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ASSESSMENT OF WATER QUALITY OF SELECTED FRESH WATER BODIES OF GOA (INDIA) USING WATER QUALITY INDEX (CCME-WQI)

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Water bodies receiving contaminants from point and non-point sources incur changes in physicochemical features, degradation of water quality emanating from biochemical reactions between dissolved solids and microbionts. The present paper describes the application of CCME WQI to know the water quality of four freshwater bodies from Goa and to see the suitability of the water for recreation, drinking, irrigation, and livestock. Canadian Council of Ministers of the Environment (CCME) has developed the Water Quality Index (WQI), which is one of the practical tools to solve data management problems and evaluate success and failures in management strategies for improving water quality. Water Samples from selected water bodies were collected every month for two years. A total of eight physicochemical parameters *viz;* pH, temperature, turbidity, TDS, BOD, nitrates, phosphates, and total chlorophyll were analyzed using standard protocols. Based on the results, the index values and their ranks for drinking, recreation, irrigation, and livestock were recorded as poor water quality due to various point and non-point pollutant sources. The results are alarming, and a necessary action plan needs to be implemented to monitor water quality and proper management of these water bodies.

Keywords: *CCME WQI, Physicochemical parameters, water bodies, water quality*

A healthy aquatic environment supports diverse inhabitants, protects drinking water quality, allows recreational activities, and provides appropriate ecosystem services (Said *et al.* 2004). Water quality is a crucial component of a healthy watershed. Water resources used for domestic, industrial, irrigation, and drinking purposes receive significant contaminants from the point- and non-point sources (Mahagamage and Manage, 2014). Biochemical reactions occurring within water affect its physicochemical parameters. Quick changes in these parameters are indicators of water quality changes and are often compared with water quality guidelines or standards to assess the pollution level (Hacioglu and Dulger, 2009). Drinking water quality guidelines and standards are designed to provide clean and safe water for human consumption (Al-Janabi *et al.* 2012). Decision-making often becomes difficult while comparing several parameters simultaneously. Therefore, the Water Quality Index (WQI) is the best source that provides a convenient means of summarizing complex water quality data that the public can easily understand (Giriyappanavar and Patil, 2013). The Canadian Water Quality Index (CWQI), developed by the Canadian Council of Ministers of the Environment, is a tool for communicating information and assessing changes in water quality over time (CCME, 2001). The application of CCME WQI requires Water Quality Guidelines (WQGs), and the model essentially consists of three measures of variance from selected WQGs (scope, frequency, and amplitude) that combine to produce a value between 0 and 100 and represents the overall water quality (Khan *et al.*2005).Many of these freshwater bodies are under stress in Goa due to anthropogenic activities. Hence, their health needs to be checked. Singh and Kamal (2014) analyzed surface water samples from rivers in and around the mining talukas of Goa. The surface water quality was evaluated by testing various physicochemical parameters such as pH, TDS, BOD, etc. The WQI for all samples was found in the range of 34 to 107. The highest value of WQI was observed during the monsoon season, while the lowest was during the post-monsoon season. Most of the water samples within the study area were found within Good to moderate categories**.** Radhan *et al.* (2015) calculated the water quality index (WQI) of the

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Mandovi estuary of Goa and reported a dominance of PO_4–P, NO_2–N, NH_3–N, total suspended solids (TSS), and turbidity. The WQI suggested that an increase in nutrients, turbidity, and TSS during SW monsoon increases the WQI values beyond 2, rendering the water polluted at some locations. The present study was aimed to assess the application of the CCME Water Quality Index to monitor the changes in surface water quality in four freshwater bodies of Goa for drinking, aquatic, recreational, irrigation, and livestock.

MATERIALS AND METHODS

Study area: Goa encompasses an area of 3,702 km^2. It lies between the 14°53′54″ N and 15°40′00″ N latitudes and 73°40′33″ E and 74°20′13″ E longitudes. Two water bodies each from North Goa (Syngenta lake and Khandolapond) and South Goa (Lotus lake and Curtorim lake) were selected for the study. Syngenta lake is in the premises of M/s Syngenta Agro Chemicals at Corlim in Tiswadi taluka located on the banks of Cumbarjua canal situated between 15.5° N latitude 73.94°E longitudes. Khandola Pond is situated between 15.5°N Latitude and 73.9°E longitude at Marcela in Ponda taluka. It is a source of irrigation to areca nut plantations existing in the surrounding areas. Lotus lake is situated between 15.2°N Latitude and 73.9°E longitude at Benaulim in Salcete taluka. The lake is polluted and has abundant growth of aquatic weeds. Curtorim lake is situated between 15.2°N Latitude and 74.0°E longitude at Curtorim in Salcete taluka. Lake is a source of irrigation for paddy crops (**Fig. 1).**

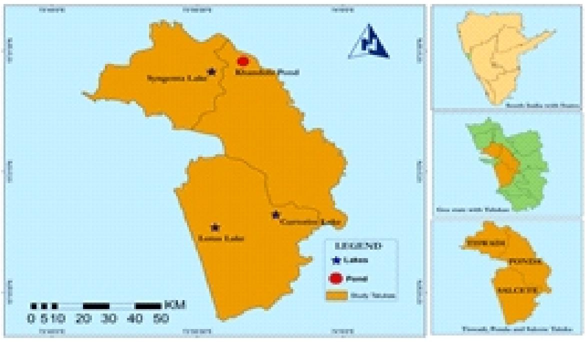

Figure 1: Location map of study sites

Sampling and analysis: Analysis of water samples was carried out every month from January 2014 to December 2015. A total of eight parameters were analyzed every month. The pH was measured using a digital Ph meter, and the temperature was recorded using a thermometer. The total dissolved solids were measured using the gravimetric method (APHA, 2012) and turbidity using a turbidity meter. The BOD test (5 days) was carried out by titration method using sodium thiosulphate (APHA, 2012). Nitrates were determined by spectrophotometer (WTW Photolab 6100 VIS) using stock nitrate solution PDA method (Rao, 1988). Phosphates were determined by the Stannous chloride method (APHA, 2012), while total chlorophyll was estimated by Arnon's method (Arnon, 1949). As per the technical Report Canadian Water Quality Index 1.0 (CCME, 2001), the detailed formulation of WQI was described as follows:

F1 (Scope) represents the percentage of variables that do not meet their guideline values at least once during the time period under consideration (“failed variables”), relative to the total number of variables measured:

$$F1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}} \times 100\right]$$

F2 (Frequency) signifies the percentage of individual tests that do not meet guideline values (“failed tests”):

$$F2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}} \times 100\right]$$

F3 (Amplitude) represents the amount by which failed test values do not meet their guideline values. F3 was calculated in three steps. The number of times an individual concentration was greater than (or less than, when the objective was minimum) the objective was termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$\text{Excursion} = \left[\frac{\text{Failed test value}}{\text{Guideline value}} - 100\right]$$

For the cases in which the test value must not fall below the objective:

$$\text{Excursion} = \left[\frac{\text{Guideline value}}{\text{Failed test value}} - 100\right]$$

The collective amount by which individual tests were out of compliance was calculated by summing the excursions of individual tests from their guideline values and dividing by the total number of tests. This variable referred to as the normalized sum of excursions, or *nse*, was calculated as:

$$\text{nse} = \left[\frac{\text{n}\Sigma\text{excursion i} = 1}{\text{Number of tetsts}}\right]$$

F3 was then calculated by an asymptotic function that scaled the normalized sum of the excursions from guideline value (*nse*) to yield a range between 0 and 100.

$$\text{F3} = \left[\frac{\text{nse}}{0.01\text{nse} + 0.01}\right]$$

Once these factors were obtained, the index itself was calculated by summing up the three factors as if they were courses. The sum of the squares of each factor was therefore equal to the square of the index. This method gave the index a three-dimensional space defined by each factor along one axis. With this model, the index changes is direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

$$\text{CCME WQI} = \left[100 - \frac{\sqrt{\text{F21} + \text{F22} + \text{F23}}}{1.732}\right]$$

The divisor 1.732 normalized the resultant values between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best" water quality. During the present study, the collected data were subjected to CCME WQI calculator software to understand the water quality of study sites. According to the CCME WQI, water quality was ranked in five categories (Table 1).

RESULTS AND DISCUSSION

The result of analyzed parameters showed wide seasonal variations, as shown in Tables 2to 5.

Eight water quality parameters(pH, temperature, turbidity, TDS, BOD, NO_3, PO_4, and total chlorophyll) were considered necessary for irrigation, drinking, and aquatic life, seven parameters (except total chlorophyll) were selected for livestock, three parameters (BOD, NO_3, and PO_4) were considered for recreation. The results obtained are depicted in Tables 6 to 9. The pH of water in the studied water bodies ranged from 5.9 to 7.8. The pH of surface water is an essential indicator of water quality. A pH range of 5.0 to 8.5 is considered ideal for phytoplankton growth (Robert *et al.* 1974). As pH levels move away from this range, it caused stress in the

Table :1 CCME WQI- and categorization of water quality.

Rating	WQI	Categorization
Excellent	95 - 100	Water quality is protected with a virtual absence of threat or impairment conditions very close to natural levels.
Good	80 - 94	Water quality is protected with only a minor degree of threat. The condition rarely deviates from natural conditions.
Fair	65 - 79	Water quality is usually protected but occasionally threatened. Conditions sometimes deviate from normal levels.
Marginal	45 - 64	Water quality is frequently threatened; conditions often deviate from normal levels.
Poor	0 - 44	Water quality is almost always threatened; conditions regularly deviate from natural levels.

Table 2: Monthly variations in physicochemical parameters of Syngenta lake

Parameter/ Months of study (24)	**pH**	**Temp (^{0}C)**	**TDS** (mg/L)	**Turbidity** (NTU)	**BOD** (mg/L)	**Nitrates** (mg/L)	**Phosphates** (mg/L)	**Total Chlorophyll** (mg/L)
Jan	6.1	25	620	22	10.53	0.2	0.1	14.22
Feb	5.9	28	745	28	10.11	0.72	0.12	12.32
Mar	6.2	28	685	34	12.57	0.82	0.23	10.76
April	6.2	30	634	42	14.09	0.31	0.1	14.79
May	6.3	31	645	49	13.22	0.54	0.24	21.77
Jun	6.4	30.8	621	46	11.34	0.33	0.27	20.78
Jul	6.8	28.4	687	48	8.5	0.41	0.25	16.4
Aug	6.4	27.4	606	51	6.07	0.5	0.19	18.52
Sep	6.23	28.4	616	46	8.12	0.53	0.2	20.92
Oct	6.09	29	604	41	12.87	0.48	0.15	21.38
Nov	6.5	29	560	37	11.34	0.31	0.19	19.33
Dec	6.7	28	538	33	10.51	0.29	0.1	17.27
Jan	6.12	23	614	29	11.5	0.21	0.11	15.21
Feb	6	25	645	26	11.79	0.34	0.07	12.37
Mar	6.2	29	668	34	12.57	0.73	0.09	11.76
April	6.22	30	698	42	15	0.24	0.1	19.7
May	5.9	32	665	49	15.62	0.32	0.2	26.77
Jun	6.2	31	681	48	18.34	0.37	0.25	22.7
Jul	6.25	28	692	51	13.5	0.43	0.29	17.42
Aug	6.45	27.5	742	53	10.6	0.59	0.31	12.59
Sep	6.47	28	767	47	12.4	0.57	0.28	14.97
Oct	6.3	29	694	43	17.97	0.53	0.22	23.43
Nov	6.17	29	660	41	14.32	0.45	0.17	18.37
Dec	6.37	28	638	39	10.57	0.37	0.12	14.29

Legend: Values are an average of three readings

systems of aquatic organisms and reduced their survival rate. Apart from organisms, extreme pH levels increase the solubility of nutrients like P, N, C, etc. Certain heavy metals like Pb, Cu, Cd, etc., become more mobile, increasing the risk of absorption in aquatic life. Metals tend to be more toxic at lower pH as they are more soluble in acidic waters (Ramachandra and Solanki, 2007). The water temperature at the study sites varied from 25 to 31^{o}C, with maximum temperature recorded in May and minimum in January (winter season). Water temperature plays an essential role in controlling the occurrence and abundance of phytoplankton (Nanzeen 1980).

The seasonal change of productivity is related to variations in temperature and photic conditions (Sondergaard and Sand 1979). The TDS were least in Khandola pond (32.60 to 51.45 mg L^{-1}), followed by Syngenta lake (604 to745 mg L^{-1}), Lotus lake (616 to 1078 mg L^{-1}), and were maximum at Curtorim lake (922 to 1389 mg L^{-1}). Beeton (1965) attributed the increase in TDS to cultural eutrophication and

Table 3: Monthly variations in physicochemical parameters of Khandola pond

Parameters/ Months of study	**pH**	**Temp (^{0}C)**	**TDS** (mg/L)	**Turbidity** (NTU)	**BOD** (mg/L)	**Nitrates** (mg/L)	**Phosphates** (mg/L)	**Total Chlorophyll** (mg/L)
Jan	7.14	25	41.2	17.2	0	0.27	0.01	2.8
Feb	6.1	28	49.6	19	0	0.23	0.02	2.7
Mar	6	28	40.23	18	0	0.56	0.01	3.08
April	6.1	30	43.7	18.4	0	0.47	0.04	3.33
May	6	31	51.54	18.7	0	0.36	0.02	3.97
Jun	6.8	30.8	38.7	16.4	0	0.5	0.02	3.24
Jul	6.4	30.8	32.6	24.37	0	0.58	0.3	3.01
Aug	6.2	28.4	47.6	30.44	0	0.34	0.25	2.78
Sep	6.4	27.4	50.21	27.2	0	0.38	0.15	3.31
Oct	6.4	28.4	49.3	21.37	0	0.31	0.15	3.69
Nov	6.45	29	41	17.76	0	0.3	0.1	3.45
Dec	6.47	28	40.45	14.47	0	0.29	0.02	3.1
Jan	7.12	23	43.25	17.27	0	0.21	0.01	3
Feb	6.15	25	41	18	0	0.23	0.02	2.97
Mar	6.1	29	40.26	18	0	0.5	0.01	3
April	6.1	30	46.77	18.46	0	0.49	0.04	3.83
May	6	32	54.4	18.7	0	0.32	0.02	4.97
Jun	6.19	31	39.7	16.4	0	0.35	0.02	5.25
Jul	6.3	28.2	36.2	28.37	0	0.28	0.01	3.1
Aug	6.2	27.5	49.8	31	0	0.33	0.02	3.07
Sep	6.4	28.1	52.76	28.2	0	0.38	0.04	3.01
Oct	6.38	29	47.32	23.3	0	0.32	0.03	4.67
Nov	6.4	29	42.1	18.7	0	0.29	0.02	3.4
Dec	6.44	28	39.4	15.4	0	0.27	0.01	3.22

Legend: Values are an average of three readings

suggested the separation of oligotrophic (TDS<100 ppm) and eutrophic (TDS>100 ppm)lakes based on TDS values.]

Turbidity measurements are used as an indicator of water quality based on clarity and estimated total suspended solids in water. The values ranged from22 to 53 NTU in Syngenta lake, 15.4 to 31 NTU in Khandola pond, 29 to 54.78 NTU in Lotus lake, and 26 to 56.7 NTU in Curtorimlake. Increased turbidity levels in the monsoon were due to rainfall and surface runoff. Similar observations have been recorded earlier (Saxena *et al.* 1966).BOD showed significant monthly variations during the entire study period, with maximum values in summer and minimum in winter. BOD levels varied from 6.07 to 18.34 mg L^{-1} at Syngenta lake, 18.79 to 47.83 mg L^{-1} at Lotus lake, and 21.89 to 59.9 mg L^{-1} at Curtorim lake. An increase in BOD caused rapid depletion of DO. Ahipathi and Puttaiah (2006) reported that high BOD in summer might be due to the increased oxygen demand for the degradation of organic wastes in the water body. A decrease in BOD levels in late- and post-monsoon may be due to low temperature that slowed down the microbial activity (Bhatt *et al.* 1999). High nitrate levels were found during monsoon and low levels during the post-monsoon season.

Table 4: Monthly variations in physicochemical parameters of Lotus lake

Parameters/ Months of study	**pH**	**Temp** (^{0}**C**)	**TDS** (mg/L)	**Turbidity** (NTU)	**BOD** (mg/L)	**Nitrates** (mg/L)	**Phosphates** (mg/L)	**Total Chlorophyll** (mg/L)
Jan	7.8	25.5	616.5	29	36.89	1.43	0.01	27.03
Feb	6.6	29	673.2	33	32.33	1.58	0.03	25
Mar	6.46	29	782	33	32.43	1.66	0.1	25.63
April	6	30	968	38	36.89	1.76	0.25	27.65
May	5.9	31	997	42	18.79	1.81	0.25	30.47
Jun	6	30	962	37.4	37.71	2.16	0.3	33.23
Jul	6.73	30	1078	43	21.89	4.55	2.41	23.25
Aug	6	26.2	910	52.78	25.95	3.16	1.92	22.41
Sep	6.5	28.4	825	42.1	27.96	3.38	0.78	16.52
Oct	6	29	845	37.2	27.57	4.45	0.6	25.2
Nov	6.6	29	785	31.27	33.72	3.06	0.19	24.77
Dec	6	28	726	29.8	37.71	2.38	0.1	26.54
Jan	6.8	25	735	31	39.89	1.76	0.27	29.13
Feb	6.66	29	682.2	37	42.33	1.65	0.2	26.1
Mar	6.46	29	698	43	37.43	1.75	0.21	27.6
April	6	30	784	48	46.89	1.7	0.18	29.86
May	5.87	32	708	52	48.91	1.81	0.25	37.42
Jun	6	31	662	53.46	47.83	2.24	0.39	39.23
Jul	6.7	30	1209	48	41.8	2.95	1.01	30.07
Aug	6.78	26	1410	54.78	39.74	3.19	1.62	27.46
Sep	6	28.4	1120	52.1	37.9	3.38	1.7	27.77
Oct	5.4	29.1	975	48.7	44.5	2.55	1.03	35.2
Nov	6.2	29	878	41.2	39.7	2.17	0.17	29.17
Dec	6.5	28.4	786	39.5	35	2.02	0.11	26.44

Legend: Values are an average of three readings

Similar observations have been reported by Prabhakar *et al.* (2012).

The entry of nitrates into water resources increases the growth of nuisance algae and macrophytes and triggers eutrophication. The nitrate levels in water bodies varied from 0.20 to 0.54 mg L^{-1}in Syngenta lake, 0.23 to 0.58 mg L^{-1}in Khandola pond, 1.43 to 4.55 mg L^{-1}in Lotus lake and 0.80 to 2.76 mg L^{-1}in Curtorim lake. Phosphate concentrations ranged from 0.07 to 0.31 mg L^{-1} in Syngenta lake, 0.01 to 0.30 mg L^{-1} in Khandola pond, 0.01 to 2.41 mg L^{-1} in Lotus lake, and 0.01 to 1.72 mg L^{-1} in Curtorim lake. Higher concentration observed may be due to the inflow of domestic waste, washing activities, and cattle bathing. Phosphate and nitrate deplete DO, resulting in algal blooms (Ansar and Khad 2005). Chlorophyll content varied from 10.76 to 23.43 mg m^{-3} at Syngenta lake, 2.7 to 5.25 mg m^{-3} at Khandola pond, 16.52 to 39.23 mg m^{-3} at Lotus lake, and 19.04 to 54.4 mg m^{-3} at Curtorim lake. High chlorophyll content was observed during late summer and October. This may be due to

Table 5: Monthly variations in physicochemical parameters of Curtorim lake

Parameters/ Months of study	**pH**	**Temp** (^{0}**C**)	**TDS** (mg/L)	**Turbidity** (NTU)	**BOD** (mg/L)	**Nitrates** (mg/L)	**Phosphates** (mg/L)	**Total Chlorophyll** (mg/L)
Jan	6.8	25.5	1124	26	36.89	0.8	0.01	28.6
Feb	6.9	29	1207	32	32.45	1.27	0.02	27.4
Mar	6.7	29	1308	33	32.75	1.5	0.01	29.22
April	6.9	30	1420	33	36.98	1.78	0.04	30.15
May	6.72	31	1285	34	38.25	2.57	0.12	34.47
Jun	7.6	30	1389	35	37.77	1.32	0.15	27.23
Jul	7.68	30	1317	42	32.43	2.27	1.72	23.25
Aug	7.52	26.2	1210	45	26.35	2.76	0.49	21.78
Sep	7.68	28.4	1118	41	21.89	1.43	0.55	19.04
Oct	6.4	29	922	37	29.9	1.27	0.3	28.39
Nov	6.9	29	971	32	25.95	1.19	0.19	23.31
Dec	6.6	28	1104	29	29.6	1.27	0.1	27.37
Jan	6.7	25	1135	27.5	37.8	0.93	0.19	31
Feb	7.19	29	1076	34	42.4	1.43	0.3	37.24
Mar	6.7	29	1108	36	42.76	1.67	0.48	39.2
April	6.89	30	1140	37.3	46.98	1.51	0.4	44.5
May	6.72	32	1295	41	50.25	1.55	0.47	47.78
Jun	6.6	31	1395	45	57.4	2.3	1.15	52.2
Jul	6.68	30	1457	54	42.03	2.45	1.22	45.2
Aug	6.5	26	1465	56.7	40.35	2.64	1.54	40.07
Sep	6.18	28.4	1308	41.3	41.89	2.4	0.95	43.04
Oct	5.45	29	1220	39	59.9	1.73	0.4	54.4
Nov	6.33	29.1	1107	35.6	51.05	1.65	0.2	47.03
Dec	6.64	28	1034	30	44.7	1.38	0.16	39.07

Values are an average of three readings.

increased water temperature, which accelerated primary production (Mandal *et al.* 2005). Most of the parameters exceeded drinking water standards prescribed by WHO. Of the four three water bodies, viz; Syngenta, Lotus, and Curtorimlakes showed eutrophication while the Khandola pond showed mesotrophic condition. The water bodies received pollutants from wastewater, sewage, solid waste, and chemicals from surrounding areas. The in all the four water bodies was of poor quality with index values <40**.** The scope (F_1) values for all the water bodies were 100 or near 100. This is primarily because of the failure of most of the parameters to reach the objectives. The condition observed in Khandola pond was slightly different with the scope values ranging from 62 to 100 with the parameters DO, phosphates and nitrates passing the objectives. Frequency (F_2)ranged from 50 to 84 at Syngenta lake, 39 to 80 at Khandola pond, 60 to 87 at Lotus lake and 54 to 80 at Curtorim lake, indicating that the analytical results do not comply with the guidelines and water was unsuitable for drinking, aquatic, recreation and irrigation purpose. Amplitude (F_2) values were 100 or nearing 100, indicating the difference between the overall non-compliance of analytical results and guidelines

Table 6: CCME WQI for Syngenta lake 2014-15

Data Summary	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	15	11	5	10	8	22
Categorization	Poor	Poor	Poor	Poor	Poor	Poor
F1 (Scope)	93	100	100	100	100	75
F2 (Frequency)	54	60	84	78	73	50
F3 (Amplitude)	100	100	100	92	100	100

Table 7: CCME WQI for Khandola Pond 2014-15

Data Summary	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	26	24	6	8	19	29
Categorization	Poor	Poor	Poor	Poor	Poor	Poor
F1 (Scope)	64	70	100	100	80	62
F2 (Frequency)	47	49	80	78	58	39
F3 (Amplitude)	100	100	100	97	100	99

Table 8: CCME WQI for Lotus Lake 2014-15.

Data Summary	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	11	10	4	9	7	17
Categorization	Poor	Poor	Poor	Poor	Poor	Poor
F1 (Scope)	100	100	100	100	100	88
F2 (Frequency)	60	67	87	78	76	56
F3 (Amplitude)	100	100	100	94	100	100

Table 9: CCME WQI for Curtorim Lake 2014-15.

Data Summary	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	12	11	6	8	8	17
Categorization	Poor	Poor	Poor	Poor	Poor	Poor
F1 (Scope)	100	100	100	100	100	88
F2 (Frequency)	56	62	80	78	73	54
F3 (Amplitude)	100	100	100	96	100	100

CONCLUSION

Based on CCME WQIs average values, the water quality of all four water bodies was poor and unsuitable for drinking, irrigation, recreation, and livestock. Most of the parameters exceeded WHO guideline values. CCME WQI assessment of water from the selected water bodies had summarized complex water quality data that can be easily understood, and this information can be of great value for water users (public), water suppliers (municipalities), and scientists. Further, this analytical study would enhance the socio-eco features of these water bodies by implementing utility-based restoration and development programs. Awareness camps may be organized to induce and encourage the locals to maintain the ecology and hydrology of the water bodies.

REFERENCES

Ahipathi MV, and Puttaiah ET 2006 Ecological characteristics of Vrishabhavathi River in Bangalore, India. Environmental Geology, **49**

1217 - 1222.

Al-Janabi ZZ, Kubaisi AR and Jwad AM 2012 Assessment of Water Quality of Tigris River by using Water Quality Index (CCME -WQI). *Journal of Al-Nahrain University* **15 (1)** 119-126.

Ansar A and Khad F 2005 Eutrophication: An ecological vision. The Botanical Review, **71(4)** 449 - 482.

APHA 2012 Standard Methods for Examination of Water and Wastewater. American Public Health Association. Washington, DC.

Arnon DI 1949 Copper enzymes in isolated chloroplasts, polyphenol oxidase in *Beta vulgaris*. *Plant Physiology,* **24(1)** 1 - 5.

Beeton AM 1965 Eutrophication of the St. Lawrence Great Lakes. *Limnological Oceanography* **10** 240 - 254.

Bhatt LR, Lacoul P Lekhak HD and Jha PK1999 Physicochemical characteristics and phytoplankton of Taudaha Lake, Kathmandu. *Pollution Research,* **18(4)** 353 - 358.

Canadian Council of Ministers of the Environment (CCME) 2001.*Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0*, Technical Report, Canadian Council of Ministers of the environment. Winnipeg, MB, Canada.

Giriyappanavar BS, and Patil RR 2013 Application of CCME WQI in Assessing Water Quality for Fort Lake of Belgaum Karnataka. I*ndian Journal of Applied Research,* **3(4)** 32-33.

Hacioglu N and Dulger B 2009 Monthly variation of some physico-chemical and microbiological parameters in Biga Stream (Biga, Canakkale, Turkey), *African Journal of Biotechnology,* **8 (9)** 1929-1937.

Khan AA, Annette T Paterson R Haseen K and Richard W 2005 Application of CCME Procedures for Deriving Site Specific Water Quality Guidelines for the CCME Water Quality Index. *Water Quality Research Journal Canada*, **40(4)** 448-456.

Mahagamagea ML, and Manage PM 2014 *Water Quality Index (CCME-WQI) Based Assessment Study of Water Quality in Kelani River Basin, Sri Lanka.* Research Gate The 1st Environment and Natural Resources International Conference 6 - 7 November 2014, The Sukosol Hotel, Bangkok, Thailand, Pp199-204.

Mandal OP, Sinha AK and Sinha KMP 2005 Studies on primary productivity of a wetland. *Fundamentals of Limnology* (Ed. Kumar, A.) Pp230 - 237.

Nazneen S 1980 Influence of hydrological factors on seasonal abundance of phytoplankton in Kinjharlake, Pakistan, *Hydrobiology* **65(2)** 269 - 282.

Prabhakar C, Saleshrani K Tharmaraj K and Kumar VM 2012 Seasonal variation in hydrological parameters of Krishnagiri dam, Tamil Nadu, India. *International Journal of Pharmaceutical and Biological Archieves* **3(1)** 134 - 139.

Radhan VR, Sagayadoss J Seelan E Vethamony P Shirodkar P Zainudin Z and Shirodkar S 2015 Southwest monsoon influences the water quality and waste assimilative capacity in the Mandovi estuary (Goa state, India). *Chemistry and Ecology* **31(3)** 217-234.

Ramachandra TV, and Solanki M 2007 *Ecological assessment of lentic water bodies of Bangalore*. Environmental Information System Centre for Ecological Sciences, Indian Institute of Science, Technical Report: Pp25.

Rao NN, 1988 *Manual on Water and Wastewater Analysis*. NEERI, Nagpur.

Robert DS, Robert WH and Evereff LG 1974 Phytoplankton distribution and water quality indices of Lake Head. *Phycology* **10(1)** 232 - 333.

Said A, Stevens DK and Sehlke G 2004 An innovative index for evaluating water quality in streams, Idaho, USA. Environmental Management, 34:406-414.

Saxena KL, Chakraborty RN Khan AQ and Chattopadhya SN 1966 Pollution studies of the river Ganga near Kanpur. *Indian Journal of Environmental Health* **8** 270 -285.

Singh G, and Kamal RK 2014 Application of water quality index for assessment of surface Water Quality status in Goa. *Current World Environment* DOI: http://dx.doi.org./10.12944/CWE.9.3.54

Sondergaard M, and Sand-Jensen K 1979 Physico-chemical environment, phytoplankton biomass, and production in oligotrophic soft water lake Kalgaard, Denmark. *Hydrobiologia,* **63** 241 - 253.