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On the Seasonal Changes in the Surface Water Chemistry of Museum Lake, Thiruvananthapuram, Kerala, India

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ABSTRACT: The surface water chemistry of Thiruvananthapuram Museum Lake was carried out in the period of February 2013 to January 2014. Correlation study of the parameters and overall CCME WQI (Canadian Council of Ministers of the Environment Water quality Index) was also prepared in the study for the lake water. The parameters analysed are cations such as Ca^{2+}, Na^{+}, Mg^{2+} and K^{+} and the anions like PO_4^{-}, Si_4^{-} , NO_3^{-} and NO_2^{-}. Abiotic factors like water pH, Temperature, Conductivity, TDS, Total Alkalinity and Total Hardness were also analysed. The pH ranged between 6.5 to 7.4. The total hardness ranged between 50.8-99 mg/L which shows the water is moderately hard one. During the pre monsoon period, water temperature showed a positive correlation with total alkalinity (r= 0.915) pH (r= 0.841) and TDS (0.876). Dissolved Oxygen (DO) value showed a positive correlation with Biological Oxygen Demand (BOD) (r= 0.999). The overall CCME water quality index was 80.81 which indicate the water body is protected with only a minor degree of threats. The quality of the water is an essential element of the Thiruvananthapuram Zoo environment with respect to both healths of the ecosystem and zoo tourism enjoyment. Moreover, if maintained properly, this water body can be treated as a major drinking water source for the zoo animals.

Keywords: biological oxygen demand, correlation study, phosphate, total hardness, water quality index.

INTRODUCTION

Zoological parks and urban museums play a significant role in biodiversity conservation as well as a source of economy to the state. Globally, zoological gardens are known to offer great opportunities for entertainment, education, to contribute to wildlife conservation, and promote scientific research, especially for environmentalists and conservationists, as the rate of extinction of wild life increases (Gupta, 2013). The Thiruvananthapuram Museum and Zoo is the one with unique construction and conservations in mind. This is a rare and unique institution where a Botanical garden, Natural history Museum, and a Zoological Garden are in a single compound which displays the British architectural prowess. There are very few such parks in India to sustain a freshwater ecosystem inside too. A small water source was exist in the Thiruvananthapuram Zoo naturally, which was further excavated and developed by a British Engineer, Hinglobe in 1859 mainly for recreational purpose. It receives water from precipitation mainly the South-West monsoon (June-September) North- East monsoon (October- December) and also by seepage. The lake is generally deep with the marginal slope ranging from 3 to 6 meters. The museum lake is perennial water body but an artificial one (with 156 year old since from its construction in

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1859), has never lost its water level even in the scorching summers.

Water is a precious resource for life to exist. Freshwater in its chemistry is a combination of inorganic matter in ionic forms and also as dissolved gases. Major ions present in natural water include the cations $Ca^{2+,}$ Na^{+}, Mg^{2+} and K^{+} and the anions HCO_3^- , SO_4^-, Cl^-. Water is a good solvent and it dissolves minerals and retains them in solution. Dissolved Organic Carbon in smaller concentrations also influences the ionic balance of the water. Water chemistry is affected by climate, geology and often autochthonous activities from surrounding ecosystem. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem and depends on the abiotic factors (Dhawale and Ghyare, 2015). Increased pollution level in the water contributes to health hazards and leads to deterioration of the ecosystem (Joseph *et al*., 2009). On the other hand, in case of pristine aqua systems, such studies shall contribute towers the protection and preservation of its good water quality (Muniyan and Ambedkar, 2011). Protecting and preserving the quality of any water body is a significant duty of today. Although it is inside a protected area the quality of the water is to be determined regularly so that measures to check the source of pollution can be done.

Lakes and rivers are highly heterogeneous in nature and several studies have been carried out for the documentation of this heterogeneity which focused on the physical and chemical parameters of water. Seasonal changes in the water chemistry of water bodies have been studied and evaluated worldwide. Castañé *et al*. (2015) has studied the water quality of Luján River in Buenos Aires. Physico chemical analysis of Usma River was studied by Ugwu and Wakawa (2012). Water quality refers to the overall physical, chemical, and biological characteristics of water. Kennel *et al*. (2007) has studied the water quality status of an urban river system in river Bagmati in Nepal. Gaytan *et al*. (2009), has made an initial appraisal of water quality of Lake Santa in Mexico. Singh and Balasingh (2011) have made a study on the limnological characteristics of Kodaikanal Lake with special reference to phytoplankton diversity. Raj and Azeez (2009) have studied the spatial and temporal variations in the surface water chemistry of Bharathapuzha River. Dhinamala *et al*. (2015) has studied the nutrient status of Pulicat Lake. The nutrient levels and phytoplankton presence reflect the water quality status. The overall environmental status of the ecosystem can be obtained from different physico chemical and biological parameters studied. Sheela *et al*. (2010) has studied the environmental status of the Veli- Akkulam Lake in Thiruvananthapuram. Correlation studies are used to assess and interpret the quality relationship between various chemical parameters of the aquatic system. Bhatnagar and Devi (2012) have used correlation studies to assess the lentic water quality of Bhrahmasarovar in India.

Water quality is usually calculated using water quality index. Water quality index is a number that has a finite scale to differentiate between polluted water and very clean water. This number converts different water quality data into one simple indicator that can be used to describe the overall quality of water. Water quality index is an efficient tool which aims to provide solitary numerical value for a large and comprehensive water quality data to illustrate the water quality. Therefore, it is a simple tool for decision makers on the quality and possible uses of a water body (Tiwari and Mishra, 1985; Bordalo *et al.*, 2001; Cude, 2001, Kannel *et al.,* 2007; Ramakrishnaiah *et al*., 2009). The CCME WQI is based on a formula developed by the British Columbia Ministry of Environment, Lands, and Parks that was modified by Alberta Environment. Lumb *et al*. (2006), Pal *et al*. (2015), and Al-Janabi *et al*. (2015) have observed the CCME WQI as an efficient tool in monitoring water quality.

Regular water quality monitoring of water resources are necessary for sustainability of ecosystem health and hygiene, agricultural use and domestic use (Pal, 2015). The quality of the water is an essential element of the Thiruvananthapuram Zoo environment with respect to both healths of the ecosystem and zoo tourism enjoyment. This can be treated as a major water source for animals if it can be maintained properly at the quality levels.

MATERIALS AND METHODS

Study Area

The Thiruvananthapuram museum and zoo is one of the oldest of its kind in India, located at the heart of the city (08˚30' N, 076˚57'E). Swathi Thirunal (1813-1847), illustrious king and music composer who ruled southern Kerala (Travancore) during 1830-1847 could be said to be the visionary behind establishment of the Thiruvananthapuram Museum and Zoo. The lake was constructed for recreational purpose. Water was pumped into the lake and seepage and precipitation formed the source of water. The animal excreta and the washings were drained earlier into the lake. Later with more and more concerns over beautification of the zoo, the water of the lake was drained out and cleaned twice in 1990 and in 2010. At present, washings and excreta from the animal cages are drained out through separate pipes into the main city drainage system. Water of this lake is now pumped out for daily cleaning of animal cages, for their bathing and to fill the tanks of the water loving animals and also for watering the plants in the garden and zoo premises. Although it is in the midst of a busy city, the zoo lake is now out of any kind of pollution as there is no dumping of wastes. The Museum Lake is unaffected by any strong anthropogenic perturbations and pollution. It is considered as a protected ecosystem under the custody of Directorate of Zoo and Museums, Government of Kerala. The Central Zoo Authority established in 1992 under the Ministry of Environment and Forest of India, enacts uniform management code to all the Zoos in the country and provides financial and technical support for the Zoos.

The zoo is extended over 55 acres and the water body is 1.90 acre in area. Along one side of the lake is an island lushed with green shrubs and lianas. This ecosystem encompasses diversity of fishes in turn, forms food for a good number of winged beauties.

No significant works have been done in Govt Museum and Zoo, Thiruvananthapuram especially on the water chemistry and quality of the lentic body inside.

Water chemistry provides current status of the quality of water. This determines the healthy status of the associated flora and fauna of that ecosystem. A wide variety of exotic and indigenous flora is associated with the water body which provides enough shade to the surface water along its periphery. The riparian vegetation provides food and shelter for a good number of birds. Nesting of Little Grebe and Oriental darter on the zoo premises near the lake was already reported.

Although it is in the midst of a busy city, the museum lakes are undisturbed ecosystem except for reports of plastic bottles and carry bags thrown carelessly by the zoo visitors.

In recent years, many scientific studies are conducted to know about the water chemistry and quality parameters. The study was carried out for a period of one year from February 2013 to January 2014. The parameters analysed are cations such as Ca^{2+}, Na^{+}, Mg^{2+} and K^{+} and the anions like PO_4^{-}, Si_4^{-}, NO_3^{-} and NO_2^{-}. Abiotic factors like water pH, Temperature, Conductivity, TDS, Total Alkalinity and Total Hardness are also calculated following APHA (2012). The analysis samples were taken in one litre clean plastic bottles from selected sites of the lake.

Correlation study was calculated using PAST software ver. 1.34 was done for the statistical analysis of the data obtained.

Calculation of CCME Water Quality Index

The calculation for water quality index was done from a set of ten physico chemical parameters. CPCB (2009) recommended standards for inland surface water were applied to categorize the water. Canadian Council of Ministers of the Environment developed a water quality index which includes three essential measures of variance (Scope, Frequency and Amplitude). CCMEWQI was based on the water quality index developed by British Columbia in 1995. These measures of variance come together with a set of range of values classifying quality of water into five classes namely; poor, marginal, fair, good and excellent.

The detailed formulation of the WQI as described in the Canadian WQI Technical report (CCME, 2001) is as follows:

Mathematical formulation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) is:

$$CCME\ WQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right] \qquad (1)$$

where F1 (Scope) represents the extent of water quality guideline non-compliance over the time period of interest.

$$F_1 = \frac{No. of\ failed\ variables}{Total\ no. of\ failed\ variables} \times 100 \qquad (2)$$

F2 (Frequency) represents the percentage of individual tests that do not meet objectives (failed tests).

$$F_2 = \frac{No. of\ failed\ tests}{Total\ no. of\ failed\ tests} \times 100 \qquad (3)$$

F3 (Amplitude) represents the amount by which, failed test values do not meet their objectives. F3 is calculated in three steps.

Step 1. Calculation of Excursion

Excursion is the number of times that an individual concentration is:

1. Greater than the objective when the objective under consideration is maximum. In this case the excursion is calculated as:

$$Excrusion_i = \frac{failed\ tests\, valuei}{objectivej} - 1 \qquad (4)$$

2. Less than the objective when the objective under consideration is minimum. The expression for the excursion in this case is given as:

$$Excrusion_i = \frac{objectivej}{failed\ tests\, valuei} - 1 \qquad (5)$$

Step 2. Estimation of Normalized Sum of Excursions

The normalized sum of excursions (nse), represents the collective amount by which individual tests are out of compliance. It is estimated by summing the excursions of individual tests from their objectives and dividing by the total number of tests for both meeting objectives and not meeting objectives:

$$nse = \frac{\sum_{i=1}^{n} \text{excrusioni}}{Sum\, of\ tests} \qquad (6)$$

Step 3. Estimation of F3 (Amplitude)

F3 (Amplitude) is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range of values from 0 to 100.

$$F_3 = \frac{nse}{0.01nse + 0.01} \quad (7)$$

RESULTS AND DISCUSSIONS

The chemical composition is the main characteristics of water quality that define its fitness for particular kinds of water use (Nikanorov and Brazhnikova, 2015). The quality determines the diversity of micro and macro flora and fauna associated with the ecosystem. Water quality evaluation is considered as a critical issue in recent years, especially when freshwater is becoming a scarce resource in the future (Gokot *et al*., 2012).

The result of the physico chemical attributes (minimum and maximum values of the water body for the Pre monsoon, Monsoon and Post monsoon period) are shown in Figure 1, 2 and 3.

The mean and standard deviation values for the parameters are shown in Table 1.

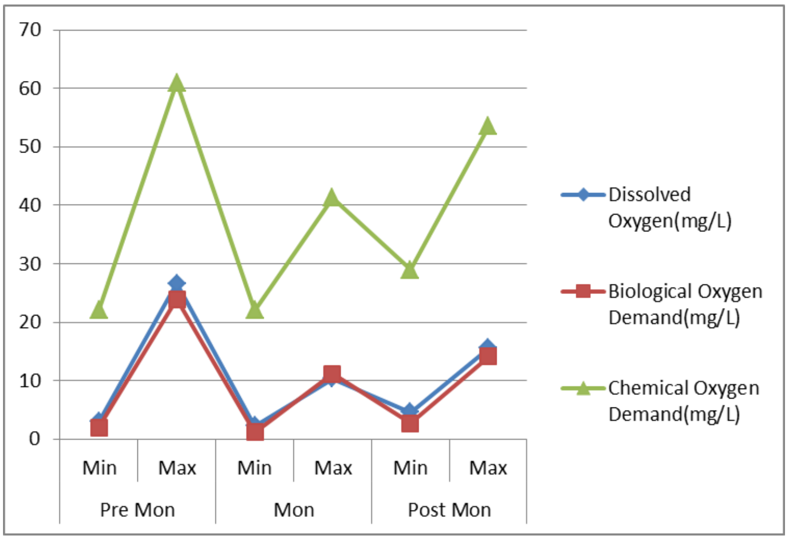

Fig. 1. Maximum and Minimum values for the three seasons for DO, BOD and COD

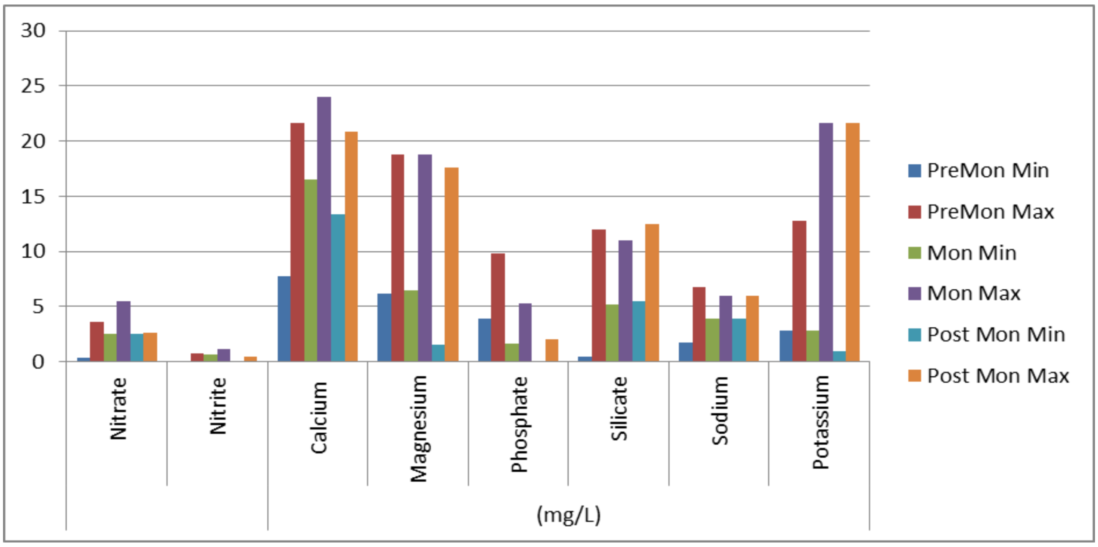

Fig. 2. Maximum and Minimum values for the three seasons for Ca^{2+}, Na^+, Mg^{2+} and K^+ PO_4^-, Si_4^- , NO_3^- and NO_2^-

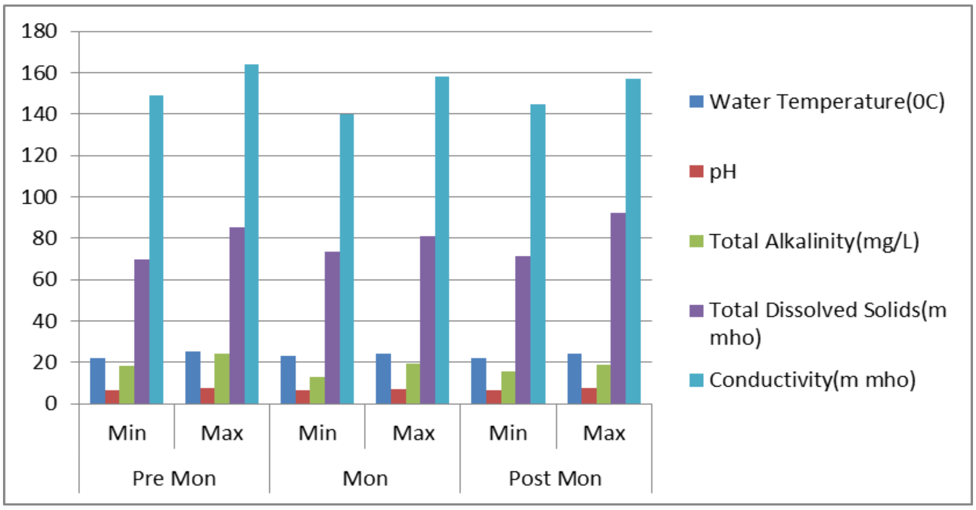

Fig. 3. Maximum and Minimum values for the three seasons for WT, pH, TA, TDS and Conductivity

Table 1. Standard Deviation and Mean for the three seasons

Parameters	Pre Monsoon	Monsoon	Post Monsoon
WT	23.7±1.5	23.25±0.5	23±0.82
pH	6.9±0.42	6.8±0.34	6.9±0.52
DO	11.29±10.98	8.28±4.02	8.08±5.11
BOD	10.07±10.11	8.29±4.29	6.00±5.45
COD	43.60±16.30	30.08±9.67	43.35±10.35
TA	21.56±2.99	16.63±3.38	17.35±1.27
NO3	1.73±1.55	3.99±1.54	2.60±0.07
NO2	0.39±0.30	0.90±0.21	0.22±0.18
CaH	13.4±5.95	18.65±3.59	17.23±3.05
TH	69.44±26.76	62.59±8.22	63.25±30.54
MgH	13.30±5.30	14.11±5.88	11.03±6.77
Phos	6.87±3.22	3.46±2.12	1.43±0.91
Sili	5.35±5.19	8.06±3.35	9.72±3.00
Na	4.88±2.17	4.94±1.22	5.13±1.05
K	6.16±4.48	12.24±10.81	11.68±11.48
TDS	76.30±7.35	77.72±3.47	76.41±10.46
Cond	156.20±6.28	147.10±8.16	153.88±6.05

(WT- ^{o}C; TDS & Cond -m mho; Others in mg/L)

The water temperature showed a range and a deviation between 23.7±1.5 and 23.25±0.5 during Post monsoon and Monsoon respectively and 23±0.82 during Post monsoon period. The pH values observed is between 6.5- 7.6 which confirms the suitability of the living organisms in the water body. The dissolved oxygen in the current study ranges between 2.25-26.6 mg/L. Dissolved Oxygen (DO) reached maximum during the pre monsoon and least during the monsoon. Higher DO means rate of oxygen replenishment in water is greater than O_2 consumption and this is healthy for almost all aquatic systems (Adak *et al.*, 2002). The two important sources of oxygen in water are: diffusion of oxygen from the air into the water and the photosynthetic activity of aquatic autotrophs. Dissolved Oxygen determines the parameter for the survival of fishes and other aquatic organisms. Measurement of DO can be used to indicate the degree of pollution by organic matter and also in assessing water pollution (Laluraj *et* *al*., 2002). Oxygen is also needed for many chemical reactions that are important to ecosystem functioning such as, oxidation of metals, decomposition of dead, and decaying matter, etc. (Ramachandra and Solanki, 2007).

Seasonal average of Biological Oxygen Demand (BOD) was 10.07 mg/L for Pre monsoon and 8.29 and 6.0 mg/L during Monsoon and Post monsoon seasons respectively. The value for BOD reached highest (23.93 mg/l) during the month of February. High BOD is an indicator of degradation activity by the microbes on organic matter and thereby, reduction of oxygen content in the lake (Jacob *et al*., 2008; Ajayan and Kumar, 2014). The lake is organically polluted with autochthonous sources such as the leaf debris from the riparian vegetation, the visiting birds and bats excreta.

The Chemical Oxygen Demand (COD) for the Pre monsoon was 43.60±16.30 and 30.08±9.67 and 43.35±10.35 for Monsoon and Post monsoon respectively. The dissolved solids especially Calcium and Magnesium result in the Total Hardness of the water. The TH for the water ranged between 20.5 – 99 mg/L. The degree of hardness increases as the amount of Calcium and Magnesium increases. Hardness with 60-120 mg/L is considered as moderately hard water. The water in the present study is a moderately hard one. It was noticed that as the content of Ca and Mg increases, the content of hardness also shoots up (Skipton, 2009).The maximum permissible limit of hardness is 200 mg/l (BIS, 2012).

Nitrates are the oxidised forms of nitrogen and the end product of the aerobic decomposition of organic nitrogenous matter. Nitrogen along with phosphorus is termed as a bio stimulant. The evaluation of nitrate is paramount importance in understanding the nutritional status of water bodies. In drinking water sources, the permissible limit of nitrates are 45 mg/L. The nitrate concentration in surface water is normally low (0–18 mg/l) but can reach high levels as a result of agricultural runoff, refuse dump runoff or contamination with human or animal wastes (WHO 2011). The NO_3^- values were 1.73±1.55 for Pre monsoon and 3.99±1.54 and 2.60±0.07 for Monsoon and Post monsoon period respectively. Pseudomonas, Klebsiella and *Staphylococcus* have significant ability to remove nitrate from water (Olaolu *et al*., 2013). Ajayan *et al*. (2015) has isolated Pseudomonas sp, Klebsiella oxytoca and Staphylococcus sp from the lake water.

Phosphates are the growth limiting nutrient and can be the nutrient that limits the primary productivity in water. The presence of phosphates ranged between 3.88-9.85 mg/L during Pre monsoon and 1.62- 5.3 and 0.08-2.02 mg/L during Monsoon and Post monsoon period respectively. A higher concentration of phosphate during the Pre monsoon period is due to low water level and pollution (Kamal *et al*., 2007; Sahni and Yadav, 2012). In the present study, the pollution is mainly organic pollution which is mainly due to the leaf litter that falls from the riparian vegetation.

The values for Na, K, Silicate, TDS and Conductivity are under the acceptable range as prescribed by BIS 10500: (2012).

The correlation coefficients (r) between various pairs of the parameters during the three seasons are furnished in Tables 2, 3 and 4 for Pre monsoon, Monsoon and Post monsoon period respectively. A high correlation coefficient (near 1 or -1) means a good relationship between two variables and a correlation coefficient around zero means no relationship. During the pre monsoon period, the water temperature showed a positive correlation with total alkalinity (r= 0.915) pH (r= 0.841), and TDS (0.876). DO showed positive correlation with BOD (r= 0.999). Hardness of the surface water is positively correlated with anions namely, Nitrate, Phosphate and Silicate and with cations like Ca^{2+}, Mg^{2+} and Na^{2+}. Hence from the correlation analysis, it signifies that the hardness of the surface water samples are of both types- temporary and permanent.

Table 2. Correlation Coefficient between Physico chemical parameters Pre Monsoon 2013

	WT	pH	DO	BOD	COD	TA	NO3-	NO2-	CaH	TH	MgH	Phos	Sil	Na	K	TDS	Cond
WT		0.841	-0.592	-0.557	-0.184	0.915	-0.469	0.857	0.289	-0.143	-0.224	0.261	0.085	-0.577	0.602	0.876	0.430
pH			-0.341	-0.312	0.268	0.905	-0.336	0.903	-0.172	-0.48	-0.519	-0.301	-0.131	-0.915	0.8099	0.997	0.357
DO				0.999	-0.108	-0.232	0.968	-0.702	0.033	0.432	0.525	-0.432	0.534	0.252	-0.622	-0.365	0.420
BOD					-0.130	-0.192	0.974	-0.68	0.058	0.446	0.537	-0.432	0.561	0.237	-0.616	-0.334	0.459
COD						-0.159	-0.347	0.336	-0.994	-0.931	-0.887	-0.806	-0.857	-0.627	0.664	0.203	-0.62
TA							-0.126	0.746	0.251	-0.07	-0.119	-0.001	0.274	-0.668	0.512	0.928	0.676
NO3-								-0.706	0.279	0.627	0.703	-0.224	0.727	0.349	-0.720	-0.342	0.587
NO2-									-0.233	-0.632	-0.693	-0.102	-0.412	-0.836	0.926	0.906	0.014
CaH										0.889	0.837	0.820	0.839	0.551	-0.579	0.105	0.644
TH											0.994	0.616	0.908	0.755	-0.876	-0.437	0.596
MgH												0.534	0.910	0.758	0.909	-0.476	0.593
Phos													0.387	0.616	-0.383	-0.234	0.123
Sil														0.422	-0.683	-0.088	0.872
Na															-0.899	-0.844	-0.07
K																0.786	-0.25
TDS																	0.390
Cond																	

Table 3. Correlation Coefficient between Physico chemical parameters Monsoon 2013

	WT	pH	DO	BOD	COD	TA	NO3-	NO2-	CaH	TH	MgH	Phos	Sil	Na	K	TDS	Cond
WT		-0.576	0.302	0.180	0.773	-0.419	0.480	0.696	-0.193	0.490	-0.183	-0.577	0.577	0.577	0.577	0.642	0.898
pH			0.60	0.69	-0.96	0.98	-0.99	-0.90	-0.68	0.42	0.90	0.99	-0.99	-0.99	-0.99	-0.89	-0.87
DO				0.99	-0.37	0.73	-0.68	-0.35	-0.99	0.97	0.88	0.60	-0.60	-0.60	-0.60	-0.43	-0.13
BOD					-0.48	0.81	-0.77	-0.45	-0.99	0.94	0.93	0.69	-0.69	-0.69	-0.69	-0.53	0.26
COD						-0.89	0.92	0.91	0.47	-0.17	-0.76	-0.96	0.96	0.96	0.96	0.91	0.96
TA							-0.99	-0.82	-0.80	0.58	0.96	0.98	-0.98	-0.98	-0.98	-0.87	-0.76
NO3-								0.88	0.76	-0.52	-0.94	-0.98	0.98	0.98	0.98	0.85	0.81
NO2-									0.443	-0.17	-0.70	-0.88	0.88	0.88	0.88	0.682	0.914
CaH										-0.949	-0.928	-0.689	0.689	0.689	0.689	0.526	0.247
TH											0.766	0.428	-0.428	-0.428	-0.428	-0.263	0.066
MgH												0.908	-0.908	-0.908	-0.908	-0.770	-0.58
Phos													-1	-1	-1	-0.912	-0.86
Sil														1	1	0.912	0.869
Na															1	0.912	0.869
K																0.912	0.869
TDS																	0.830
Cond																	

Table 4. Correlation Coefficient between Physico chemical parameters Post Monsoon 2013

	WT	pH	DO	BOD	COD	TA	NO3-	NO2-	CaH	TH	MgH	Phos	Sil	Na	K	TDS	Cond
WT		-0.860	-0.024	0.024	0.702	0.386	0	0.179	0.070	0.648	0.660	-0.848	0.144	0.535	0.732	0.001	0
pH			0.010	0.686	-0.673	-0.508	-0.108	-0.099	0.327	-0.685	-0.687	0.491	0.326	-0.699	-0.899	0.107	-0.10
DO				0.993	0.684	0.852	-0.971	0.970	0.623	0.708	0.701	0.278	0.416	-0.705	-0.437	0.971	-0.97
BOD					0.665	0.809	-0.992	0.978	0.708	0.676	0.671	0.224	0.516	-0.755	-0.495	0.992	-0.99
COD						0.915	-0.653	0.794	0.394	0.991	0.994	-0.358	0.287	-0.05	0.285	0.654	-0.65
TA							-0.761	0.868	0.312	0.951	0.946	0.046	0.125	-0.231	0.096	0.761	-0.76
NO3-								-0.978	-0.790	-0.649	-0.646	-0.142	-0.618	0.786	0.532	-0.999	1
NO2-									0.722	0.792	0.790	0.039	0.551	-0.641	-0.346	0.978	-0.97
CaH										0.317	0.325	-0.258	0.969	-0.771	-0.626	0.790	-0.79
TH											0.999	-0.254	0.188	-0.40	0.297	0.650	-0.64
MgH												-0.273	0.200	-0.037	0.300	0.647	-0.64
Phos													-0.428	-0.407	-0.481	0.140	-0.14
Sil														-0.647	-0.550	0.619	-0.61
Na															0.941	-0.785	0.786
K																-0.532	0.532
TDS																	-0.99
Cond																	

During the monsoon season, Silicate showed strong positive correlation with Sodium and Potassium (r=1). During the post monsoon period DO showed significant correlation with BOD. There was a negative correlation with water temperature and Nitrate and Conductivity (r=0).

The results of the various parameters used for calculating the WQI is given in Table 5.

The values for DO, BOD and Phosphates showed some deviations from the objective values and are responsible for the value of water quality index.

The calculated values of CCME WQI for Museum Lake is given in Table 6.

Table 6 presents a summary of three measures of variance, i.e. F1 (scope), F2 (frequency), and F3 (amplitude) of water use for protection of aquatic life. The table shows, F3 has lower values than F1 and F2. It denotes that there are a less percentage of individual failed tests.

Table 7 shows the categories of water quality based on WQI value obtained.

Table 5.The parameters used for calculating WQI

Month	pH	DO	BOD	COD	TA	NO_3^-	TH	PHOS	TDS	COND
FEB	6.71	26.6	23.93*	48.75	19.50	3.61	75.5	3.88	71.16	156.89
MAR	6.58	2.95*	1.95	42.63	18.5	0.53	69	9.46*	69.5	149.06
APR	7.5	3.7*	3.2*	61	24	0.39	34.25	4.29	85.29	154.6
MAY	7.1	11.9	11.2*	22	24.25	2.37	99	9.85*	79.23	164.23
JUN	7.1	10.38	11.2*	22	19.5	2.5	66	5.3*	76.6	140.1
JULY	7.06	10.38	11.2*	22	19.5	2.83	66	5.3*	73.34	141.8
AUG	6.5	2.25*	1.15	35	13	5.52	50.8	1.62	79.86	148.39
SEPT	6.5	10.1	9.59*	41.3	14.5	5.1	69	1.62	81.06	158.1
OCT	7.6	4.91*	2.99	29	15.8	2.63	20.5	1.98	71.16	156.9
NOV	6.98	15.53	14.1*	53.5	18.8	2.49	93	1.62	92.1	144.8
DEC	6.5	4.6*	2.66	46.8	17	2.63	69	0.08	71.2	156.9
JAN	6.5	7.29	4.23*	44.1	17.8	2.63	70.5	2.02	71.16	156.9
Objective	6-9	>5	<3	<250	<200	<10	<200	<5	<500	<300

Table 6. Calculated values of CCME WQI

Term of the Index	Values
Scope F1	30
Frequency F2	14.166
Nse	0.2159
Amplitude F3	1.776
CCME WQI	**80.81**

Table 7. Categories of water quality based on WQI value

WQI Value	Comments about water quality	Description
95-100	Excellent	Conditions very close to natural or pristine levels and water is protected with a virtual absence of threat.
80-94	Good	Conditions rarely depart from natural or desirable levels and the water is protected with only a minor degree of threat.
65-79	Fair	Water quality is protected but occasionally threatened or impaired.
45-64	Marginal	Water quality is frequently threatened or impaired.
0-44	Poor	Water quality is almost always threatened or impaired.

The water quality index results show that it comes under the category Good. The water body is an undisturbed ecosystem in the midst of the busy city and which is inside a busy tourist area. The DO, BOD and Phosphate values do not meet the desired limit for water quality. All other parameters taken to calculate the water quality index falls under the acceptable limits of quality standards.

CONCLUSION

The water chemistry changes observed in the present study shows no threats to the water body. The lake is carefully protected well under the CZA and the Department of Museum and Zoo. Though the abandoned water bottles thrown by the zoo tourists are a threat to the water, strict rules and regulations are to be made to check this. The overall water quality index implicates that the conditions rarely depart from natural or desirable levels and the water is protected with only a minor degree of threat. The water is capable of protecting and preserving the aquatic fauna and flora and the good number of birds associated with the lake. Regular monitoring of the water quality status is a requirement in order to prevent the quality deterioration. Moreover, if maintained properly this water body can be treated as a major drinking water source for the animals.

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REFERENCES

Anila, P., Ajayan, A. and Kumar, K.G. (2014) A Preliminary Study of the Physico Chemical Parameters of the Pond in Thiruvananthapuram Zoo, Kerala, India with Special Reference to Phytoplankton Diversity Journal of Aquatic Biology and Fisheries, 2(2): 36- 40C.

Anila, P., Ajayan, J., Ajit, B. and Kumar, K.G. (2015). Microbial Quality of the Lake inside Thiruvananthapuram Zoological Garden, Kerala, India IJABPT, 6(3: 49-55.

APHA, American Public Health Association (2005). Standard Methods for the Examination of Water and Wastewater, 21st Edition Washington, DC.

Bhatnagar, A. and Devi, P. (2012). Applications of correlation and regression analysis in assessing lentic water quality: a case study at Brahmsarovar Kurukshetra, India. International Journal Of Environmental Sciences. 3(2): 813-820.

Bordalo, A.A., Nilsumranchit, W. and Chalermwat, K. (2001). Water quality and uses of the Bangpakonk River (Eastern Thailand), Water Research, 35(15): 3635–3642.

Canadian Council of Ministers of the Environment (2001). Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0, user's manual in Canadian Environmental Quality Guidelines, 1999, Winnipeg.pp: 1-5.

Central Pollution Control Board, CPCB (1995). Classification of Inland surface waters (CPCB Standards). Water Quality Parivesh, 1(4): 6.

Cude, C. (2001). Oregon water quality index: A tool for evaluating water quality management effectiveness. Journal of American Water Resources Association, 37(1): 125–137.

Dhawale, P.G. and Ghyare, B.P. (?). Assessment of Physico-Chemical Status of Water in Pus Dam of Pusad Tahsil Journal of Natural Sciences Research, 5(9): 1-6

Dhinamala, K., Pushpalatha M., Samuel T. and Raveen R. (2015). Seasonal variations of nutrients in Pulicat Lake, Tamil Nadu, India. International Journal of Fisheries and Aquatic Studies. 3(2): 264-267.

Gokot, B., Varol, M., Kekleyen, A. and Kekleyan, A. (2010). Spatial and temporal variations in surface water quality of the dam reservoirs in the Tigris River basin, Turkey *Catena*. 92: 11-21.

Indian Standard DRINKING WATER — SPECIFICATION (Second Revision) Bureau of Indian Standards (2012) pp 18 Downloaded on 24/04/2015.

Jacob (2008). Seasonal variation of hydrographic parameters and distribution of nutrients in the Veli - Akkulam Lake Complex. Indian Hydrobiology, 11(2): 281-288.

Kamal, D., Khan. A.N., Rahman, M.A., and Ahmed, F. (2007). Studies in physico-chemical properties of water of Mouri river Khulna, Bangladesh. Pakistan J. of Biological Sciences 10(5): 710-717.

Kannel, P.R., Lee, S., Lee, Y.S., Kanel, S.R. and Khan, S.P. (2007). Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment. Environmental Monitoring and Assessment, 132: 93–110.

Laluraj, C.M., Gopinath, G. and Dinesh Kumar, P. K. (2005). Groundwater chemistry of shallow aquifers in the costal zones of Cochin. India Applied Ecology and Environmental Research, 3(1): 133–139.

Lumb, A., Halliwell, D. and Sharma T. (2006). Application of CCME Water Quality Index to monitor water quality: A case of the Mackenzie River Basin, Canada. Environ. Monot. Assess. Basin, Canada, Environ.Monot.Assess. 113 (1-3): 411-429.

Mihir, P., Nihar, R., Samal, Malabika, B., Roy and Pankaj, K., Roy (2015). Water Quality Index as a Reliable Indicator of Water Pollution Level-A Case Study of Rudrasagar Lake, Tripura. IJIRSET, 4(8): 7801-7806.

Muniyan, M. and Ambedkar, G. (2011). Seasonal Variations in Physicochemical Parameters of Water Collected from Kedilam River at Visoor Cuddalore District, Tamil Nadu, India. International Journal of Environmental Biology. 1(2): 15-18.

Nikanorov and Brazhnikova, L.V. (2015). Types and Properties of Water – Vol. II - Water Chemical Composition of Rivers, Lakes And Wetlands– A.M. Downloaded on 15/09/2015.

Nikhil R. and Azeez, P. A. (2009). Spatial and temporal variations in surface water chemistry of a tropical river, the river Bharathapuzha in India. CURRENT SCIENCE, 96(2).

Okeke, C.O. and Igboanua, A.H. (2003). Characteristics and Quality Assessment of Surface Water and Groundwater Recourses of Akwa Town, Southeast, Nigeria. J. Niger Assoc. Hydrol. Geol., 14: 71-77.

Olaolu, T.D., Akpor, OBand, and Aderiye, B.I. (2013). Investigation of the Effect of Initial Biomass on Nitrate and Phosphate Removal from Synthetic Wastewater by Selected Bacteria Isolates Journal of Natural Sciences Research, 3(11): 39-49.

Øyvind, Hammer., D.A.T. Harper and P.D. Ryan PAST -PAlaeontological STatistics, ver. 1.34

Patricia, M., Castañé., Aníbal Sánchez-Caro, and Alfredo Salibián (2014). Water quality of the Luján river, a lowland watercourse near the metropolitan area of Buenos Aires (Argentina). Environ Monit Assess (2015) 187:645.

Prathap, Singh, R., and G. S. Regini Balasingh (2011). Limnological Studies of Kodaikanal Lake(Dindigul District), in special reference to Phytoplankton Diversity. Indian Journal of Fundamental and Applied Life Sciences. 1 (3):112-118.

Ramachandra, T, V. and Malvikaa Solanki. (2007). Ecological Assessment of Lentic Water Bodies of Bangalore. ENVIS Technical Report: 25 Jan 2007 Environmental Information System [ENVIS] Centre for Ecological Sciences, Indian Institute of Science, Bangalore, pp 105.

Ramakrishnaiah, C. R., Sadashivaiah, C., and Ranganna, G. (2009) Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry, 6: 523-530.

Roberto Gaytán, José de Anda, and Fernando González-Farías (2009). Initial appraisal of water quality of Lake Santa Ana, Mexico. Lakes and Reservoirs: Resources and Management. 14: 49-55

Sabu, Joseph, Byma, Benziger, and Jobin, Thomas. (2010). Hydrochemistry and Environmental Status of Pazhayar River, Kanyakumari District, Southern Tamil Nadu. Recent Trends in Water Research: Hydrogeochemical and Hydrological Perspectives S Chidambaram AL Ramanathan, K Shivanna and R Arthur James(Eds.), Ik International Pvt Ltd. 178-190

Sahni, Kavita. and Yadav, Sheela. (2012). Seasonal variation in physico-chemical parameters of Bharawas Pond,Rewari, Haryana. Asian J. Exp. Sci. 26 (1): 61-64.

Sharon, O, Skipton and Bruce J Dvorak. (2009). Drinking water: Hard water (Calcium and Magnesium) NebGuide Downloaded on 27/01/2015. Pp 3.

Sheela, A. M., J. Letha, and Sabu Joseph (2011). Environmental status of a tropical lake system. Environ Monit Assess., 180(1): 427-449.

Ugwu, A. I. and R.J. Wakawa (2012). A Study of Seasonal Physicochemical Parameters in River Usma. American Journal of Environmental Science, 8 (5): 569-576.

Varsha, Gupta. (2013) Feces of Captive Wild Mammal use as Bio-Indicator of Heavy Metal Pollution in Urban Air IJIRSET, 2(6): 2404-2411.

WHO (2011), World Health Organisation. Guidelines for drinking water quality, Geneva.

Fourth Edition, pp 198 Downloaded on 24/04/2015.

Zahraa, Zahraw, Al-Janabi., Abdul-Hameed, M., Jawad Al-Obaidy, and Abdul-Rahman, Al-Kubaisi. (2015). Applied of CCME Water Quality Index for Protection of Aquatic Life in the Tigris River within Baghdad city. Journal of Al-Nahrain University, 18 (2): 99-107.