

# CHANGING TRENDS OF SOME BIO-PHYSICO-CHEMICAL CHARACTERISTICS OF SAGARDIGHI OF COOCH BEHAR, WEST BENGAL, INDIA

*Abdul Miraj\**

*Sudip Kumar Bhattacharya\*\**

## ABSTRACT

*Present work was designed to study the changing trends of some important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India. To evaluate the water quality of the lake, bio-physico-chemical parameters (tested by West Bengal Pollution Control Board, Siliguri laboratory) were studied on the monthly basis for a period of five years between June 2011 to May 2016. There were seven physical parameters, interalia, Temperature, pH, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Total Fixed Solids (TFS), Turbidity, and Electrical Conductivity (EC); thirteen chemical parameters, interalia, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Alkalinity (TA), calcium, magnesium, chloride, sulphate, sodium, phosphate, nitrate-N, potassium, Total Hardness (TH) and two bacteriological parameters, Total Coliform(TC) and Fecal Coliform(FC). The present work provides baseline information on changing trends of bio-physico-chemical status of Sagardighi. This would facilitate sustainable management and conservation of ecosystem of this lake. The data obtained from this study reveals that the bio-physico-chemical parameters of Sagardighi of Cooch Behar are comparatively in moderate condition but almost all the parameters are prone to cross the critical pollution level, if necessary action is not taken in time.*

**Keywords:** Bacteriological Parameters, Changing Trends, Chemical Parameters, Physical Parameters, Sagardighi.

## INTRODUCTION

Ponds are useful wetlands located in and around human settlement. Ponds are generally semi-natural ecosystems constructed by man. The ponds are subjected to a range of physical,

---

\***Abdul Miraj** is a Ph.D. Research Scholar at Department of Geography and Applied Geography, University of North Bengal, Darjeeling, West Bengal, India. Email: abdulgeo001@gmail.com

\*\***Sudip Kumar Bhattacharya** is Assistant Professor at Department of Geography and Applied Geography, University of North Bengal, Darjeeling, West Bengal, India.

chemical and biological problems caused by human activities and climate change due to which a major concern has aroused as it can diminish their aesthetic beauty, recreational value, water quality and habitat suitability. Most of the ponds or lakes, especially near residential, commercial and administrative areas are polluted because of anthropogenic activities. The physical and chemical characteristics of water are important parameters as they directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Swingle 1969).

Increased anthropogenic activities in and around the water bodies damage the aquatic ecosystems and ultimately the physico-chemical properties of water (Upadhyay *et al.* 2010). It is well established that domestic sewage and industrial effluents falling into natural water bodies change the water quality and lead to eutrophication (Shaw *et al.* 1991). The monitoring of physico-chemical parameters of a water body is vital for both long term and short term study (Wood 1995). Good water quality resources depends on a large number of physico-chemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters are essential (Reddi *et al.* 1993).

## MATERIALS AND METHODS

### Description of Study Area

Sagardighi has been selected for study. It is the most important freshwater body which is situated in the heart of Cooch Behar town. It extends between  $26^{\circ}19'12''\text{N}$  to  $26^{\circ}19'21''\text{N}$  and  $89^{\circ}26'21''\text{E}$  to  $89^{\circ}26'28''\text{E}$  and the total surface area of this lake is 14.60 hectare. The lake was excavated by Maharaja Harendra Narayan in 1807 AD. It attracts various migratory

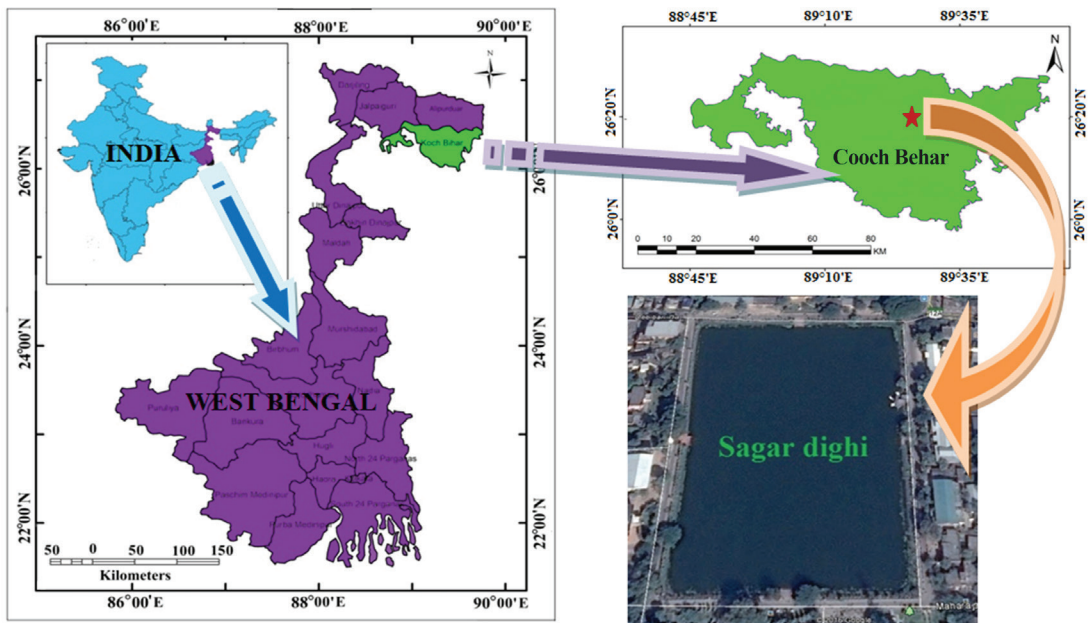


Figure 1: Locational Map of Sagardighi.

birds during the winter season. Among all ponds in Cooch Behar town the most spectacular is Sagardighi, with grand structures arrayed all around it. These buildings, built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Cooch Behar Main Branch) and numerous other on the east and RTO office, Foreigner's enrollment office, District Court in the north. Although this lake was excavated for drinking water supply control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc.

### **Collection of Water Parameters Data:**

The study of Cooch Behar Lake or Sagardighi was conducted using secondary data of five year duration between June 2011 to May 2016 of West Bengal Pollution Control Board, Siliguri Laboratory, Siliguri in Darjeeling.

### **Statistical Analysis:**

Statistical analysis like mean, standard deviation and correlation coefficient, correlation matrix etc. and some graphical representation have been made using Microsoft Excel (Version Windows 2007), a computer based programmer for windows.

### **Preparation of maps:**

The locational map was prepared by using Google Earth, Global Mapper 2011 and Arc GIS v-9.3.

## **RESULTS AND DISCUSSION**

### **Physical Parameters:**

**Temperature:** It is one of the most important parameters for aquatic environment because it governs the physical, chemical and biological properties of water. The maximum water temperature (35°C) was recorded in September, 2011 and minimum (18°C) in January, 2013(Table 1). The mean temperature is gradually high from 28.58°C (2011-12) with SD 4.54 to 29.83°C (2015-16) with SD 3.59 in (Table 1 & 2).

**pH:** pH is an important parameter because it indicates more or less overall water environment. The intensity of acidity or alkalinity of water can be measured by taking the value of pH of water. Natural water is usually alkaline due to the presence of sufficient quantities of carbonate. Here, it ranged from 6.63 (July, 2011) to 9.54 (April, 2016) during 2011-16(Table 1). Sometime pH value exceeds the permissible limit i.e. 6.5 to 8.5.

**Total Dissolved Solid (TDS):** TDS consequently may have an influence on the acceptability of water in general. Water with a very low TDS concentration may be corrosive and corrosive water may lead to toxicity in water. The variation of TDS in water may occur due to ionic composition of water. The highest TDS (271 mg/l) was recorded in August, 2012 and lowest one was 22 mg/l in November 2011(Table 1).

**Total Suspended Solid (TSS):** The TSS is a direct measurement of the concentration of suspended material present in a water sample. TSS value varied due to ionic composition of water and the factors like rainfall and biota cause changes in their concentrations. The maximum TSS (158 mg/l) was recorded in October, 2013 and minimum (4 mg/l) in January, 2011 (Table 1).

**Total Fixed Solids (TFS):** Total Solids are dried, weighed, and then ignited at  $500 \pm 50^\circ\text{C}$ . The loss of weight by ignition at  $500 \pm 50^\circ\text{C}$  is a measure of the volatile solids, which are classed as organic material. The remaining solids are the total fixed solids, which are considered as inorganic (mineral) matter. In other word, the Total Solids associated with the mineral fraction are termed Total Fixed Solids (TFS). It ranged from 4 mg/l (June, 2015) to 160 mg/l (September, 2015) during 2011-16 (Table 1).

**Turbidity:** It is another important physical parameter which is responsible for scattering and absorption of light by water. As the turbidity obstructs light penetration, it limits production of phytoplankton growth, which in turn leads to a decrease in photosynthetic activity and depletion of oxygen content. The maximum turbidity (39.1/NUT) was recorded in May, 2013 and minimum (3.11/NUT) in February, 2016 (Table 1), whereas the permissible limit (BIS standard) of turbidity is 5/NUT.

**Electrical Conductivity (EC):** EC value is an index to represent the total concentrations of soluble salt in surface water. The highest EC ( $98.8 \mu\text{S}/\text{cm}$ ) was recorded in August, 2012 and lowest one was ( $42 \mu\text{S}/\text{cm}$ ) in November 2011 (Table 1). EC showed a positive correlation with Total Alkalinity ( $r=0.686$ ) (Table 2).

### Chemical Parameters:

**Dissolved Oxygen (DO):** DO indicate the health of the ecosystem and refers to the volume of oxygen present in water body. It is an important water quality parameter to be measured because it prevails over biological and physicochemical attributes of surrounding water. Oxygen enters into water by aerial diffusion and as a photosynthetic byproduct of aquatic plants and algae. The DO depends upon the temperature, salinity and pressure of water. The DO value indicates the degree of pollution in the water bodies (Gopalkrushna, 2011). It ranged from 5.2 mg/l in July 2011 to 9.9 mg/l in February, 2012 during 2011-16 (Table 1).

**Biochemical Oxygen Demand (BOD):** It is one of the most important components for the aquatic community. It is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The maximum BOD (7.1 mg/l) was recorded in May, 2012 and minimum (0.85 mg/l) in July, 2011 (Table 1). The mean BOD is gradually low from 3.42 mg/l with SD 2.14 in 2011-12 to 2.28 mg/l with SD 0.72 in 2015-16 (Table 1 & 2).

**Chemical Oxygen Demand (COD):** The oxygen required by the organic matters in water to be oxidized by a strong chemical oxidant which is known as Chemical Oxygen Demand (COD). Sometimes BOD cannot be determined accurately due to the presence of toxins and other such unfavorable conditions. Under such circumstances, COD plays an important role for assessment of organic matters in water. It ranged from 14.4 mg/l (October, 2011) to 78 mg/l

(July, 2011) during 2011-16 (Table 1), whereas the permissible limit (WHO standard) of COD is 10 mg/l. It showed a positive correlation with turbidity ( $r=0.647$ ) (Table 2).

**Total Alkalinity (TA):** TA of water is an important parameter, which determines the amount of chemical needed to be added in water treatment. Alkalinity is an anionic phenomenon. The highest alkalinity value (68mg/l) was recorded in December 2012 and the lowest (15.2 mg/l) in March 2013. This shows a positive correlation with calcium ( $r=0.686$ , Table 1 and 2) and conductivity ( $r=0.748$ , Table 1 and 2).

**Calcium:** Calcium content is present in hard water as well as soft water. Calcium in wetland water is most essential for the growth of aquatic vegetation and lives. It ranged from 2.83mg/l (April, 2013, ) to 27.25 mg/l (August, 2015) during 2011-16 (Table 1).

**Magnesium:** It is an important chemical component of water. It is essential for the chlorophyll bearing bacteria, algae and plants. Magnesium concentration ranged from 0.54 mg/l to 8.75mg/l.

**Chloride:** It is one of the major inorganic anions in water and waste water. Chloride content increases in water bodies due to organic matter decomposition. The important source of chloride in the water is the discharge of domestic and industrial sewage. Hence, the chloride concentration serves as an indicator of pollution by sewage disposal and industrial wastes. The maximum chloride (17.61mg/l) was recorded in November, 2016 and minimum (1.96 mg/l) in May, 2016 (Table 1).

**Sulphate:** Sulphate is naturally occurring anions in all kinds of natural water. Industrial waste and domestic sewage are responsible for increase of its concentrations in water. The tolerance limit of sulphate in water is 200 mg/l while, excessive limit considered is 400mg/l. Sulphate concentration ranged from 0.055mg/l in January, 2011 to 16.33 mg/l in June, 2013

**Sodium:** Sodium content in water is essential chemical component. The maximum sodium (1 mg/l) was recorded in March, 2013 and minimum (6mg/l) in September, 2011 (Table 1).

**Phosphate:** In natural water, phosphorous occurs as phosphate. It is essential for the growth of organisms and act as nutrient that limits the primary productivity of water body that stimulates the growth of photosynthesis of aquatic micro and macro organisms. The maximum phosphate (0.587mg/l) concentration was recorded in July, 2014 and minimum (0.007 mg/l) in February, 2014 (Table 1).

**Nitrate-N:** Nitrate-N concentration enters fresh water through discharge of sewage, industrial wastes and runoff from agricultural fields, the concentration and rate of supply of nitrate in the land use practices of the surrounding watershed. In present study, Nitrate-N concentration ranged from 0.003 mg/l to 0.68mg/l (Table 1).

**Potassium:** Potassium concentration is very low ( $<10$  mg/l) in natural waters since rocks, which contain potassium, are relatively resistant to weathering. It is usually found in ionic form and the salts are highly soluble. Though found in small quantities it plays a vital role in the metabolism of fresh water environment (Ramachandra *et al.*, 2012). The maximum potassium (3 mg/l) was recorded in January, 2013 and minimum (0.78 mg/l) in September, 2013 (Table 1).

**Total Hardness (TH):** Total Hardness normally indicates the total calcium and magnesium salts present in water along with some other polyvalent metals such as iron, aluminum, manganese etc. It determines the suitability of water for domestic, industrial and drinking purposes. The total hardness of the water body was in the range between 14.14 mg/l in June, 2011 to 84 mg/l in December, 2011 (Table 1). Total Hardness showed a positive correlation with calcium ( $r=0.883$ , Table 1 and 2) and magnesium ( $r=0.698$ , Table 1 and 2).

### **Bacteriological Parameters**

Total Coliform and Fecal Coliform are the two bacteriological parameters considered here which indicate the presence of pathogens in water of the lake. The maximum Total Coliform (170000 MPN/100ml) was recorded in August, 2011 and minimum (1700 MPN/100ml) in April, 2013 (Table 1). The maximum Fecal Coliform (27000 MPN/100ml) was recorded in August, 2011 and minimum (500 MPN/100ml) in April, 2013 (Table 1), whereas the permissible limit of Total Coliform and Fecal Coliform is 500 MPN/100ml (CPCB standard) and 10-100 MPN/100ml (Malaysia standard) respectively. Total Coliform showed a positive correlation with Fecal Coliform ( $r=0.877$ ) (Table 2).

**Table 1a: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal**

Parameters	Unit	2011												2012					Range	Mean	Standard Deviation
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
BOD	mg/l	3.35	0.85	1.5	6.6	4.9	5.6	1.1	1.7	9.6	19.2	3.2	4	2.2	6.4	5.5	6.9	7.1	0.85-7.1	3.42	2.14
Calcium	mg/l	4.12	6.59	2.99	2.99	4	6.6	17.2	14.4	24.96	39.6	40	58.41	58.3	57.5	66	9.1	8.8	4-19.2	7.49	4.03
Chloride	mg/l	30	78	33.6	48.9	8.1	8.2	8.1	9.8	9.2	9.8	9.8	9.8	9.9	9	9	9.1	8.8	2.94-6.8	4.78	1.45
COD	mg/l	30	78	33.6	48.9	8.1	8.2	8.1	9.8	9.2	9.8	9.8	9.8	9.9	9	9	9.1	8.8	14.4-78	40.02	18.10
Conductivity	µS/cm	50.6	57.3	48.9	46.7	47.7	51.8	49.3	51.4	58.3	57.5	66	60	46.7-66	53.79	5.92	1.32	8.73	5.2-9.9	8.73	1.32
Dissolved O <sub>2</sub> (DO)	mg/l	7.8	5.2	8.2	8.1	9.8	9.2	9.8	9.8	9.2	9.8	9.8	9.8	9.9	9	9	9.1	8.8	5.2-9.9	8.73	1.32
Fecal Coliform	MPN/100ml	22000	9000	27,000	9000	9000	7000	11000	8000	8000	8000	1300	1700	3000	1300-27000	10750.00	8441.40				
Magnesium	mg/l	0.98	1.96	0.99	1.45	4.37	1.94	8.75	1.46	4.37	1.73	3.88	2.3	0.98-8.75	2.85	2.23					
Nitrate-N	mg/l	0.15	0.04	0.27	0.17	0.12	BDL	0.02	BDL	0.04	7.92	6.66	7.89	6.63-7.94	7.28	0.47					
pH	Unit	7.25	6.63	7.01	7.94	6.93	7.24	7.63	7.31	6.95	7.92	6.66	7.89	6.63-7.94	7.28	0.47					
Phosphate-P	mg/l	0.037	0.044	0.014	0.02	0.03	0.23	0.02	0.05	0.01	0.087	0.027	0.011	0.01-0.23	0.05	0.06					
Potassium	mg/l	2	1	1	1	1	1	1	1	1	1	1	1	1-2	1.08	0.29					
Sodium	mg/l	2.5	1.46	4.03	6	2.35	2.35	3.73	5.69	3.36	4.71	4.71	2.75	1.46-6	3.64	1.43					
Sulphate	mg/l	0.055	0.16	NT	2.95	2.65	2.75	6.38	2.78	1.63	2.02	0.62	2.42	0.055-6.38	2.22	1.75					
Temperature	°C	32	33	31	35	32	25	25	20	23	27	30	30	20-35	28.58	4.54					
Total Alkalinity	mg/l	18	20	22	20	22	24	68	30	24	32	28.5	24.7	18-68	27.77	13.36					
Total Coliform	MPN/100ml	70000	17000	1,70,000	17,000	50000	11000	14000	11000	13000	5000	2700	5000	2700-170000	32141.67	47811.42					
Total Dissolved Solids(TDS)	mg/l	154	36	30	36	40	22	26	84	46	83	54	64	22-154	56.25	37.02					
Total Fixed Solids(TFS)	mg/l	16	8	10	10	30	6	10	40	26	30	22	16	6-40	18.67	10.83					
Total Hardness as CaCO <sub>3</sub>	mg/l	14.14	24.24	20.2	18	32	32	84	24	34	16	32.69	28	14.14-84	29.94	18.36					
Total Suspended Solids(TSS)	mg/l	48	42	18	38	28	4	6	4	92	30	16	142	4-142	39.00	40.70					
Turbidity	NTU	17.4	28.6	7.11	8.57	17.2	10.2	13.9	9.25	22.4	12.5	19.6	10.7	7.11-28.6	14.79	6.44					

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

**Table 1b: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal**

Year	Parameters	Unit	2012												2013					Range	Mean	Standard Deviation
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
	BOD	mg/l	6.3	3.2	3.8	4.8	4.1	4.3	8	5.66	6.7	2.87	3.82	7.78	61	69	19.32-73	43.77	18.90			
	Calcium	mg/l	5.82	5.6	7.2	5.6	8	8	3.83	3.83	5.74	2.87	3.82	7.78	61	69	2.87-7.78	4.79	1.75			
	Chloride	mg/l	3.91	3.74	4.78	3.83	3.83	37.44	27.04	39.12	41.6	66.56	73	53	57	53	42-58	51.75	4.79			
	COD	mg/l	21.12	37.44	32.64	19.32	47	42	50	52	53	56	58	57	53	53	42-58	51.75	4.79			
	Conductivity	µs/cm	56	50	47	42	42	42	42	42	42	42	42	42	42	42	42-58	51.75	4.79			
	Dissolved O <sub>2</sub> (DO)	mg/l	8.6	6.4	6.5	8	8.3	8.2	8.9	8.8	8.9	8.8	8.6	7.9	7.6	7.6	6.4-8.9	8.03	0.83			
	Fecal Coliform	MPN/100ml	2300	1300	1100	3300	2700	1700	2100	2200	2200	1300	1100	500	1400	1400	500-3300	1750.00	790.28			
	Magnesium	mg/l	1.79	1.73	2.3	1.73	2.3	2.3	1.152	2.55	5.61	1.02	1.53	5.05	1.02	1.53	1.02-5.61	2.42	1.44			
	Nitrate-N	mg/l	0.1	0.01	0.008	0.01	0.007	0.01	BDL	BDL	BDL	BDL	0.01	0.006	0.01	0.006	0.006-0.1	0.02	0.03			
	pH	Unit	8.02	8	7.21	7.65	8.5	8.27	7.57	8.1	8.35	7.3	7.96	7.63	7.21-8.5	7.88	0.41	0.41	0.41			
	Phosphate-P	mg/l	0.026	0.021	0.019	0.021	0.034	0.049	0.063	0.058	0.075	0.061	0.083	0.062	0.019-0.083	0.05	0.02	0.02	0.02			
	Potassium	mg/l	1	<1.00	1	<1.00	1	<1.00	3	1	<1.00	1	<1.00	1	<1.00	1.40	1-3	1.40	0.89			
	Sodium	mg/l	4.71	3.36	2.75	2.35	2.75	1.88	2.85	5	2.38	1	1	1.13	1.5	2.74	1-5	2.74	1.27			
	Sulphate	mg/l	1.5	7.19	5	0.29	0.468	5.37	0.075	4.29	2.22	2.24	2.24	3.17	3.33	2.93	0.075-7.19	2.93	2.23			
	Temperature	°C	29	32	32	29	28	30	26	18	26	28	28	34	31	28.58	18-34	28.58	4.12			
	Total Alkalinity	mg/l	20.9	19	20.9	22.8	22.8	24.7	26.6	28.5	26.6	15.2	15.2	20.9	26.1	22.92	15.2-28.5	22.92	3.80			
	Total Coliform	MPN/100ml	8000	14000	8000	22000	17000	13000	17000	14000	8000	8000	5000	1700	8000	11308.33	1700-22000	11308.33	5818.07			
	Total Dissolved Solids(TDS)	mg/l	88	271	115	33	43	62	74	75	26	26	68	64	52	80.92	26-271	80.92	64.54			
	Total Fixed Solids(TFS)	mg/l	16	10	10	20	28	60	88	40	24	24	30	18	44	32.33	10-88	32.33	22.91			
	Total Hardness as CaCO <sub>3</sub>	mg/l	20.8	20	22	24	22	28	24	23.1	21.47	17.7	17.7	12.39	42.09	23.13	12.39-42.09	23.13	7.07			
	Total Suspended Solids(TSS)	mg/l	40	40	26	98	24	12	28	42	44	44	44	44	60	41.83	12-98	41.83	21.65			
	Turbidity	NTU	9.56	7.89	5.26	4.18	5.14	6.64	8.84	7.36	17.4	31.7	31.7	14.8	39.1	13.16	4.18-39.1	13.16	11.20			

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level



**Table 1c: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal**

Parameters	Unit	Year												Standard Deviation		
		2013						2014								
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Range	
BOD	mg/l	2.2	3	3.1	3.6	2.4	1.9	2.1	3.4	3.4	3.4	2.8	1.8	4.5	2.85	1.8-4.5
Calcium	mg/l	5.6	6.4	8.8	13.6	7.2	6.4	7.2	6.4	6.4	7.2	8	9.6	12	8.20	5.6-13.6
Chloride	mg/l	6.84	10.76	10.53	8.81	2.94	3.91	6.85	4.89	5.87	4.87	31.2	7.83	15.65	7.48	2.94-15.65
COD	mg/l	53	28.52	15.84	46.72	49.28	31	26.88	24.84	42.32	31.2	74	85	85	36.26	15.84-53
Conductivity	µs/cm	51	56	50	53	50	51	51	53	56	70	74	85	85	58.33	50-85
Dissolved O <sub>2</sub> (DO)	mg/l	7.2	7.8	6.9	8.2	7.8	8.2	7.8	6.8	7.8	6.9	6.9	6.9	6.8	7.43	6.8-8.2
Fecal Coliform	MPN/100ml	2700	9000	8000	2200	2600	5000	2600	2200	2200	2100	1100	1100	1700	3450.00	1100-9000
Magnesium	mg/l	3.46	3.46	2.88	1.73	0.58	1.15	1.73	1.73	2.3	1.15	2.3	4.61	4.61	2.26	0.58-4.61
Nitrate-N	mg/l	0.008	0.02	0.008	0.05	0.02	0.007	0.007	0.02	0.008	0.005	0.19	0.68	0.68	0.09	0.005-0.68
pH	Unit	7.35	7.16	7.2	7.32	7.28	7.38	7.2	7.22	7.23	7.13	7.22	7.58	7.58	7.27	7.13-7.58
Phosphate-P	mg/l	0.055	0.051	0.042	0.031	0.039	0.033	0.035	0.057	0.007	0.041	0.029	0.123	0.123	0.05	0.007-0.123
Potassium	mg/l	<1.0	<1.0	<1.0	0.78	<1.0	<1.0	1	1	1	1	2	1	1	1.11	0.78-2
Sodium	mg/l	1.813	2.86	2.35	4.43	<1.00	1.35	2.75	2.75	1.34	2.35	3.29	4.37	4.37	2.70	1.34-4.43
Sulphate	mg/l	16.33	2.54	3.49	1.41	0.74	1.74	1.82	0.75	0.92	0.94	0.79	0.45	0.45	2.66	0.45-16.33
Temperature	°C	30	31	34	35	28	26	26	22	24	30	29	30	30	28.75	22-35
Total Alkalinity	mg/l	20	24	24	28	24	24	26	18	22	42	36	30	30	26.50	18-42
Total Coliform	MPN/100ml	13000	16000	14000	8000	11000	11000	8000	6000	5000	6000	5000	7000	7000	9166.67	5000-16000
Total Dissolved Solids(TDS)	mg/l	63	92	90	65	82	64	78	48	75	75	111	47	47	74.17	47-111
Total Fixed Solids(TFS)	mg/l	68	32	16	16	32	16	22	12	54	20	16	30	30	27.83	12-68
Total Hardness as CaCO <sub>3</sub>	mg/l	26	28	32	40	20	20	24	22	26	24	32	46	46	28.33	20-46
Total Suspended Solids(TSS)	mg/l	42	54	88	78	158	42	24	16	44	44	22	146	146	63.17	16-158
Turbidity	NTU	13.8	10.4	5.24	3.46	3.65	3.75	4.34	6.28	4.27	6.12	5.61	22.3	22.3	7.44	3.46-22.3

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

**Table 1d: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal**

Parameters	Unit	Year												Standard Deviation							
		2014						2015													
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Range	Mean	
BOD	mg/l	2.6	1.6	3	1.8	2.4	4.5	1.7	2.8	2.1	2.6	2.2	2.4	2.6	2.4	1.6-4.5	2.48	0.77			
Calcium Chloride	mg/l	5.92	7.83	4.89	11.21	10.42	9.6	10.92	6.72	10.08	8.4	6.72	5.92	11.2	10.42	5.92-12	9.53	2.08			
COD	mg/l	18.32	41.28	33.16	37.44	55.12	41	35.36	24	22.08	44.16	28.56	18.32	24	41.28	18.32-55.12	33.71	10.80			
Conductivity	µs/cm	62.7	65	92	98.8	72.15	67	69	70	66	60	71	62.7	65	98.8	60-98.8	72.15	12.79			
Dissolved O <sub>2</sub> (DO)	mg/l	8.7	7.2	8.2	7.4	7.49	6.8	7.4	7.5	7.2	7.4	7.4	8.7	7.2	7.4	6.8-8.7	7.49	0.55			
Fecal Coliform	MPN/100ml	2600	1400	1700	1300	1700	1300	1700	9000	5000	1700	1400	2600	2700	1400	1300-9000	2625.00	2260.78			
Magnesium	mg/l	4.26	1.15	0.54	0.96	4.32	1.73	2.42	3.63	2.27	3.02	1.81	4.26	0.58	1.15	0.54-4.32	2.22	1.34			
Nitrate-N	mg/l	NT	0.004	NT	0.003	0.02	0.05	0.02	BDL	NT	0.09	0.006	NT	0.007	0.004	0.003-0.09	0.03	0.03			
pH	Unit	7.56	7.49	8.8	8.5	8.73	7.6	7.12	6.96	7.57	7.33	7.89	7.75	7.56	7.49	6.96-8.8	7.78	0.60			
Phosphate-P	mg/l	0.038	0.027	0.029	0.025	0.045	0.239	0.587	0.019	0.013	0.027	0.027	0.056	0.038	0.027	0.013-0.587	0.09	0.17			
Potassium	mg/l	1	1	1	1	BDL	1	1	1	1	1	1	1	1	1	1-1	1.00	0.00			
Sodium	mg/l	3	3.36	3	3.36	2.35	2.86	2	2	3	3	2.75	3	3	3.36	2-3.36	2.88	0.40			
Sulphate	mg/l	0.97	1.94	0.95	1.67	1.09	0.68	2.17	3.38	2.5	3.71	0.14	0.66	0.97	1.94	0.14-3.71	1.66	1.12			
Temperature	°C	24	29	28	32	29.67	32	32	33	30	28	29	27	24	29	24-33	29.67	2.67			
Total Alkalinity	mg/l	36	34	40	42	38.13	36	38	44	34	40	31.5	38	36	34	31.5-44	38.13	4.02			
Total Coliform	MPN/100ml	7000	8000	9000	7000	8000	8000	4000	14000	11000	7000	5000	7000	9000	8000	4000-14000	8083.33	2609.71			
Total Dissolved Solids(TDS)	mg/l	61	61	77	45	84	49	91	93	93	44	84	61	37	61	37-93	64.58	20.21			
Total Fixed Solids(TFS)	mg/l	12	6	6	6	17.40	18	14	14	10	8	8	12	10	6-68	17.40	18.33				
Total Hardness as CaCO <sub>3</sub>	mg/l	29.6	34	30	32	44	30	29.4	23.1	23.1	31.5	23.1	29.6	30	34	23.1-44	31.03	5.51			
Total Suspended Solids(TSS)	mg/l	56	24	28	64	25	24	46	56	16	16	38	56	22	24	16-64	38.00	16.92			
Turbidity	NTU	8.76	7.07	6.14	9.12	14.1	4.57	10.2	3.44	6.16	8.27	4.67	8.76	7.07	6.58	3.44-14.1	7.42	2.91			

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

**Table 1e: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal**

Parameters	Unit	Year												Standard Deviation						
		2015						2016												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Range	Mean
BOD	mg/l	2.4	1.7	2	2.5	2.8	2.8	3.9	3.1	1.7	1.6	2	2.3	1.4	1.4-3.9	2.28	0.72			
Calcium	mg/l	9.62	12.83	27.25	10.42	16.03	7.83	17.61	13.69	12.72	12.02	15.23	10.42	12.02	9.62-27.25	14.09	4.79			
Chloride	mg/l	6.84	10.76	4.89	13.69	7.83	22	27.84	34.56	31	23	39	60.48	62.4	1.96-17.61	9.37	4.71			
COD	mg/l	46.8	19.76	25	33	22	79.81	87.74	77.12	68.89	66.97	73.42	84.51	80.1	66.97-87.74	80.34	7.32			
Conductivity	µs/cm	86.6	87.18	7.9	6.8	8	8.6	8.8	8.7	7.3	7	8	8.7	7.9	6.8-8.8	7.90	0.71			
Dissolved O <sub>2</sub> (DO)	mg/l	7.1	800	2200	2700	3300	14000	2600	2100	6000	1200	1100	800	800	800-14000	3250.00	3670.65			
Fecal Coliform	MPN/100ml	3.84	BDL	0.01	0.02	7.31	0.027	0.089	0.114	0.083	0.184	0.023	0.055	0.047	0.012	0.015	0.015-0.184	0.08	0.05	
Magnesium	mg/l	0.56	0.01	8.73	0.029	2	1	1	1	BDL	BDL	2	1	BDL	1-2	1.50	0.53			
Nitrate-N	mg/l	BDL	0.01	0.02	0.04	0.07	0.1	0.05	0.09	0.13	0.06	0.1	0.12	0.01-0.13	0.07	0.04				
pH	Unit	8.79	8.73	7.31	8.33	7.86	7.6	8.6	7.7	8.45	8.62	9.54	8.75	7.31-9.54	8.36	0.63				
Phosphate-P	mg/l	0.139	0.029	0.027	0.089	0.114	0.083	0.184	0.023	0.055	0.047	0.12	0.015	0.015-0.184	0.08	0.05				
Potassium	mg/l	2	2	1	1	1	1	BDL	BDL	2	1	2	BDL	BDL	1-2	1.50	0.53			
Sodium	mg/l	3	5	3	3	3	3	BDL	1	4	3.36	3.36	3	5	1-5	3.34	1.10			
Sulphate	mg/l	2.96	2.13	4.29	4.38	5.49	4.08	5.16	6.56	BDL	6.12	0.88	2.38	0.88-6.56	4.04	1.78				
Temperature	°C	32	34	30	33	31	30	26	22	26	26	30	34	30	22-34	29.83	3.59			
Total Alkalinity	mg/l	46	42	52	46	60	46	48	34	62	48	40	44	34-62	47.33	7.83				
Total Coliform	MPN/100ml	11000	3000	5000	7000	5000	33000	7000	6000	17000	3300	2600	3300	2600-33000	8600.00	8702.25				
Total Dissolved Solids(TDS)	mg/l	70	49	35	59	84	41	64	73	91	93	90	23	23-93	64.33	23.48				
Total Fixed Solids(TFS)	mg/l	4	30	20	160	10	12	26	54	18	6	38.73	46.92							
Total Hardness as CaCO <sub>3</sub>	mg/l	48	34	78	42	62	36	60	48	36	56	40	48	34-78	49.00	13.06				
Total Suspended Solids(TSS)	mg/l	48	22	24	38	52	20	84	28	26	94	22	20	20-94	39.83	25.42				
Turbidity	NTU	24.3	6.28	10.2	11.4	4.18	11.5	7.18	5.04	3.11	10.2	8.39	10.4	3.11-24.3	9.35	5.51				

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

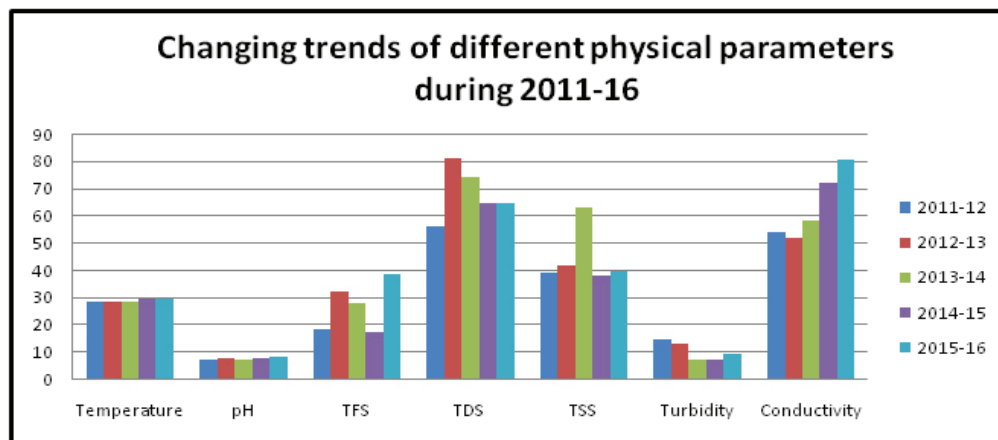
**Table 2: Correlation Matrix of Bio-Physico-Chemical Parameters of Sagardighi of Cooch Behar, West Bengal**

Parameters	BOD	Calcium	Chloride	COD	Conductivity	Dissolved O <sub>2</sub> (DO)	Fecal Coliform	Magnesium	Nitrate-N	pH	Phosphate-P	Potassium	Sodium	Sulphate	Temperature	Total Alkalinity	Total Coliform	Total Dissolved Solids(TDS)	Total Fixed Solids(TFS)	Total Hardness as CaCO <sub>3</sub>	Total Suspended Solids(TSS)	Turbidity	
BOD	1	-0.273	-0.142	0.148	-0.271	0.319	-0.212	-0.120	0.122	0.002	-0.075	-0.098	0.160	-0.082	-0.063	-0.318	-0.062	0.208	0.000	-0.273	0.151	0.136	
Calcium		1	0.340	-0.098	0.563	-0.049	-0.133	0.378	0.041	0.229	0.130	-0.023	0.043	0.172	0.029	0.748	-0.215	-0.247	0.029	0.883	-0.013	-0.087	
Chloride			1	-0.219	0.440	-0.042	-0.014	0.166	0.219	0.084	0.047	0.142	0.013	0.184	0.040	0.339	-0.028	-0.030	0.232	0.305	0.187	-0.002	
COD				1	0.069	0.025	-0.264	0.191	0.027	0.063	0.034	0.011	-0.152	0.009	0.031	-0.158	-0.264	-0.098	0.098	-0.009	0.120	0.647	
Conductivity					1	-0.178	-0.303	0.247	0.189	0.484	0.165	0.195	0.106	-0.054	0.259	0.686	-0.328	-0.056	0.121	0.527	0.038	0.028	
Dissolved O <sub>2</sub> (DO)						1	0.229	0.269	-0.012	0.133	-0.023	-0.036	0.251	0.092	-0.295	0.027	0.114	-0.008	0.075	0.071	-0.099	0.093	
Fecal Coliform							1	-0.024	0.252	-0.382	-0.128	-0.042	0.011	-0.017	0.097	-0.131	0.877	-0.067	-0.151	-0.091	-0.112	0.092	
Magnesium								1	0.142	0.171	0.057	0.057	-0.045	0.370	-0.057	0.448	-0.109	-0.161	0.151	0.698	0.060	0.277	
Nitrate-N									1	-0.015	0.028	0.051	0.392	-0.155	0.082	-0.004	0.112	-0.084	-0.073	0.081	0.322	0.167	
pH										1	0.019	0.297	0.157	0.057	0.107	0.404	-0.229	0.060	0.215	0.232	-0.035	-0.113	
Phosphate-P											1	0.067	-0.116	-0.010	0.088	0.143	-0.123	-0.137	-0.006	0.125	0.028	0.062	
Potassium												1	0.218	0.257	-0.197	0.053	0.166	0.348	0.127	0.048	0.011	0.043	
Sodium													1	-0.071	-0.062	0.128	-0.132	-0.025	-0.102	0.031	-0.132	-0.205	
Sulphate														1	0.006	0.146	-0.049	0.152	0.240	0.286	-0.085	0.001	
Temperature															1	0.017	0.090	0.127	-0.049	0.016	0.141	0.115	
Total Alkalinity																1	-0.215	-0.138	0.093	0.763	-0.143	-0.185	
Total Coliform																	1	0.164	-0.040	-0.198	-0.034	0.127	
Total Dissolved Solids(TDS)																		1	0.033	-0.232	0.060	-0.167	
Total Fixed Solids(TFS)																			1	0.087	0.030	0.060	
Total Hardness as CaCO <sub>3</sub>																				1	0.010	0.074	
Total Suspended Solids(TSS)																						1	0.104
Turbidity																							1.000

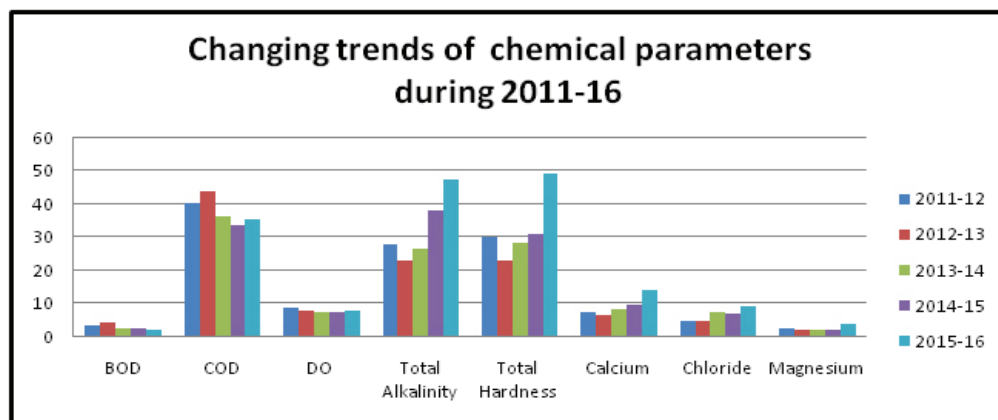
(Values are shown as r = coefficient correlation)

**CONCLUSION**

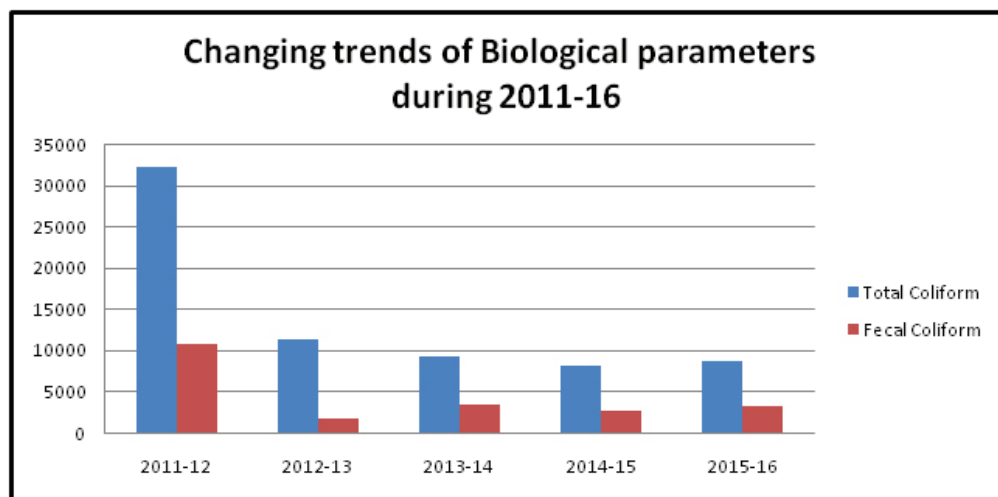
The bio-physico-chemical parameters of Sagardighi are within the tolerance limits except pH, COD, Turbidity, Total Coliform and Fecal Coliform. Among them, value of COD, Total Coliform and Fecal Coliform were always above permissible limit. Therefore, we generally say that the water quality of Sagardighi is moderately suitable for bathing and swimming as well as for the growth of aquatic fauna and flora. However, fluctuations in bio-physico-chemical parameters, if they continue, would result in imbalance in the ecosystem in long run. After detailed study of bio-physico-chemical data of Sagardighi for five years (2011-2016), it is revealed that water quality is comparatively in moderate condition but almost all the parameters are prone to cross their critical pollution level. Therefore an urgent effort must be taken to develop ecosystem-based management strategies with inputs from scientists, resource managers, policy makers, government and non-government organizations and environmentalist to save this heritage water-body.



**Figure 2: Changing Trends of Different Physical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)**



**Figure 3: Changing Trends of Different Chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)**



**Figure 4: Changing Trends of Different Biological Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)**

**Table 3: Changing Trends of Different Bio-Physio-chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)**

Parameters	Mean					Standard Deviation	
	Unit	2011-12	2012-13	2013-14	2014-15		2015-16
BOD	mg/l	3.42	4.42	2.85	2.48	2.28	0.860755
Calcium	mg/l	7.49	6.58	8.2	9.53	14.09	2.949876
Chloride	mg/l	4.78	4.79	7.48	7.11	9.37	1.951904
COD	mg/l	40.02	43.77	36.26	33.71	35.4	4.044251
Conductivity	µs/cm	53.79	51.75	58.33	72.15	80.34	12.42199
Dissolved O <sub>2</sub> (DO)	mg/l	8.73	8.03	7.43	7.49	7.9	0.522858
Fecal Coliform	MPN/100ml	10750	1750	3450	2625	3250	3630.238
Magnesium	mg/l	2.85	2.42	2.26	2.22	3.89	0.695895
Nitrate-N	mg/l	0.12	0.02	0.09	0.03	0.07	0.041593
pH	Unit	7.28	7.88	7.27	7.78	8.36	0.456815
Phosphate-P	mg/l	0.05	0.05	0.05	0.09	0.08	0.019494
Potassium	mg/l	1.08	1.4	1.11	1	1.5	0.218449
Sodium	mg/l	3.64	2.74	2.7	2.88	3.34	0.412068
Sulphate	mg/l	2.22	2.93	2.66	1.66	4.04	0.889112
Temperature	°C	28.58	28.58	28.75	29.67	29.83	0.616336
Total Alkalinity	mg/l	27.77	22.92	26.5	38.13	47.33	10.02211
Total Coliform	MPN/100ml	32141.67	11308.33	9166.67	8083.33	8600	10293.15
Total Dissolved Solids(TDS)	mg/l	56.25	80.92	74.17	64.58	64.33	9.594407

Total Fixed Solids(TFS)	mg/l	18.67	32.33	27.83	17.4	38.73	9.058688
Total Hardness as CaCO <sub>3</sub>	mg/l	29.94	23.13	28.33	31.03	49	9.82244
Total Suspended Solids(TSS)	mg/l	39	41.83	63.17	38	39.83	10.60562
Turbidity	NTU	14.79	13.16	7.44	7.42	9.35	3.377465

## FUTURE SCOPE

On the basis of our present observation and detailed data base of important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India, we feel that further time-series analysis of quality of water of this water body and a detailed study of these parameters should be conducted.

## REFERENCES

1. Ahmed KK, GC Halder and SB Saha (1993). *Limnological studies on Kaptai Lake. Final Report*. Fisheries Research Institute, Mymensingh, Bangladesh. pp. VII+36.
2. Akpan ER and Offem JO. (1993). "Seasonal variation in water quality of the Cross River, Nigeria". *Rev. Hydrobiol. Trop.* **26**: 95-103.
3. Bashar MA, SS Basak, KB Uddin, AKM Saiful Islam and Y Mahmud (2015). "Seasonal Variation of Zooplankton Population with Reference to Water Quality of Kaptai Lake, Bangladesh". *Bangladesh Research Publications Journal*, **11**: 127-133.
4. Brett JR (1979). *Environmental factors and Growth*. In: W.S. Hoar, D.J. Randall and J.R. Brett (Eds.). *Fish Physiology, Environmental relations and behavior*, New York: Academic Press, pp.599-677.
5. Gopalkrushna, M.H. (2011). "Determination of Physico-Chemical parameters of Surface Water Samples in and around Akot City", *International Journal of Research in Chemistry and Environment*, Vol.1(2): 183-187.
6. Hall A, Valente IMC *et al.* (1977). "The Zambezi River in Mozambique: The physico-chemical Status of the Middle and Lower Zambezi prior to the closure of the Cubora Bassa Dam". *Freshwater Biology*, **7**: 187-206.
7. Hussainy SV (1967). "Studies on the limnology and primary production of a tropical lake". *Hydrobiology*, **30**: 335-352.
8. Jhingran AG (1989). *Reservoir Fisheries Management in India. Central Inland Capture*. Fisheries Research Institute, Barrackpore, West Bengal, India. Bulletin No. **45**: 65 pp.
9. Kabir AKMN and Naser MN (2011). "Physico-chemical aspects of Chandbill Oxbow Lake of Meherpur, Bangladesh. Dhaka Univ", *Journal of Biological Science*, **20**: 31-39.

10. Ramachandra, T.V.; SubashChandran, M.D.; Joshi, N.V.; Rajinikanth, R. and Kumar Raushan. (2012). Sahyadri Conservation Series 4, *Environmental Information System (ENVIS) Technical Report: 21*, India.
11. Rani R; Gupta BK; and Srivastava, KBL (2004). "Studies on water quality assessment in Satna city (M.P): Seasonal Parametric Variations", *Nature, Environment and Pollution Technology 3*: 563-565.
12. Reddi, K.R.; Jayaraju, N.; Suriyakumar, I and Sreenivas, K. (1993). "Tidal fluctuation in relation to certain physico-chemical parameters in Swarnamukhi River Estuary, East Coast of India". *Ind. J. Mar. Sci. 22*: 223-234
13. Sarma, D. and A. Dutta (2012). "Ecological Studies of two riverine wetlands of Goalpara District of Assam, India", *Nature, Environment and Pollution Technology, 11*(2): 297-302
14. Swarup, K and SR Singh(1979). "Limnological Studies of Suraha Lake (Ballia) I. Variations in the water quality". *Journal of Inland Fisheries and Sociology, 11*: 22-23.
15. Swingle, H.S. (1969). *Methods of analysis for waters, organic matter and pond bottom soils used in Fisheries Research*. Auburn University, Auburn, Alabama. pp. 119.
16. Thirupathaiah, M and Ch. S Sammaiah (2012). "Analysis of water quality using physico-chemical parameters in Lower Manair reservoir of Karimnagar district, Andhra Pradesh". *International Journal of Environmental Science, 3*: 172-175.
17. Upadhyay, K.; Mishra, P. and Gupta, A.K. (2010). "Studies on the physico-chemical status of two ponds at Varanasi and Bhadohi under biotic stress", *Plant Arch. 10*(2): 691-693.
18. Wood, A. (1995). "Constructed wetland in water pollution control fundamental to their understanding", *Water Science and Technology, 32*: 21-29.
19. Wurts, WA and RM Durborow (1992). *Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds*. Southern Regional Aquaculture Center, Publication No. 464.
20. Yadava, Y.S.(1987). *Studies on the Limnology and Productivity of an Oxbow Lake in Dhubri District of Assam (India)*. Ph.D. Thesis, Gauhati University, Assam.