



RESEARCH ARTICLE

Impact of Climate Change on Water Quality of Shoolkere Lake, Bangalore

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Abstract

An attempt has been made to ascertain the water quality of Shoolkere Lake with regard to physico-chemical parameters like temperature, pH, turbidity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Dissolved Oxygen, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Free CO₂, chloride, alkalinity, hardness, phosphate, nitrate, sulphate and iron. Seasonal variations in the water quality parameters were investigated during the monitoring period from January to December 2010. The relationship between various physico-chemical parameters were analyzed statistically by Pearson correlation analysis. The results revealed that the condition of this Lake in different seasons showed fluctuations in physico-chemical parameters. Correlation coefficient showed positive and negative relationships between the physico-chemical parameters and also showed high significant positive relationship ($p < 0.01$ level) and significant positive relationship ($p < 0.05$ level).

Keywords: Water quality, Shoolkere Lake, physico-chemical parameters, Pearson correlation analysis.

Introduction

Pollution caused by human activities primarily affects physico-chemical characteristics of water, leading to destructions of community disrupting delicate food webs and deteriorating the lake environment. Water quality in lakes depends upon natural degradation process of eutrophication. Impacts of human activities, which accelerate eutrophication process by several orders of magnitude then a process that would normally take thousands of years if left to nature. The hastening of eutrophication is an account of waste water discharges and agricultural runoff. The physico-chemical parameters of any lake provide first hand information about water quality characteristics and pollution in lake. The aquatic ecosystem presents a great contrast to terrestrial ecosystem and aquatic organisms display such a wide range of adaptations that they continue to attract the attention of biologists.

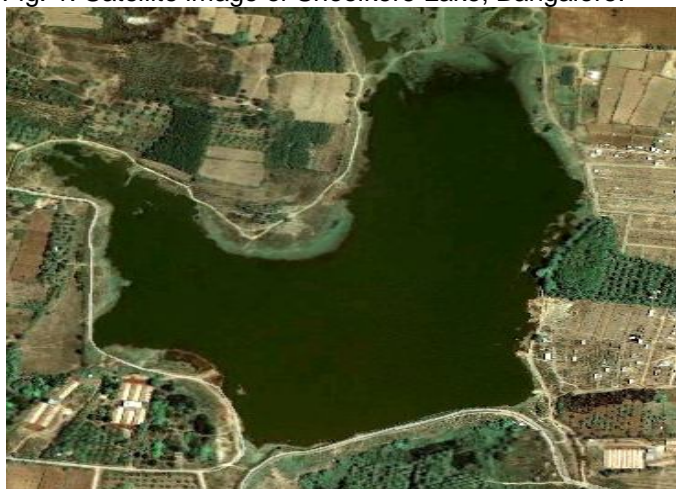
Goldman and Horne (1993) studied on physico-chemical factors that influence the aquatic biota. Batcha (2003) investigated water chemistry and biology in a shallow lake of Pamootis (Greece). Surendra *et al.* (2005) studied physico-chemical properties of some fresh water bodies of some districts of Rajasthan. Elizabeth and Naik (2005) investigated the water analysis on Hussainsagar Lake of Hyderabad. Dey and Hazra (2005) studied comparative limnological of two ponds (Blue and milk pond) of Chandraneswar temple in India. Kanungo *et al.* (2006) studied physico-chemical characteristics of Doodhadahri pond of Raipur, Chhattisgarh.

Ram and Mohan (2006) studied water quality of freshwater lakes of Kolar Taluk, Karnataka. Ram and Mohan (2008) studied the nutrient overloading of a few lakes in Bangalore, Karnataka, India. Krishna Ram and Ramachandra Mohan (2009) investigated the water quality status of freshwater lake (Thalli Lake) Krishnagiri, Tamil Nadu. Latha and Ramachandra Mohan (2010a) studied water quality of the Lake Kommaghatta, Bangalore. Latha and Ramachandra Mohan (2010b) studied water quality of Hoskerehalli Lake of Bangalore, Karnataka. Against these backdrops, this study was aimed to analyze the physico-chemical characteristics of Shoolkere Lake, Bangalore which can directly influence the general condition of the water body.

Materials and methods

Study area: Bangalore experiences a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation of 920 m (3,020 ft.), Bangalore usually enjoys a more moderate climate throughout the year, although occasional heat waves can make things very uncomfortable in the summer. The coolest month being January with an average low temperature of $15 \pm 1^\circ\text{C}$ and the hottest month is April with an average high temperature of 33.6°C . Bangalore receives rainfall from both the northeast and the southwest monsoons and the wettest months are September, October and August. The lakes of Bangalore occupy about 4.8% of the city's Geographical area (741 km²) covering both urban and rural areas.

Fig. 1. Satellite image of Shoolkere Lake, Bangalore.



The study area selected was Shoolkere Lake, ($12^{\circ} 56' 58.05''$ N Latitude and $77^{\circ} 27' 32.80''$ E Longitude and elevation of 2654 ft.). Satellite image of the study area is shown in Fig. 1.

Collection of water sample and analysis: During the period of investigation (January 2010 to December 2010) monthly analysis of the surface water samples from the study Lake for the experimental estimation of the levels of physico-chemical parameters were made by collecting the water in clean polythene containers. Sampling was made in the morning between 7:30 a.m to 9:30 a.m. Water temperature was measured at the site using centigrade thermometer. pH were measured in the field using pH meter. For analyzing DO and BOD, water samples were collected in BOD bottles (300 mL). DO was also fixed on the spot. All the measurements and estimations were made following APHA (2005) and Trivedy and Goel (1984).

Statistical analysis: The relationship between various physico-chemical parameters of water samples were analyzed statistically conducting Pearson correlation analysis (Tiwari and Patel, 1991; Mariappan and Vasudevan, 2002).

Results and discussion

Physico-chemical characteristics of an aquatic system reflect not only the quality of system but also the type and density of its biota. Analysis of such parameters generates information regarding pollution pattern and magnitude of pollutant loading of aquatic system. The season wise physico-chemical parameters of Shoolkere Lake, Bangalore and its seasonal mean values, seasonal standard deviation, seasonal coefficient variation has been presented in Table 1. Table 2 represents correlation matrix between various physico-chemical parameters of Shoolkere Lake from January to December 2010.

Water temperature: Water temperature is an important parameter, because it influences the biota in a water body by affecting activities such as behavior, respiration and metabolism. It is necessary to study temperature variations in water bodies, ecophysiological and toxicological aspects in animals because, water density and oxygen content are temperature related and hence, temperature indirectly affects osmoregulation and respiration of the animal (De, 2002). In the present study, the maximum temperature was recorded as $31.32 \pm 2.52^{\circ}\text{C}$ and coefficient variation was 8.04% recorded during summer; minimum value was recorded $26.75 \pm 2.10^{\circ}\text{C}$ and coefficient variation was 7.85% recorded during winter. The overall mean was $28.48 \pm 2.47^{\circ}\text{C}$ and coefficient variation was 8.67% (Table 1). Water temperature is positively correlated with pH, BOD, COD, chloride, alkalinity and showed significant correlation with sulphate. Water temperature is negatively correlated with turbidity, TDS, EC, DO, total hardness, phosphate and nitrate (Table 2). The water temperature was consistently lower than atmospheric temperature. In the present investigation the temperature values were maximum during summer and minimum during winter. Low temperature recorded in winter may be due to high water level, lesser solar radiation, low atmospheric temperature and high temperature in summer is because of low water level, high solar radiation and clear atmosphere. Similar, results have been reported by Anita *et al.* (2005), Narayana *et al.* (2008) and Jawale and Patil (2009).

pH: In the present study, maximum pH value was recorded as 8.0 ± 0.18 and coefficient variation was 2.25% recorded during summer, minimum value was recorded as 7.4 ± 0.15 and coefficient variation was 2.02% recorded during winter. The overall mean was 7.72 ± 0.30 and coefficient variation was 3.88% (Table 1). pH show positive correlation with BOD, COD, chloride, alkalinity, total hardness and sulphate and negative correlation with turbidity, TDS, EC, DO, phosphate and nitrate (Table 2). In the present investigation, maximum pH value recorded in summer may be due to low water level and concentration of nutrients in water. The low pH value was due to dilution caused by the rainwater during monsoon. Similar trend was reported by Philipose (1960), Sahai and Sinha (1969), Rao (2004), Nirmal Kumar *et al.* (2005), Pawar and Pulle (2005), Rajashekhar *et al.* (2007) and Vasumathi *et al.* (2009) who observed pH in range of 7.0 to 7.85 and stated that pH of water is important for the biotic communities because most of the plant and animal species can survive in narrow range of pH from slightly acidic to slightly alkaline condition.

Turbidity: In the present study, the maximum turbidity value was recorded as 25 ± 2.58 (FAU) and coefficient variation was 10.32% recorded during monsoon.

Table 1. Seasonal variations in physico-chemical parameters of Shoolkere Lake during Jan to Dec 2010.

Parameter	Summer	C.V%	Monsoon	C.V%	Winter	C.V%	Average	C.V%
Water temperature(°C)	31.32±2.52	8.04	27.37±2.21	8.07	26.75±2.10	7.85	28.48±2.47	8.67
pH	8.0±0.18	2.25	7.77±0.12	1.54	7.4±0.15	2.02	7.72±0.30	3.88
Turbidity (FAU)	11.5±1.29	11.21	25±2.58	10.32	16.25±3.09	19.01	17.58±6.84	38.90
Total dissolved solids (mg/L)	225±50	22.22	425±125.83	29.60	375±50	13.33	341.66±104.08	30.46
Electrical conductivity (µmhos/cm)	351.56±78.12	22.22	66.06±196.61	29.60	585.93±78.12	13.33	533.85±162.62	30.46
Dissolved oxygen (mg/L)	5.7±0.60	10.52	6.33±0.62	9.79	7.88±1.24	15.73	6.63±1.12	16.89
Biological oxygen demand (mg/L)	5.47±0.46	8.40	5.08±0.28	5.51	4.8±1.24	25.83	5.11±0.33	6.45
Chemical oxygen demand (mg/L)	8.85±0.7	7.90	8.42±1.37	16.27	4.45±0.95	21.34	7.24±2.42	32.61
Chloride (mg/L)	82.25±26.91	32.71	52.55±6.85	13.03	44.12±32.39	73.41	59.64±20.02	33.56
Alkalinity (mg/L)	191.5±9.98	5.21	96±6.32	6.58	64.32±9.35	14.53	117.27±66.20	56.45
Total Hardness (mg/L)	156.5±52.11	33.29	245.5±96.94	39.48	166.5±29.04	17.44	189.5±48.75	25.72
Phosphate (mg/L)	3.5±1.62	46.28	4.62±0.54	11.68	4.42±1.18	26.69	4.18±0.59	14.11
Nitrate (mg/L)	3.39±0.21	6.19	6.10±0.94	15.40	4.62±0.75	16.23	4.70±1.35	28.72
Sulphate (mg/L)	23.4±3.51	15	15.52±3.66	23.58	14.95±4.78	31.97	17.95±4.72	26.29

Table 2. Correlation matrix among the physico-chemical parameters of Shoolkere Lake during Jan to Dec 2010.

Parameter	Water Temp.	pH	Turbidity	TDS	EC	DO	BOD	COD	Chloride	Alkalinity	TH	Phosphate	Nitrate	Sulphate
Water Temp.	1	0.862	-0.683	-0.933	-0.933	-0.804	0.954	0.673	0.996	0.993	-0.480	-0.957	-0.763	0.998*
pH		1	-0.218	-0.622	-0.622	-0.994	0.974	0.955	0.902	0.915	0.031	-0.678	-0.330	0.827
Turbidity			1	0.900	0.900	0.115	-0.434	0.081	-0.618	-0.594	0.969	0.865	0.993	-0.729
TDS				1	1.000**	0.536	-0.783	-0.361	-0.898	-0.885	0.764	0.997*	0.945	-0.954
EC					1	0.536	-0.783	-0.361	-0.898	-0.885	0.764	0.997*	0.945	-0.954
DO						1	-0.945	-0.981	-0.852	-0.867	-0.136	0.597	0.229	-0.763
BOD							1	0.863	0.977	0.982	-0.196	-0.827	-0.535	0.933
COD								1	0.734	0.754	0.326	-0.430	-0.036	0.623
Chloride									1	1.000*	-0.403	-0.929	-0.705	0.989
Alkalinity										1	-0.375	-0.917	-0.683	0.984
TH											1	0.714	0.933	-0.536
Phosphate												1	0.918	-0.974
Nitrate													1	-0.804
Sulphate														1

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

Minimum value was recorded as 11.5±1.29 (FAU) and coefficient variation was 11.21% recorded during summer. The overall mean was 17.58±6.84 (FAU) and coefficient variation was 38.90% (Table 1). Turbidity showed positive correlation with TDS, EC, DO, COD, total hardness, phosphate and nitrate and negative correlation with BOD, chloride, alkalinity and sulphate (Table 2). In the present investigation, the turbidity values were maximum during monsoon may be due to influx of rain water from catchments area, cloudiness, less penetration of light, washes silts, sand, high organic matter and low transparency due to suspended inert particulate matter. However, low values of turbidity in summer may be due to clear atmosphere, evaporation of water and high light penetration. Similar results have been reported by Kulkarni *et al.* (1995), Narayana *et al.* (2008) and Reddy Vasumathi *et al.* (2009).

Total Dissolved Solids (TDS): Solids refer to suspended and dissolved matter in water. They are very useful parameter describing the chemical constituents of the water and can be considered as general of edaphically relation that contributes to productivity within the water body (Goher, 2002). In the present study, the maximum value of TDS was recorded as 425±125.83 (mg/L) and coefficient variation was recorded 29.60% during monsoon; minimum value of TDS was recorded as 225±50 (mg/L) and coefficient variation was 22.22% during summer. The overall mean was 341.66±104.08 (mg/L) and coefficient variation was 30.46% (Table 1). In the present investigation, TDS showed high significant positive relationship with electrical conductivity, it showed significant positive relationship with phosphate, it showed negative relationship with BOD, COD, chloride, alkalinity and sulphate (Table 2).

High values of TDS during monsoon may be due to siltation, deterioration, heavy precipitation and mixing run off rain water which carried mud, sand etc. mixed in the water. Similar results have been reported by Jawale and Patil (2009) and Salve and Hiware (2006) who reported seasonal analysis and stated that low TDS recorded in winter season while maximum value in monsoon due to addition of solids from surface run off in Wanparakalpa reservoir, Nagapur near Parali Vaijanath Dist. Beed, Maharashtra.

Electrical conductivity (EC): Electrical conductivity is a numerical expression ability of an aqueous solution to carry electric current. This ability depends on the presence of ions, their total concentration, mobility, valence, relative concentrations and temperature of measurement. In the present study, the maximum value of EC was recorded as 664.06 ± 196.61 ($\mu\text{mhos/cm}$) and coefficient variation was recorded 29.60% during monsoon; minimum value of EC was recorded as 351.56 ± 78.12 ($\mu\text{mhos/cm}$) and coefficient variation was 22.22% during summer. The overall mean was 533.85 ± 162.62 ($\mu\text{mhos/cm}$) and coefficient variation was 30.46% (Table 1). Electrical conductivity increases with increase in total dissolved solid. In the present investigation, electrical conductivity showed significant positive relationship with turbidity and phosphate, it showed negative relationship with pH (Table 2). High value of electrical conductivity in monsoon could be due to inflow of high quantum of domestic sewage in rainy season and low values in summer might be due to higher temperature and stabilization of water due to sedimentation and increased concentration of salts because of discharged domestic sewage and organic matter in the lake. Similar results have been recorded by Narayana *et al.* (2008) who reported high electrical conductivity in monsoon.

Dissolved oxygen (DO): Sources of oxygen in water are by diffusion of oxygen from the air into the water, photosynthetic activity of aquatic autotrophs and inflowing streams. DO is a very important parameter for the survival of fishes and other aquatic organisms. Diffusion of oxygen or transfer of oxygen in these organisms is efficient only above certain concentrations of oxygen. Too low concentrations of oxygen may not be enough to sustain life. Oxygen is also needed for many chemical reactions that are important to Lake functioning (oxidation of metals, decomposition of dead and decaying matter, etc.). Measurement of DO can be used to indicate the degree of pollution by organic matter. In the present study, the maximum value was recorded as 7.88 ± 1.24 (mg/L) and coefficient variation was 15.73% during winter. Minimum value was recorded as 5.7 ± 0.60 (mg/L) and coefficient variation was 10.52% during summer. The overall mean was 6.63 ± 1.12 (mg/L) and coefficient variation was 16.89% (Table 1).

In the present study, DO showed positive relationship with turbidity, TDS, EC, phosphate, nitrate and showed negative relationship with water temperature, pH, BOD, COD, chloride, alkalinity, total hardness and sulphate (Table 2). In the present investigation, the maximum DO in winter might be due to low atmospheric temperature and intensive photosynthetic activity and minimum DO in summer months might be due high metabolic rate of organisms. Similar results have been reported by Hazalwood and Parker (1961) and Manawar (1970).

Biological Oxygen Demand (BOD): BOD is an indication of the organic load and it is a pollution index especially for water bodies receiving organic effluent (Ndimele, 2012). In the present study, the maximum BOD value recorded as 5.47 ± 0.46 (mg/L) and coefficient variation was 8.40% during summer and minimum value recorded as 4.8 ± 1.24 (mg/L) and coefficient variation was 25.83% during monsoon. The overall mean was 5.11 ± 0.33 (mg/L) and coefficient variation was 6.45% (Table 1). In this study, BOD showed positive relationship with water temperature, pH, COD, chloride, alkalinity and sulphate and negative relationship with turbidity, TDS, EC, DO, total hardness, phosphate and nitrate (Table 2). In the summer season, the metabolic activities of various aerobic and anaerobic microorganisms increased with the higher water temperature thus, causing considerable decrease in the level of water. But, during the rainy season the large volume of fresh water diluted the organic matter resulting in decrease of the BOD values. A similar problem was acute during a summer season in India (Bagde and Verma, 1985; Palharya and Malvia, 1988).

Chemical Oxygen Demand (COD): COD is a measure of oxygen required for complete oxidation of organic matter by a strong oxidant. The high COD values indicate that some degree of non-biodegradable oxygen demanding pollutants were present in the water. In the present study, the maximum value was recorded as 8.85 ± 0.7 (mg/L) and coefficient variation was 7.90% during summer and minimum value was recorded as 4.45 ± 0.95 (mg/L) and coefficient variation was 21.34% during winter. The overall mean was 7.24 ± 2.42 (mg/L) and coefficient variation was 32.61% (Table 1). In the present study, COD showed positive relationship with water temperature, pH, chloride, alkalinity, total hardness, sulphate and negative relationship with TDS, EC, DO, phosphate and nitrate (Table 2). The COD was high during summer due to high rate of oxidation (Parateesam and Sudha Gupta, 1994).

Chlorides: Chlorides as chloride anions (Cl^-) are major anions in wastewater. The chloride concentration is higher in organic wastes and its higher level in natural water is definite indication of pollution from domestic sewage.

The ecological significance of chloride lies in its potential to regulate salinity of water and exert consequent osmotic stress on biotic communities. The increase in chloride concentration in Lakes, Rivers and Dams is due to the discharge of municipal and industrial wastes reported by Kant and Raina (1990). In the present study, the maximum value was recorded as 82.25 ± 26.91 (mg/L) and coefficient variation was 32.71% during summer and minimum value was recorded as 44.12 ± 32.39 (mg/L) and coefficient variation was 73.41% during winter. The overall mean was 59.64 ± 20.02 (mg/L) and coefficient variation was 33.56% (Table 1). In the present investigation, chloride showed positive relationship with water temperature, pH, sulphate and significant positive relationship with alkalinity, it showed negative relationship with turbidity, TDS, EC, DO, hardness, phosphate and nitrate (Table 2). Lower value during winter could be attributed to dilution effect and renewal of water mass after summer stagnation and also may be due to high sedimentation rate on relatively stable environmental condition. Maximum value during summer could be due to higher concentration of chloride resulted from evaporation. Similar results have been reported by Nirmal *et al.* (2005), Chouhan and Sharma (2007), Narayana *et al.* (2008) and Reddy Vasumathi *et al.* (2009) that the chloride maximum value recorded in May while minimum recorded in August.

Alkalinity: Alkalinity of surface water is primarily a function of carbonate, hydroxide content and also includes the contributions from borates, phosphates, silicates and other bases. Total alkalinity is the sum of hydroxides, carbonates and bicarbonates. Total alkalinity is a measure of capacity of water to neutralize a strong acid. The maximum value was recorded as 191.5 ± 9.98 (mg/L) and coefficient variation was 5.21% during summer. Minimum value was recorded as 64.32 ± 9.35 (mg/L) and coefficient variation was 14.53% during winter. The overall mean was 117.27 ± 66.20 (mg/L) and coefficient variation was 56.45% (Table 1). In the present investigation, alkalinity showed positive relationship with water temperature and pH and showed negative relationship with turbidity, TDS, EC, DO, hardness, phosphate and nitrate (Table 2). In the present investigation, the alkalinity values were maximum during summer and minimum during monsoon. This may be attributed to increase in the rate of organic decomposition when CO_2 is liberated, which reacts with water to form HCO_3^- , thereby increasing the total alkalinity in summer. The decrease was due to dilution caused by the rainwater during monsoon. This was further supported by the observations made by Moss (1973) and Wetzel (1983).

Hardness: Hardness is due to concentration of alkaline earth metals. Ca^{++} and Mg^{++} are the principal cations imparting hardness.

Ca^{++} and Mg^{++} are the most abundant elements in natural surface and ground water and exist mainly as carbonates, bicarbonates and carbon dioxide constituted major source of inorganic carbon to producers in an aquatic ecosystem. They also act as buffers regulating the pH of the medium. In the present study, the maximum value was recorded as 245.5 ± 96.94 (mg/L) and coefficient variation was 39.48% during monsoon. Minimum value was recorded as 156.5 ± 52.11 (mg/L) and coefficient variation was 33.29% during summer. The overall mean was 189.5 ± 48.75 (mg/L) and coefficient variation was 25.72% (Table 1).

In the present investigation, total hardness showed positive relationship with turbidity, electrical conductivity and total dissolved solids and it showed negative relationship with DO, BOD, chloride, alkalinity and sulphate (Table 2). Maximum total hardness value recorded during the monsoon may be due to leaching of rocks in catchment area. Hardness is mainly due to calcium and magnesium, the major cation present in natural waters as calcium and magnesium. Its concentration restricts water use, while it is an important component in the exoskeleton of arthropods and shells in mollusca (Piska, 2000). Similar results have been reported by Pawar and Palle (2005) who studied on Pethwadaj Dam, Nanded, Maharashtra and the maximum values were recorded during monsoon while minimum during winter. Salve and Hiware (2006) reported that the total hardness was higher in winter, moderate in monsoon and lower in summer.

Phosphate: Phosphate is a nutrient for plant growth and a fundamental element in the metabolic reaction of plants and animals. It controls algal growth and primary productivity. Excess amounts of phosphorus can cause eutrophication leading to excessive algal growth called algal blooms. In the present study, the maximum value was recorded as 4.62 ± 0.54 (mg/L) and coefficient variation was 11.68% during monsoon. Minimum value was recorded as 3.5 ± 1.62 (mg/L) and coefficient variation was 46.28% during summer. The overall mean was 4.18 ± 0.59 (mg/L) and coefficient variation was 14.11% (Table 1). In the present study, phosphate showed significant positive relationship with EC, TDS, and positive relationship with turbidity, DO, total hardness and nitrate and negative relationship with water temperature, pH, BOD, COD, chloride, alkalinity and sulphate (Table 2). In the present investigation, the phosphate values were maximum during monsoon and minimum during summer. Maximum during monsoon might be due to the washing activities, there is an entry of detergents in the water body and during summer season the relatively low level of phosphate have been reported which may be attributed to abundance of phytoplanktons. Similar results have been reported by Chary (2003) and Rao (2004).

Nitrate: Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters, because it is a product of aerobic decomposition of organic nitrogenous matter. Significant sources of nitrates are fertilizers, decayed vegetable and animal matter, domestic and industrial effluents and atmospheric washouts. In the present study, the maximum value was recorded as 6.10 ± 0.94 (mg/L) and coefficient variation was 15.40% during monsoon. Minimum value was recorded as 3.39 ± 0.21 (mg/L) and coefficient variation was 6.19% during summer. The overall mean was 4.70 ± 1.35 (mg/L) and coefficient variation was 28.72% (Table 1). In the present study, nitrate showed positive relationship with turbidity, electrical conductivity, total dissolved solids and total hardness, phosphate and negative relationship with temperature, pH, BOD, COD, chloride alkalinity and sulphate (Table 2). In the present investigation, values of nitrate were maximum during monsoon and minimum during summer season. Nitrate levels in surface water often show marked seasonal fluctuations with higher concentrations being found during monsoon months compared to summer and winter months. During summer months, the reduction in nitrates could be due to algal assimilation and other biochemical mechanism and nitrate value higher during monsoon may be due to surface run off and domestic sewage and specially washing activities. Similar results have been reported by Gohram (1961) and Rajashekhar *et al.* (2007).

Sulphate: Sulphate is present in fertilizers and contributes to water pollution and increases sulphate concentration in water body. They also come from runoff water, which contain relatively large quantities of organic and mineral sulphur compounds. The supply of sulphate ions in surface water under natural conditions are due to the reactions of water with sulphate containing rock and with the biochemical and partly chemical oxidation of sulphides and other compounds of sulphur (Singh, 1984). In the present study, sulphate showed significant positive relationship with water temperature, positive relationship with pH, BOD, COD, chloride and alkalinity and negative relationship with turbidity, TDS, EC, DO, TH, phosphate and nitrate (Table 2).

The maximum value was recorded as 23.4 ± 3.51 (mg/L) and coefficient variation was 15% during monsoon. Minimum value was recorded as 14.95 ± 4.78 (mg/L) and coefficient variation was 31.97% during winter. The overall mean was 17.95 ± 4.72 (mg/L) and coefficient variation was 26.29% (Table 1). In the present investigation, the sulphate values were maximum during monsoon and minimum during winter. Maximum sulphate concentration during monsoon may be due to the dilution and utilization of sulphate by aquatic plants. However, the low sulphate concentration was noted during winter may be due to biodegradation and low water level.

Similar results have been reported by Reddy *et al.* (2009), Telkhade *et al.* (2008) and Shanthi *et al.* (2006) who observed high value in monsoon.

Conclusion

The present study showed detailed physico-chemical characteristics and quality of water in Shoolkere Lake, Bangalore, India. The summer, monsoon and winter seasons shows different seasonal fluctuations in various physico-chemical parameters. The water of present lake is useful for irrigation as well as fish culture. The correlation coefficient indicates positive and negative correlation of physico-chemical parameters with each other. Positive correlation mean, one parameter increase with increase in other parameters and negative correlation mean one parameter increase with other parameters decrease. To improve quality of water, there should be continuous monitoring of pollution level and maintaining the favorable conditions are essential for fish survival, growth and reproduction in Shoolkere Lake, Bangalore.

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