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Abiotic characteristics of Mirik Lake water in the hills of Darjeeling, West Bengal, India

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ABSTRACT

The present study was carried out to assess the physico-chemical status of surface water of Mirik lake in Darjeeling from seven selected locations during October 2005 – September 2007. The highest and lowest air and water temperatures were recorded respectively during summer and winter months. The pH values, as found to be lower in Sites 1 and 2, may be due to regular discharge of waste water from major and minor drains. The highest and lowest electrical conductivities in summer and monsoon respectively were due to dehydration and dilution of rainwater at different times. DO values were found to be higher during monsoon and winter seasons, while lowest value was recorded in summer. DO showed a significant negative correlation with free CO_2. The highest and lowest total alkalinity and total hardness values were found respectively during summer and monsoon. Chloride values were found to be highest during winter and the lowest value was recorded during monsoon. Higher BOD values were recorded at Sites 1, 2 and 6. All the parameters varied significantly among sites and seasons. Public awareness is very much important to control the discharge of wastes into the lake and long term scientific monitoring is necessitated to evaluate the status of the lake for its longevity.

Key Words: Mirik Lake; Physico-chemical; sampling sites; seasonal variations.

INTRODUCTION

Lakes in the Himalayan region are unique in its geographical setting, geomorphology and biota. The Himalayan lakes draw special interest to environmentalist as they have been influenced by the biotic pressure over several thousands of years and continue to be rapidly deteriorating in the wake of ever increasing stress. Darjeeling is universally described as the “Queen of Hills” for its uniqueness and versatility.

A number of investigations on different physico-chemical parameters of water have been studied earlier on the Himalayan lakes [1, 2] and reservoirs [3, 4] of India, investigations on the water bodies of Darjeeling Hills are very scanty. In this context, the present study was undertaken to evaluate the abiotic characteristics of Mirik Lake in Darjeeling hills.

Study area
Mirik is one of the famous hill resorts in the Kurseong sub-division of Darjeeling district of West Bengal, India at an altitude of 1767 meters. It extends between 26^{0} 53'N and 88^{0}10'E and covers an area of 135.9 ha. "Sumendu Lake" or "Mirik Lake" is an artificial reservoir of Mirik Town. It was constructed in 1979 under "Mirik Tourist Project" for the facilitation of commercial tourism. The area, under jurisdiction of Mirik Municipal Corporation, is overall controlled by Darjeeling Gorkha Hill Council (DGHC). This lake has been included under National Lake Conservation Programme formulated by the Ministry of Environment and Forests, Government of India.

The total lake area is about 16.19 ha with approximate length of 1.25 km and the peripheral road is about 3.5 km. The arch-type over bridge across the lake is 24.38 m long. Initially maximum depth of the lake was 7.92 m while minimum was 1.83 m. While eastern bank of the lake is flat at ground level, the western bank, having hill slopes, is covered by a rich forest of about ten thousand *Cryptomaria japonica* trees.

The lake is fed by both perennial streams and rainwater. Since the lake is situated in a valley encircled by hill ridges with extensive natural drainage network, it receives wastewater from human settlements through numerous inlets. There is one out-fall point through which the spillover water of the lake is discharged into the river Mechi, situated to the Western side of the lake. The catchments area consists of residential areas, vacant lands and commercial centers comprising of hotels, restaurants and other shops.

Mirik Lake and its surroundings as a whole contain multifarious recreational features like boating, jogging, organizing fair, picnic and many others. This is the most beautiful lake of Darjeeling district where visitors come from different parts of the world. Besides attracting tourists, the lake water also serves as a major source of drinking water to the local people.

MATERIALS AND METHODS

Various ecological parameters of Mirik Lake waters were studied for two years from October 2005 to September 2007. Considering length of the lake as well as point and non-point sources of pollution seven sampling sites were identified in the Lake. The water samples were collected every month at regular intervals from these locations with the help of paddle-boat. The brief descriptions of the sites (Fig. 1) are as follows:

Site 1 (26^{0}53'08.49" N and 88^{0}11'08.32" E) is 250 m away from DGHC Nursery toward North- West. This site is located at the point where wastes from hotels and residential area join into the lake. Car washing also takes place at this site.

Site 2 (26^{0}53'16.80" N and 88^{0}11'14.95" E) is situated at the flank of the lake where tourists assemble to observe the fishes that agglomerate specifically here for consuming various food items thrown by the visitors. Wastes from hotels and residential areas also join at this site.

Site 3 (26^{0}53'.20" N and 88^{0}11'01" E) is located at 100 m away from the concrete bridge of the lake towards South East. This site is situated near the proposed children park area. Human activity is comparatively lesser at this site.

Site 4 (26^{0}53'.017" N and 88^{0}10'.927" E) is located at the centre of concrete bridge over the lake. Some amount of surface runoff joins here.

Site 5 (26^{0}53'38.40" N and 88^{0}10'55.11" E) is situated at 90 m away from the water intake point towards North East. This water intake well is used for water treatment plant under PHED having a capacity of 1MGD (Million Gallon per Day) to cater the water supply for the people of Mirik Municipality area.

Site 6 (26^{0}53'27.99" N and 88^{0}10'56.53" E) is the area where waste water is discharged primarily from Mirik market. Bathing and washing of clothes take place at this site.

Site 7 (26^{0}53'34.53" N and 88^{0}10'51.89" E) is situated near the outlet of Mirik Lake which joins to the Mechi River through weirs. Washing of clothes and bathing take place near this site.

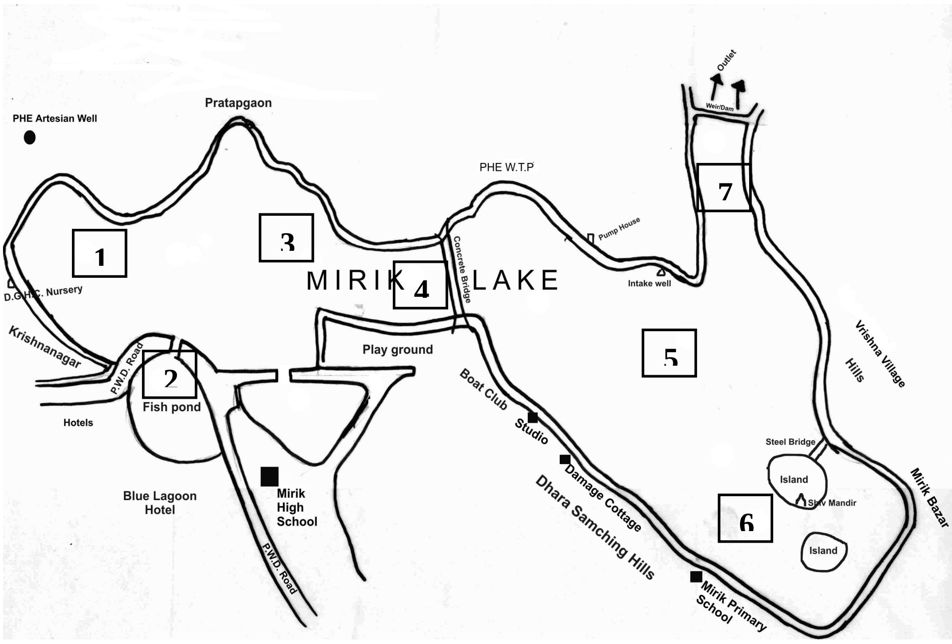


Fig. 1. Location of sampling sites at Mirik Lake, Darjeeling

The air and water temperatures were estimated on the spot by glass thermometer. While pH of water was measured at the site by Hanna's pocket pH meter, DO was fixed at the field and subsequently analysed in the laboratory following Winkler's method. For other physico-chemical parameters water samples were collected in plastic bottles and transported in ice bags to the laboratory. The samples were stored temporarily in refrigerator prior to actual analyses. Samples for BOD tests were incubated for 5 days at 20^0 C in BOD incubator in the laboratory. The physico-chemical parameters like Conductivity, DO, free CO_2, total alkalinity, total hardness, chloride and BOD were analyzed following standard methods [5, 6, and 7]. For seasonal interpretations, the periods March to June, July to October and November to February were considered as summer, monsoon and winter respectively. The present data is based on the average values of two years seasonal data.

RESULTS AND DISCUSSION

The air temperatures of all the study sites varied from 12.38^0C in winter to 23.01^0C in summer (Fig. 2). The air temperature, which was relatively low in Mirik due to its altitude, varied significantly amongst sites and seasons (Fig. 2), and showed positive and significant correlation with water temperature (Table 1).

The highest (21.44^0C) water temperature was recorded during summer and the lowest (10.99^0C) was found during winter (Fig. 2). The highest water temperature recorded during the summer months was primarily due to higher air temperature and greater penetration of sunlight. Welch [8] and Munawar [9] observed that shallower the water body more quickly it reacts to the change in the temperature. The water temperature showed significant positive correlation with BOD (Table 1).

The pH of all the study sites varied between 6.61 and 7.36 (Fig. 3). The lowest pH, indicating marginally acidic, was observed in monsoon and the highest was recorded in summer. The acidic nature of Himalayan lakes was also reported by Zutshi et al. [1] and Rawat et al. [2]. Obviously, the pH levels were within the limits set for protection of aquatic life (6.5-9.0, USEPA [10]). While the pH values showed significant positive correlation with DO, it had a significant negative correlation with free CO_2 and BOD. The variations of pH were significant amongst sites and seasons (Fig. 3)

Throughout the monitoring period, the highest conductivity (133.39 μmhos cm^{-1}) was observed at Site 2 in summer, while the lowest (50.03 μmhos cm^{-1}) was recorded at Site 1 in monsoon. Higher conductivity during summer was also reported by Bhowmik et al. [11, 12] in Barnoo reservoir, Madhya Pradesh. This could be associated with the lower water volume in the lake during summer and winter, coupled with the mixing of wastewater from a number of drains entering the lake. Unni [13] studied the ecology of river Narmada and reported that the highest conductivity during summer was presumably due to sewage input. During monsoon months the conductivity values were lower due to dilution. Adebisi [14] and Mishra [15] stated the inverse relation of conductivity with water level which corroborates our findings. The conductivity that varied significantly amongst sites and seasons (Fig. 3), showed highly significant positive correlations with free CO_2, total alkalinity, total hardness and BOD, while there was negative correlation with DO (Table 1). Mariappan and Vasudevan [16] also recorded its positive correlation with total alkalinity and total hardness in drinking water ponds at eastern part of Sivaganj district, Tamilnadu.

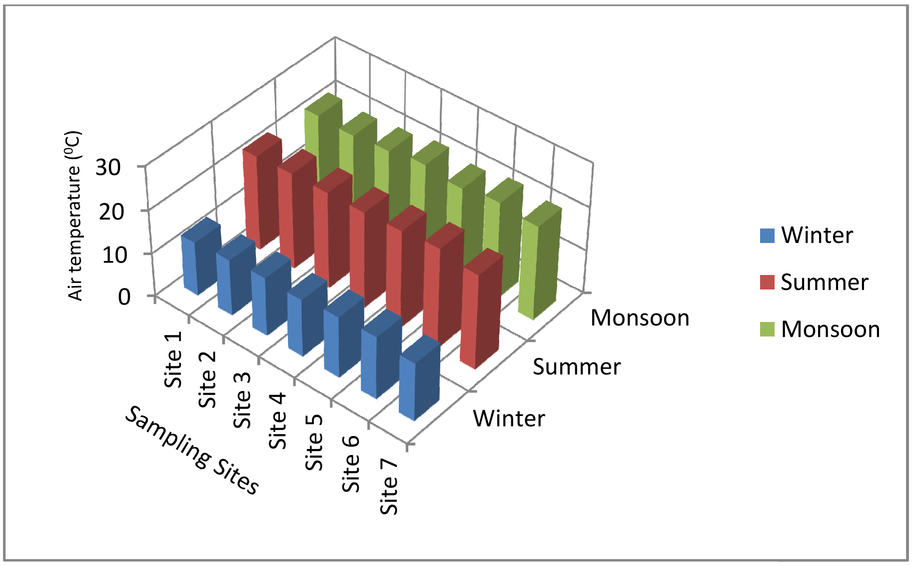
The dissolved oxygen of all the study sites ranged between 5.26 and 9.09 mgL^{-1} during the whole study period. The highest dissolved oxygen was observed at Site 4 during monsoon and lowest was recorded at Site 2 during summer (Fig. 4). Low DO can be attributed to decreased level of atmospheric oxygen, absence of turbulent flow and anthropogenic activities. While studying algal ecology of stream, polluted through gold mining winter water strand, Hancock [17] discussed seasonal average and fluctuations in DO; and reported its minimum value in summer. The DO values of the lake also showed significant differences amongst sites and seasons (Fig. 4), and there was a significant positive correlation with pH. Similar observations were recorded by Verghese et al. [18] in a tropical pond and Shastri and Pendse [19] in Dahikhuta reservoir of Maharashtra. Further, DO showed a highly significant negative correlation with free CO_2, total alkalinity, total hardness and BOD in the present study (Table 1).

During the whole study period the highest free CO_2 (10.23 mgL^{-1}) was recorded at Site 2 during summer and lowest of 4.53 mgL^{-1} was found during monsoon at Site 4 (Fig. 4). The highest free CO_2 values were observed at those locations where pH values were relatively low and the values varied significantly between the sites and seasons (Fig. 4). Free CO_2 showed a significant negative correlation with DO and positive correlation with total hardness and BOD (Table 1). Rawat et al. [2] also recorded negative correlation between free CO_2 and DO in Deoria Tal Lake.

Bicarbonate alkalinity of the Mirik lake waters constituted the total alkalinity which ranged between 23.08 and 45.63 mgL^{-1} during the whole study period (Fig. 5). The highest total alkalinity was observed in summer and lowest in monsoon. The higher values of total alkalinity in summer may be due to low water level and presence of excess free $CO_{2,}$ produced in the process of decomposition. The minimum values of bicarbonate alkalinity, as observed during monsoon months, might be attributed to the dilution effect [20, 21 and 19] and less favorable condition for photosynthetic conversion to carbonates [22, 23 and 24]. High alkalinity during summer and sharp decline in monsoon was supported by Ray et al. [25], and Pehwa and Mehrotra [26] . Total alkalinity was significantly different amongst seasons and showed a significant positive correlation with total hardness (Table 1). Similar observations were reported by Barat and Jha [27] in Mahananda river and Thappa Chetry and Pal [28] in Koshi river. The higher values of total alkalinity in summer may be due to low water level and presence of excess free $CO_{2,}$ produced in the process of decomposition. Munawar [9], Hegde et al. [29], and Sunder [30] observed the accumulation of bicarbonate in summer due to increased rate of decomposition. Adebisi [14] showed inverse relationship between alkalinity and water level.

During the whole study period the highest total hardness (26.88 mgL^{-1}) was recorded at Site 2 during summer and lowest of 13.25 mgL^{-1} was found during monsoon at Site 5 (Fig. 5). On the basis of Sawyer's classification [31], the water of Mirik lake can be categorized as soft water (hardness less than 75 mgL^{-1}). The higher values of total hardness during summer might be due to higher temperature and low water level in the lake as well as due to the addition of calcium and magnesium salts from detergents and soap, used for bathing and cloth washing. The lower values of total hardness during monsoon months might be due to dilution on account of rainfalls. Ajmal and Razi-Ud Din [32] observed a higher hardness value in summer in the rivers Hindon and Kali in India. The hardness of Mirik Lake showed a significant negative correlation with DO and a significant positive correlation with conductivity, free CO_2 and total alkalinity (Table 1). The hardness varied significantly between sites and seasons (Fig. 5).

The chloride of all the study sites varied between 15.65 and 19.56 mgL^{-1} during the whole study period (Fig. 6). The highest chloride level was observed at Sites 2 and 4 during winter while lowest value was recorded during monsoon. The maximum concentration of chloride in winter and summer seasons conferred with the influx of incoming domestic sewage. Enhanced chloride content was earlier correlated with high degree of organic pollution and eutrophication [33]. Since human and animal excreta contains an average of 5 gmL^{-1} chloride [34], contamination of water from domestic sewage can be monitored by chloride assays of the concerned water bodies. Munawar [9] suggested that higher concentration of chloride in water is an influx of pollution of animal origin and there is a direct correlation between chloride concentration and pollution level. The increase in chloride concentration in lake with the discharge of municipal and industrial waste was also reported by Ownbey and Key [35] in north temperate lakes. Bhuvaneswaran et al. [36] studied the water quality of Adyar in Chennai city and reported that high levels of chlorides may be due to sewage dumping. The chloride concentrations in Mirik lake varied significantly amongst sites (Fig. 6).



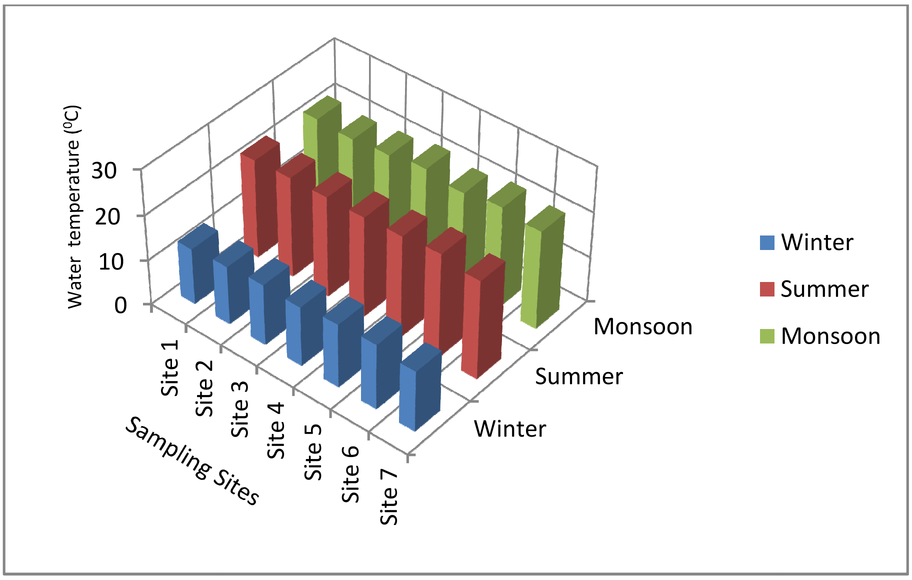
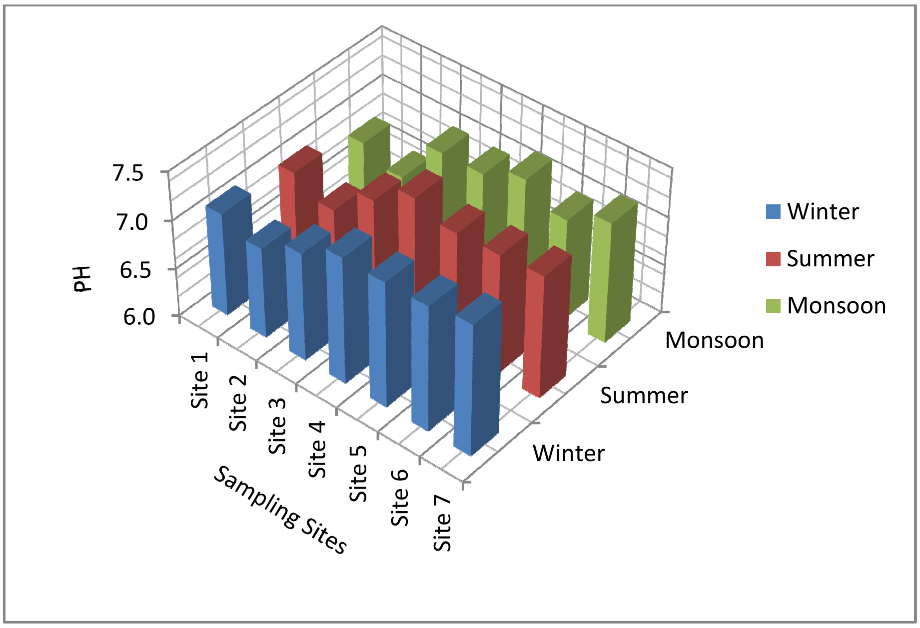


Fig.2. Seasonal variation in air temperature and water temperature of water at seven sampling sites of Mirik lake. ANOVA: air temperature-Site $F_{2.99}$=4.81, P<0.05; Season $F_{6.93}$=1277.58, P<0.01; water temperature-Site $F_{4.82}$=6.95, P<0.01; Season $F_{6.93}$=1453.8, P<0.01.



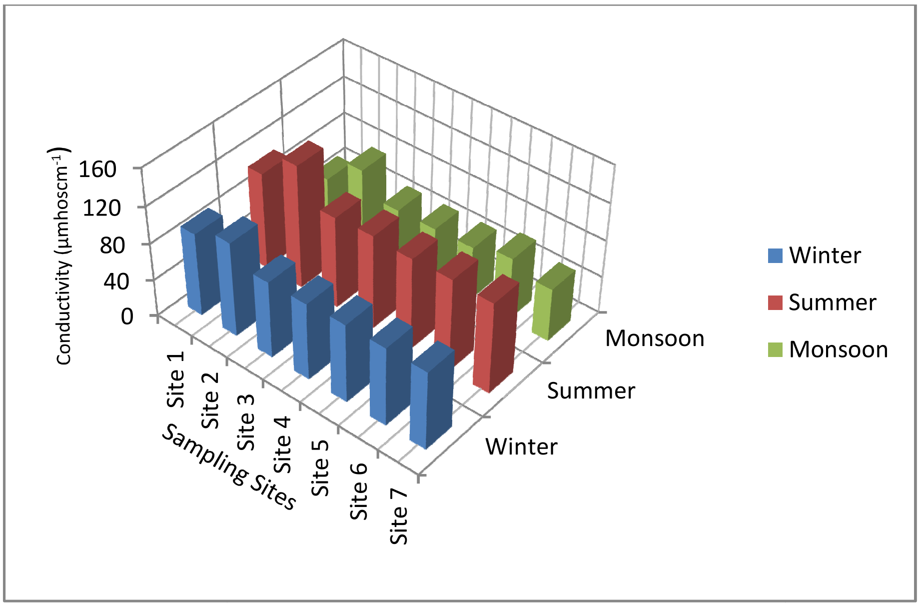
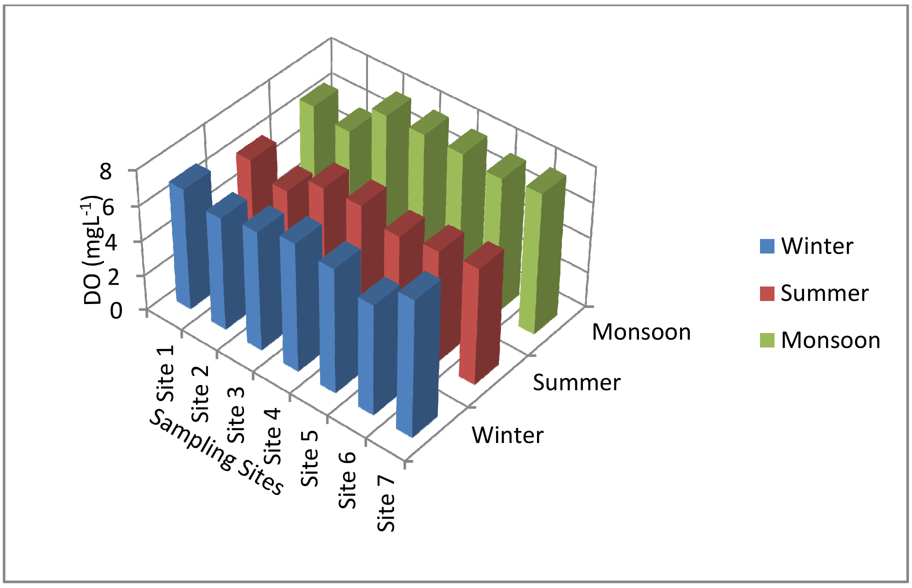


Fig. 3. Seasonal variation in pH and conductivity of water at seven sampling sites of Mirik lake. ANOVA: pH-Site $F_{4,82}$=3588.37, P<0.01; Season $F_{6,93}$=8.65, P<0.01; conductivity- Site $F_{4,82}$=10.65 P<0.01; Season $F_{6,93}$=142.35 , P<0.01.

During the whole study period the highest (4.80 mgL^{-1}) and lowest (2.68 mgL^{-1}) biochemical oxygen demand were recorded at Sites 1 and 7 respectively (Fig. 6). BOD levels of water of Mirik lake often exceeded the desired limits of both class A (for drinking purpose after disinfection, BOD: 2.0 mgL^{-1} or less) and class B (for outdoor bathing, BOD: 3.0 mgL^{-1} or less), as per designated water quality criteria [37]. Higher values of BOD were found in Site 1, Site 2 and Site 6. According to Hynes [38] BOD values of 3.0 mgL^{-1} or more is of doubtful quality and that with more than 5.0 mgL^{-1} is bad. Accordingly the water of Mirik Lake appears to be organically polluted. Higher BOD values in Sites 1 and 2 might be attributed to sewage contamination through incoming drains. BOD values remained higher during monsoon due to inflow of sewage with runoff. Presence of high level of bacteria in Mirik lake water during monsoon [39] also confirms contamination of sewage. BOD, which varied significantly amongst sites and seasons (Fig. 6), showed a positive correlation with free CO_2 and significant negative correlation with DO (Table 1).



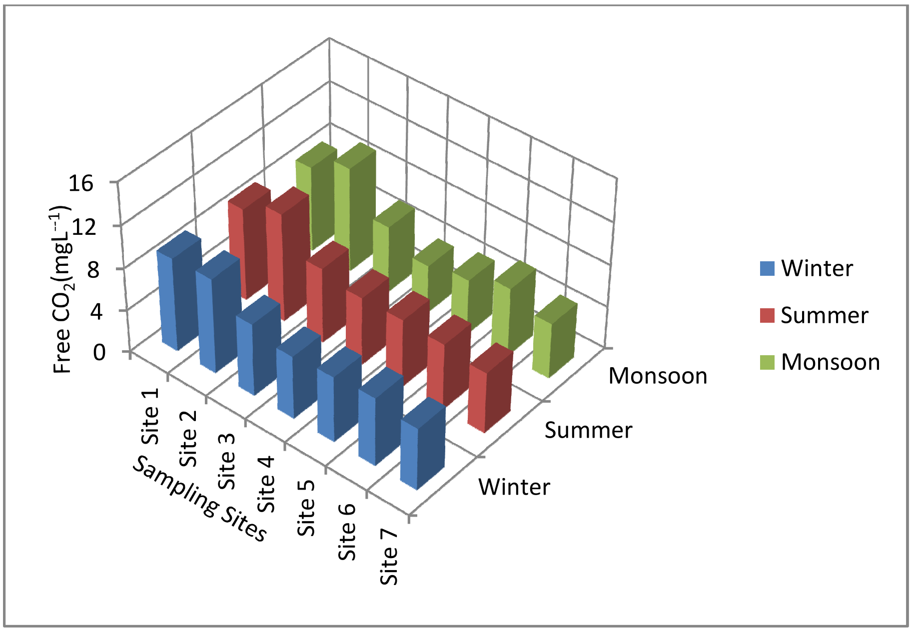
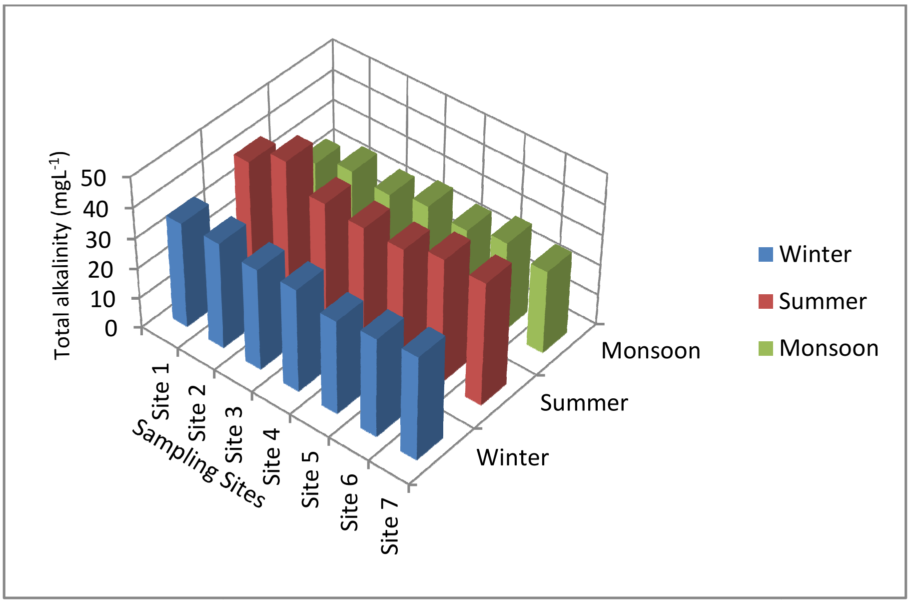


Fig. 4. Seasonal variation in DO and free CO_2 of water at seven sampling sites of Mirik lake. ANOVA: DO-Site $F_{2.99}$=4.52, P<0.05; Season $F_{6.93}$=16.01, P<0.01; free CO_2- Site $F_{4.82}$=36.06, P<0.01, Season $F_{3.89}$=4.72, P<0.05.



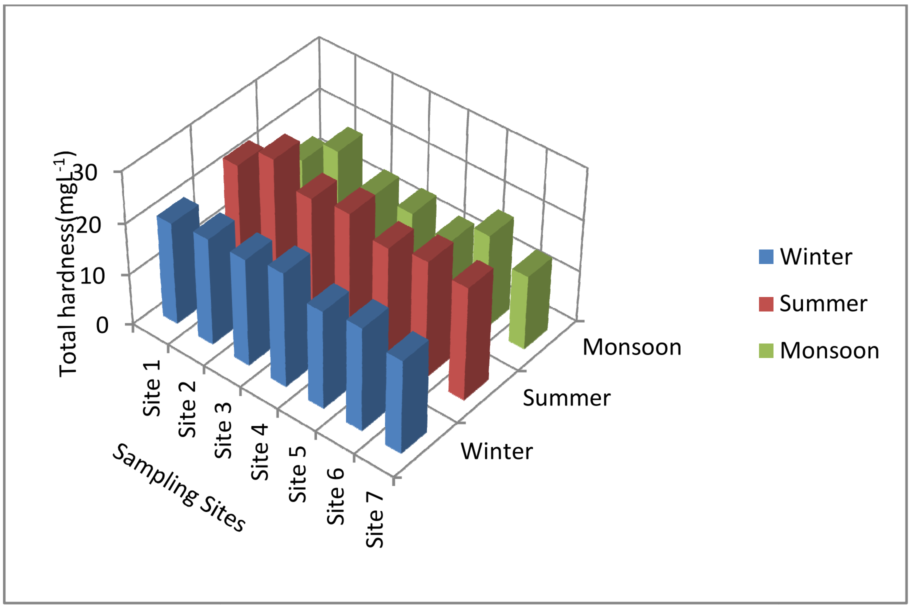
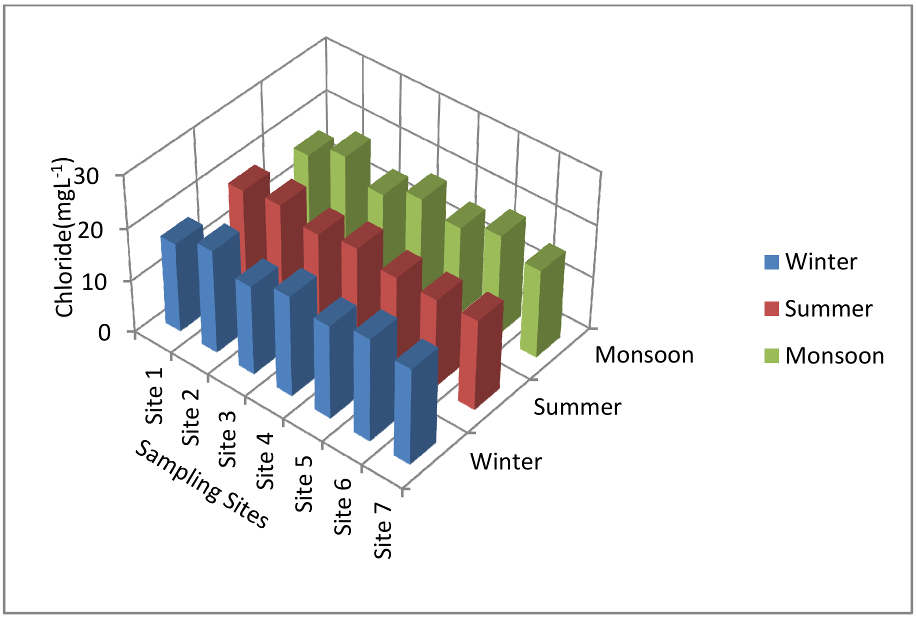


Fig. 5. Seasonal variation in total alkalinity and total hardness of water at seven sampling sites of Mirik lake. ANOVA: total alkalinity- Season $F_{6.93}$=66.84, P<0.01; total hardness- Site $F_{2.99}$=4.47, P<0.05, Season $F_{6.93}$=61.37, P<0.01.



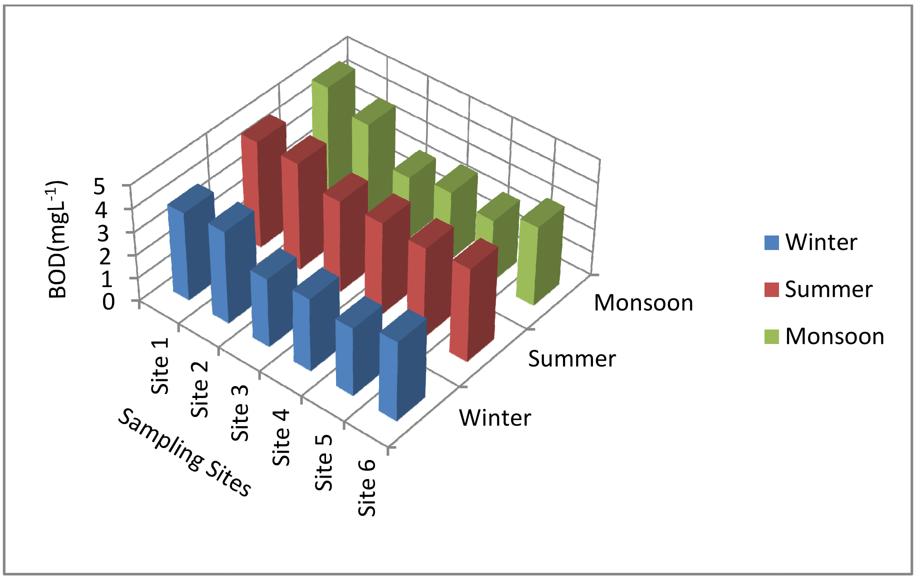


Fig. 6. Seasonal variation in chloride and BOD of water at seven sampling sites of Mirik lake. ANOVA: chloride- Site $F_{4.82}$=5.13, P<0.01, P<0.05; BOD- Site $F_{4.82}$=10.95 P<0.01; Season $F_{6.93}$=18.74.

Table 1. Pearson's Coefficient of Correlation for air temperature and physico-chemical parameters of Water at all the Sites from October, 2005- September, 2007. N=21, d.f.=19

Water temperature (^{0}C)	pH	Transparency (cm)	Conductivity (µmhos cm^{-1})	Dissolved oxygen (DO) (mgL^{-1})	Free Carbon dioxide (CO_2) (mgL^{-1})	Total alkalinity (mgL^{-1})	Total hardness (mgL^{-1})	Chloride (mgL^{-1})	BOD (mgL^{-1})
0.9990****	-0.20135	0.1865	-0.0663	0.0545	-0.0983	0.0472	-0.0547	-0.2575	0.3046
	-0.1880	0.2009	-0.0741	0.0651	-0.1107	0.0443	-0.0638	-0.2708	0.2886
		0.2594	-0.0276	0.3780*	-0.7906****	0.1634	0.0143	-0.0824	-0.5954***
				-0.7699****	0.5086**	0.9377****	0.9416****	0.3539	0.5318**
					-0.7375****	-0.6111***	-0.7722****	-0.2020	-0.7977****
						0.2665	0.4361**	0.2246	0.7357****
							0.8992****	0.2220	0.4315*
								0.3915*	0.5149**
									0.0846

*i) **** Significant at 0.2% level (P<0.002), *** significant at 1% level (P<0.01), ** significant at 5% level (P< 0.05), * significant at 10% level*
ii) Values not marked denote non-significant correlation

CONCLUSION

From the present investigation it was confirmed that Sites 1, 2 and 6 were more polluted than the other areas. The results also suggest that the quality of the Lake water is not suitable for either drinking or bathing purposes. The long term scientific monitoring is very much necessitated to evaluate the status of the lake for its longevity. Intermittent monitoring of water quality and creation of database would be an important task which can help in reviewing the management strategies and action plan from time to time. Public awareness is very much important to control the discharge of wastes from the shops, restaurants, hotels and households adjoining the lake. Besides, the domestic sewage should be treated fully before discharging into the Lake.

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