Spatiotemporal Variation of Pollutant Levels in the Sainthamaruthu Coastal Lagoon

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Abstract

Sainthamaruthu coastal lagoon is situated at the southern end of Kalmunai Municipal Council, which is one of the potential resources for waterfront development in Kalmunai and represents a typical geographical feature in the eastern part of Sri Lanka. However, due to various anthropogenic activities lagoon faces a threat of pollution. Identification of water pollutants in a lagoon is vital for conservation and sustainable utilization. The present study aimed to examine the spatiotemporal variations of surface water quality of Sainthamaruthu lagoon and to evaluate pollution levels of the lagoon concerning physicochemical water quality parameters. Data were collected biweekly in 2022 where the precise location of each location was recorded using a portable GPS unit. Samples were collected using clean high-density plastic bottles. The pH, water temperature, electric conductivity (EC), salinity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Solids (TS), Total Suspended Solid (TSS), turbidity, hardness, and alkalinity were tested and data were analyzed statistically to interpret the results. The results showed that the spatial variation in every location was fluctuating in all parameters with increasing and decreasing trends and temporal variation of all parameters have shown significant ($p < 0.05$) differences within the studied period except for turbidity, DO, TS, and alkalinity. This study concludes that the Sainthamaruthu lagoon has been polluted and measures should be taken to prevent the pollution for sustainable use of the lagoon in the future.

Keywords: Water Quality Parameters, Pollution, Spatiotemporal Variation

I. INTRODUCTION

Lagoons are shallow coastal water bodies that are isolated from the ocean by a string of barrier islands that run parallel to the beach. 13% of all coastal areas on Earth are made up of coastal lagoons, which are frequently altered by anthropogenic and natural factors (Kjerfve, 1994). The geology, geomorphology, monsoonal seasons, and other significant climatic elements are closely related to the creation, evolution, configuration, and distribution of lagoons in Sri Lanka (Silva *et al*, 2013).

Lagoons provide numerous resources for human use including goods, for example, food, water, fuel, medicine, and services like serving as natural barriers, fixing and sinking of carbon, and providing nursery and feeding grounds for important fish species. Despite all these benefits, most of the lagoons are experiencing multiple human pressures including over -exploitation of the resources, land reclamation for settlement or industrial development, urbanization, eutrophication, pollution, and hydrological modifications.

Sainthamaruthu Coastal Lagoon is situated in the south end of Kalmunai Municipal Council at the Sainthmaruthu village, and it is called Thona by the native language of the people (Jowsi, 2014). Thona is one of the potential resources for waterfront development in Kalmunai and represents a typical geographical feature in the eastern part of Sri Lanka. This water body functions as a drainage creek during the rainy season, while it is closed water in the dry season. The current scenario of the lagoon is on the verge of contamination, emits a bad smell to the surroundings, is highly polluted and deterioration of water quality due to, - the discharge of wastewater directly into the lagoon, outlets of stormwater drainage canals discharge untreated grey water into the lagoon, piles of solid waste

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dumped into the lagoon, stagnation of water and growth of aquatic plants. These causes are creating environmental pollution, mixing the contaminated water with groundwater so creating waterborne diseases, and creating a habitat for mosquito breeding, wells have adversarial impacts due to the seeping of the latrines into the water, creating foul odor so air pollution also has in the surrounding area and surrounding people are highly subjected to dengue, cholera and other infectious diseases. People who live close to the lagoon and other contaminated water sources frequently suffer from diarrhea and other infectious diseases. The main causes of disease transmission include the indiscriminate intake of groundwater that is very close to latrines, mixing contaminated water with groundwater, and connecting sewerage effluent to the groundwater. Well water, which is quite close to restrooms, is the primary cause of 70% of water-borne infections (Ameer, 2017). All these identified problems the lagoon need to remedied and treated for better human survival in the surroundings. So, to treat the lagoon the status of physico – chemical and biological parameters are needed to be known. In this view, the present study was conducted with the aims to analyzing spatial and temporal variations of pollutants in the Sainthamaruthu coastal lagoon and finding whether the water is polluted.

II. METHODOLOGY

A. Description of the Study Area

The study area of Sainthamaruthu lagoon is located at 7º 38’ 88” latitude and 81º 84’ 17” longitude in Karaithivu Divisional Secretariat (DS), Sainthamaruthu Divisional Secretariat (DS), and Kalmunai Tamil Divisional Secretariat (DS) area.

B. Sampling

The precise location of each sampling point was determined according to the 500 m distance using a portable GPS unit (Figure 01). Five sampling points were selected and each point has three replicates. Readings were taken biweekly between July 2022 and September 2022. Samples were collected using clean high - density plastic bottles. Water samples for Biological Oxygen Demand (BOD) analysis were collected separately into aluminum foil - wrapped plastic bottles. Samples were kept in ice packs in coolers and transported to the laboratory and stored in a refrigerator at 4ºC till analysis was completed. Standard procedures outlined by the Environmental Protection Agency (EPA, 1983) and American Public Health Association (APHA, 1998) were used to analyze water samples at the environmental laboratory, Department of Civil Engineering, Faculty of Engineering, South Eastern University of Sri Lanka (SEUSL) and Biosystems engineering laboratory, Faculty of Technology, SEUSL.

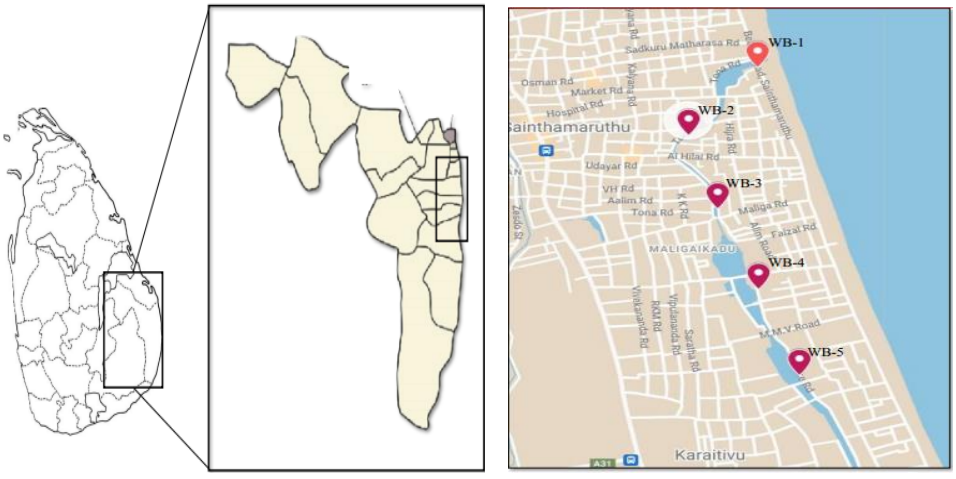

Figure 01: Sampling Locations

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C. Analysis

pH was tested using pH meter. Before testing meter was calibrated using three buffer solutions, they are pH 4.01, pH 7.00, and pH 10.01respectively. EC, Temperature, Salinity and TDS were tested using Multi- parameter analyzer (HANNA, H19829). The turbidity was measured using a turbidity meter (HACH, TL2350), which was calibrated using standard methods before taking the measurements. Total Solid (TS) and Total Suspended Solid (TSS) were analyzed by gravimetric method. DO is measured by using DO Meter (HANNA, HI 9146). A meter probe was slowly placed inside the aluminum foil wrapped bottles and reading was recorded directly. BOD was measured by using 5day incubation method. Initially dissolved oxygen content (DO1) of a particular sample was recorded. Then sample water bottles were incubated at 20^0 C for 5 days. After 5 daysdissolved oxygen content (DO2) was measured and BOD was computed from the difference between the initial and final DO. Hardness was determined by the EDTA titrimetric method and it can be found by adding a small amount of a dye such as Erichrome Black T (EBT) is added to an aqueous solution and Ca++, Mg++ ions form chelated complexes of wine red colour with EBT. Alkalinity was determined by the titrimetric method. Descriptive analysis and one - way ANOVA were used for the statistical analyses of results obtained at a 95% confidence level using the Microsoft Excel 2013 package and SPSS (v.26).

III. RESULTS AND DISCUSSION

A. pH Variation

pH values in the present study were observed in the range of 6.80 to 7.42 and this values were below the standard level of 7.8 - 8.3 for aquatic water (CEA, 2001). The highest mean value was recorded in location 3 (7.32) and the lowest mean value was recorded in location 2 (6.84) in 1st and 3rd sampling time respectively (Table 02). However this variation was not significant ($p < 0.05$) among all locations. Moreover, 7.19 highest mean value was recorded in 1st week and it has a significant difference with in the weeks. As organic substances decay, carbon dioxide forms and combines with water to produce a weak acid called carbonic acid. A large amount of carbonic acid lowers the pH. This was demonstrated at sampling point 2. The values changed with time due to variations in temperature, salinity and biological activity.

Table 01: Temporal Variation of All Parameters

Week	pH	Temperature	EC	Salinity	TDS	DO	BOD	Turbidity	TS	TSS	Hardness	Alkalinity
Week 1	7.19 ± 0.04^{a}	26.94 ± 0.11^{b}	676.27 ± 51.36^{a}	0.33 ± 0.03^{a}	337.47 ± 25.52^{a}	6.26 ± 0.29^{a}	6.36 ± 0.27^{b}	22.87 ± 4.74^{b}	517.67 ± 36.01^{b}	358.47 ± 14.18^{b}	357 ± 13.57^{a}	380.33 ± 17.05^{a}
Week 2	6.98 ± 0.01^{b}	25.59 ± 0.05^{c}	317.13 ± 5.27^{b}	0.15 ± 0.00^{b}	158.53 ± 2.64^{b}	5.43 ± 0.18^{b}	6.89 ± 0.49^{b}	32.84 ± 5.63^{ab}	526.66 ± 39.60^{b}	461.40 ± 32.25^{a}	303 ± 9.11^{b}	347.00 ± 12.43^{b}
Week 3	6.91 ± 0.02^{b}	27.45 ± 0.10a	332.47 ± 5.46^{b}	0.16 ± 0.00^{b}	166.20 ± 2.85^{b}	5.77 ±0.25 ^{ab}	8.60 ± 0.46^{a}	39.83 ± 5.57^{a}	682.67 ± 67.16^{a}	384.40 ± 20.76^{ab}	312 ± 18.43^{ab}	360.67 ± 8.85^{ab}

Results are presented in the form of arithmetic mean ± standard error.

Table 02: Spatial Variation of pH

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	7.06 ± 0.00^{a}	7.30 ± 0.06^{a}	7.32 ± 0.04^{a}	7.10 ± 0.10^{a}	7.16 ± 0.09^{a}
08.08.2022	6.97 ± 0.01^{a}	6.95 ± 0.0 ^{a}	7.00 ± 0.54 ^{a}	6.95 ± 0.05 ^{a}	6.99 ± 0.0 ^{a}
30.08.2022	6.97 ± 0.02 ^{a}	6.84 ± 0.0 ^{a}	6.92 ± 0.06 ^{a}	6.92 ± 0.02 ^{a}	6.91 ± 0.02^{a}

Results are presented in the form of arithmetic mean ± standard error.

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B. Temperature Variation

Analyzed data showed that the temperature fluctuation of the surface water of Saintamaruthu lagoon during the study period was varied with maximum and minimum temperature at 27.93°C and 25.22 °C respectively and it fell below the standard range of 28˚C - 32˚C (CEA, 2001). The highest mean value was recorded in location 3 (27.76°C) and the lowest mean value was recorded in location 5 (25.44°C) (Table 03). However this variation was not significant ($p < 0.05$) among all locations in the 1st and 3rd sampling time but there was a significant difference among the locations in the 3rd sampling. In addition highest mean value 27.57 was recorded in 3rd week and the lowest value was recorded 25.59 in 2nd week. And it has significant with in the weeks.

C. EC Variation

EC variation during the study period ranged from 287 – 956 µS/ cm. There was highest mean value was recorded in location 5 (906.33) and the lowest mean value was recorded in location 1 (295) in 1st and 2nd sampling weeks, respectively (Table 04). These variations were significant ($p < 0.05$) among all locations. Various industrial and urban activities with low volumes of water may have contributed to the high EC level in locations 5 and 3. Moreover highest mean value 676.27 was recorded in 1st week and the lowest value 317.13 was recorded in 2nd week. And it has been significant within the weeks.

D. Salinity Variation

Results from the study indicated that salinity ranged from 0.14 to 0.47 PSU. The highest mean value (0.45) was recorded in location 5 and the lowest mean value (0.7) was recorded in location 5 at the 1st and 3rd sampling times, respectively (Table 05). The variation of salinity among all locations was significantly different ($p < 0.05$). Moreover, the highest mean value 0.33 was recorded in 1st week and the lowest value 0.15 was recorded in 2nd week. And it has been significant within the weeks. According to the statistical analysis salinity of the lagoon was below the acceptable range of 1-35 PSU because drainage channels were directly connected with the lagoon and stagnated. Also in the dry season there is no sea water intrusion therefore salinity was low.

E. TDS Variation

TDS value has increased because of mud and natural materials. During the sampling period, the lagoon outfall was closed by sand, therefore the lagoon water had been stagnant so the TDS levels increased in many sample locations. Analyzed data showed that the TDS variation ranged from 143 to 478 mg/l and observed TDS values of lagoon water fell below the acceptable range of 450 -2000 mg/l for aquatic water (CEA, 2001). The highest mean value (453.33) was recorded in location 5 and the lowest mean value (147.33) was recorded in location 1 at 1st and 2nd sampling times, respectively (Table 06). This variation significantly differ among the locations ($p < 0.05$). Also highest mean value 337.47 and lowest mean value 158.53 were recorded in 1st and 2nd week respectively. These variations significantly differ within the weeks.

F. DO Variation

Analyzed data indicate that DO was varied with the maximum and minimum levels at 7.64 and 3.98 mg/l respectively. The highest mean value (7.28) was recorded in location 3 and the lowest mean value (4.45) was recorded in location 4 at the 1st and 3rd sampling time, respectively (Table 07). There was a significant variation among all the locations ($p < 0.05$). In location 4, there was a low level of DO recorded, which may be the reason for the direct connection of drainage channels with the lagoon. High levels of organic content and microbial activities with a low volume of water may have been attributed to a low level of DO during the dry period. Highest mean value of 11.19 was recorded in the 3rd week and the lowest mean value 9.38 was recorded in the 1st week. However this variation was not significant among the weeks.

G. BOD Variation

Unpolluted waters typically have a BOD value of 2 mg/L while those receiving wastewater may have values up to 10 mg/l or more (Chapman, 1996). The high BOD recorded in the current study is thus an indication of a large quantity of organic waste in the lagoon. BOD variation in the study period ranged from 4.48 to 11.12 mg/l. These levels exceeded the maximum acceptable limit of 5 mg/l for aquatic water (Brian, 2013). There was highest mean value was recorded in location 3 (10.14) and the lowest mean value was also recorded in location 3 (5.12) in the 3rd and 2nd sampling weeks, respectively (Table 08). There

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was a significant variation among all the locations ($p < 0.05$). Moreover highest mean value of 8.60 was recorded in 3rd week and the lowest value of 6.36 was recorded in 1st week. And it has been significant within the weeks.

Table 03: Spatial Variation of Temperature

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	26.76 ± 0.40 ^{a}	27.02 ± 0.69 ^{a}	26.53 ± 0.11 ^{a}	26.96 ± 0.11 ^{a}	27.42 ± 0.09 ^{a}
08.08.2022	25.79 ± 0.08 ^{a}	25.67 ± 0.09 ^{a}	25.60 ± 0.12 ^{a}	25.47 ± 0.05 ^{a}	25.44 ± 0.12 ^{a}
30.08.2022	26.78 ± 0.21^{b}	27.49 ± 0.69^{a}	27.76 ± 0.98 ^{a}	27.72 ± 0.09 ^{a}	27.48 ± 0.04 ^{a}

Table 04: Spatial Variation of EC

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	603.67 ± 34.93^{b}	473.67 ± 10.67^{c}	896.00 ± 32.15^{a}	501.67 ± 12.45^{bc}	906.33 ± 28.12^{a}
08.08.2022	295 ± 2.31^{b}	303 ± 2.73^{b}	317 ± 15.09^{ab}	328.33 ± 2.60^{ab}	342 ± 3.60^{a}
30.08.2022	307 ± 6.11^{c}	324 ± 5.51^{abc}	323.33 ± 10.48^{bc}	350.67 ± 5.78^{ab}	355 ± 3.46^{a}

Table 05: Spatial Variation of Salinity

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	0.29 ± 0.01^{b}	0.23 ± 0.01^{c}	0.44 ± 0.02 ^{a}	0.24 ± 0.00^{bc}	0.45 ± 0.01^{a}
08.08.2022	0.14 ± 0.00 ^{b}	0.14 ± 0.00 ^{ab}	0.15 ± 0.01 ^{ab}	0.16 ± 0.00^{ab}	0.16 ± 0.00 ^{a}
30.08.2022	0.14 ± 0.00 ^{c}	0.15 ± 0.00^{abc}	0.15 ± 0.00^{bc}	0.16 ± 0.00 ^{ab}	0.7 ± 0.00 ^{a}

Table 06: Spatial Variation of TDS

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	302 ± 17.56^{b}	236.33 ± 5.33^{c}	444.67 ± 16.92^{a}	251 ± 6.11^{bc}	453.33 ± 14.17^{a}
08.08.2022	147.33 ± 1.20^{b}	152.00 ± 1.52 ^{b}	158.33 ± 7.75^{ab}	164.00 ± 1.15^{ab}	171.00 ± 1.53^{a}
30.08.2022	153.33 ± 2.84 ^{c}	162 ± 3.00^{bc}	161.66 ± 5.24^{bc}	175.33 ± 3.18^{ab}	178.66 ± 2.73^{a}

Table 07: Spatial Variation of DO

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	6.63 ± 0.53^{ab}	5.56 ± 0.71 ^{ab}	7.28 ± 0.10^{a}	4.98 ± 0.50 ^{b}	6.83 ± 0.36 ^{ab}
08.08.2022	6.27 ± 0.61^{a}	5.51 ± 0.05 ^{ab}	5.68 ± 0.09 ^{ab}	4.73 ± 0.10 ^{b}	4.96 ± 0.08 ^{b}
30.08.2022	6.92 ± 0.57 ^{a}	5.62 ± 0.20 ^{ab}	5.84 ± 0.25 ^{ab}	4.45 ± 0.09 ^{b}	6.05 ± 0.44 ^{ab}

Table 08: Spatial Variation of BOD

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	5.35 ± 0.23 ^{b}	6.24 ± 0.38^{ab}	5.84 ± 0.25 ^{ab}	6.61 ± 0.69 ^{ab}	7.76 ± 0.36 ^{a}
08.08.2022	7.75 ± 0.24 ^{ab}	6.25 ± 0.20 ^{b}	5.12 ± 0.35 ^{b}	5.79 ± 0.51 ^{b}	9.58 ± 1.32 ^{a}
30.08.2022	6.53 ± 0.74 ^{b}	8.36 ± 0.69 ^{ab}	10.14 ± 0.51 ^{a}	8.03 ± 1.26 ^{ab}	9.97 ± 0.13 ^{ab}

Table 09: Spatial Variation of Turbidity

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	8.67 ± 2.81^{b}	11.28 ± 3.01 ^{b}	13.63 ± 6.79 ^{ab}	44.43 ± 12.72 ^{a}	36.33 ± 5.24 ^{ab}
08.08.2022	6.15 ± 2.36 ^{a}	39.33 ± 16.19 ^{a}	33.33 ± 14.19 ^{a}	50.55 ± 9.37 ^{a}	34.82 ± 3.71 ^{a}
30.08.2022	11.96 ± 5.91^{c}	25.59 ±4.27^{bc}	36.14 ± 3.07^{b}	59.55 ± 4.33 ^{a}	64.93 ± 3.45 ^{a}

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H. Turbidity Variation

Analyzed data indicate that turbidity varied with maximum and minimum levels at 72.96 and 4.71mg/l respectively. The higher turbidity recorded at all locations, may be the reason for the large quantity of organic waste in the lagoon. The highest mean value was recorded in location 5 (64.93) and the lowest mean value was recorded in location 1 (6.15) in 1st and 3rd sampling weeks respectively (Table 09). However this variation was not significant ($p < 0.05$) among all locations in 2nd sampling time but there was a significant difference among the locations in 1st and 3rd sampling. In addition, the highest mean value of 39.83 was recorded in 3rd week and the lowestvalue of 22.87 was recorded in 1st week. And it has not been significant within the weeks.

I. Total Solid Variation

Results from the study indicate TS to range from 200 to 1200 mg/l. The highest and lowest mean values were recorded in location 2 at 3rd and 1st Sampling time, respectively (Table 10). The variation of TS among all locations was not significant ($p < 0.05$) in 2nd and 3rd sampling time. However, there was a significant difference in 1st sampling time. Moreover, the highest mean value of 682.67 was recorded in 3rd week and the lowest value of 517.67 was recorded in 1st week. And it has not been significant with in the weeks.

J. Total Suspended Solid Variation

TSS was varied with the maximum and minimum level at 683 and 245 mg/l, respectively and these values fall above the acceptable limit for aquatic water bodies of 25 mg/l (Gadhia, Surana and Ansari 2012). The highest mean value was recorded in location 3 (536.66) and the lowest mean value recorded in location 1 (294) in the 2nd and 3rd sampling weeks, respectively (Table 11). However this variation has not been significant ($p < 0.05$) among all locations. In addition highest mean value of 461.40 was recorded in 2nd week and the lowest value of 358.47 was recorded in 1st week. And it has significantly different with in the weeks.

K. Hardness Variation

Excessive amounts of precipitation cause abundant outflow of fresh water into lakes and it decrease the hardness of water. Analyzed data indicate that hardness was varied with maximum and minimum levels at 230 and 555 mg/l, respectively. The highest mean value was recorded in location 4 (405) and the lowest mean value was recorded in location 1 (248.33) in 1st and 2nd sampling weeks, respectively (Table 12). These variations were significant ($p < 0.05$) among all locations in 1st and 3rd sampling time. However this variation is not significant among the locations in 2nd sampling. In addition highest mean value 357 was recorded in 1st week and the lowest value was recorded 303 in 2nd week. And it has significantly different with in the weeks.

L. Alkalinity Variation

Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes. According to the analyzed data the highest mean value recorded was in location 5 (436.67) and the lowest mean value recorded was in location 1 (280) in 1st and 2nd sampling weeks respectively (Table 13). This variation was significant ($p < 0.05$) among all locations. Moreover, the highest mean value of 380.33 was recorded in 1st week and the lowest value of 347.00 was recorded in 2nd week. However this variation was not significant ($p < 0.05$) among the weeks.

IV. CONCLUSION

The results of the study revealed that, the quality parameters tested slightly exceeded the standard levels for aquatic systems according to the spatial and temporal distribution. pH, temperature, salinity, and TDS are below the standard level and DO, BOD, turbidity, TSS, hardness and alkalinity are above the standard level. Spatial variation of every location shows that there were fluctuations in all the parameters with increasing and decreasing trends. EC, salinity, TDS, DO, BOD, hardness, and alkalinity significantly different among all the locations. Temporal variation of all parameters has significant difference within the weeks except turbidity, Dissolved Oxygen, Total Solids, and alkalinity. The variation observed for water quality parameters may be due to the influence of various factors such as, pollution from municipal, industrial, and agricultural runoff, discharge of wastewater directly into the lagoon, stagnation of water and growth of aquatic plants, climate Central Environmental Authority. Factors, lack of public awareness inadequate service of solid waste collection and so on. Since there are spatial and temporal fluctuations in quality parameters, this study suggests that regular

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monitoring is essential to conserve this aquatic system.

Table 10: Spatial Variation of TS

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	447 ± 116.54 [ab]	375 ± 46.58[b]	547 ± 18.48 [ab]	533.33 ± 35.36 [ab]	686 ± 28.51 [a]
08.08.2022	500 ± 0.00[a]	400 ± 57.74 [a]	466.66 ± 120.18 [a]	700 ± 57.73 [a]	566.66 ± 88.19 [a]
30.08.2022	766.66 ± 33.33 [a]	846.66 ± 181.23 [a]	666.66 ± 218.58 [a]	400 ± 115.47 [a]	733.33 ± 66.66 [a]

Table 11: Spatial Variation of TSS

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	323.33 ± 41.64 [a]	407.33 ± 8.01 [a]	365.33 ± 22.26 [a]	378 ± 24.58 [a]	318.33 ± 36.17 [a]
08.08.2022	442 ±78.34 [a]	491.66 ±104.08 [a]	536.66 ± 60.09 [a]	484.66 ± 56.64 [a]	352 ±53.61 [a]
30.08.2022	294 ± 5.29 [a]	388.66 ± 45.04 [a]	453.33 ± 52.68 [a]	390.66 ± 46.41 [a]	395.33 ± 39.28 [a]

Table 12: Spatial Variation of Hardness

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	325 ± 2.89 [a]	358.33 ± 12.02 [a]	376.67 ± 24.21 [a]	405 ± 33.29 [a]	320 ± 45.37 [a]
08.08.2022	248.33 ± 1.66[b]	296.66 ±18.33 [b]	316.66 ± 1.66 [a]	331.66 ±16.91 [a]	321.66 ± 9.28 [a]
30.08.2022	278.33 ± 1.66 [a]	385 ± 85.78 [a]	288.33 ± 29.20 [a]	301.66 ± 6.01 [a]	306.66 ± 7.26 [a]

Table 13: Spatial Variation of Alkalinity

Sampling date	Location 1	Location 2	Location 3	Location 4	Location 5
20.07.2022	285 ± 40.10 [b]	371.67 ± 1.67 [ab]	393.33 ± 8.33 [ab]	415 ± 15.0 [a]	436.67 ± 37.68 [a]
08.08.2022	280 ± 2.88 [b]	345.00 ±7.63 [b]	353.33 ±31.79 [ab]	383.33 ±32.45 [a]	373.33 ± 1.66 [ab]
30.08.2022	308.33 ± 1.66 [b]	378.33 ± 15.89 [a]	365 ± 24.66 [ab]	368.33 ± 7.26 [ab]	383.33 ± 1.67 [a]

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