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TIME SCALE VARIATION OF SOME SELECTED GENERAL WATER QUALITY PARAMETERS OF BATTICALOA LAGOON, SRI LANKA

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ABSTRACT

The present study was conducted to find out the time scale variation of some water quality parameters of the Batticaloa Lagoon in Sri Lanka from January 2019 to April 2019. Ten sampling locations in the middle part of the lagoon were selected. Nowadays the quality of lagoon water is reducing due to natural and anthropogenic activities such as flooding, dumping garbage at coastal area, drain the household outlet towards the lagoon, washing animals such as cattle and buffalo near the coastal area, washing fishing equipment inside the lagoon and releasing chemicals from farm land and due to the natural disasters. However, no information available on time scale variation of physico-chemical parameters in the lagoon water throughout the day. Therefore, characterizing spatial and temporal dynamics of water quality in terms of physico-chemical parameters of the lagoon is an important finding to formulate the management plan against its effect on dependent economic activities for instance fishing, tourism, irrigation and aquaculture industry such as prawn farming and crab culture. The water quality parameters were analysed within a day at different time intervals to identify the relationship between the temperature and other water quality parameters in the study area. Water quality parameters such as temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), pH, Dissolved Oxygen (DO) and Turbidity were measured at 15-30 cm below the water surface from different locations of the lagoon from morning 6.00 am to evening 6.00 pm daily. High values of EC and TDS were recorded in the lagoon water near the bar mouth. The temperature of the water depends on atmospheric temperature by the time at which sample was taken. The temperature of the lagoon in some areas may also depend on atmospheric temperature, external surrounding factors such as concrete pavement and discharges from surroundings etc. There was no significant variation of EC, TDS and turbidity observed with time during the day. As far as the pH is concerned, the sampling locations, far away from the bar mouth area showed comparatively low pH values. Further, the findings of this study will be considered as baseline information about the time scale variation of water quality and essential tool for future researchers in the Batticaloa lagoon management.

KEYWORDS: *Batticaloa lagoon, Electrical conductivity, Temperature, Turbidity*

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1. INTRODUCTION

Deterioration of water quality is a common phenomenon in many aquatic systems such as lagoons, lakes and rivers etc. These water bodies suffer from anthropogenic activities from the surroundings and the impacts would be further aggravated by the effects of climate change events such as extreme floods & droughts, sea-level rise and subsequent seawater intrusions. Reduction of water quality of the lagoon due to anthropogenic activities is one of the most pressing threat to estuaries causing diminishing water quality as a consequence of urban growth and land use that increase the impervious surface area and non-point source runoff of nutrients and remains (Choi and Blood, 1999).

Batticaloa lagoon is one of the estuarine lagoons situated on the East Coast of Sri Lanka. It is the largest coastal water body in the District and occupies an area of 168 km^2 (Green Tech Consultants, 2009). This lagoon has been subjected to increasing anthropogenic pressure (Sugirtharan *et al*., 2013) and frequent flood owing to the growing population, agricultural and industrial wastes that are discharged directly into the lagoon.

The physicochemical parameters such as temperature, pH, DO, turbidity and salinity are the most important parameters which, influence biochemical reactions within the lagoon and are used for testing the water quality of an aquatic ecosystem. According to FAO (1998), the water quality of the water resources may vary throughout the day mostly as a result of photosynthesis, and throughout the night due to respiration. Such changes in the concentration of these parameters are indicative of changes in the condition of the water system (Aknaf *et al*., 2017). There are several studies on the water quality of Batticaloa lagoon that were conducted in the recent past. However, there are no information available to find out the time scale variation throughout the day. Therefore, characterizing spatial and temporal dynamics of Physico-chemical parameters of the Lagoon over a long period is an important step to formulate the management plan against its effect on dependent economic activities such as fishing, tourism, irrigation and aquaculture industry like prawn farming and crab culture (Sugirtharan *et al.,* 2017). Temporal and spatial complexities of the lagoon mouth also affect the transportation and mixing of saline water and intrusion into the lagoon (Banerjee and Srivastava, 2009). By considering this, the present study was conducted to find the time scale variation of water quality of Batticaloa lagoon as an important step to prepare the management plan for this lagoon.

2. METHODOLOGY

The study area

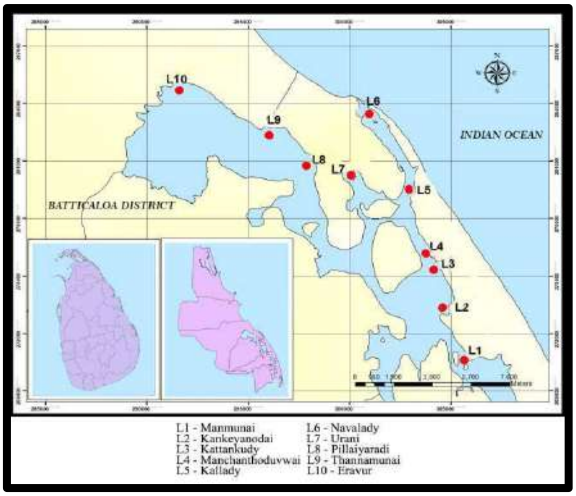

Figure 1: Location of the Study Area.

Batticaloa lagoon is located between 7° 24' - 7° 46'N, and 81° 35' - 81° 49'E, is one of the most productive brackish water bodies in Sri Lanka. More than 90% of the lagoon is located in Batticaloa District and the rest lies in Ampara district. Batticaloa lagoon is 56 km long (Shanmugaratnam, 1995) and extends from Kittangi/Kalmunai in Ampara District in the south to Pankudaweli in Batticaloa district in the north. Lagoon area receives about 1000- 1700 mm of rainfall per annum, primarily (about 60%) from the Northeast monsoon (NEM) during October to February. It has a dry spell of five months from May to September. Winds are generally moderate, ranging from 7–15 km per hour with the evening stronger winds.

The mainland use around the lagoon is agriculture particularly paddy cultivation. Other land uses include urban areas, road networks, and freshwater bodies adjoining the Batticaloa lagoon, the Batticaloa Lagoon itself and associated vegetation such as mangrove. The maximum depth of the lagoon is about 4 meters (Scot, 1989) and the average water depth is around 1.5 m (MG Consultants, 2010).

Table 1. Time scale variation of water quality parameters of Batticaloa lagoon.

Time	Mean temperature ºC	TDS ppt	EC mS/cm	pH	Turbidity FTU	DO Mg/l	Salinity Ppm
6.00am	27.8[h]	2.87[a]	5.51[a]	7.55[c]	12.91[a]	16.01[a]	14[a]
7.00am	28.6[h]	2.95[a]	5.69[a]	7.67[bc]	13.45[a]	15.47[a]	14[a]
8.00am	29.7[g]	2.91[a]	5.59[a]	7.77[abc]	12.35[a]	15.80[a]	14[a]
9.00am	31.1[ef]	2.86[a]	5.53[a]	7.80[abc]	16.43[a]	15.80[a]	14[a]
10.00am	32.5[d]	2.91[a]	5.60[a]	7.91[abc]	16.27[a]	16.23[a]	13[a]
11.00am	33.6[bc]	2.94[a]	5.70[a]	7.93[abc]	16.08[a]	15.78[a]	13[a]
12.00pm	34.6[a]	2.84[a]	5.43[a]	8.09[abc]	14.12[a]	16.10[a]	13[a]
1.00pm	33.9[ab]	2.83[a]	5.44[a]	8.19[ab]	15.88[a]	17.74[a]	13[a]
2.00pm	34.2[ab]	2.99[a]	5.79[a]	8.23[ab]	18.37[a]	16.50[a]	13[a]
3.00pm	32.8[cd]	3.03[a]	5.81[a]	8.25[a]	17.09[a]	15.68[a]	13[a]
4.00pm	32.5[d]	3.04[a]	5.83[a]	8.22[ab]	16.99[a]	17.28[a]	14[a]
5.00pm	31.9[ed]	3.09[a]	5.90[a]	8.22[ab]	14.70[a]	16.55[a]	14[a]
6.00pm	30.9[f]	3.06[a]	5.90[a]	8.17[ab]	15.65[a]	16.93[a]	14[a]

Sampling locations

Ten (10) locations such as Manmunai (L1), Kankeyanodai (L2), Kattankudy (L3), Manchanthoduwai (L4), Kallady(5), Palameenmadu (L6), Urani (L7), Pillaiyarady (L8), Thannamunai (L9) and Eravur (L10) in the Batticaloa lagoon area were identified in the present study to collect water samples for the analysis during the period from January to March 2019 (Figure 1).

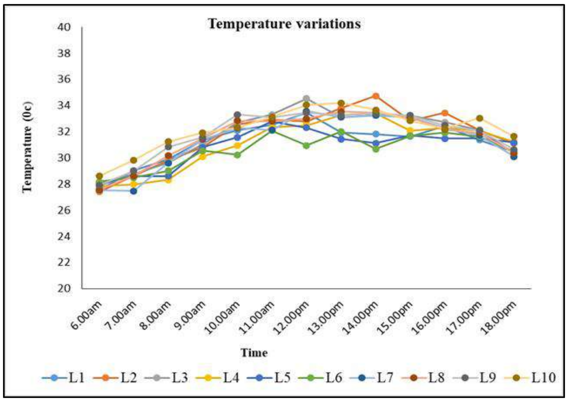

Figure 2: Time scale variation of temperature of Batticaloa lagoon at different locations.

The main reason for selecting those ten locations was to get linear distance from bar mouth in North and South direction of lagoon to understand the variation in the water quality with the distance. Surface water samples (15-30 cm depth at all the sampling points) were collected from 6.00 am to 6.00 pm at one-hour time interval within the day. This procedure was repeated three times at each location during 10 days' interval. At every sampling location, sampling was done in different time interval. The reason for sampling during the day time due to the change of the direction of wind breeze that might cause the temperature difference between the land and water. It frequently happens during the day time as the influence of solar heat.

Sample analysis

In-situ field measurements were taken for pH, EC and TDS using portable digital pH/EC/TDS meter (model: HI 98130) and DO using portable digital DO meter (HANNA-Model HI 8043 model) and turbidity by portable digital turbidity meter (HI 93703). Flow Direction and flow velocity of lagoon water were determined by float method. Finally, measured data were analyzed using MS Excel and SPSS software (version 22).

3. RESULTS AND DISCUSSION

Temperature

Table 1 and Figure 2 shows the temperature variation within the lagoon during the experimental period. Water temperature is the most important water quality parameter in the aquatic environment. It affects metabolic activities, growth, feeding, reproduction, distribution and migratory behaviors of aquatic organisms (Sugirtharan *et al*., 2015)

The results revealed that the mean temperature of the Batticaloa lagoon ranged from 27.4^{o}C to 33.9 C^0 and the lagoon water temperature were within the acceptable range for the aquatic species (15^{0}C to 40^{0}C)**.** The minimum temperature was recorded during the early morning and the maximum temperature was recorded in Eravur at 2.00 pm.

The temperature gradually increased with time and reached the peak in the late afternoon (1.00 pm), then gradually decreased with time. Sugirtharan *et al*. (2017) revealed that, mean temperature of the Batticaloa lagoon ranges from 28.3 ^{0}C to 32.0 ^{0}C during twelve-month sampling period and the lowest temperature (26.1^{0}C) was experienced in March 2013 at Kattankudy and highest temperature of 33.6^{0}C was experienced at Sathurukondan during May 2013. It is obvious that water temperature increases as the atmospheric temperature rises. Kaushal *et al*. (2010) also reported that an increase in the river water temperature coincided with the rise of historical air temperature. The higher turbid condition was observed during the sampling at the sites of Kattankudy, Eravur and Kankeyanodai. Suspended particles may also contribute to the rise of temperature in those areas because of their absorption capacity.

Aknaf *et al*., (2017) also reported that, water temperature of the Marchica lagoon varied significantly with sampling stations and presented a regular seasonal cycle with minimum in January and a maximum in July, and therefore did not look as if to pose any hazard to the lagoon system. Sugirtharan *et al.*, (2017) reported that, the slight variations were due to sampling time and the variation in the atmospheric temperature during day and night and the wind action within the lagoon environment. They further noticed that Temperature of lagoon was high (above 33 ^{0}C) during the period of April 2013 to August 2013. During the sample collection the places where higher organic and plastic waste accumulation indicated higher values of temperature.

In the present study, temperature showed significant differences in the mean value between morning and afternoon hours (Table 1) further, temperature showed a significant positive correlation with the time interval. ($r = 0.498$, $p=0.001$).

Time scale variation of Total dissolved solids

The United States Environmental Protection Agency (USEPA) Secondary Regulations advise a maximum contamination level (MCL) of 500 mg/l (0.5 ppt) for TDS. When TDS levels exceed 1000 mg/l (1 ppt), it is generally considered unsuitable for human consumption. The present study revealed that TDS concentrations exceeded the desirable limit of 1 ppt. Chapman, (1992) indicated that if the EC value exceed the limits in upstream than downstream, the salt intrusion occurs in nearby ground water sources. Bilotta and Brazier (2008) also mentioned that, high TDS concentration could cause a reduced development and survival of fish eggs and larvae.

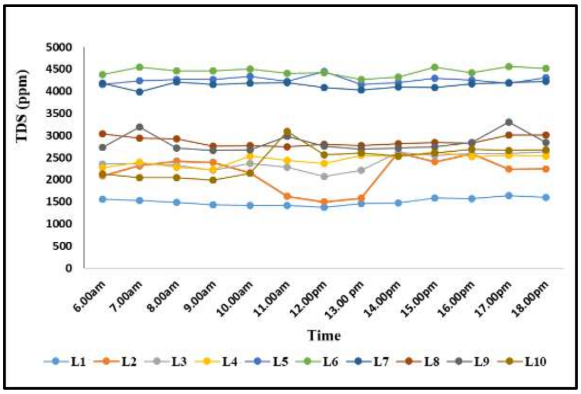

Figure 3: Time scale variation of TDS of Batticaloa lagoon water

Figure 03 depicted the variation of TDS of Batticaloa lagoon (1.37 ppt to 4.55 ppt) water during the sampling period. As far as the mean TDS values for the study period (January to March) is concerned, a lower mean value (2.83 ppt) was observed at the Manmunai area and a higher value (3.09 ppt) was observed in the Navalady area. However, there is no significant variation was found in TDS and EC of the lagoon water collected at an hourly interval within a day (Table 01).

Sugirtharan *et al.*, (2017) reported that, the EC and TDS of the Batticaloa Lagoon fall within 0.24 dS/m to 36.6 dS/m and 0.1 ppt to 18.3 ppt, respectively. Lowest value of EC (0.24 dS/m) and TDS (0.1 ppt) was found at Manmunai area (L13) during February 2013 and the highest EC (36.6 dS/m) and TDS (18.3 ppt) were observed during October 2013 at Navalady (L1) which is very closer to the sea outlet than the other locations. The figure 3 showed three lines at top of graph indicated the places where the EC value greater than other places. The places which close to bar mouth, distance wise showed higher values because of the sea water intrusion due to the lagoon.

Time scale variation of Electrical conductivity

A similar trend was also observed in the EC of the Batticaloa lagoon at a different time interval. Where mean EC values ranged from 5.43 - 5.9 mS/cm. The higher value of TDS and EC was observed in the places such as Navalady (L6) and Kallady (L5) which are located closer to the ocean. The direction of water movement due to the wind pattern might have influenced the variation of ionic concentration of the lagoon during morning and evening time. At the same time, the tidal effect may also be the reason for the change in EC and TDS value because of the opened bar mouth.

Time scale variation of pH

The pH ranged from 7.0 to 9.2, the lowest value was observed at Manmunai area (L1) and the highest value was observed in Thannamunai area (L9).

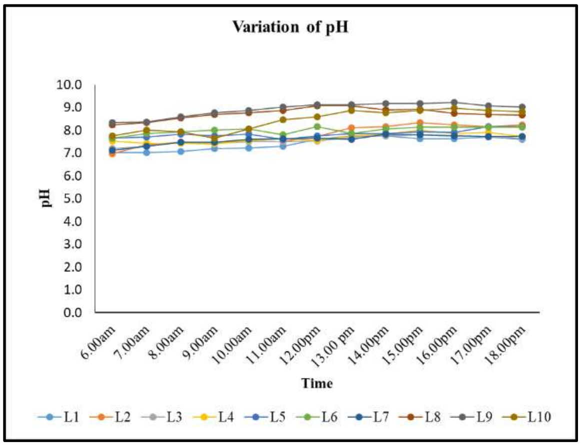

Figure 4: Time scale variation of pH in Batticaloa lagoon

The variation of pH value at different locations might have influenced by several factors such as bottom sediments, presence of organic matters, microbial activity, algal blooms, concentration of basic ions, amount of urban wastage discharged in to the lagoon, connection with seawater, agricultural runoff and presences of industries which release their effluents in to the lagoon etc.

The pH of lagoon water collected at 6.00 am showed significant mean differences with the samples collected after 1.00pm (Table 1). However, there is no significant difference in pH values were noticed among the other samples collected at 6.00am to 12.00pm. Similarly, there is no significant mean pH differences observed for the samples collected from 1.00 pm to 6.00pm. Hydrogen ion concentration or pH is one of the vital environmental characteristic which decides the survival, metabolism, physiology and growth of aquatic organisms (Lawson, 2011).

Sugirtharan *et al.*, (2017) revealed that, the pH variation in Batticaloa lagoon was ranging from 7.32 to 8.87 and difference of pH at 18 different locations during twelve sampling occasions indicate that the highest pH (8.87) was observed at Sathurukondan during May 2013 whereas, the lowest pH (7.32) was noted at Kiddangi and these pH values varied at different locations.

Time scale variation of Dissolved Oxygen

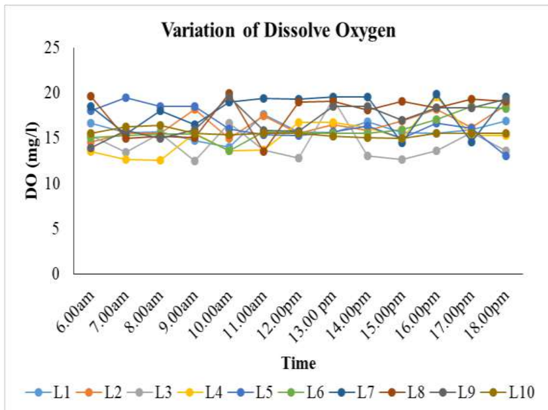

Figure 5: Time scale variation of DO in Batticaloa lagoon

The present study found that the DO was ranging from 12.5mg/l to 19.93mg/l during the sampling period (January to March). The study was conducted during the monsoon period thus lagoon water height was increased due to the accumulation of water may be the reason for the high DO content during this period. Aknaf *et al.* (2017) reported that, very low dissolved oxygen concentration may be created by the dreadful conditions of carbon-based matter, the very low hydrodynamics and too raised up temperatures. Higher dissolved oxygen concentration in Nador lagoon waters were found for the period of winter time reaching 12.75 mg/l and low level was recorded in summer (2.5 mg/l).

Table 2: Correlation coefficient values of water quality parameters of Batticaloa lagoon.

	Temperature	TDS	EC	pH	DO	Turbidity	salinity
Temperature	1						
TDS	0.024	1					
EC	0.071	-0.302**	1				
pH	0.244**	0.075	-0.089	1			
DO	-0.117*	-0.343**	-0.026	-0.189**	1		
Turbidity	0.023	-0.388**	0.090	0.454**	0.037	1	
Salinity	0.026	-0.008	-0.032	-0.005	-0.040	-0.065	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

However, there were no significant differences in the mean values of DO was found with the time interval within a day (Table 01). Sugirtharan *et al*. (2017) reported that, mean values of DO concentration of the samples collected in all locations in the Batticaloa Lagoon ranged from 5.9 mg/l to 7.6 mg/l in different Locations and showed that there was no any spatial variation with the increasing distance from bar mouth. The recent study also didn't find any relation between DO value and distance from bar mouth. The increase in turbulence of the lagoon was observed during sample collections, might have increased DO concentration in most of the locations.

Time Scale Variation of Turbidity

The present study indicated that the lowest value of 1.7 (FTU) at Navalady, where appearance of water was very clear. The highest value was observed (47.5FTU) at the Pillaiyarady area during the sampling period and lagoon water with suspended solids during sample collection due to heavy wind. As far as the mean values of turbidity from all locations are concerned it varied from 12.35 – 18.37 FTU.

Further, there is no significant mean differences observed with the time interval within a day (Table 1). Sometimes, turbidity values changed suddenly due to external factor such as heavy wind, flow speed etc. UNEP and WHO (1996) also reported that turbidity in water also depends on wind speed, the water flow speed, presence of suspended particles, drainage from urban wastage, effects of bottom-feeding fish, the density of phytoplankton, agricultural runoff and rainfall. Sugirtharan *et al*. (2017) further revealed that, high contents of suspended solids with runoff water from neighboring area enters into the lagoon during intense rainfall and

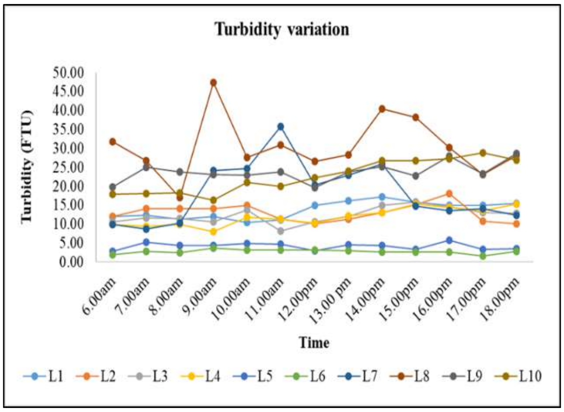

Figure 6: Time scale variation of turbidity in the Batticaloa lagoon

heavy wind amplified the tidal action of lagoon thus increasing the turbidity. They further reported that the mean values of turbidity fluctuated from 10 to 25 FAU. Opening of sluice gate to drain the excess water from major irrigation tank of the Batticaloa district also carries sediments from upper catchment area to the lagoon.

Pearson correlation coefficient values of water quality parameters of Batticaloa lagoon

The table 2 illustrates that TDS, salinity, EC had non-significant positive correlation with temperature. The pH shows highly significant positive correlation with temperature. The DO shows significant negative correlation with temperature.

4. CONCLUSION

The temperature followed by pH are the major parameters that varied significantly with the short time scales within a day. Other parameters such as EC, TDS, turbidity and DO were not significantly varied within a short time scales of the day. Changing the pattern of water temperature was mainly related to air temperature. The sampling locations which are far away from the bar mouth area showed lower EC and TDS.

TDS, salinity, EC had non-significant positive correlation with temperature whereas the pH shows highly significant positive correlation. In addition, the DO shows significant negative correlation with temperature. Wind and tidal action also influenced on the changes of turbidity in lagoon water. These findings helps in understanding of the degree of variability of basic water quality parameters at a short time interval within a day.

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