National Journal of Life Science, **Vol. 12(2) 2015 : 145-154** ISSN : 0972-995X (Print), 2321-7960 (Online)

MONTHLY VARIATIONS IN PHYSICO-CHEMICAL PARAMETERS OF WATER OF PROTECTED WETLAND, BAKHIRA LAKE, SANT KABIR NAGAR (UTTAR PRADESH), INDIA

A. K. PANDEY* and PRAKASH CHANDRA

ICAR-National Bureau of Fish Genetic Resources, Canal Ring Road, Lucknow (U.P.)

ABSTRACT : Colour, odour, temperature, pH, salinity, dissolved oxygen (DO) and carbon-di-oxide (DCO_2), biological oxygen demand (BOD), chemical oxygen demand (COD), conductivity, total dissolved solids (TDS), total solids (TS), dissolved solids (DS), suspended solids (SS), fixed solids (FS), volatile solids (VS), chloride, phosphate, sulphate, nitrate, total nitrogen (TN), fluoride as well as oil and grease contents of the protected Bakhira lake water were recorded during March,2013-February,2015. Temperature of lake water ranged between 20.1±0.2-34.8±0.5°C with minimum in January and maximum in June. pH of the lake water varied between 7.23±0.3-9.03±0.2, salinity 0.18-0.20 ppt with maximum value during March and July, dissolved oxygen (DO) fluctuated between 5.02±0.2-6.20±0.4 mg/l and dissolved carbon-di-oxide (DCO_2) from 11.2±0.3 to 12.9±0.4 mg/l with low values during winter months. BOD of the lake water ranged between 6.5±2.4-12.4±2.4 mg/l and COD 17.6±4.1-57.7±4.06 mg/l. Conductivity of the water ranged between 212.6±4.6-371±7.2 µS/cm. TDS of the water ranged between 152.5±3.5-326.3±3.5 mg/l with the high values during June-October, TS 160.0±0.34-312.0±0.34 mg/l with high value in August whereas DS between 144.0±0.34-266.0± 0.34 mg/l, the high values in June and August. SS in the lake water varied between 4.0±0.34-44.0±0.34 mg/l with the lowest value in May and highest in August, FS 104.0 (December)-252.0 mg/l (August) while VS 40.0 (December)-72.0 mg/l (January). Chloride content of the water ranged from 8.0±0.01 (May) to 19.0±0.01 mg/l (January), phosphate from <0.003±0.01 to 0.39±0.01 mg/l during the period with high values in May and low in January whereas sulphate from 2.90±0.09-16.2±0.09 mg/l. Nitrate content of the lake water ranged from <1.00±0.06-4.25±0.06 mg/l while total nitrogen between 3.04±0.09-10.08±0.09 mg/l. Fluoride content of the lake water ranged from 0.30±0.05 to 1.54±0.09 mg/l and oil and grease <2.5 (March) to 16.0 mg/ml (August). The present study demonstrates that the various physico-chemical parameters of the lake water are within the optimal range for fish life.

Key words : *Physico-chemical parameters, Protected water body, Bakhira lake, Sant Kabir Nagar, India.*

INTRODUCTION

Bakhira lake (also known as Badhanch Tal or Moti Jheel) is the largest natural flood plain wetland of about 44 km (water speared area of 29 sq/km) of eastern Uttar Pradesh. It is located in district Sant Kabir Nagar (26°52'-26°56'N; 83°52'-85°5'E), about 54 km from Gorakhpur on Khalilabad-Mendawal road. Bakhira lake is a perennial water body which covers an area of 1,582.35 ha, however, it inundates about 1,296.64 ha more in monsoon season thus extending the total water area up to 2,878.99 ha. Field surveys conducted during March,2013-February,2015 revealed that this lake receives water through a number of nullahs like Ghaghara nallah, Nevas (26°52'36.4"N; 083°08'46.2"E), Baraka Ghaghra nallah, Govindpur (26°52'12.7"N; 083°09'05.8"E), Baraipar nallah (26°54'40.9"N; 083°05'39.3"E), Vandah nallah, Bakhira (26055'41.9"N; 083005'16.4"E) and Van Rakshak Chauki, Dhaurapar (26°56'36.7"N; 083°06'05.0"E) but the most important being the perennial Bahwa nallah (N26°56' 15.5"; E 083°07'41.2") draining water from the vast catchment areas covering Bansi (Siddharthnagar). Bakhira lake drains into river Rapti (near Pali Block, Gorakhpur) through the Eastern Churma nullah (26°50'00.1"N; 083°13'25.4"E). Earlier the lake got connected with river Rapti for about six months but with the erection of Barrage at Pali (1998), inflow of water from Rapti has been stopped, however, outflow is regulated to protect the people inhabiting in the low-lying area and standing crops being cultivated in the catchment areas of the lake. Water from Bakhira lake is being drained out through two canals at Nevas and Dhodha for irrigation of agricultural crops. At present, water column of the lake has been reduced due to poor rain during 2013-2015. It is pertinent to remark that this lake is heavily infested with aquatic weeds like *Ipomaea aquatica*, *Eichhorhia crassipes*, *Hydrilla verticillata*, *Ceratophyllum demersum*, *Nymphoides* spp., *Elecharis* spp., *Jussieua repens*, *Vallisneria spiralis*, *Potamageton crispus*, *Naja* spp., *Spirodela polyrrhiza*, *Chara* spp., *Spirogyra* spp., *Oedogonium* spp., *Nitella* spp., *Eichornia cressipes* and *Aurundo donax* which have affected fishery of the lake. Bakhira lake has been declared as Bird Sanctuary in 1990 providing a wintering and staging ground for a number of local and migratory birds. Since thorough understanding of the physico-chemical profiles of the water is required to know the pollution threat to the water bodies, an attempt has been made to record the physico-chemical parameters of water of the protected Bakhira lake which is one of the important wetlands of eastern Uttar Pradesh (Yadava & Sugunan,1990).

MATERIAL AND METHODS

Physico-chemical parameters of water samples of the protected Bakhira lake were recorded at monthly intervals from the 4 sampling stations (S-1, S-2, S-3, S-4) (Fig.1) dur-

*Corresponding author (email : akpandey.ars@gmail.com) Received 18.10.2015 Accepted 10.11.2015

Table. 1 Physico-chemical parameters of water at the 4 sampling stations of Bakhira lake.

Station	Water temp. (°C)	pH	DO (ppm)	D CO_2 (ppm)	Salinity (ppt)	Conductivity (µs/cm)	TDS (mg/l)
March							
S-1	26.4±0.5	7.96±0.3	5.64±0.5	12.4±0.5	0.20	278.5±5.2	168.4±4.1
S-2	26.4±0.6	8.08±0.2	5.28±0.6	12.9±0.4	0.20	280.8±5.8	152.5±3.5
S-3	25.8±0.3	7.98±0.4	5.64±0.4	10.8±0.6	0.20	298.4±4.9	158.5±3.2
S-4	26.2±0.4	8.00±0.5	6.12±0.5	11.2±0.3	0.20	310.6±6.2	161.6±3.4
April							
S-1	29.6±0.5	7.64±0.2	5.42±0.3	12.4±0.6	0.18	312.4±6.3	171.6±3.8
S-2	29.8±0.8	7.23±0.3	5.58±0.5	12.8±0.5	0.20	328.5±6.8	174.3±4.1
S-3	30.2±0.6	7.42±0.4	5.02±0.2	11.9±0.3	0.19	321.4±6.2	168.6±3.9
S-4	30.4±0.4	7.72±0.2	5.16±0.4	11.8±0.4	0.18	332.8±6.7	164.5±3.4
May							
S-1	30.6±0.3	7.86±0.3	5.18±0.3	12.8±0.5	0.20	349.2±7.0	194.3±4.2
S-2	30.2±0.5	7.92±0.2	5.24±0.4	12.2±0.3	0.18	352.4±7.2	201.4±3.8
S-3	30.8±0.4	8.15±0.4	5.45±0.2	11.8±0.4	0.18	361.5±7.4	230.6±4.1
S-4	30.4±0.6	8.18±0.3	5.89±0.3	11.6±0.6	0.20	342.6±7.8	222.8±3.6
June							
S-1	34.6±0.4	7.88±0.4	5.64±0.4	12.4±0.5	0.18	354.2±6.2	228.6±3.8
S-2	34.5±0.3	8.12±0.3	5.76±0.2	12.9±0.4	0.20	371.4±6.8	234.4±4.2
S-3	34.4±0.2	7.98±0.2	5.68±0.2	11.8±0.5	0.18	358.6±7.1	238.5±4.4
S-4	34.8±0.5	8.10±0.2	6.12±0.3	11.9±0.6	0.20	356.5±6.9	227.4±4.1
July							
S-1	27.5±0.6	8.00±0.3	6.12±0.3	11.8±0.5	0.20	388.6±6.2	256.6±4.3
S-2	27.3±0.5	8.22±0.4	6.20±0.4	12.2±0.4	0.20	389.5±6.8	268.4±4.5
S-3	27.8±0.4	9.02±0.2	5.82±0.2	11.7±0.6	0.20	371.7±7.2	242.3±4.1
S-4	27.6±0.3	8.99±0.3	5.96±0.3	11.8±0.5	0.20	368.2±7.0	248.6±4.4
August							
S-1	31.2±0.5	7.64±0.4	5.42±0.5	12.4±0.5	0.18	344.4±5.2	312.4±4.8
S-2	31.2±0.4	7.23±0.3	5.58±0.3	12.8±0.3	0.20	338.5±6.1	305.3±4.5
S-3	31.1±0.6	7.42±0.2	5.02±0.2	11.9±0.4	0.19	328.7±5.8	296.7±4.2
S-4	31.1±0.5	7.72±0.5	5.16±0.3	11.8±0.6	0.18	351.4±6.2	298.4±4.5
September							
S-1	30.2±0.4	7.64±0.3	5.42±0.4	12.4±0.3	0.18	311.3±4.2	278.5±4.1
S-2	29.5±0.6	7.23±0.4	5.58±0.3	12.8±0.5	0.20	322.6± 5.1	258.6±3.8
S-3	30.2±0.7	7.42±0.3	5.32±0.2	11.9±0.4	0.19	316.3±4.8	326.3±3.5
S-4	29.4±0.8	7.72±0.2	5.16±0.3	11.8±0.3	0.18	328.2±4.9	220.4±3.2
October							
S-1	28.2±0.6	7.64±0.2	5.42±0.5	12.4±0.6	0.18	301.4±5.6	268.5±4.5
S-2	28.5±0.4	7.23±0.3	5.58±0.3	12.8±0.5	0.20	298.6±5.2	252.4±4.2
S-3	28.6±0.3	7.42±0.4	5.22±0.4	11.9±0.4	0.19	296.8±4.8	236.5±3.9
S-4	28.4±0.2	7.72±0.3	5.16±0.2	11.8±0.3	0.18	302.2±5.1	228.3±3.5
November							
S-1	27.6±0.4	7.64±0.4	5.42±0.3	12.4±0.5	0.18	222.4±4.2	198.4±3.2
S-2	27.4±0.5	7.23±0.3	5.58±0.4	12.8±0.6	0.20	232.5±4.0	202.5±3.6
S-3	28.1±0.3	7.42±0.2	5.11±0.5	11.9±0.5	0.19	214.2±4.1	192.3±3.1
S-4	27.8±0.4	7.72±0.4	5.16±0.2	11.8±0.4	0.18	228.3±4.3	205.4±3.6
December							
S-1	22.2±0.3	7.64±0.3	5.42±0.3	12.4±0.6	0.18	248.8±4.4	208.6±3.6
S-2	22.5±0.4	7.23±0.4	5.58±0.4	12.8±0.5	0.20	238.6±4.2	212.4±3.9
S-3	22.8±0.5	7.42±0.2	5.18±0.2	11.9±0.4	0.19	218.4±4.4	179.5±3.5
S-4	22.7±0.4	7.72±0.3	5.16±0.2	11.8±0.3	0.18	222.5±4.2	158.5±3.2
January							
S-1	20.3±0.2	7.86±0.2	5.18±0.3	12.8±0.6	0.20	224.4±4.2	212.4±3.4
S-2	20.8±0.3	7.92±0.3	5.24±0.2	12.2±0.5	0.18	212.6±4.6	208.6±3.2
S-3	20.2±0.4	8.15±0.4	5.45±0.4	11.8±0.4	0.18	228.5±4.8	178.5±3.0
S-4	20.1±0.2	8.18±0.2	5.89±0.3	11.6±0.3	0.20	231.2±4.8	188.3±3.2
February							
S-1	22.1±0.3	7.86±0.3	5.18±0.2	11.8±0.5	0.18	262.3±4.2	176.5±3.6
S-2	21.8±0.2	7.98±0.4	5.15±0.3	12.1±0.5	0.20	256.5±3.8	168.4±3.1
S-3	21.8±0.4	7.85±0.3	5.18±0.4	11.5±0.4	0.18	248.4±4.1	169.7±3.2
S-4	22.2±0.3	7.98±0.4	5.24±0.2	11.2±0.3	0.20	261.6±4.5	194.5±3.8

Fig.1 Bakhira lake showing the four sampling stations.

ing March,2013-February,2015 with the help of water analysis kit (Thermo Scientific,USA) and average values recorded. However, the detailed analysis of water samples collected from the two sampling sites (S-1, S-4) of the lake (selected based on pollution status) were also done at CSIR-Indian Institute of Toxicology Research (IITR), Lucknow following the methods of APHA (2012).

RESULTS AND DISCUSSION

The average values of physico-chemical parameters of water samples collected from the 4 sampling stations of Bakhira lake during March,2013-February,2015 have been summarized in Table.1. However, the detailed analysis of water samples collected from the two sampling sites (S-1, S-4) of the lake were done at CSIR-Indian Institute of Toxicology Research, Lucknow and the results are summarized in Table.2.

Colour : In the present study, the colour (visual observation) of Bakhira lake at the four different sampling sites varied from light brown (rainy season) to brownish (winter and summer).

Odour : The odour of water represents dissolved impurities which are often organic in nature. In the present study during March,2013-February,2015, the odour of Bakhira lake at sampling site S-1 and S-2 was found to be slightly unpleasant whereas at sampling sites S-3 and S-4, it was odourless.

Temperature : It is one of the most important physical factors which regulates natural processes within the environment. The greatest source being solar radiation. Most of the solar radiation is absorbed directly by the water. Water temperature of water of Bakhira lake at the four different sites ranged between 20.1±0.2-34.8±0.5°C during the period. The lowest temperature was recorded in January and highest in June (Fig. 2).

pH : pH of natural water is governed to a large extent by the interaction of H^+ ions arising from the dissociation of H_2CO_3 and from OH^- ions produced during the hydrolysis of bicarbonate. pH of Bakhira lake water showed alkaline condition during the period and ranged between 7.23±0.3-9.02±0.2 at the four sampling stations. However, water samples of the two sites (S-1, S-3) depicted pH ranging from 7.12±0.24-9.43±0.24. Low pH was recorded in September whereas high pH in April and July (Fig.3) (Table.2).

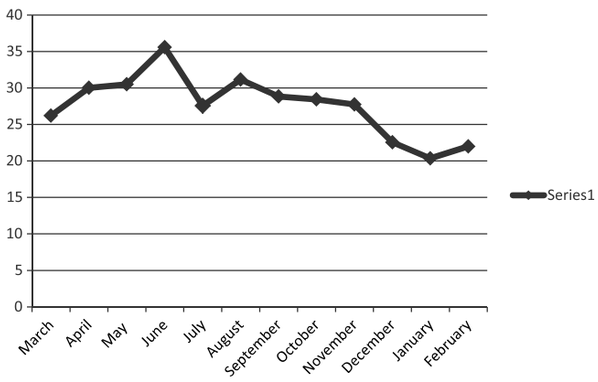

Fig.2 Average monthly variations in water temperature (°C) of Bakhira lake.

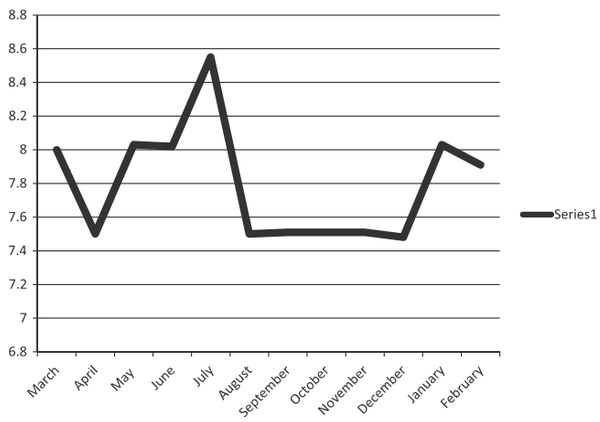

Fig.3 Average monthly fluctuations in water pH of Bakhira lake.

Dissolved oxygen : It is one of the most important parameters in water quality assessment and reflects the physical and biological processes occurring in the medium. In natural water, dissolved oxygen (DO) is the most important chemical factor as regulator of metabolic processes in plant and animal community and as indicator of water condition. Non-polluted surface water is normally saturated with dissolved oxygen. The dissolved oxygen at the four sampling stations fluctuated between 5.02±0.2-6.20±0.4 mg/l during the period. High concentration of dissolved oxygen was observed during March, June and July (Fig.4) which may be due to enhanced photosynthetic activities.

Dissolved carbon di-oxide : The dissolved carbon di-oxide (DCO_2) in the water of Bakhira lake at the four sampling stations fluctuated from 10.8±0.6 (March) to12.9±0.4 mg/l (June) during the period (Fig.5).

Salinity : Salinity of Bakhira lake water at the four sampling stations ranged from 0.18-0.20 during the period, the average highest value was recorded in March and July (Fig.6).

Conductivity : It is a measure of resistance of a solution to electrical flow. The electrical conductivity has always been used by limnologist as a valuable method to estimate the degree of salt contents and total dissolved solid in water. Conductivity is an index of the amount of soluble salts present in water which ranged between 212.6±4.6-371.7±6.8 µS/cm at the four sampling stations of Bakhira lake (Fig.7). However, water samples of the two sites (S-1, S-4) analyzed at CSIR-IITR, Lucknow depicted conductivity in the range of 212.0-350.6 S/cm. Generally, the electrical conductivity of Bakhira lake water is low during winter (November-January) but high in summer (April-June) and rainy season (July-October). In general, water of Bakhira lake had fairly low contents of dissolved salts at all the sampling stations suggesting less metallic load in the water.

Biological oxygen demand (BOD) : It is the measure of oxygen required by micro-organisms for biological oxidation of organic matter. The BOD test is useful in pollution control management and evaluation of self-purification capacities of river which serves as a measure to assess the quality of wastes that can be safely assimilated. Biological oxygen demand of Bakhira lake at the two different sites (S-1, S-4) ranged between 6.5±2.4-12.4± 2.4 mg/l during the period (Table.2).

Chemical oxygen demand (COD) : It is the measure of oxygen required for chemical oxidation of organic matter present in the water. Chemical oxygen demand of different sampling sites of Bakhira lake during the period were ranged between 17.6±4.1-57.7±.4.1 mg/l (Table.2).

Total dissolved solids : Total dissolved solids (TDS) in the water of Bakhira lake at the four sampling stations ranged from 152.5±3.5 (March) to 326.3±3.5 mg/l (September). In general, average high values of TDS were observed during July-October (Table.1 & Fig.8).

Total solids : Total solids (TS) in the water of Bakhira lake collected at the two different sites (S-1, S-4) showed the value ranging between 160.0±0.34-312.0±0.34 mg/l with the high value in August.

Dissolved solids : Dissolved solids (DS) in the water of Bakhira lake collected at the two different sites (S-1, S-4) showed the value ranging between 144.0±0.34-266.0±0.34 mg/l., the high values in June and August

Suspended solids : Suspended solids (SS) in the water of Bakhira lake collected at the two different sites (S-1, S-4) depicted the value ranging between 4.0±0.34-46.0±0.34 mg/l, the highest value being in the month of August.

Fixed solids : Fixed solids (FS) in the water of Bakhira lake collected at the two different sites (S-1, S-4) depicted the value ranging between 104.0-252.0 mg/l, the higher values observed during May-September..

Volatile solids : Volatile solids (VS) in the water of Bakhira lake collected at the two different sites (S-1, S-4) depicted the value ranging between 40.0-72.0 mg/l, the lowest value in December and highest in January.

Chloride : It occurs naturally in all types of water, however, its concentration remains quite low and is generally less than that of bicarbonates. The most important source of chloride in

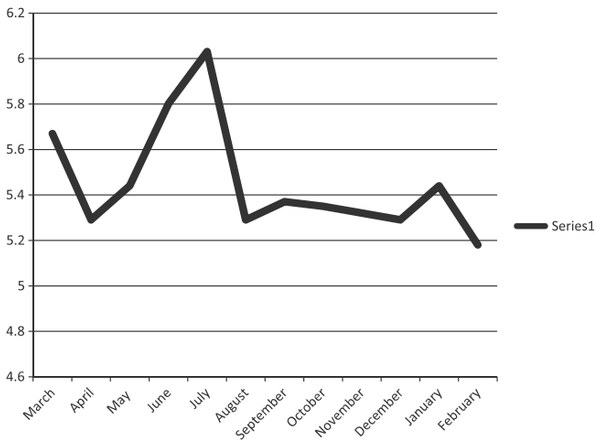

Fig.4 Average monthly variations in dissolved oxygen of Bakhira lake water.

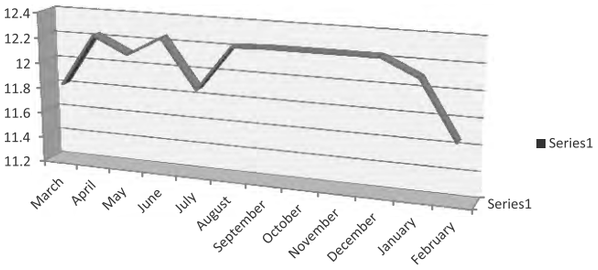

Fig.5 Average monthly fluctuations in dissolved carbon di-oxide of Bakhira lake water.

water is the discharge of domestic sewage. Chloride content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged from 8.0±0.01-19.0±0.01 mg/l, the maximum value was recorded during January.

Phosphate : Phosphate in surface water is normally derived from the leaching of minerals from the rocks or soil, decomposing organic matter and drainage from agricultural areas, especially those which have been fertilized, municipal waste water treatment plants and certain industrial wastes. Phosphate content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged from <0.003±0.01 (January) to 0.39± 0.01 mg/l (May) during the period under report.

Sulphate : It is a naturally-occurring anion in all kinds of natural water. It is found in particularly higher concentration due to accumulation of soluble salt in soil and shallow aquifers. Sulphate content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged between 2.36±0.09 (May) - 16.20±0.09 mg/l (November) during the period.

Nitrate : Nitrate represents the highest oxidized form of nitrogen. It is the important nutrient in freshwater bodies for the growth of phytoplankton. Most of the surface water are, therefore, deficient in nitrate. Nitrate (as NO_3^{-1}) content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged from <1.00±0.06 to 4.25±0.06 mg/l during the period

Total nitrogen : Total nitrogen content of the water of Bakhira lake at the two sampling stations (S-1, S-4) varied from 3.36±0.09-10.08±0.09 mg/l during the period.

Fluoride : Fluoride content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged from 0.30±0.05 (March) to1.54±0.09 mg/l (April) during the period.

Oil and grease : Oil and grease content of the water of Bakhira lake at the two sampling stations (S-1, S-4) ranged from <2.54.0 (March) to 16.0 mg/ml (August) during the period.

Generally, lake functions are directly related to their physical, chemical and biological integrity (Wetzel,1975; Lal & Pandey,1999 and Ramachandra,2002). Hence, congenial (optimal) physico-chemical parameters should be maintained in the water bodies for sustainable fisheries (Wetzel, 1975; Lal & Pandey,1999 and Ramachandra,2002). Limno-logical studies and variations in physico-chemical characteristics of the freshwater lakes and rivers of the country have been recorded during the past (Swarup & Singh,1976; Verma *et al.*,1980; Kanungo & Naik,1987; Jain *et al.*,1996; Gopal & Zutshi,1998; Pandey *et al.*,1999; Joshi *et al.*,2009; Mishra *et al.*,2012 and Sharma & Soni,2013). Domestic sewage, fertilizer factory and industrial effluents pollute majority of freshwater resources in India (Ghosh *et al.*,1974; Chari,1985; Jain *et al.*,1995; Lal & Pandey,1994,1995,1999; Basheer *et al.*, 1996; Gopal & Zutshi,1998; Moundiotiya *et al.*,2004; Singh & Singh,2007; Saksena *et al.*,2008; Shiddamallaya & Pratima,2008; Gupta *et al.*,2011; Jayalakshmi *et al.*,2011; Saxena & Saksena,2012; Prajapati & Dwivedi,2013; Yadav *et al.*,2013; Barki & Singa,2014; Katakwar,2014; Saini *et al.*, 2015 and Talwar *et al.*,2015). Such studies of Ramgarh lake, located 56 km away from Bakhira lake has also been made in the past (Sahai & Sinha,1969; Sinha,1969; Srivastava *et al.*, 2006,2007; Singh & Singh,2009; Singh *et al.*,2011,2013, 2014; Singh & Upadhyay,2012; Tiwari,2013; Barnwal *et al.*, 2014,2015 and Bharati & Pandey,2015). Temperature of Bakhira lake water at the four different sites ranged between 20.1±0.2-34.8±0.5°C during the period, with minimum in January and maximum in June. Similar variations in water temperature have also been recorded in other water bodies (Ghosh *et al.*,1974; Basheer *et al.*,1996; Srivastava *et al.*, 2003; Chaurasia & Pandey,2007; Singh & Singh,2009; Srivastava *et al.*,2009; Mishra *et al.*,2011; Biswas *et al.*,2012; Verma *et al.*, 2013; Choudhary *et al.*,2014 and Dixit *et al.*, 2015), however, water temperature was generally low in the water bodies located in subtropical Himalyan region (Joshi & Singh,2001; Agarwal & Raiwar,2010 and Bisht *et al.*,2013). pH of the water collected from the 4 sampling stations of Bakhira lake ranged between 7.23±0.3-9.02±0.2 which are within the permissible limit of tolerance of fish (Ghosh *et*

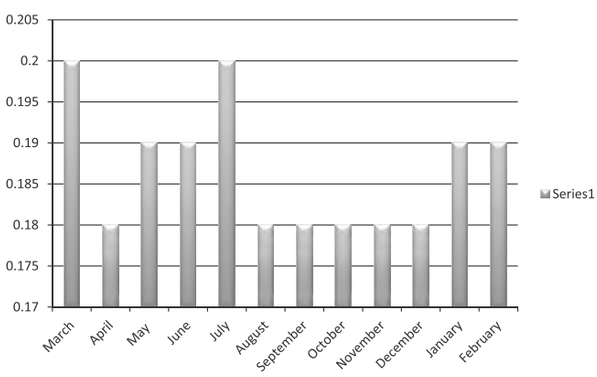

Fig.6 Average monthly variations in salinity of water of Bakhira lake.

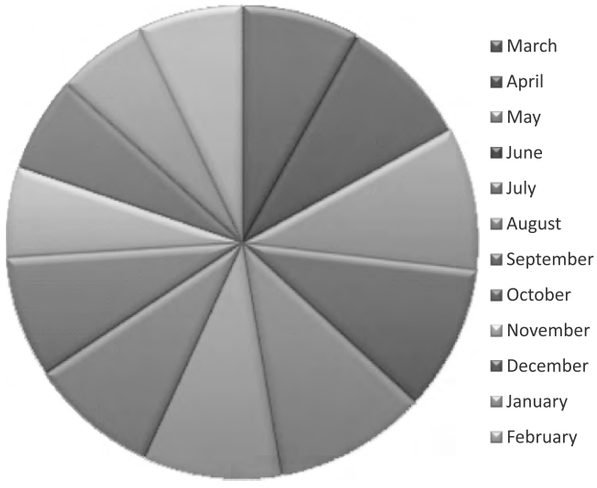

Fig.7 Average monthly fluctuations in conductivity of Bakhira lake water.

Table. 2 Physico-chemical parameters of water at two sampling stations of Bakhira lake.

Month	pH	BOD	COD (mg/l)	Total solids	Dissolved solids	Suspended solids	Fixed solids	Volatile solids	Chloride	Phosphate as P	Sulphate as SO_4^{-2}	Nitrate as NO_3 -	Total nitrogen	Fluoride	Oil & grease	Conductivity (µS/cm)
								April								
S-1	9.43±0.236	8.0±2.4	22.0±4.06	186.0±0.34	168.0±0.34	18.0±0.34	130.0	56.0	11.0±0.01	0.36±0.01	6.42±0.09	4.15±0.06	10.08±0.09	1.17±0.05	12.0	277.5
S-4	8.34±0.236	9.0±2.4	30.8±4.06	188.0±0.34	152.0±0.34	36.0±0.34	142.0	46.0	14.0±0.01	0.33±0.01	5.42±0.09	2.31±0.06	7.94±0.09	1.54±0.05	14.0	307.8
								May								
S-1	9.12±0.236	6.5±2.4	17.6±4.06	220.0±0.34	198.0±0.34	22.0±0.34	170.0	50.0	8.0±0.01	0.39±0.01	2.36±0.09	2.8±0.06	6.72±0.09	1.18±0.05	8.0	312.8
S-4	9.17±0.236	6.6±2.4	22.0±4.06	236.0±0.34	232.0±0.34	4.0±0.34	182.0	54.0	9.0±0.01	0.35±0.01	2.96±0.09	1.91±0.06	3.36±0.09	1.02±0.05	13.0	328.2
								June								
S-1	7.53±0.236	8.4±2.4	24.48±4.06	252.0±0.34	230.0±0.34	22.0±0.34	198.0	54.0	9.0±0.01	0.33±0.01	3.36±0.09	2.81±0.06	8.4±0.09	0.94±0.05	8.0	350.6
S-4	7.57±0.236	7.6±2.4	20.4±4.06	242.0±0.34	224.0±0.34	18.0±0.34	196.0	46.0	10.0±0.01	0.29±0.01	3.96±0.09	3.4±0.06	10.08±0.09	0.98±0.05	6.0	337.4
								August								
S-1	7.48±0.236	7.0±2.4	27.44±4.06	312.0±0.34	266.0±0.34	46.0±0.34	252.0	60.0	9.0±0.01	0.027±0.01	3.92±0.09	2.43±0.06	7.28±0.09	0.83±0.05	16.0	344.5
S-4	7.53±0.236	7.5±2.4	31.36±4.06	292.0±0.34	248.0±0.34	44.0±0.34	240.0	52.0	11.0±0.011	0.30±0.01	4.46±0.09	2.2±0.06	8.4±0.09	0.85±0.05	16.0	332.3
								September								
S-1	7.12±0.236	8.0±2.4	28.56±±4.06	282.0±0.34	256.0±0.34	26.0±0.34	236.0	46.0	16.0±0.011	0.026±0.011	1.22±0.09	2.13±0.56	8.96±0.09	0.53±0.05	6.0	322.8
S-4	7.2±0.236	9.4±2.4	32.96±4.06	212.0±0.34	184.0±0.34	28.0±0.34	162.0	50.0	16.0±0.011	0.016±0.01	3.82±0.09	1.5±0.06	7.84±0.09	0.56±0.05	5.0	310.5
								November								
S-1	7.57±0.236	11.2±2.4	38.8±4.06	176.0±0.34	144.0±0.34	32.0±0.34	120.0	56.0	14.0±0.011	0.27±0.01	16.20±0.09	3.02±0.6	9.52±0.09	0.78±0.05	8.0	212.2
S-4	7.37±0.236	12.4±2.43	1.04±4.06	190.0±0.34	164.0±0.34	26.0±0.34	142.0	48.0	18.0±0.011	0.28±0.01	15.60±0.09	1.95±0.06	8.4±0.09	0.67±0.05	8.0	222.6
								December								
S-1	7.52±0.236	8.8±2.4	29.8±4.06	202.0±0.34	184.0±0.34	18.0±0.34	162.0	40.0	14.0±0.011	0.34±0.01	14.40±0.09	1.46±0.06	6.72±0.09	0.67±0.05	6.0	245.7
S-4	7.46±0.236	9.2±2.4	37.3±4.06	160.0±0.34	144.0±0.34	16.0±0.34	104.0	56.0	9.0±0.011	0.32±0.01	12.20±0.09	1.47±0.06	8.4±0.09	0.78±0.05	8.0	217.8
								January								
S-1	7.48±0.236	8.5±2.4	23.9±4.06	232.0±0.345	210.0±0.345	22.0±0.345	160.0	72.0	19.0±0.011	0.06±0.012	3.00±0.086	4.25±0.06	9.52±0.09	0.62±0.05	12.0	228.2
S-4	7.42±0.236	7.5±2.4	20.5±4.06	168.0±0.345	150.0±0.345	18.0±0.345	120.0	48.0	16.0±0.011	<0.003±0.012	2.90±0.09	<1.0±0.06	7.28±0.09	0.39±0.05	6.5	232.6
								March								
S-1	7.71±0.236	11.2±2.4	57.7±4.06	194.0±0.345	168.0±0.345	26..0±0.345	138.0	56.0	13.0±0.011	0.034±0.012	4.50±0.09	<1.0±0.06	5.04±0.09	0.52±0.05	<2.5	258.4
S-4	7.48±0.236	12.4±2.4	54.4±4.06	186.0±0.345	164.0±0.345	22.0±0.345	126.0	60.0	14.0±0.011	0.057±0.012	3.10±0.09	2.06±0.06	6.72.09	0.30±0.05	8.5	238.6

al.,1974). Srivastava *et al.* (2007) and Singh & Singh (2009) recorded alkaline pH (8.0-8.6) of Ramgarh lake while Gupta and Pandey (2014) found alkaline pH (8.0-8.5) of water of Surajkund pond located in Gorakhpur (Uttar Pradesh). Ghosh *et al.* (1974) and Mishra *et al.* (2011) also recorded alkaline pH ranging from 7.30 to 8.90 in a sewage-fed pond near Khardah (Barrackpore) and Rani lake (Rewa), respectively. Biological oxygen demand (BOD) and chemical oxygen demand (COD) of Bakhira lake were 6.5±2.4-12.4±2.4 mg/l and 17.6±4.1-57.7±4.1 mg/l, respectively suggesting low pollution load. BOD and COD of Rani lake (Rewa) water varied between 8.14-17.47 and 31.89-54.74 ppm, respectively. Chaurasia and Pandey (2007) found high BOD in water ponds of Ayodhya-Faizabad while Srivastava *et al.* (2007), Singh *et al.* (2013), Barnwal *et al.* (2014,2015) and Pandey (2015) also observed high values of BOD and COD of water of Ramgarh lake (eastern Uttar Pradesh). Further, Manna *et al.* (2003) and Biswas *et al.* (2012) found high BOD in man-made lotic fish culture ponds located in Kalyani (West Bengal) and Budha Talab at Chhattisgarh, respectively. BOD and COD are generally low for unpolluted water bodies (Rajshekhar *et al.*,2007; Agarwal & Raiwar,2010; Shinde *et al.*,2010; Parte,2012 and Saini *et al.*,2015). Conductivity of Bakhira lake water ranged between 212.6±4.6-371±7.2 µS/cm suggesting less metal load in the water. However, conductivity of Ramgarh lake water was comparatively high than those recorded for Bakhira lake (Pandey,2015).

Generally, total dissolved solids, total solids, dissolved solids, suspended solids and volatile solids contents of Bakhira lake water were low and exhibited monthly/seasonal variations with low values during winter months. Though Shinde *et al.* (2010), Parte (2012) and Gupta & Pandey (2014) have recorded high total solids in water of the several water bodies, Agarwal and Raiwar (2010) reported low values (102 ±0-250±2 mg/l) in water of Tehri dam reservoir (Garhwal-Himalaya). Chloride content of Bakhira lake water ranged between 8.0±0.01-19.0±0.01 mg/l with high values in September, November and January. The values of chloride content observed in this lake were lower than those reported in water of Surajkund pond (Gupta & Pandey,2014) and Ramgrah lake (Pandey,2015). Ghosh *et al.* (1974) recorded higher values of chloride in the sewage-fed pond near Khardah (West Bengal). Seasonal variations in chloride content of other water bodies have also been recorded (Gonzalves & Joshi,1946; Rajshekhar *et al.*,2007; Shinde *et al.*,2010; Parte,2012 and Gupta & Pandey,2014) and high chloride content depicts pollution load, suggesting eutrophicaton of the water bodies (Ghosh *et al.*,1974 and Barnwal *et al.*,2014, 2015). Phosphate content of water of Bakhira lake is low as reported for Budha Talab, Chhattisgarh (Biswas *et al.*,2012), however, the values are much lower as reported for sewage-fed ponds (Ghosh *et al.*,1974 and Basheer *et al.*,1996). Sulphate content of Bakhira lake water ranged between 2.36± 0.09 (May)-16.20±0.09 mg/l (November) which are comparatively lower than those observed for Ramgarh lake (Pandey, 2015). Nitrate and total nitrogen contents of Bakhira lake water were generally comparable to the values recorded for Ramgarh lake (Pandey,2015). High values of nitrate and total nitrogen depict high productivity of the lake (Swarup & Singh,1976; Ramachandra,2002; Pathak *et al.*,2004 and Parte,2012). Similar observations have also been recorded from the sewage-fed pond near Khardah (Barrackpore) (Ghosh *et al.*,1974). The main source of nitrate is domestic sewage (Ramachandra,2002 and Singh & Singh,2009) which are getting discharged directly into Bakhira lake from the nearby villages and Bahwa nallah draining water from the vast catchment areas of Bansi (Siddharthnagar).

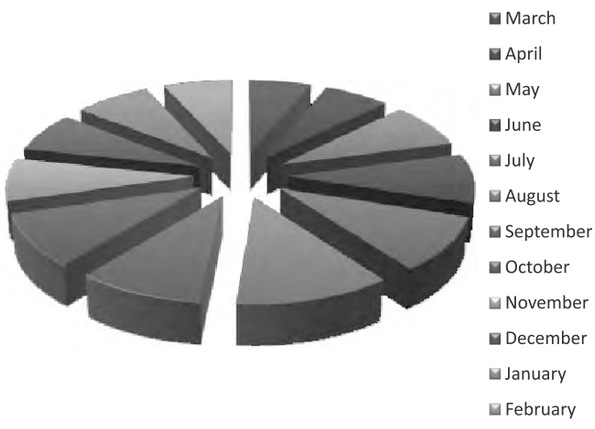

Fig.8 Average month-wise fluctuation in total dissolved solids (TDS) of Bakhira lake.

Fluoride in highly toxic to fish and other aquatic organisms (Neuhold & Sigler,1962; Hamilton & Haines,1995; Camargo,2003; Cao *et al.*,2013; Pearcy *et al.*,2015 and Singh & Tripathi,2015), however, water quality variables like hardness, chloride and alkalinity do substantially modify its toxicity (Neuhold & Sigler,1962; Hamilton & Haines,1995; Camargo,2003 and Pearcy *et al.*,2015). Its content in the water of Bakhira lake ranged from 0.30±0.05 (March) to 1.54± 0.09 mg/l (April) which are comparable to those recorded for Ramgarh lake (Pandey,2015). Pradhan *et al.* (2014) also found similar fluoride contents in different water bodies of Jaipur. It has been suggested that fluoride concentration as low as 0.5 mg/l can adversely affects fish and aquatic invertebrates and the safe levels below this is recommended in order to protect freshwater organisms from fluoride pollution (Camargo,2003). Fluoride content in drinking water between 0.8-1.2 mg/l is recommended for prevention of tooth decay and strengthening of skeleton and above 1.5 mg/l causes fluorosis leading to pitting of tooth enamel and deposition in bones (Fawell *et al.*,2006 and WHO,2012). Oil and grease content of the water of Bakhira lake fluctuated between <2.54.0 (March)-16.0 mg/ml (August), the values being lower in September, November and December. Similar trend in variations in oil and grease values have also been recorded in water of Ramgarh lake (Pandey,2015). The high values during monsoon season may probably be due to the washing of the content through rain water. Oil and grease contains many low and high molecular weight hydrocarbons that are toxic because fish are particularly susceptible to absorbing these compounds due to high oil and fat contents (Stenstrom *et al.*, 1986). These compounds get dissolved easily into their tis-

sues through contact with the skin and gills. Effects of these compound on fish larvae range from mortality to abnormal development and deformities. Since the effects of oil can last for many years, these can have devastating effect on local fish population (Irwin,1997; Inyang *et al.*,2002; FAO,2012 and Islam *et al.*,2013). Effluents containing oil and grease should be treated properly before releasing into the water body (Yu *et al.*,2013). The present study demonstrates that the various physico-chemical parameters of water of the protected Bakhira lake are within the optimal range of fish life.

ACKNOWLEDGMENTS

We are grateful to the Director, ICAR-National Bureau of Fish Genetic Resources, Lucknow for extending the facilities of carry out the work. Financial support provided by the Uttar Pradesh State Fish Biodiversity Board (UPSBB), Lucknow in thankfully acknowledged. Help extended by the staff of Bakhira Bird Sanctuary (Government of Uttar Pradesh), Jaswal (Sant Kabir Nagar) is appreciated.

REFERENCES

Agarwal, A. K. and Raiwar, G. (2010). Physico-chemical and microbiological study of Tehri dam reservoir, Garhwal, Himalaya. *India. J. Amer. Sci.*, **6(6)** : 65-71.

APHA (2012) *Standard Methods for the Examination of Water and Wastewater : 16th edn.* American Public Health Association, Washington, D. C.

Barki, D. N. and Singa, P. K. (2014). Water quality assessment in terms of water quality index. *Global J. Biol. Agric. Hlth. Sci.*, **3(3)** : 69-71.

Barnwal, P.; Tripathi, M. and Singhal, S. K. (2014). Water quality analysis of lake - a case study. In : *Energy Technology and Ecological Concerns : A Contemporary Approach* (ed. Mishra, G. C.). Gyan Bandhu Pub., New Delhi, pp. 76-81.

Barnwal, P.; Mishra, S. and Singhal, S. K. (2015). Risk assessment and analysis of water quality of Ramgarh lake, India. *J. Integr. Sci. Technol.*, **3** : 22-27.

Basheer, V. S.; Asif, A. and Aftab, A. (1996). Seasonal variations in the primary productivity of a pond receiving sewage effluents. *J. Inland Fish. Soc. India*, **28(1)** : 76-82.

Bharati, A. K. and Pandey, G. (2015). Assessment of water quality in Ramgrah Tal at Gorakhpur, India. *Intern. J. Sci. Res. Develop.*, **3** : 1040-1043.

Bisht, A. S.; Ali, G,; Rawat, D. S. and Pandey, N. N. (2013). Physico-chemical behaviour of three different water bodies of sub-tropical Himalayan region of India. *J. Ecol. Natur. Environ.*, **5(12)** : 387-395.

Biswas, P.; Vardia, H. K.; Ghosh, A. and Biswas, P. (2012). Water quality of Budha Talab, Chhattisgarh. *J. Inland Fish. Soc. India*, **44** : 94-97.

Camargo, J. A. (2003). Fluoride toxicity to aquatic organisms : a review. *Chemosphere*, **50** : 251-261.

Cao, J.; Chen, J.; Wang, J.; Wu, X.; Li. Y. and Xie, L. (2013). Tissue distributions of fluoride and its toxicity in the gills of a freshwater teleost, *Cyprinus carpio*. *Aquat. Toxicol.*, **130** : 68-76.

Chari, M. S. (1985). Aquatic pollution and its effect on the fauna and flora of a freshwater pond at Aligarh, India. *Geobios*, **1** : 49-65.

Chaurasia, M. and Pandey, G. C. (2007). Study of physico-chemical characteristics of some water ponds of Ayodhya-Faizabad. *Indian J. Environ. Protec.*, **27** : 1019-1023.

Choudhary, P.; Dhakad, N. K. and Jain, R. (2014). Studies on the physico-chemical parameters of Bilawali tank, Indore (M.P.) India. *IOSR J. Environ. Sci. Tech. Food Tech.*, **8(10)** : 37-40.

Dixit, A. K.; Pandey, S. K.; Mehta, R.; Ahmad, N.; Gunjan and Pandey, J. (2015). Study of physico-chemical characteristics of different pond water of Bilaspur district, Chhattisgarh, India. *Environ. Skept. Crit.*, **4(3)** : 89-95.

FAO (2012). *Environmental Emergencies Affecting Fisheries*. 1-3. Fisheries & Aquaculture Department, FAO, Rome.

Fawell, J.; Bailey, K.; Chilton, J.; Dahi, E.; Fewtrell, L. and Mangara, Y. (2006). *Fluoride in Drinking Water*. WHO. IWA Pub., London, p. 134.

Ghosh, A.; Rao, L. H. and Banerjee, S. C. (1974). Studies on the hydro-biological conditions of a sewage-fed pond with a note on their role ion fish culture. *J. Inland Fish. Soc. India*, **6** : 51-61.

Gonzalves, E. A. and Joshi, D. B. (1946). Freshwater algae near Bombay. The seasonal succession of the algae in a tank of Bandra. *J. Bombay Nat. Hist. Soc.*, **46** : 154-178.

Gopal, B. and Zutshi, D. P. (1998). Fifty years of hydro-biological research in India. *Hydrobiologia*, **384** : 267-290.

Gupta, A. K. and Pandey, G. (2014). Assessment of physico-chemical water quality parameters of Surajkund pond in Gorakhpur. *Intern. J. Eng. Sci. Res.*, **3(1)** : 23-25.

Gupta, P.; Agarwal, S. and Gupta, I. (2011). Assessment of physico-chemical parameters of various lakes of Jaipur, Rajasthan, India. *Indian J. Fund. Appl. Life Sci.*, **1(3)** : 246-248.

Hamilton, S. J. and Haines, T. A. (1995). Influence of fluoride on aluminum toxicity to Atlantic salmon (*Salmo salar*). *Can. J. Fish. Aquat. Sci.*, **52** : 2432-2444,

Inyang, L. E. D.; Essien, G. E.; Moses, B. S.; Gundlach, E. R.; Gilfillan, E. S. and Page, D. S. (2002). Analysis of potential effects of the Idoho-QIT oil spill on river-estuarine fisheries in Nigeria. In : *Proceedings of the 25th Arctic and Marine Oil Spill Program (AMOP). Technical Seminar*. Environment Canada, Calgary, pp. 941-957.

Irwin, R. J. (1997). *Environmental Contaminants Encyclopedia : Oil and Grease Entry.* National Park Service, Water Resources Division, Fort Collins, Colorado.

Islam, M. S.; Islam, M. S.; Hossain, M. M. M.; Sikder, M. N. A.; Morshed, M. M. and Hossain, M. B. (2013). Acute toxicity of the mixtures of grease and engine wash oil on fish, *Pangasius sutchi*, under laboratory conditions. *Intern. J. Life Sci. Bt Pharm. Res.*, **2(1)** : 306-317.

Jain, S.; Gupta, S. K. and Salman, S. (1995). Seasonal changes in heavy metals in water and sediment of a eutropic lake. *Indian J. Environ. Protec.*, **16** : 197-202.

Jain, S. M.; Sharma, M. and Thakur, R. (1996). Seasonal variations in physico-chemical parameters of Haloli reservoir of Vidisha district. *J. Ecobiol.*, **8** : 181-188.

Jayalakshmi, V.; Lakshmi, N. and Charya, M. A. (2011). Assessment of physico-chemical parameters of water and waste waters in and around Vijayawada. *Intl. J. Res. Pharm. Biomed. Sci.*, **2** : 1041-1046.

Joshi, D. M.; Kumar, A. and Agrawal, N. (2009). Studies on physico-chemical parameters to assess the water quality of river Ganga for drinking purpose in Hardwar district. *Rasayan J. Chem.*, **2(1)** : 195-203.

Joshi, P. C. and Singh, A. (2001). Analysis of certain physico-chemical parameters and planktons of freshwater hill stream at Nanda Devi Biosphere Reserve. *Uttar Pradesh J. Zool.*, **21** : 177-179.

Kanungo, V. K. and Naik, M. L. (1987). Physico-chemical and biological characteristics of nineteen ponds of Raipur. In : *Perspective in Hydro-biology* (eds. Rao, K. S. and Shrivastava, S.), Vikram University, Ujjain, pp. 157-160.

Katakwar, M. (2014). Water quality and pollution status of Narmada river's Anjan tributary in Madhya Pradesh. *Intern. J. Curr. Res. Acad. Rev.*, **2(11)** : 93-98

Lal, S. and Pandey, A. K. (1994). Histopathological alterations in gill, kidney, liver and intestine of *Puntius sophore* (Hamilton) exposed to the fertilizer factory effluents. In : *Nat. Symposium on Pests of Agricultural Importance and Their Management* (eds. Dwivedi, B. K.; Pandey, G.; Pandey, A. K. and Chaubey, A. K.). Bioved Research Society, Allahabad, p. 10.

Lal, S. and Pandey, A. K. (1995). Effects of fertilizer factory effluents on the fishery of Chilwa lake. In : *Eighty-Second Indian Science Congress*. Jadhavpur University, Calcutta, pp. 71-72.

Lal, S. and Pandey, A. K. (1999). Ecotoxicological problems due to pollution in Indian freshwater bodies with particular reference to the fertilizer factory effluents in Chilwa lake, Gorakhpur. In : *Environmental Toxicology* (eds. Dwivedi, B. K. and Pandey, G.). Bioved Research Society, Allahabad, pp. 212-144.

Manna, N. K.; Banerjee, S. and Bhowmik, M. L. (2003). Hydrobiology of wastewater-fed man-made lotic fish culture ponds in relation to pollution : physico-chemical characteristics. *Philippine J. Sci.*, **132** : 47-58.

Mishra, R. M.; Prajapati, R. K.; Dwivedi, V. K. and Mishra, A. (2011). Water quality assessment of Rani lake of Rewa (M.P.). *GERF Bull. Biosci.*, **2(2)** : 11-17.

Mishra, V.; Sharma, S. K.; Sharma, B. K.; Upadhyay, B. and Choubey, S. (2012). Phytoplankton, primary productivity and certain physico-chemical parameters of Goverdhan Sagar lake of Udaipur. *Univ. J. Environ. Res. Tech.*, **2** : 569-574.

Moundiotiya, C.; Sisodia, R.; Kulshreshtha, M. and Bhatia, A. L. (2004). A case study of the Jamwa-Ramgarh wetland with special reference to physico-chemical properties of water and its environs. *J. Environ. Hydrol.*, **12** : 1-7.

Neuhold, J. M. and Sigler, W. E. (1962), Chlorides affect the toxicity of fluorides to rainbow trout. *Science*, **135** : 732-733.

Pandey, A. C.; Pandey, A. K. and Das, P. (1999). Fish and fisheries in relation to aquatic pollution. In : *Environmental Issues and Resource Management* (eds. Das, P.; Verma, S. R. and Gupta, A. K.). Nature Conservators, Muzaffarnagar, pp. 67-112.

Pandey, A. K. (2015). Fish diversity of Ramgarh and Bakhira lake : comparison of present status with pristine data for conservation and sustainable utilization. *Project Completion Report*. Uttar Pradesh State Bio-diversity Board, Lucknow.

Parte, P. S. (2012). Assessment of water quality of Kanhargaon Reservoir, district Chhindwara (M.P.) with special reference to composite fish culture. *Ph.D. Thesis*. A.P.S. University, Rewa.

Pathak, V.; Tyagi, R. K. and Mahavar, L. R. (2004). Evaluation of potential energy resources and its utilization in wetlands of Uttar Pradesh. *J. Inland Fish. Soc. India*, **36(1)** : 9-17.

Pearcy, K., Elphick, J. and Burnett-Seidel, C. (2015). Toxicity of fluoride to aquatic species and evaluation of toxicity modifying factors. *Environ. Toxicol. Chem.*, **34** : 1642-1648.

Pradhan, C.; Andrew, P. E. and Chauhan, S. S. (2014). Comparative study on the analysis of water quality of different water bodies of Jaipur. *Intern. J. Geol. Earth Environ. Sci.*, **4(2)** : 1-5.

Prajapati, U. B. and Dwivedi, A. K. (2013). Impact of industrial wastes on the water quality of tropical river, Ami (India). *J. Appl. Natu. Sci*., **3** : 219-223.

Rajshekhar, A. U.; Lingaiah, M. S.; Rao, S. and Piska, R. S. (2007). The studies on water quality parameters of minor reservoir, Nagergul, Rangareddy district, Andhra Pradesh. *J. Aquat. Biol.*, **21** : 113-117.

Ramachandra, T. V. (2002). Physico-chemical and biological analysis of water. In : *Winter School on Essentials in Iimnology and Geographical Information System* (LIMGIS-2001). Energy and Wetland Research Group (Centre for Ecological Science). Indian Institute of Science, Bangalore, pp. 1-28.

Sahai, R. and Sinha, A. B. (1969). Investigations of bio-ecology of inland waters of Gorakhpur (U.P.). I. Limnology of Ramgarh lake. *Hydrobiologia*, **34** : 439-447.

Saini, D.; Dube, K. K.; Shrivastava, S. B. and Pandey, A. K. (2015). Seasonal and diel variations in plankton production in relation to physico-chemical parameters and its implication on fisheries in river Narmada from Lamhetaghat to Bhedaghat near Jabalpur. *J. Exp. Zool. India*, **18** : 951-960.

Saksena, D. N.; Garg, R. K. and Rao, R. J. (2008). Water quality and pollution status of Chambal river in National Chambal Sanctuary, Madhya Pradesh. *J. Environ. Biol.*, **29** : 701-710.

Saxena, M. and Saksena, D. N. (2012). Water quality and trophic status of Raipur reservoir in Gwalior (M.P.). *J. Natu. Sci. Res.*, **2(8)** : 82-96.

Sharma, R. K. and Soni, D. K. (2013). Aqua status of Surha Tal, located in district Ballia (U.P.). *J. Env.. Res. Dev..*, **7** : 577-1585.

Shiddamallaya, N. and Pratima, M. (2008). Impact of domestic sewage on freshwater body. *J. Environ. Biol.*, **29** : 303-308.

Sinde, S. E.; Pathan, T. S.; Rout, K. S.; More, P. R. and Sonawane, D. L. (2010). Seasonal variations in physico-chemical characteristics of Harsool-Savangi Dam, district Aurangabad. *The Ecoscan*, **4** : 37-44.

Singh, J. and Upadhyay, S. K. (2012). Seasonal variations in heavy metals in Ramgarh lake, Gorakhpur. *Intern. J. Lakes Rivers*, **5(2)** : 63-74.

Singh, J.; Upadhyay, S. K.; Pathak, R. K. and Gupta, V. (2011). Accumulation of heavy metals in soil and paddy crop (*Oryza sativa*) irrigated with water of Ramgarh lake. *Toxocol. Environ. Chem.*, **93** : 462-473.

Singh, J.; Upadhyay, S. K. and Pathak, R. K. (2013). Seasonal variations in physico-chemical characteristics and cyanobacterial diversity of a lake in northern India. *Toxocol. Environ. Chem.*, **95** : 458-471.

Singh, M. and Singh, A. K. (2007). Bibliography of environmental studies in natural characteristics and anthropogenic influences of the Ganga river. *Environ. Monit. Assess.*, **129** : 421-432.

Singh, N. and Tripathi, M. (2015). Fluoride toxicity in freshwater

fishes and aquaculture : a review. *Indian J. Life Sci.*, **4** : 115-124.

Singh, R.; Singh, V. K. and Dwivedi, A. K. (2014). Determination of water quality index of sewage water for quick assessment of biomonitoring and bioremediation. *Biolife*, **2** : 297-305.

Singh, Y. and Singh, A. P. N. (2009). Physico-chemical characteristics of Ramgarh lake, Gorakhpur district, Uttar Pradesh. *Biochem. Cell. Arch.*, **9** : 273-281.

Sinha, A. B. (1969). Investigations on the ecology of Ramgarh lake. *Ph.D. Thesis*. University of Gorakhpur, Gorakhpur.

Srivastava, N.; Agarwal, M. and Tyagi, A. (2003). Study of physico-chemical characteristics of water bodies around Jaipur. *J. Environ. Biol.*, **24** : 177-180.

Srivastava, N.; Harit, G. and Srivastava, R. (2009). A study of physico-chemical characteristics of lakes around Jaipur. *J. Environ. Biol*., **30** : 899-894.

Srivastava, S. K.; Pandey, G. C.; Mahanta, P. C.; Patiyal, R. S. and Lakra, W. S. (2006). Seasonal variations in hydro-biological parameters of Ramgarh lake, Gorakhpur. *J. Adv. Zool.*, **27** : 46-51.

Srivastava, S. K.; Pandey, G. C.; Mahanta, P. C. and Gopal, K. (2007). Assessment of water quality of a freshwater body, Ramgarh lake, Gorakhpur (U.P.). *Asian J. Microbiol. Biotech. Environ. Sci.*, **9** : 665-668..

Stenstrom, M. K.; Fam, S. and Silverman, G. S. (1986). Analytical methods for quantitative and qualitative determination of hydrocarbons and oil and grease in water and sediments. *Environ. Technol, Lett.*, **7** : 655-636.

Swarup, K. and Singh, S. R. (1976). Limnological studies on Suraha lake : variation in water quality. *J. Inland Fish. Soc. India,* **11(1)** : 22-23.

Talwar, R.; Agrawal, S.; Bajpai, A. and Malik, S. (2015). Assessment of concentration and variations due to seasonal effect on the presence of heavy metals in the water of Upper lake, Bhopal. *Curr. World Environ.*, **9(2)** : 1-6.

Tiwari, F. (2013). Limnological studies of Ramgarh lake in Eastern Uttar Pradesh. *Afr. J. Basic Appl. Sci.*, **5** : 145-148.

Verma, S. R.; Shukla, G. R. and Dalela, R. C. (1980). Studies on the pollution of Hindan river in relation to fish and fisheries. *Limnologica*, **12** : 33-75.

Verma, P. U.; Chandawat, D. K. and Solanki, H. A. (2013). Pollution status of Nikol lake located in eastern Ahmedabad, Gujarat, India. Intern. *J. Innov. Res. Sci. Eng. Technol.*, **2** : 3603-3609.

Wetzel, R. G. (1975). *Limnology*. W.B. Saunders Co., Philadelphia.

WHO (2012). *Water Sanitation and Health. Fluoride*. 1-2. World Health Organization, Geneva.

Yadav, P.; Yadav, V. K.; Yadav, A. K. and Khare, P. K. (2013). Physico-chemical characteristics of a freshwater pond of Orai (U.P.). Central India. *Octa J. Biosci.*, **1** : 177-183.

Yadava, Y. S. and Sugunan, V. V. (1992.). *Suraha Tal : Prospects for Fisheries Development*. Bull. No. 64. Central Inland Fisheries Research Institute, Barrackpore, p. 17.

Yu, L.; Han, M. and He, F. (2013). A review of treating oily wastewater. *Arabian J. Chem*. <http://dx.dpoi.org/10.1016/j.arabjc.2013.07.020>.