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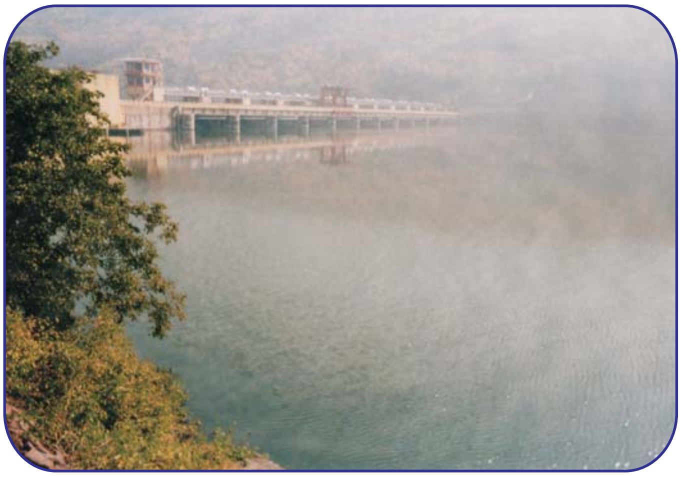

View showing sampling site at Jawahar Sagar Lake, Rajasthan

Editorial

The Salim Ali Centre for Ornithology and Natural History (SACON) brings out the first issue of SAROVAR SAURABH (volume-5), an ENVIS Newsletter on wetland ecosystems, sponsored by the Ministry of Environment and Forests, Government of India. The major goal of the Newsletter is to share information about wetlands with various users and, to highlight conservation issues of relevance to wetland community of professionals, managers, environmentalists and other stakeholders.

This newsletter deals with a paper on aeration system of Lower Lake, Bhopal and diatom diversity of Jawahar Sagar Lake, Rajasthan. The Newsletter also gives obituary to former Director, Dr. Ravi Sankaran, SACON due to his sudden demise in January 2009. It is again hoped that stakeholders in wetland conservation and all other ENVIS centres can make use of these information effectively to create public awareness for further wetland conservation.

To make this effort worth while, the editorial team of SAROVAR SAURABH seeks active participation of its readers in terms of providing information, news, views, photographs and articles on issues of wetland conservation. To make the newsletter a truly effective forum for all wetland conservation related issues of the country, feedback and contributions from scientific communities and research groups are highly appreciated.

PERFORMANCE EVALUATION OF AERATION SYSTEMS INSTALLED IN LOWER LAKE, BHOPAL

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Abstract

Lower lake is a small, artificial, closed lake (Lat. 23° 16′ N & Long. 72° 25′E) located east end of the Upper lake, Bhopal, India. These two lakes together known as Bhoj Wetland. The Lower lake is urban eutrophic lake where the amount of nutrient concentration is very high and oxygen depletion is very prominent. This lake receives a large amount of raw sewage and untreated wastewater from it's densely populated habitation. Organic enrichment of lake through floral offering, idol immersion and decomposition of aquatic weeds are also the significant cause of its eutrophication. In order to reduce the impact of nutrient concentration and bacterial growth, different aeration systems *i.e.* floating fountain, ozonizer and floating fountain cum ozonizer were installed in the lake. These aeration systems are very effective in improving water quality by increasing DO levels, consequently leading to the reduction of BOD and COD levels. Aeration units as oxygenate the lake water which directly increases the biodiversity of the lake ecosystem.

Keywords: Aeration; Bhoj wetland; Eutrophication; Floating fountain; Ozonizer; Performance.

Introduction

The Lower lake is a small, artificial, man made lake. It is an integral part of Bhoj wetland ecosystem and a source of raw water for the urban development and domestic water needs like washing, bathing etc. As in the case of many urban water bodies all over India, the Lower lake was subjected to all kinds of negative anthropogenic stresses. It is an urban eutrophic lake receives a large amount of raw sewage and untreated wastewater from its densely populated habitation and its water quality is far more deteriorated than Upper lake. The lake receives its water mainly from point and non-point sources, which carry significant quantity of untreated sewage and wastewater from its adjoining settlements. Sewage would become a resource or pollutant depending upon the state of treatment and their use (Okun, 2002). Organic enrichment of lake through floral offering during ritual practices, idol immersion and decomposition of aquatic weeds are some of the significant causes of its eutrophication.

The idol immersion activity, a religious practice is responsible for adding pollution load of biodegradable and non-degradable substances in the water bodies. The idols are made up of plaster of paris, clay, cloth, paper, bamboo, thermocol, adhesives, paints, coloured pigments etc supported by small iron rods (Bajpai *et al.*, 1993). Vyas *et al.*, (2008) found a drastic water quality improvement in Upper lake at sheetal das ki bagia after shifting of idol immersion site. Sakthivel *et al.*, (2005) studied the environmental impact of Ganesh idol immersion at Juhu and Mahim beaches. Anaerobic conditions predominate throughout extensive areas of highly eutrophic lakes (Hutchinson, 1975). As a result the hypolimnion is often observed with the phenomenon of frequent oxygen depletion with the consequent increase in BOD, COD etc. (Pani and Misra, 2000).

Aeration shows promise as a lake restoration technique to relieve many of the problems associated with hypolimnetic anoxia. Two strategies were delineated by Fast *et al.*, (1973): 1) destratification—the entire lake is mixed, and 2) hypolimnetic aeration—stratification is maintained while oxygenating the hypolimnion. Aeration has been used successfully to relieve low dissolved oxygen conditions (McWilliams, 1981). This technique can restore oxygen to the hypolimnion and lower concentrations of reduced compounds that are toxic or repelling to fishes (Gebhart and Summerfelt, 1976; Carr and Martin, 1978). Aeration system transfer oxygen into liquid media by either diffusing gas through a gas-liquid interface, or dissolving gas into the liquid solution using a semi-permeable membrane (Rosso and Stenstrom, 2006). Pani and Misra (2003) reported that artificial aeration/ozonisation is very effective in lake ecosystem for increasing oxygen concentration in hypolimnion and improvement of water quality of a eutrophic lake. Zue *et al.*, (2004) studied performance characteristics of aeration systems in which passive aeration was suitable for a small scale swine farm and forced aeration system should be considered for middle and large scale swine farms with a high extent of industrialization. Bahl *et al.*, (2005) reported that artificial aeration units have significant impact on water quality of the lake. Dixit *et al.*, (2007) reported that the floating fountain cum ozonizer (dual aeration system) is more effective in improving water quality of degraded water body. Verma *et al.*, (2007) evaluate the study of water quality parameters of Lower lake, Bhopal and found the similar results.Verma, (2007) studied physico-chemical parameters of Upper and Lower lakes with special referene to aeration units and found significant water quality improvement due to these units. Verma (2008) studied the restoration of Bhopal lakes through innovative technique and found that aeration units had more influence in improving the water quality.

Hence in order to increase the oxygen level and to reduce the impact of nutrient concentration and bacterial growth, different aeration systems *i.e.* floating fountain cum ozonizer, floating fountain and ozonizer were installed in the lake under Bhoj Wetland Project. Performance evaluation of different aeration systems were studied to assess the effectiveness of artificial aeration units in improving the water quality of the lake.

Material and Methods

The evaluation study for performance of aeration systems three different sampling stations of Lower lake namely Neelam Park (station 1) having floating fountain cum ozonizer (dual aeration system), Bhoipura (station 2) possess floating fountain and Khatlapura (station 3) having ozonizer type of aeration units. Water samples were collected from the site of aeration systems at different intervals and sampling was done six hourly *i.e.* before, during and after operation of aeration units.

The water samples were collected from the surface and bottom layers of the lake and subjected to physico-chemical and bacteriological analysis following the procedure prescribed by APHA (1995) and NEERI manual (1991). The parameter namely DO, BOD, COD nutrient concentration and total coliform (MPN) were analyzed at regular intervals.

Results and discussion

On the basis of the comparative study and observation recorded for the performance evaluation of three aeration systems installed in Lower lake, Bhopal are as follows;

Dissolved Oxygen (DO): DO ranged from 6.4-12.6 mg/L at surface layer while 2.4-6.4 mg/L at bottom layer at station 1 and 5.6-8.8 mg/L at surface layer while 1.6-4.2 mg/L at bottom layer at station 2 and 7.6-10.8 mg/L at surface layer while 2.4-6.4 mg/L at bottom layer at station 3 of Lower lake (**fig 1**). The maximum increase in the DO was recorded when the aeration units were operational and better performance was given by floating fountain cum ozonizer. An adequate supply of DO is essential for the survival of aquatic organism. Bajpai and Misra (2006) reported that after the installation of aeration units under the Bhoj Wetland Project water quality of Upper lake improved as DO was increased while BOD, COD and nutrient were decreased.

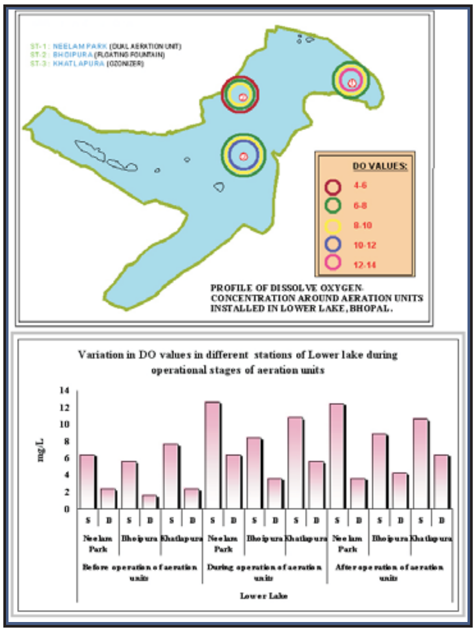

Fig 1. Variation in DO values of Lower Lake

Biological Oxygen Demand (BOD):

BOD ranges from 4.4-7.2 mg/L at surface layer while 10.4-14.4 mg/L at bottom layer at station 1 and 12.0-18.0 mg/L at surface layer while 16.0-24.0 mg/L at bottom layer at station 2 and 8.6-12.0 mg/L at surface layer while 16.0-28.0 mg/L at bottom layer at station 3 (**fig 2**). The minimum value of BOD was recorded at the surface layer during the functioning period and floating fountain cum ozonizer is the best aeration unit for reduction in BOD. BOD indicates the presence of microbial activities and dead organic matter on which microbes can feed. Rao *et al.*, (1994) studied the sewage pollution of lake in Ooty and found inverse relation of dissolved oxygen with BOD.

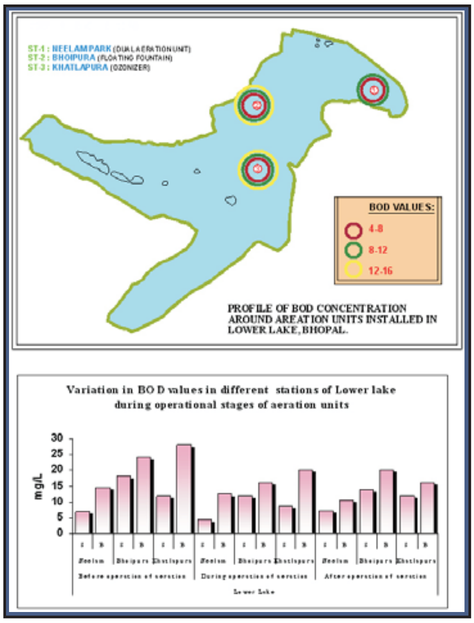

Fig.2 Variation in BOD values of Lower Lake

Chemical Oxygen Demand (COD): COD indicates the pollution level of a water body as it is related to the organic matter present in the lake (WQM Report, 1999). COD concentrations in the range of 72-80 mg/L at surface layer while 88-92 mg/L at bottom layer at station 1 and 92-108 mg/L at surface layer while 86-112 mg/L at bottom layer at station 2 and 64-96 mg/L at surface layer while 80-110 mg/L at bottom layer at station 3 (**fig 3**). A significant fall in the COD was observed during the operation of floating fountain cum ozonizer aeration unit. Hsu *et al.*, (2007) reported that the COD of phenol waste water can be effectively removed with high ozone utilization rate by calcium-binding reaction.

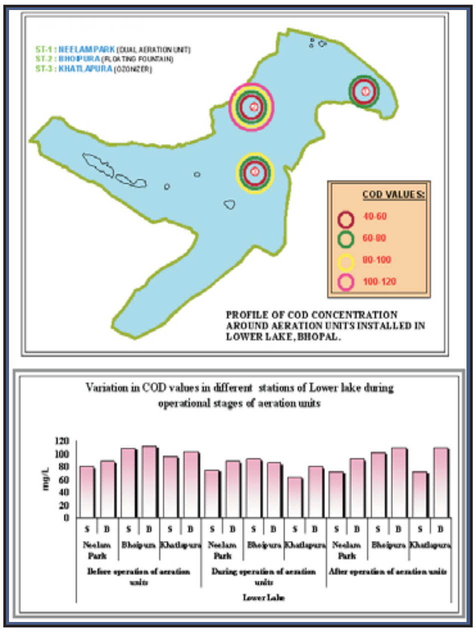

Fig.3 Variation in COD values of Lower Lake

Nutrient concentration: The nitrate content of water was found in the range of 1.055-1.632 mg/L at surface layer while 1.421-1.941 mg/L at bottom layer at station 1 and 1.761-1.871mg/L at surface layer while 1.842-2.107 mg/L at bottom layer at station 2 and 1.121-1.145 mg/L at surface layer while 1.180-1.327 mg/L at bottom layer at station 3 (**fig 4**).

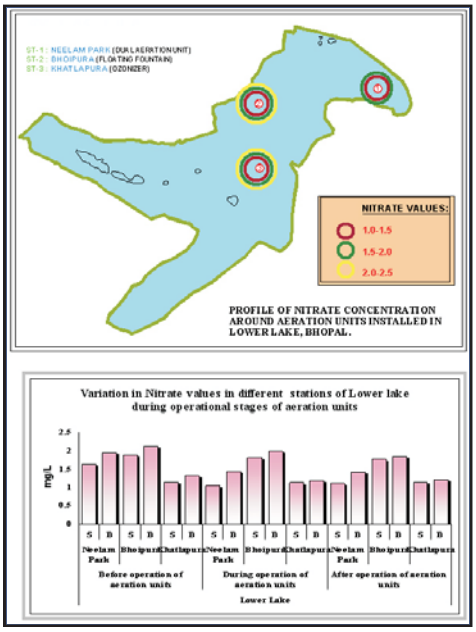

Fig.4 Variation in Nitrate values of Lower Lake

The maximum limit for nitrate is 50 mg/L (WHO, 1984). The lowest concentration of nitrate in water was recorded during functioning intervals of aeration units.

BOD ranges from 4.4-7.2 mg/L at surface layer while 10.4-14.4 mg/L at bottom layer at station 1 and 12.0-18.0 mg/L at surface layer while 16.0-24.0 mg/L at bottom layer at station 2 and 8.6-12.0 mg/L at surface layer while 16.0-28.0 mg/L at bottom layer at station 3 (**fig 2**). The minimum value of BOD was recorded at the surface layer during the functioning period and floating fountain cum ozonizer is the best aeration unit for reduction in BOD. BOD indicates the presence of microbial activities and dead organic matter on which microbes can feed. Rao *et al.*, (1994) studied the sewage pollution of lake in Ooty and found inverse relation of dissolved oxygen with BOD.

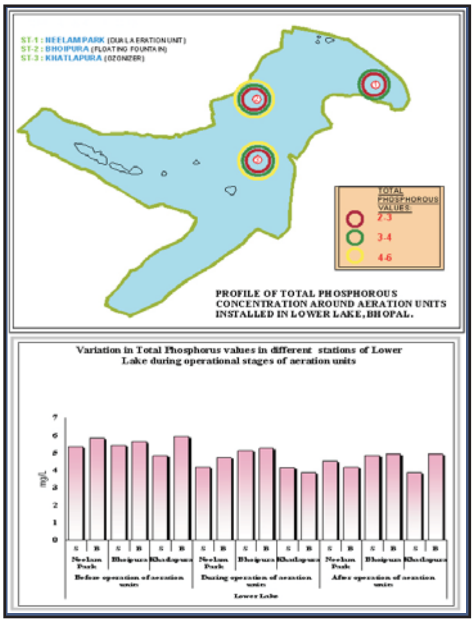

Fig.5 Variation in Phosphorus values of Lower Lake

For phosphate, USEPA (1985) suggested 0.08 mg/L for lakes as critical level for eutrophication. The amount of phosphate is comes out to be much higher than the acceptable limits. While comparing the three intervals of time a reduction was found in phosphate concentration during functional intervals. Tiwari *et al.*, (2004) studied the Shahpura lake and found that the lake water has very high phosphate content as compared to acceptable limits and thus lake is highly eutrophic.

The introduction of large quantities of nutrients, mainly nitrogen and phosphorus to lake waters can cause eutrophication problems (Michelutti *et al.*, 2002; Kouimtzis *et al.*, 1994; Fytianos *et al.*, 2002).

Total Coliform (MPN): Most probable number was found in the range from 1200-2200/100 mL at surface layer while 1800-2400/100 mL at bottom layer at station 1 and 1800-2400/100 mL at surface layer while 2200-3200/100 mL at bottom layer at station 2 and 1400-1800/100 mL at surface layer while 1800-2400/ 100 mL at bottom layer at station 3 (**fig 6**). The MPN values were found lesser when the aeration units were operational. As per result, ozonizer has better performance in reduction of MPN count but overall performance of floating fountain cum ozonizer is better. Verma *et al.*, (2006) reported that the minimum value of MPN was recorded when ozonizer is operational and dual aeration system is more effective in improving water quality of the lake. Bahl *et al.*, (2006) studied that pathogenic microbial population reduced due to artificial aeration unit.

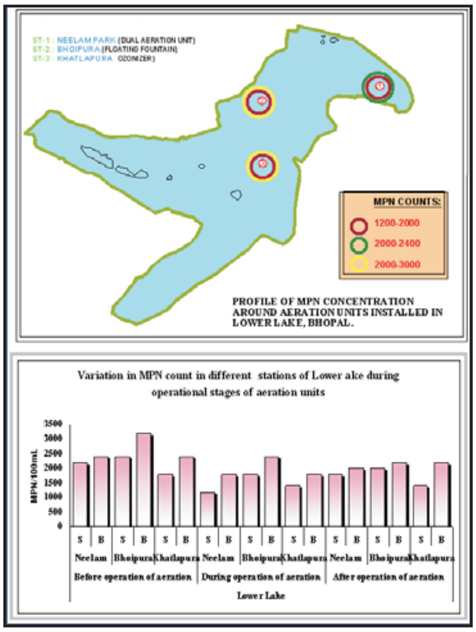

Fig.6 Variation in Coliform (MPN) counts of Lower Lake

Conclusion

Aeration to make oxygen available for microbial degradation and recycling of organic matter is one of the effective techniques in water quality management. These devices apart from beautification are effective in improvement of the water quality and biodiversity. The floating fountain cum ozonizer (dual aeration system) installed at Neelam park station in Lower lake has the best performance for reduction of BOD and COD. This aeration unit had more influence in improving the water quality by way of higher increase in dissolved oxygen concentration and deactivating active nutrients particularly of phosphorus and nitrate. Ozonizer is effective for controlling the growth of MPN count. However continuous inflow of sewage at Neelam park has affected the performance of floating fountain cum ozonizer but over all performance of this unit is significant.

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Feather touch conservationist

Ravi Sankaran
1963-2009

An administrator's hat rarely fits a field biologist well. Ravi Sankaran was trained to slog it out in the field. He was a quintessential man of the field by temperament. But he brought as much zest to board rooms of the Salim Ali Centre for Ornithology and Natural History (SACON). Classrooms or *machan*, fundraising meets or workshops, Ravi was full of curiosity, fun and laughter. A researcher, teacher, mentor and director of SACON for the last seven months of his life - a life cut short in its prime, on January 17, by a cardiac arrest. Ravi was 45.

Ravi's affinity for the field developed during a stint at the Bombay Natural History Society (BNHS) in the late 1980's. The then curator of the society J.C. Daniel took the young graduate student under his wing. The young field biologist research on the lesser florican in Western India was pioneering. It provided the basic framework for conservation of this endangered species, and of other species and habitats he studied subsequently. In 1991, the University of Bombay awarded Ravi PhD for his thesis on floricans.

(Source: *Down to Earth, Feb 16-28, 2009*)

PHYSICOCHEMICAL CHARACTERISTICS AND DIATOM DIVERSITY OF JAWAHAR SAGAR LAKE - A WETLAND OF RAJASTHAN

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Abstract

The physicochemical characteristics and diatom population of Jawahar Sagar wetland, Rajasthan were studied during the period from December, 2004 to December, 2005. During limnological investigations the range of various parameters varied as follows: water temperature (18.5°C-32°C); electrical conductance (0.183 - 0.257 mS); DO (6.4 -10.4 mg/l); free CO_2 (nil - 14 mg/l); carbonate alkalinity (nil -10 mg/l); total alkalinity (80.0 -142.0 mg/l); total hardness (64.0 -96.0 mg/l); dissolved silicates (2.45 - 7.37 mg/l); sulphate (3.06 - 10.64 mg/l); orthophosphate (0.01 - 1.28 mg/l) and nitrate–nitrogen (nil - 0.047 mg/l). The average hydrogen-ion concentration (pH) was observed to be in the alkaline range (7.4-8.8). The diatom community of Jawahar Sagar comprised of thirty five species representing 7 centric forms and 28 pennate types. Among the above *Melosira granulata, Melosira varians, Melosira herzogii, Diatoma elongatum, Fragilaria crotoneinsis* and *Synedra acus* were the most dominant species. It can be concluded that the water quality of Jawahar Sagar is quite congenial for the well being of aquatic life and exhibit potential of higher bilogical productivity.

Key words: Limnology, Jawahar Sagar Lake, Diatom

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INTRODUCTION

Wetlands are specialized ecosystems which perform important ecological functions and have many ecological, socio-economic and cultural values. One of the very important functions of the wetlands is to provide suitable habitat for the breeding of resident birds as well as a wintering ground for short and long distance migratory water birds. Wetlands are generally rich in their floristic and faunal diversity which is often much higher than that in many other ecosystems. Wetlands occur extensively throughout the world in all climatic zones and are estimated to cover about 6% of the earth surface. In India the large seasonal and spatial variability in the rainfall enhances the diversity of wetlands ranging from floodplain to coastal wetlands, natural to man made wetlands in Himalayan and arid and semi-arid regions of the country. There are more man made wetlands than natural ones in India created to cater the needs of water for drinking, domestic, agricultural and industrial uses.

Hydrology is the major determinant of all the ecological characteristics of the wetlands, both natural and man-made, which may be affected by several natural processes and anthropogenic factors. In the present paper an attempt has been made to evaluate the physicochemical characteristics and diatom diversity of a wetland namely, Jawahar Sagar Lake, Rajasthan for a period from December 2004 to December 2005.

STUDY AREA

Jawahar Sagar Dam is located at Jawahar Nagar in tehsil Taleda, district Bundi of Rajasthan. It is an important hallmark of the state of Rajasthan which plays various roles. Jawahar Sagar Wetland came in existence in the year of 1972 by constructing a dam on river Chambal as a part of the chain of dams constructed under the Chambal Valley Projects. Jawahar Sagar Dam is situated at a short distance of 29 km upstream and 26 km downstream from the Kota city and Rana Pratap Sagar Dam, Rawatbhata, respectively. It produces hydel power of 60 MWfrom the 3 units.

Apart from being a major source of producing power and electricity, Jawahar Sagar Dam releases excess water during times of severe water shortage. The excess water is used for agricultural and drinking purposes by inhabitants of Kota city and the neighboring areas.

Jawahar Sagar Lake is a wetland with adjoining forest block, breeding sites of Gavials surrounded by dry deciduous forest. Besides acting as an important habitat for local and migratory birds it supports a large population of fish and species of conservation interest like Sloth Bear, Caracal, Gavial, Crocodile and Leopard. The major floristic elements recorded include bamboo, *Anogeissus pendulla*, *Syzygium cumini*. The morphometric features of the wetland are shown in table 1.

Table1. Morphometric features of Jawahar Sagar

S. No.	Items	Jawahar Sagar
1.	Locations:	
	Latitude	24°82.792N
	Longitude	76°52.072E
2.	Catchment area (Km^2)	27,195
3.	Maximum depth (m)	11
4.	Mean depth (m)	8
5.	Length of dam (m)	393
6.	Height of dam (m)	45
7.	Climate:	
	Summer	Max. 43.6^0 C; Min. 27.7^0 C
	Winter	Max. 24.5^0 C; Min. 10.6^0 C
	Rains annually (mm)	880
8.	Nature of dam	Concrete Cemented

MATERIALS AND METHODS

For the present study one sampling site was identified near the dam. Only surface water samples were collected for physicochemical analysis using one liter capacity plastic bottles. The sampling frequency was kept monthly for a period of thirteen months from December 2004 to December 2005. In all fifteen physicochemical water quality parameters were monitored. The collected samples were immediately observed for parameters like temperature, pH, alkalinity, free CO_2 and dissolved oxygen in the field whereas other parameters like EC, hardness, dissolved silicates, sulphate, orthophosphate and nitrate nitrogen were analyzed in the laboratory. The methods given by APHA (1985), Sharma and Saini (2003) were followed for assessment of physicochemical parameters.

For the study of diatom population of the lake a known volume of water sample was filtered through plankton net of bolting silk no.25 and preserved in 4% neutral formalin. Quantitative analyses of diatom samples were carried out in the laboratory using Sedgewick Rafter Cell. The diatoms were identified with the help of Edmondson (1959) and Weber (1971).

RESULTS AND DISCUSSION

Physicochemical characteristics

The data on physicochemical features of the lake showed notable variations as presented in Table 2.

Temperature

The surface water temperature of the wetland varied between a minimum of 18.5^{0}C (January) to a maximum of 34^{0}C (June) with an annual average of 26.9^{0}C (Table-2). Based on thermal classification of lakes (Das, 1989), Jawahar Sagar lake belongs to typical lake of tropical latitude whose water temperature varies between 25^{0}C to 30^{0}C in summer and 16^{0}C to 20^{0}C in winter.

Hydrogen –ion – concentration

The pH of the investigated water body was observed to be on the alkaline side. It varied between 7.4 (January) to 8.8 (April) units with an annual average of 8.1 (Table 2). The higher value of pH during summer may be due to increased photosynthetic activity by phytoplankton and macrophytes. Similar observations were made by Satpathy *et al.* (2007). According to Boyd and Pillai (1984) photosynthetic activity leads to following reaction:

$$2HCO_3 \rightarrow Co_2 + CO_3^{2-} + H_2O$$

As plants remove carbondioxide (CO_2) for use in photosynthesis, carbonates accumulate and subsequently undergo hydrolysis as follows:

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$$

Accumulation of OH^- causes the pH to rise. According to Sarwar and Wazir (1988), the lake can be categorized as 'slightly alkaline' due to the predominance of calcium, carbonates and bicarbonates. This also coincided with the results of Pearsall (1930) and Zafar (1966) who concluded that the pH of water is dependent upon the relative quantities of calcium, carbonates and bicarbonates.

Electric conductance

The EC varied with a minimum of 0.183 (July) to a maximum of 0.257 mS (August). The conductivity was observed to be lower during summer and higher in winter and monsoon (Table 2). Higher values during the winter (December to March) and monsoon (August to November) season can be attributed to the liberation of ions from the decomposed plant matter (Sarwar and Majid, 1997). Rawson (1960) categorized water as eutrophic with electrical conductance above 0.20 mS. The onset of eutrophic nature may also attributed for the impoundment studied.

Dissolved oxygen

Dissolved oxygen is an important limnological parameter indicating level of water quality and organic production in the lake. Survival of aquatic organisms especially fishes depend upon level of dissolved oxygen in the water. During the present study, the DO of surface water varied from a minimum of 6.4 (November) to 10.4 (January) with an annual average of 8.1 mg/l (Table 2). The dissolved oxygen was higher in winter (December, 2004 to March, 2005) and monsoon (August to October 2005) whereas Lower values were seen in summer (April to July 2005).The higher values of dissolved oxygen in winter and monsoon months may be due to higher solubility of oxygen at relatively lower temperature and churning i.e. circulation and mixing of water due to surface runoff and release of water from upstream, respectively. The lower values of dissolved oxygen during summer months can be attributed to the fact that the rise in temperature leads to the warming of water and ultimately helps in an increase of mineralization of nonliving matter which demands oxygen (Kumar *et al.*, 2005) and decrease in solubility of oxygen at higher temperature. The level of oxygen concentration in aquatic ecosystem is dependent on temperature, photosynthetic activity, respiration of biotic communities and organic loading. For supporting fish life there should be at least 3.00 ppm dissolved oxygen in water (Tarzwell, 1957). Accordingly the wetland studied maintained a congenial level of dissolved oxygen.

Free CO_2

Free carbondioxide showed an irregular pattern in the lake which reflects less load of organic matter in water. It was frequently present during winter and occasionally in summer (May) and monsoon (November) months (Table 2). Gang (1994) reported similar occasional presence of free carbondioxide in some water bodies of Jodhpur, Rajasthan. It varied between nil to 14 with an annual average of 5.3 mg/l. As per Dwivedi and Pandey (2002) the main source of CO_2 is decomposition of organic matter and respiration of plants and animals. The absence of free carbondioxide in most of the summer and monsoon months may either be due to its complete utilization in photosynthetic activity or because of its inhibition by the presence of calcium carbonate in water. For fish life 1.5 to 10 mg/l of free CO_2 is most favorable while according to Swingle (1967) free CO_2 concentration of more than 15 ppm is detrimental to fish. In Jawahar Sagar Lake free CO_2 was found almost within favorable limits. Moderate range of free carbon dioxide was required for growth and occurrence of bacteria, which existed during winter months (December 2004 to March 2005).

Carbonate alkalinity

In surface waters of Jawahar Sagar Lake carbonate alkalinity was absent whenever free carbon dioxide was present. It fluctuated between nil to 10 mg/l with an annual average of 4.2 mg/l. The absence of carbonate alkalinity coincided with presence of free CO_2 and bicarbonates.

Total alkalinity

Total alkalinity ranged between 80.0 to 142.0 mg/l with an annual average of 107.0 mg/l (Table 2). Spence (1964) suggested that a water body with alkalinity values above 60.0 mg/l is nutrient rich and is good for the production fish food organisms. Sugunan (1989) observed that

Reservoirs having total alkalinity values of 40-90 mg/l were medium productive and above 90.0 mg/l were highly productive. Accordingly, the level of average total alkalinity of Jawahar Sagar also confirmed its good productive nature.

Total hardness

Total hardness of the water body varied from 64.0 to 96.0 mg/l with an annual average of 82.0 mg/l (Table 2). The average value of hardness coincided with findings of Sharma (1980). The hardness of water is mainly governed by the content of calcium and magnesium which largely combine with bicarbonates & carbonates (temporary hardness) and with sulphate, chlorides and other anions of minerals (permanent hardness). Kaur *et al.* (1996) also reported that high values of hardness are probably due to the regular addition of large quantities of sewage and detergents in the water body from the nearby residential localities. According to Spence (1964), waters with more than 60.0 ppm hardness are classified as 'nutrient rich' waters. According to this classification the Jawahar Sagar Lake can be categorized as 'nutrient rich' which also supported observations of total alkalinity values.

Calcium hardness

Calcium is essential for all the organisms as it regulates various physicochemical functions. It is required as micronutrient for algae also, through it is known to be essential nutrient for the metabolism of plants. In the present study, calcium hardness varied between 40.0 to 60.0 mg/l with an annual average of 52.0 mg/l (Table 2). Ohle (1934) categorized water body as 'calcium rich' having calcium values > 25 mg/l. He observed that the biota of the lakes in north Germany to be good when calcium ranged between 10 to 25 mg/l and very good to rich if the calcium exceeded 25 ppm. The present studies corroborate the findings of Oble (1934).

Magnesium hardness

The magnesium content ranged from 12.0 to 48.0 mg/l with an annual average of 30.0 mg/l (Table 2). Zafar (1964) recorded a direct relationship between organic matter and magnesium.

Dissolved silicates

Silica does not occur in the nature as free element. Natural water contains silicon dioxide in form of soluble silicates. The silica values varied from a minimum of 2.45 (December) to 7.37 mg/l (June) with an annual average of 4.63 mg/l (Table 2). It was lower during winter months (December 2004 to March 2005). Similar observations were made by Kumar et al. (2008) during limnological investigations of Kishore Sagar Lake, Kota, Rajasthan. The main source of silica in a water body is from the leaching of silicates by rainwater from the catchment and partly also by the death and decay of diatoms. Ahl (1966) reported that reduction in the silica content depends upon uptake of silicon by bottom vegetation, diatoms and in the reformation of the humate complex. Zafar (1967) also noted that diatom population may be influenced by winter temperature.

Sulphate

Sulphate ions usually occur in natural waters. Domestic sewage and industiral effluents may also add to sulphate content in water. Ingestion of water containing >150 mg/l of sulphate can have laxative effect. Sulphate causes a problem of scaling in industrial water supplies and problem of odour and corrosion in waste water treatment due to its reduction to H_2S. During the present study the sulphate concentration were comparatively low without showing any definite variation and ranged between a minimum of 3.06 to maximum of 10.64 mg/l with annual average of 5.05 mg/l (Table 2).

Orthophosphate

Orthophosphate values of Jawahar Sagar Lake were slightly higher thus indicating to cross the limit of organic pollution with variations between 0.01 to 1.28 mg/l (June) with an annual average of 0.74mg/l (Table 2). The phosphate content was higher during summer months (May and June). This may be due to the rapid decomposition of organic matters and evaporation in the water body due to high temperature. Similar observations were made by Chaurasia and Adoni (1985). According to Meena *et al.* (2007), value of the orthophosphate above 0.5 mg/l is indication of organic pollution. The level of orthophosphate

During the present observations confirmed the medium productive nature of the water body.

Nitrate-nitrogen

In Lake Ecosystem, the major input of nitrate is through run off but this may also be contributed from the decomposition of nitrogenous matter and its further oxidation. In the present study, NO_3-N values varied between 0.0 to 0.047 mg/l with an annual average of 0.013 mg/l (Table 2). Slightly higher concentration of nitrate-nitrogen were noted during summer months (April and July) which might be due to increased rate of decomposition of organic matter and higher rate of evaporation. Sharma *et al.* (1984) reported 0.008 mg/l nitrate-N for unpolluted water and 0.165 mg/l for polluted water of Pichhola and Rangsagar, respectively. The present observations support the unpolluted nature of the wetland under study.

Table-2. Monthly values, minima, maxima and annual average of physicochemical parameters of Jawahar Sagar Lake

S. No.	Parameter	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.
1	Temperature (°C)	22	18.5	19.5	24	28	30	31	29
2	pH (Units)	8.3	7.4	7.7	7.8	8.8	8.2	8.4	7.9
3	Ec (mS)	0.255	0.248	0.255	0.255	0.231	0.218	0.227	0.183
4	D. O. (mg/l)	6.8	10.4	8.6	8.4	7.6	7.6	7.6	7.4
5	Free CO_2 (mg/l)	12	14	12	10	0	10	0	0
6	Car. Alkalinity (mg/l)	0	0	0	0	10	0	8	10
7	Bicar. Alkalinity (mg/l)	100	86	110	128	120	80	92	70
8	Total Alkalinity (mg/l)	100	86	110	128	130	80	100	80
9	Total Hardness (mg/l)	84	92	85	86	96	92	64	88
10	Cal. Hardness (mg/l)	60	56	55	50	54	50	52	40
11	Mag. Hardness (mg/l)	24	36	30	36	42	42	12	48
12	Dissolved Silicate (mg/l)	4.24	2.45	3.7	4.71	3.77	5.29	6.3	5.51
13	Sulphate (mg/l)	3.31	4.74	3.5	3.06	5.12	6.28	4.22	4.5
14	Orthophosphate (mg/l)	0.19	0.68	0.68	0.9	0.74	1.07	1.28	0.74
15	Nitrate-Nitrogen (mg/l)	0.002	0.001	0.001	0.002	0.047	0.001	0.001	0.019
S. No.	Parameter	Aug.	Sept.	Oct.	Nov.	Mini.	Max.	Annual average	Dec.
1	Temperature (°C))	32	32	29	28	18.5	32	**26.9**	20
2	pH (Units)	8.3	8.5	7.9	8	7.4	8.8	**8.1**	7.7
3	Ec (mS)	0.257	0.24	0.236	0.246	0.183	0.257	**0.236**	0.254
4	D. O. (mg/l)	8.8	10	8	6.4	6.4	10.4	**8.1**	6.8
5	Free CO_2 (mg/l)	0	0	0	6	0	14	**5.3**	4
6	Car. Alkalinity (mg/l)	8	8	6	0	0	10	**4.2**	0
7	Bicar. Alkalinity (mg/l)	114	110	88	142	70	142	**103**	104
8	Total Alkalinity (mg/l)	122	118	94	142	80	142	**107**	104
9	Total Hardness (mg/l)	94	72	68	66	64	96	**82**	68
10	Cal. Hardness (mg/l)	56	52	54	52	40	60	**52**	58
11	Mag. Hardness (mg/l)	38	20	14	14	12	48	**30**	10
12	Dissolved Silicate (mg/l)	4.54	4.37	7.37	3.3	2.45	7.37	**4.63**	3.69
13	Sulphate (mg/l)	4.59	4.87	10.64	5.77	3.06	10.64	**5.05**	5.12
14	Orthophosphate (mg/l)	0.81	0.94	0.79	0.01	0.01	1.28	**0.74**	0.02
15	Nitrate-Nitrogen (mg/l)	0.007	0.005	0.001	0	0	0.047	**0.013**	0.001

DIATOM DIVERSITY

The diatom community of Jawahar Sagar Lake comprised of 35 species representing 6 centric forms and 28 pinnate forms. The species composition and frequency of diatom community are shown in Table 3.

The dominant diatom species recorded from the investigated site were *Synedra acus, Melosira granulata, Diatoma elongatum* and *Fragilaria crotoneinsis.* The presence of these species is indicative of the enriched status of the water-body. Lowe (1974) reported that *Melosira granulata* is favoured by sewage effluents. Vollenweider (1968) considered *Fragilaria crotoneinsis* to indicate eutrophy. Lowe (1972) considered *Synedra ulna* as eutrophic species. Palmer (1980) stated that *Synedra acus, Ghomphonema* sp., *Cyclotella michiganaina* and *Melosira varians* are found in organically rich water. According to Dickman (1975) *Cymbella, Fragilaria* sp., *Diatoma elongatum, Gomphonema olivaceum* and *Cocconies placentula* are commonly found in organically polluted waters. Richardson (1968) considered *Nitzschia* spp. to be characteristics of organically rich waters and Sommerfeld *et al.* (1975) consider it to be a typical eutorphic species. *Navicula radiosa* also inhabit bad waters. Among centric diatoms maximum (3 species) diversity was shown by genus *Melosira* whereas among pinnate forms highest diversity (4 species) was exhibited by the genus *Navicula.*

Table 3. Species compostion and relative abundance of diatoms in Jawahar Sagar Lake

A. Centric forms	Abundance	B. Pennate forms	Abundance
Cyclotella michiganaina	+	*Fragilaria crotoneinsis*	+++
Chaetoceros elmorei	+	*Fragilaria arcus*	+
Cyclotella glomerata	++	*Gomphonema olivaceum*	++
Melosira varians	+++	*Gyrosigma kutzingii*	+
Melosira granulata	+++	*Nitzschia apiculata*	+
Meslosira herzogii	+++	*Nitzschia denticulata*	+
Rhizosolenia eriensis	+	*Nitzschia paradoxa*	+
B. Pennate forms		*Navicula radiosa*	+
Amphora ovalis	+	*Navicula canalis*	+
Achnanthes lanceolata	++	*Navicula pupula*	+
Attheya zachariasi	++	*Navicula hungarica*	+
Caloneis amphisbaena	++	*Pinnularia gibba*	++
Cocconeis placentula	++	*Rhopalodia gibberula*	++
Cymbella affinis	++	*Synedra ulna*	++
Diatoma anceps	++	*Synedra acus*	+++
Diatoma elongatum	+++	*Synedra pulchella*	+
Diatoma vulgare	+	*Tabellaria fenestrata*	++
Epithemia turgida	++		
Epithemia sorex	+		

+ Present; ++ Abundant; +++ Dominant

CONCLUSION

The wetland is inhabited by mixed group of diatom species which indicated its nutritionally enriched status. Considering various physicochemical parameters it can be concluded that the present environment of the wetland is quite congenial for the well being of aquatic flora and diatoms in particular and exhibit potentiality of high aquatic productivity.

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