), Chloride (Cl^-), Level of free Carbon di oxide (CO_2), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and the amount of dissolved organic matter (DOM) in the water sample. pH of the water sample was analyzed using pH meter (Systronics), Concentration of Sodium and Potassium were analyzed using flame photometer (Systronics Flame Photometer-130, India). Concentration of Nitrite, Nitrate and Sulphate were analysed using Spectrophotometer (Systronics-118). All the remaining parameters were analyzed using titrimetric method (APHA, 2017).

Statistical analysis

All the previously recorded data of the larval density and the various physicochemical parameters of the water sample were tabulated using MS excel-2019. The raw data were then rearranged and subjected to various parametric statistical tests since the data satisfied the assumptions. Pearson Correlation was computed to determine any significant relation between the variables Principal component analysis (PCA) was done for summarizing by transforming the variables into a smaller set of linear combination (Julie 2016). The statistical analyses were done using SPSS version 28.0.

RESULTS

Among the surveyed sites in the different locations of the 13 districts, there were more prevalence *Aedes albopictus* (81.33%) in comparison to *Aedes aegypti* (14.67%) and at a few location we found co-occurrence (4.00%) of both the species 9 (Fig. 1). Test of Normality of the data were performed using Kolmogorov-Smirnov test, the data fulfils the normality assumptions and thus parametric statistical methods were chosen for analysis.

The larval density of the *Aedes* mosquitoes among the 13 districts (Fig. 2) under study ranges between 0.08 to 20.47 with mean of 8.09 larva per dip. The density of the larva (mean ± SD) was found to be highest in Kolkata (14.98±3.84) followed by North 24 Parganas (10.85±4.53) and Murshidabad

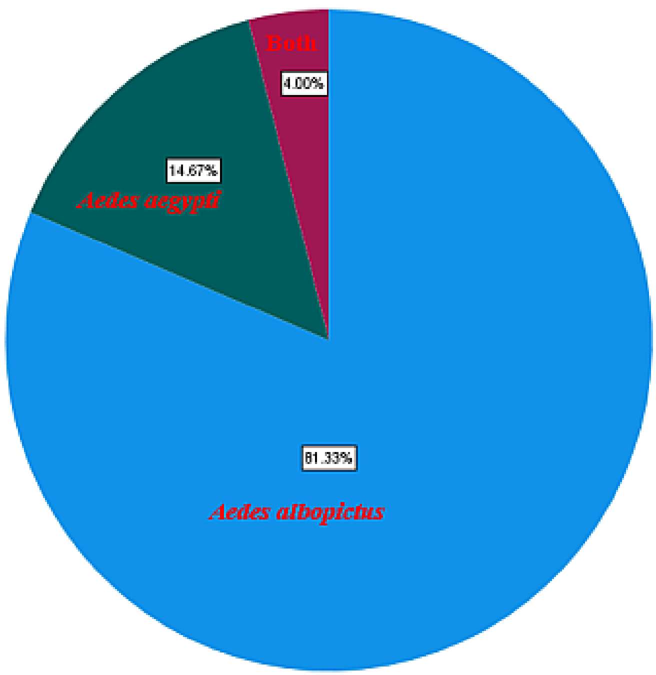

Figure 1. Prevalence and distribution of *Aedes* sp. mosquitoes in the southern districts of West Bengal, India

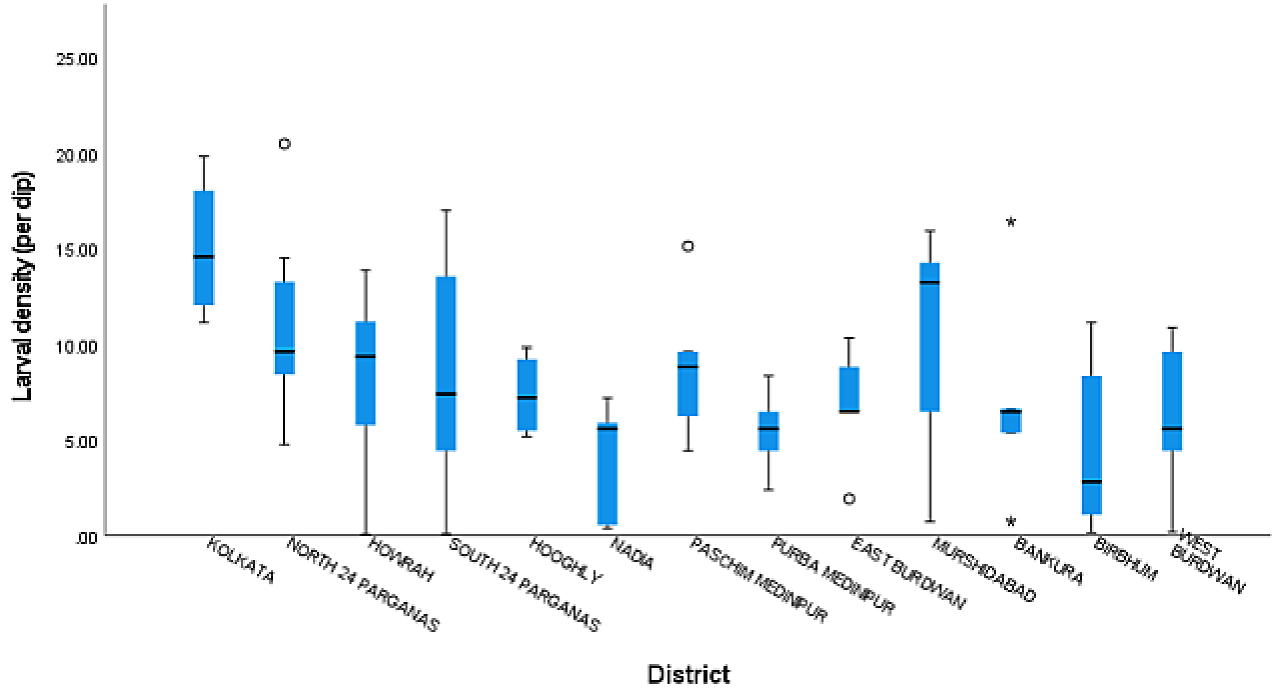

Figure 2. Box plot of the district wise larval density

(10.09±6.13). The lowest density was observed in Nadia district (3.90±3.19) preceded by Birbhum (4.68±4.79) and Purba Medinipur (5.41±2.23). Analysis of variance (ANOVA) between-groups shows statistically significant difference at $p < 0.05$ between the groups F (12,62)= 2.11, p=0.03. Post-hoc comparisons using the Tukey HSD test indicated that the mean density for Nadia district (3.90 ± 3.19) significantly differ from that of Kolkata (14.98 ± 3.84). However, the larval density did not vary significantly among any other districts under study ($p > 0.05$).

The mean ambient temperature (°C) (mean ± SD) in the studied districts during the period of study was found to be (29.65±3.67) with a highest record of 38°C from Howrah and lowest record of 23°C from East Burdwan. The humidity during the same time ranges from 43% to 96% recorded from East Burdwan and Hooghly district, respectively, with mean of 67.6%. There is a significant difference in temperature among the different districts of the region F (12, 59) = 15.42 ($p<0.001$) and humidity. F (12,57) =12.990 ($p<0.001$).

Among the analysed physicochemical parameters (Mean±SD) of the breeding habitats of the *Aedes* mosquitoes (Tables 1 and 2) the average water temperature (°C) from the breeding habitats was found to be (26.74 ± 3.6) with highest record of (31.02 ± 1.87) in Howrah district and Lowest temperature of (22.4 ± 2.3) in Burdwan district. The means of the different districts vary significantly. F (12,59) = 15.42, $p<0.001$. pH of the water of the breeding habitats ranged between 6.08(Howrah) and 9.19 (North 24 Parganas) with an average of (7.23 ± 0.60). The DO (mg/L) level varies between 0.30 to 12.20 with an average of (5.77 ± 2.76). Highest value was observed in Kolkata (7.32±4.50) and lowest in Purba Medinipur (2.18±2.63). BOD (mg/L) value ranged between 0 to 9.60 with an average of (2.97±2.02). Highest value of BOD (3.87±2.31) was recorded from Howrah while lowest value of (0.53±0.39) was recorded from Purba Medinipur. The Free CO_2 (mg/L) level in the water ranged from 0 to 16.00 with average of (6.19±3.98). The maximum value of CO_2 (9.55±4.73) was from Hooghly whereas the minimum (4.02±1.42) was from Paschim Medinipur. The alkalinity (mg/L) of the water of the breeding habitats ranged from 28.0 to 260.0 with average of (136.46±53.68). The highest value (159.60±43.71) was from East Burdwan while the lowest (101.70±54.24) was from Howrah.

The conductivity (μs/cm) values ranged from 31.0 recorded from Howrah to 902.0 recorded from South 24 Parganas. The average value was found to be

Table 1. Physicochemical parameters (Mean ± SD) of the breeding habitats of *Aedes* mosquitoes in southern part of West Bengal, India. .

Districts	Temperature (°C)	pH	DO (mg/L)	BOD (mg/L)	Free CO_2 (mg/L)	Alkalinity (mg/L)	Conductivity (µs/cm)
Kolkata	29.75±3.20	7.04±0.60	7.32±4.50	3.68±2.32	9.50±3.79	176.00±73.71	521.00±278.04
North 24 Parganas	28.91±2.51	7.33±0.71	5.89±2.71	3.67±2.55	6.95±4.94	141.64±53.42	396.73±209.29
Howrah	31.02±1.87	7.04±0.64	6.39±2.82	3.87±2.31	4.69±2.29	101.70±54.24	295.20±217.42
South 24 Parganas	30.28±1.00	7.46±0.46	5.63± 3.62	2.40±1.45	6.88±5.74	115.67±71.20	478.17±357.38
Hooghly	28.57±1.71	6.76±0.44	6.50±1.47	4.10±0.28	9.55±4.73	149.00±89.84	373.75±188.86
Nadia	25.20±2.17	7.45±0.45	5.72±1.90	2.82±2.28	7.02±6.53	132.00±39.47	250.80±82.68
Paschim Medinipur	23.00±0.71	7.01±0.58	5.30±1.67	2.00±1.35	4.02±1.42	150.00±36.74	273.00±185.19
Purba Medinipur	26.70±0.95	7.13±0.60	2.18±2.63	0.53±0.39	5.56±4.88	138.00±62.21	462.60±257.78
East Burdwan	22.60±1.14	7.15±0.61	5.05±2.70	2.44±2.45	4.94±3.08	159.60±43.71	352.60±197.70
Murshidabad	24.80±1.64	7.07±0.71	5.30±2.76	2.27±1.93	4.92±1.67	146.00±45.61	408.40±312.34
Bankura	25.20±1.30	7.85±0.64	6.42±2.98	3.80±1.27	5.48±1.24	130.20±31.39	388.40±311.18
Birbhum	23.20±2.28	7.26±0.36	7.14±1.84	3.72±1.10	6.66±4.04	140.00±50.00	341.80±170.55
West Burdwan	22.40±2.30	7.36±0.65	5.78±2.58	1.73±0.91	6.24±2.15	144.80±56.26	305.20±113.42

Table 2. Physicochemical parameters (Mean ± SD) of the breeding habitats of *Aedes* mosquitoes in southern part of West Bengal, India

Districts	TDS (mg/L)	NO_2+NO_3 (mg/L)	SO_4 (mg/L)	Cl^- (mg/L)	K^+ (mg/L)	Na^+ (mg/L)	DOM (mg/L)	Hardness (mg/L)
Kolkata	324.50±17.93	9.89±1.72	0.27±0.27	75.03±11.16	4.26±2.21	77.21±24.95	6.54 ± 0.80	183.29±113.34
North 24 Parganas	263.10±91.99	6.85±5.28	0.29±0.18	96.63±29.72	33.17±28.88	55.15±36.05	6.25 ± 2.27	169.74±98.38
Howrah	189.90±149.40	7.65±5.17	0.15±0.14	114.17±54.72	29.88±28.62	32.83±39.66	6.59 ± 2.76	131.96±91.81
South 24 Parganas	222.67±174.79	4.16±4.34	0.38±0.28	135.52±58.83	10.00±14.36	53.98±34.66	4.70 ± 2.58	195.22±133.76
Hooghly	204.25±105.85	4.16±2.77	0.20±0.31	121.00±63.51	26.02±25.80	17.98±11.63	4.24 ± 1.77	145.28±87.56
Nadia	137.00±65.59	2.06 ±1.34	0.15±0.15	158.00±33.94	41.23±42.15	12.81±12.30	3.80 ± 2.42	167.67±147.63
Paschim Medinipur	136.80±92.42	5.40±1.49	0.34±0.21	106.67±21.50	18.60±12.57	8.33±4.64	3.60 ± 1.44	148.31±18.90
Purba Medinipur	247.00±116.19	4.33±2.16	0.24±0.22	129.50±6.36	31.34±33.32	51.64±57.93	1.05 ± 0.77	187.65±73.95
East Burdwan	192.80±147.56	6.71±3.46	0.20±0.17	137.33±37.65	42.23±36.01	33.72±24.99	4.07 ± 1.56	159.03±52.16
Murshidabad	216.40±201.25	3.05±1.03	0.13±0.09	117.67±60.10	36.49±38.22	24.75±20.41	3.18 ± 2.38	136.84±73.00
Bankura	270.60±226.32	4.91±4.10	0.25±0.21	109.00±35.36	53.51±36.30	37.17±49.12	3.86 ± 1.22	88.99±59.39
Birbhum	251.40±114.41	3.26±1.91	0.12±0.09	145.00±57.98	31.79±34.68	22.75±23.49	4.20 ± 1.98	121.21±82.68
West Burdwan	201.80±139.81	7.23±5.40	0.35±0.20	113.67±63.72	35.94±30.05	31.34±17.80	3.96± 2.64	157.75±62.60

(369.05±226.46). The TDS (mg/L) value ranged from 15.0 to 722.0 with average of (219.59±153.48). The highest value (324.50±17.93) was found in Kolkata and lowest (136.80±92.42) was found in Paschim Medinipur. The average Nitrite-Nitrate (mg/L) concentration was found to be (5.57±4.09) with highest value (9.89±1.72) from Kolkata and Lowest value (2.06 ±1.34) from Nadia. The average concentration of Sulphate (mg/L) was (0.24±0.20) ranged between 0.01 to 0.70. The highest (0.38±0.28) was observed from South 24 Parganas while lowest (0.12±0.09) was observed from Birbhum. The average concentration of Chloride (mg/L) was (117.85±45.23) ranged between 56.0 to 212.12. The highest average (158.00±33.94) was observed in Nadia while lowest (75.03±11.16) was observed from Kolkata. The average concentration of Potassium (K+) (mg/L) was (30.67±29.88) ranged between 0.43 to 112.40. The highest average (53.51±36.30) was observed in Bankura while lowest (4.26±2.21) was observed from Kolkata. The average concentration of Sodium (Na+) (mg/L) was (36.69±34.94) ranged between 3.15 to 136.0. The highest average (77.21±24.95) was observed in Kolkata while lowest (8.33±4.64) was observed from Paschim Medinipur. The DOM (mg/L) in the water of the breeding habitat ranged between 0.40 to 12.00 with an average of (4.70±2.51). The highest average (6.59 ± 2.76) was observed from Howrah while the lowest (1.05 ± 0.77) was observed from Purba Medinipur. The difference

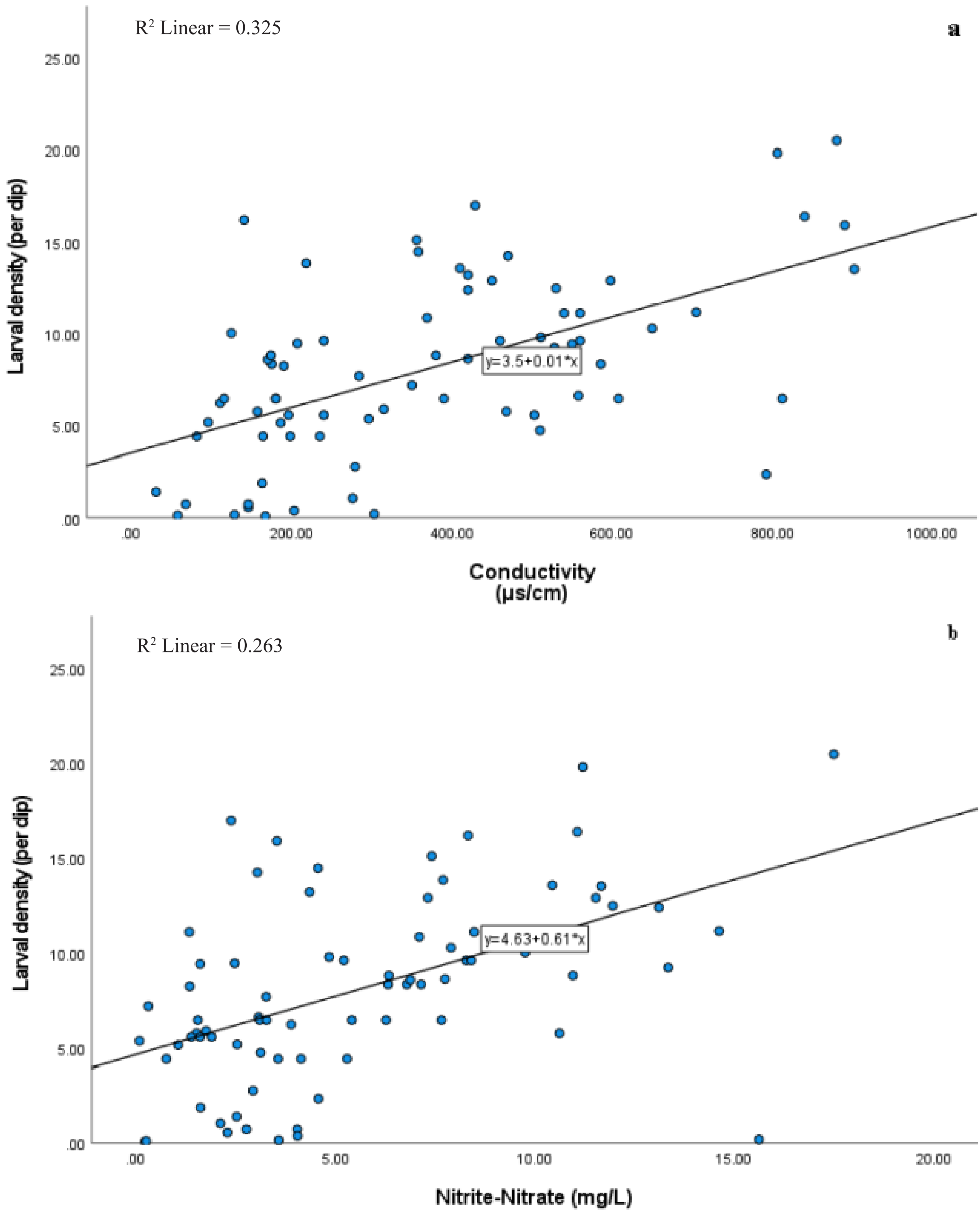

Figure 3. (a) Scatter Plot of Larval density vs Conductivity, (b) Scatter Plot of Larval density vs Nitrite-Nitrate.

Table 3. Physicochemical characteristics in relation to the larval density in the breeding habitats of *Aedes* mosquitoes in southern West Bengal, India

Parameters	Mean±SD	r	P	N
Atmospheric temp (°C)	29.65±3.67	0.41	<0.001	72
Water temp (°C)	26.74±3.59	0.33	<0.01	73
DO (mg/L)	5.77±2.76	0.33	<0.01	74
BOD5 (mg/L)	2.97±2.02	0.39	<0.01	68
Conductivity (is/cm)	369.05±226.46	0.57	<0.001	75
TDS (mg/L)	219±153.48	0.56	<0.001	74
NO2 +NO3	5.57±4.09	0.51	<0.001	75
SO4 (mg/L)	0.24±0.20	0.42	<0.001	75
CL- (mg/L)	117.85±45.23	-0.59	<0.001	48
K (mg/L)	30.67±29.88	-0.32	<0.01	75
Na (mg/L)	36.69±34.94	0.36	<0.01	75
DOM (mg/L)	4.70±2.51	0.42	<0.01	54
Hardness (mg/L)	153.29±88.62	0.30	<0.05	62

Pearson correlation coefficient (r)

among the groups for DOM was found to be statistically significant. $F (12,41) = 2.49, p<0.05$. Post Hoc analysis shows that the group mean of Purba Medinipur was significantly lower from that of Kolkata, North 24 Parganas and Howrah ($p<0.05$). The average Hardness (mg/L) was (153.29±88.62) ranged between 26.12 and 381.36. The highest average (195.22±133.76) was observed in South 24 Parganas while lowest (88.99±59.39) was observed from Birbhum.

The physicochemical parameters of pH, DO, BOD, CO_2, alkalinity, conductivity, TDS, sulphate, chloride, potassium, sodium and hardness doesn't vary significantly among the districts ($p>0.05$).

The relationship between per dip larval density and the various physicochemical parameters of the breeding habitats of the *Aedes* mosquitoes were investigated using Pearson product-moment correlation coefficient(r) (Table 3). Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a large, positive correlation found between the larval density and conductivity ($r = 0.57, n = 75, p < .001$) (Fig. 3a), TDS ($r = 0.56, n = 74, p < .001$) and Nitrite-Nitrate concentration ($r = 0.51, n = 75, p < .001$) (Fig. 3b) of the water of the breeding habitats.

Moderate positive correlation was found between Larval density and Temperature ($r = 0.33, n = 75, p < .01$), DO ($r = 0.33, n = 74, p < .01$), BOD ($r = 0.39, n = 68, p < .01$), sulphate ($r = 0.42, n = 75, p < .001$), Na ($r = 0.36, n = 75, p < .001$), DOM ($r = 0.42, n = 54, p < .01$) (Fig. 4a) and Hardness ($r = 0.30, n = 62, p < .05$). Large negative correlation ($r = -0.59, n = 48, p < .001$) was observed between larval density

Table 4. Pattern and structure matrix for PCA with Oblimin rotation

Item	Pattern Coefficients				Structure Coefficients				Commu-nalities
	Comp.1	Comp.2	Comp.3	Comp.4	Comp.1	Comp.2	Comp.3	Comp.4	
Conductivity(is/cm)	**0.863**	-0.033	-0.008	-0.060	**0.869**	0.166	-0.244	-0.217	0.760
Hardness (mg/L)	**0.788**	-0.065	0.065	0.182	**0.723**	0.085	-0.096	0.056	0.569
TDS (mg/L)	**0.720**	-0.132	-0.206	-0.262	**0.793**	0.089	**-0.422**	**-0.424**	0.757
SO_4^{2-}(mg/L)	**0.633**	-0.063	-0.009	-0.104	**0.641**	0.087	-0.186	-0.217	0.425
Na^+ (mg/L)	**0.543**	**0.448**	0.173	**0.474**	**0.511**	**0.501**	0.029	**0.378**	0.685
Larval density	**0.540**	0.257	-0.210	-0.226	**0.694**	**0.437**	**-0.451**	**-0.383**	0.669
NO_2 +NO_3	**0.448**	0.086	-0.191	-0.270	**0.568**	0.244	**-0.381**	**-0.394**	0.455
Water temp (°C)	-0.021	**0.928**	0.023	-0.055	0.190	**0.923**	-0.173	-0.111	0.855
Ambient temp. (°C)	-0.096	**0.815**	-0.195	-0.162	0.167	**0.845**	**-0.368**	-0.238	0.783
Humidity	-0.066	**0.767**	0.062	-0.013	0.091	**0.740**	-0.080	-0.042	0.557
DO (mg/L)	0.041	-0.072	**-0.941**	0.139	0.251	0.120	**-0.910**	-0.047	0.852
BOD (mg/L)	-0.005	-0.019	**-0.897**	-0.051	0.240	0.168	**-0.902**	-0.224	0.816
DOM (mg/L)	0.028	**0.439**	**-0.616**	0.137	0.266	**0.562**	**-0.687**	-0.019	0.675
Free CO_2 (mg/lit)	-0.015	0.063	0.211	**-0.705**	0.071	0.065	0.065	**-0.666**	0.486
CL^- (mg/L)	-0.239	-0.088	0.105	**0.664**	**-0.407**	-0.209	**0.316**	**0.734**	0.636
K^+ (mg/L)	-0.197	-0.121	0.109	**0.372**	**-0.321**	-0.213	0.259	**0.437**	0.280

Major loadings are bolded. Extraction Method: Principal Component Analysis; Rotation Method: Oblimin with Kaiser Normalization; Rotation converged in 10 iterations.

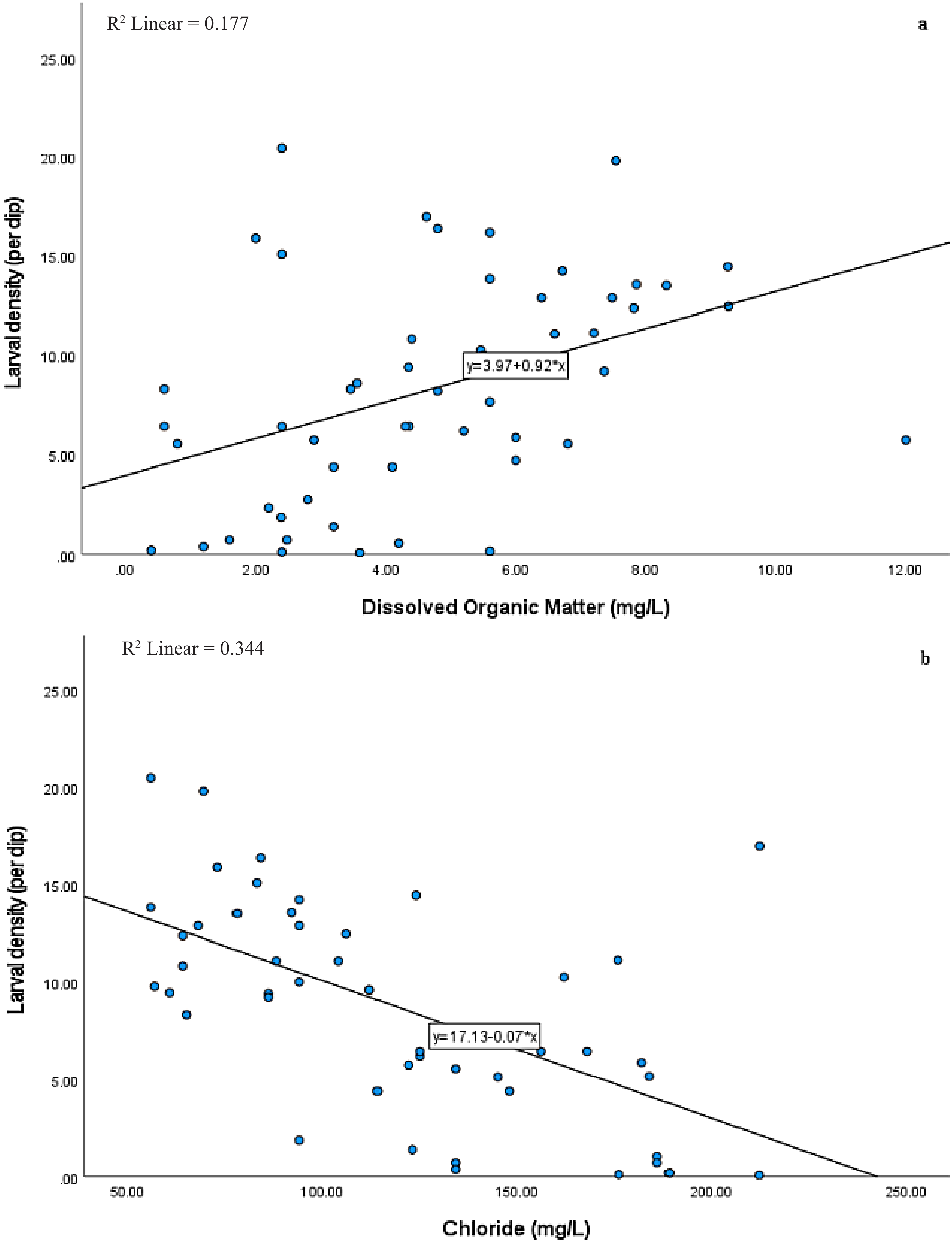

Figure 4. (a) Scatter plot of larval density vs DOM, (b) Scatter plot of Larval density vs Chloride

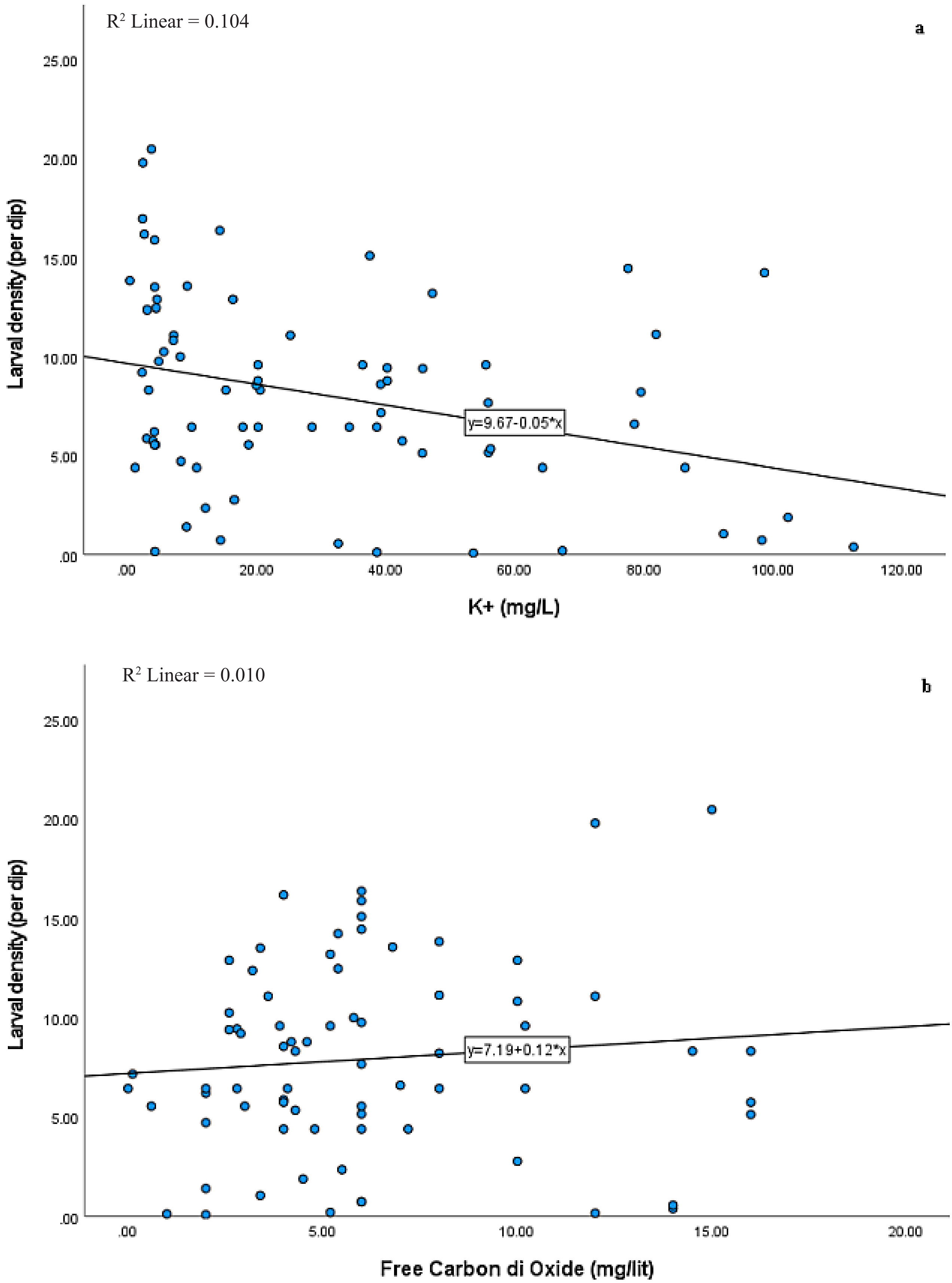

Figure 5. (a) Scatter plot of larval density vs K^+, (b) Scatter plot of larval density vs Free CO_2.

and Cl^- concentration (Fig. 4b). Medium negative correlation (r = -0.32, n = 75, p < .01) was observed between larval density and K^+ (Fig. 5a). Negligible correlation was found between larval density and pH, Humidity, Free CO_2 (Fig. 5b) and alkalinity.

All the parameters under study were subjected to principal components analysis (PCA) using SPSS version 28. Prior to performing PCA, the suitability of data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of 0.3 and above. These were taken for PCA. The parameters of alkalinity and pH was eliminated from the test since the correlation coefficients were <0.3. The Kaiser-Meyer-Olkin value was 0.66, exceeding the recommended value of 0.6 (Kaiser 1970, Kaiser 1974) and Bartlett's Test of Sphericity (Bartlett 1954) reached statistical significance (p<0.001), supporting the factorability of the correlation matrix.

Principal components analysis revealed the presence of four components (Comp.1-4) (Table 4) with eigenvalues exceeding 1, explaining 31.8%, 13.6%, 10.3%, and 8.4% of the variance respectively. An inspection of the screeplot revealed a clear break after the fourth component. Using Catell's scree test (Catell 1966) it was decided to retain four components for further investigation.

This was further supported by the results of Parallel Analysis using Monte Carlo PCA for parallel analysis, which showed only four components with eigenvalues exceeding the corresponding criterion values for a randomly generated data matrix of the same size with 100 replications. The four-component solution explained a total of 64.1% of the variance, with Component 1, 2, 3 and 4 contributing 31.8%, 13.6%, 10.3% and 8.4%, respectively. To aid in the interpretation of these four components, oblimin rotation was performed using oblique approach and assuming factors to be correlated (Tabachnick 2013). The rotated solution does not change the underlying solution, rather it presents the pattern of loadings in a manner that is easier to interpret (Thurstone 1947). The factor loadings were classified into three categories: strong (>0.75), moderate (0.75–0.50), and weak (0.50–0.30) (Liu 2003).

The first component explained 31.8% of the total variance, and it was dominated by strong positive loading of conductivity and hardness, moderate positive loading of TDS, SO_4^{2-}, Na+ and Larval density whereas weak loading of NO_2-NO_3. The second component explained 13.6% of the total variance, and it was dominated by strong positive loading of water temperature, ambient temperature, humidity and weak loading of Na^+ and DOM. The third component explained 10.3% of the total variance, and it was dominated by strong negative loading of DO and BOD whereas moderate negative loading of DOM. The fourth component explained 8.4% of the total variance, and it was dominated moderate loading of Free CO_2, Cl^-, weak loading of Na^+ and K^+. Na^+ shows multiple loading on component 1, 2, 4 and DOM shows loading on component 2, 3.

There is a weak positive correlation between pair of component - 1 and 3 (r=+0.22) and component - 3 and 4 (r=+0.20) whereas weak negative correlation was found between component -1 and 3 (r=-0.27), 1 and 4 (r=-0.18), 2 and 3 (r=-0.21). Component 2 and 4 shows negligible negative correlation (r=-.07)

DISCUSSION

Spatial distribution and abundance of *Aedes aegypti* are dependent upon the effects of anthropogenic changes on the environment (Braks 2003) and is found to be the most dominant species breeding in artificial containers (Yee 2010). The preferences for the habitats for different species of *Aedes* also vary to a great extent. The artificial containers are found to be abundantly located close to human habitation and were potentially more durable than natural containers. *A. aegypti* prefers clean water found in different domestic containers inside or near human dwellings, whereas *A. albopictus* is more likely to be present in natural containers or outdoor man-made habitats possessing a greater amount of organic debris (Rattanarithikul 1994). The number of immatures per container is heterogenous, indicating that female mosquitoes do possess a preference to oviposit in specific types of containers. Such type of containers may be epidemiologically more important than other container types (Focks 2006).

Temperature influences larval growth and development with rapid development of immatures but result in lesser production of adults in response to rise in temperature (Bayoh 2004). The current study has yielded similar findings with the immature stage revealing a moderate amount of correlation between larval density and temperature.

The ideal pH for *Aedes* mosquitoes was found to be 7.4 (Afolabi 2010), We found a wide range of pH tolerance among the *Aedes* mosquitoes starting from 6.08 up to 9.19 that evidenced the dispersal and adaptation of the *Aedes* mosquitoes to the new habitats towards seminatural areas (Paula et al 2013). The preference for habitat selection for breeding by the *Aedes* mosquitoes is dependent on several physicochemical parameters and also the nutrient composition (Olayemi 2010), consists of TDS, electrical conductivity, hardness, Sulphate, Sodium, and negatively by Chloride, Potassium. Chloride and Potassium tends to affect negatively for habitat preference by the *Aedes* mosquitoes (Chatterjee et al. 2015, Olayemi 2010).

Among the other analysed parameters BOD, DOM and NO_2-NO_3 level also affect positively to the habitat preference for oviposition behaviour of the *Aedes* mosquitoes. Larval mosquito diets mainly consist of bacteria and detritus present in the artificial container habitats (Merritt 1992). This may be explained by the facts that all these parameters indicate more availability of nutrient for the developing immatures in those container habitats. Any alteration in these factors in larval habitats may create conditions either favourable or unfavourable for mosquito biology (Amerasinghe 1995). However the successful thriving of the vector in the unconventional habitats like sewage drains (Banerjee et al. 2015), underground water tanks (Diéguez et al. 2010), and septic tank and cesspits (Burke 2010) possess some serious complications in the vector control programme.

The wide range in certain variables may be due to the facts that the wide variety of the container habitats were taken into consideration for analysis. PCA analysis results enabled us identification of four components explaining 64.1% of the variance with the first and second collectively explaining 45.4% of the variance.

CONCLUSION

The present study shows the nature of distribution of *Aedes* mosquitoes in the southern part of the state of West Bengal, their dispersal to suburban and rural areas, successful thriving and tolerance to a wide range of physicochemical parameters, which certainly have implications to the prevailing vector control measures. Vector control can be achieved by environmental manipulations of certain physicochemical parameters. Factors like conductivity, TDS and NO_2-NO_3 concentration of the container habitat could be explored further and used as index for proliferation of *Aedes* mosquitoes in this region. There is a need to redesign the control strategy to prevent the outbreak of the *Aedes* vector borne diseases in future.

ACKNOWLEDGEMENTS

The research work was funded by Department of Science and Technology and Biotechnology (DST-BT), Government of West Bengal vide Memo no. 283(SANC)/ST/P/S&T/5G-1/2018 Dt. 26.02.2019. The authors thank Vidyasagar College for Women, Kolkata for providing the facilities to carry out the research work. We also thank Ms. Tanusree Dutta, Ex-research fellow, for assisting in measurement of the physicochemical parameters.

ETHICAL STATEMENT

All entomological surveys and collections of specimens, which were carried out in private properties were done with oral permission of the residents and land owners. No endangered or protective species are involved in this study.

Authors' contribution: Mahata contributed in collection, analysis and documentation of data, statistical analysis, and preparation of tables, figures. Majumdar contributed in conceptualization, management of work, drafting primary manuscript. Bag contributed in editing, data analysis, finalizing the manuscript.

Conflict of interest: We declare that there are no competing interests.

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Received:10th October 2021
Accepted:5th March 2022