IJASRM

International Journal of Advanced Scientific Research and Management, Volume 4 Issue 1, Jan 2019

www.ijasrm.com

ISSN 2455-6378

Limnological Features of Purna River in Akola district, Maharashtra, India

Dilip Meshram, Prashant Deshmukh, G. K. Khadse and Pawan Labhasetwar

CSIR-National Environmental Engineering Research Institute (NEERI),
Nehru Marg, Nagpur- 440 020, India.

Abstract

The present investigation was carried out in order to determine the water quality of Purna River in terms of physicochemical properties and plankton biodiversity. Water samples were collected from seven different sampling locations and analyzed for physico-chemical and biological parameters. Water has sane levels of dissolved oxygen, pH, conductivity, and total dissolved solids. The river water was alkaline in nature. Higher values of electrical conductivity, total dissolved solids, chloride, sodium and potassium were attributed to the saline tract of river catchment. Hardness, nitrate, and fluoride were found within the desirable limits of Indian standards. The chemical oxygen demand and biochemical oxygen demand values were attributed to the pollution in catchment area. The moderate phytoplankton and zooplankton density were attributed to water current and turbidity of river water. Shannon - Wiener Diversity Index values indicated medium to good levels of plankton biodiversity.

Keywords*: TDS, COD, BOD, Phytoplankton, Zooplankton.*

1. Introduction

Rivers play an important role in supplying water for drinking, human developments including agriculture and transportation. Evaluation of pollution loads is important for river water quality management. Physical, chemical and biological characteristics determine the water quality. Therefore it must be evaluated for intended use of river water (Khadse et al. 2008). Water is getting polluted due to urbanization, industrialization, modernization of agriculture. Hence accurate water quality monitoring and generation of water quality information is required for proper management of water resources. Inadequate management of water systems can affect the water availability and quality (Krishnan et al. 2007; Durmishi et al. 2014).

During bio-monitoring, the species composition of planktons reflects water quality and pollution level in an aquatic ecosystem (Mengzhen et al. 2014). Most of the planktons are cosmopolitan and their distribution mainly depends on physicochemical as well as climatic conditions (Joshi 2011). Phytoplankton are tiny organisms, autotrophic primary producers playing key roles in fisheries as first level organisms in food chain for all aquatic animals both in lotic and lentic water ecosystems. The assessment of water quality based on density and diversity of phytoplankton as biological indicators has been made by many researchers (Chaturvedi et al. 1999; Tiwari and Chauhan 2006).

Zooplanktons are microscopic tiny animals that eat other plankton. They form an important link between autotrophs and heterotrophs of food web in freshwater ecosystem. They represent the food source to higher organisms in trophic levels. Zooplankton are sensitive to environmental changes and used as good indicators of water quality and influencing food chains, food webs, energy flow in an aquatic ecosystem (Dadhick and Sexena 1999; Sinha and Islam 2002). They constitute the major groups like protozoa, rotifera, cladocera, and copepoda in relation to their abundance. Distribution of zooplankton community depends on various factors including change of climatic conditions, physical and chemical parameters etc.

Small rivers play an important role for forming the water resource in river basins. In India, the water quality and biodiversity of large rivers are studied mostly. Hydrobiology and limnology of small rivers are rarely studied in recent years. Therefore more attention is required to study the small rivers with respect to qualitative, quantitative and biotic status of water quality (Sharapova 2010). Purna River in Akola district of Maharashtra state, India is important for different aspects such as source of drinking water, irrigation and wild life purposes. The present study has been conducted for exploration of physico-chemical characteristics and

plankton biodiversity since no attempts have been noticed on the limnological aspects of this river.

2. Materials and methods

2.1 Study area

The study area comprised of part of Amravati and Akola districts through which Purna river and its tributaries flow (Figure 1). The detail descriptions of sample locations are presented in table 1. The Purna river water quality gets deteriorated after it receives water from Pedhi (Amba nalla) i.e. wastewater from Amravati city and people from Akola district are more dependent on this water for their domestic uses. Therefore more emphasis is given on water quality in Akola district. River Purna is having its source in the Gawilgarh hills in 21° 36' N and 77° 36' E near Bhainsdehi in the Betul district of the Madhya Pradesh. In Maharashtra state it flows through Amravati, Akola, Buldana and Jalgaon districts meets the Tapti River in Khandesh. Purna River has several tributaries out of which Pedhi river and Amba nalla falls in study area.

Figure 1 Study area showing the sampling locations in Purna River (source: Google earth)

Table 1 Details of sampling locations in Purna River

Sampling location	Latitude (N)	Longitude (E)	Altitude (m)	Description
PR-1	20˚52'37.9"	76˚59'15.6"	296	Intake water from Purna river near Keliveli village
PR-2	20˚50'52.1"	77˚02'21.7"	261	Purna River, 2 km from Keliveli village
PR-3	20˚52'10.5"	77˚09'41.5"	280	Purna River near Katyar village
PR-4	20˚51'20.38"	77˚27'36.42"	273	Pedhi River near Kolsara village
PR-5	20˚59'09.0"	77˚41'44.7"	365	Pedhi river, near Kamunja (before confluence with Amba nallah)

2.2 Sampling and analysis

River water samples were collected for physicochemical and biological analyses from the seven selected locations during May, 2014 as per the standard method (APHA 2012).The water samples for phytoplankton were collected using sterilized 100 mL polythene bottles and immediately preserved by adding Lugols iodine solution. The zooplankton samples were collected by filtering 40 L surface water through plankton net made of bolting silk cloth of no. 25 with pore size of approximately 64 µm and preserved by adding 5% formalin solution. The estimation of dissolved oxygen and pH were carried out onsite. The remaining physicochemical parameters were analysed in laboratory as per the standard methods (APHA 2012). Identification and enumeration of phytoplankton and zooplankton were carried out by freshwater plankton keys (Prescott 1973; Pennak 1978; Edmondson 1992; Ward and Whipple 1992; Kadiri 1993; Kemdirim 2001; APHA 2012). The Shannon-Wiener diversity index (SWI) was calculated for plankton diversity (Shannon and Weaver 1949). Palmer's Pollution Index (PPI) was calculated by assigning the index factor 1 through 5 to most pollution tolerant algae and index numbers then added (Person 1989; Palmer 1969).

3. Results

The data on the physico-chemical characteristics are presented in Table 2. The pH value in the studied river stretch varied from 8.4 to 8.7. The EC values varied between 1647 and 1883 µS/cm. The TDS values varied from 988 to 1130 mg/L. Turbidity of river water was ranged from 1.6 to 15.2 NTU. The alkalinity of water samples was ranged from 296 to 472 mg/L. The average value of alkalinity with standard deviation was 364.8±75 mg/L. The total hardness varied from 316 to 372 mg/L. The average chloride content was 316.6±62mg/L. Sodium and potassium ranged between 334 to 372 mg/L and 8.6 to 9.5 mg/L respectively. The nitrate values of the samples were ranged between 5 to 14 mg/L. The average value of nitrate was 9.6±3.8mg/L. Sulphate in water ranged from 88 to 107 mg/L. Phosphate concentration was recorded between 0.12 to 1.84 mg/L. Fluoride content was recorded between 0.12 to 0.22 mg/L. In all the water samples, Chemical Oxygen Demand (COD) ranged from 16 to 48 mg/L. The average value of COD with standard deviation was 32.8±11.8 mg/L. Biological oxygen demand (BOD) of water was recorded between 8 and 28 mg/L. During the study DO was observed maximum at all locations.

IJASRM

International Journal of Advanced Scientific Research and Management, Volume 4 Issue 1, Jan 2019

www.ijasrm.com

ISSN 2455-6378

Table 2 Physicochemical Water Quality in Purna River

Parameters	Units	Quantitative data				CPCB Standard Irrigation Class E	BIS 10500-1991 Standards for Drinking (Desirable Limit)
		Min.	Max.	Average	SD		
pH	-	8.4	8.7	8.5	±0.1	6.5 – 8.5	6.5 – 8.5
Conductivity	µS/cm	1647	1883	1761	±106	2250	-
Total Dissolved Solids	mg/L	988	1130	1056.6	±63.3	2100	500
Turbidity	NTU	1.6	15.2	5.38	±5.6	-	5
Total Alkalinity as $CaCO_3$	mg/L	296	472	364.8	±75	-	200
Total Hardness as $CaCO_3$	mg/L	316	372	340	±22.8	-	300
Calcium as Ca^{2+}	mg/L	30	52	36.2	±9	-	75
Magnesium as Mg^{2+}	mg/L	52	69	60.4	±6.7	-	-
Chloride as Cl^-	mg/L	240	395	316.6	±62	600	250
Sodium as Na^+	mg/L	334	372	355.2	±16.5	-	-
Potassium as K^+	mg/L	8.6	9.5	9.1	±0.4	-	-
Nitrate as NO_3^-	mg/L	5	14	9.6	±3.8	-	45
Sulphate as SO^-_4	mg/L	88	107	95.2	±7.8	1000	200
Phosphate as PO_4^-	mg/L	0.12	1.84	0.632	±0.7	-	-
Fluoride as F^-	mg/L	0.12	0.22	0.156	±0.04	-	-
COD as O_2	mg/L	16	48	32.8	±11.8	-	Nil
BOD	mg/L	8	28	18	±8	-	-
DO	mg/L	6.6	11.7	9.3	±2.3	-	-

Density, species composition and Shannon Wiener Index of phytoplankton and zooplankton is documented in Table 3 through 6. Phytoplankton counts observed in Purna River water are presented in Table 3. The density of phytoplankton ranged from 952/ mL to 1568/ mL. In general 3 groups comprising 20 genera of phytoplankton were observed in water samples (Table 3 & 5). Chlorophyceae, cyanophyceae and bacillariophyceae were represented by 12, 3 and 5 genera respectively. Shannon-Wiener Diversity Index (SWI) for phytoplankton diversity varied from 3.42 to 3.66. The Palmer Pollution Index (PPI) values ranged between 7 and 18 **(**Table 3**).**

Table 3 Density, diversity indices and community composition of phytoplankton in Purna River

Variables	Quantitative data			
	Min.	Max.	Average	SD
Density (org./mL)	952	1568	1149	±258
SWI	3.42	3.66	3.50	±0.1
PPI	7	18	11	±4.5
Community composition (%)				
Chlorophyceae	38	67	53	±11.7
Cyanophyceae	19	27	23	±3.8
Bacillariophyceae	14	36	24	±10.7

Table 4 Density, diversity indices and community composition of zooplankton in Purna River

Variables	Quantitative data			
	Min.	Max.	Average	SD
Density (org./m^3)	2667	15133	8227	±5958
SWI	2.27	2.95	2.63	±0.2
Community composition (%)				
Protozoa	3	23	10	±9.2
Rotifera	47	73	64	±10.9
Cladocera	0	7	3	±3.5
Copepoda	17	30	23	±5.4

Zooplankton counts observed in from Purna River water are shown in Table 4. Density of zooplankton during study period varied between 2667/ m^3 and 15133/ m^3. In the present study a total 4 groups (protozoa, rotifera, copepoda and cladocera) comprising 11 genera were identified (Table 6). The

SWI values for zooplankton diversity were ranged from 2.27 to 2.95 (Table 4).

4. Discussion

The pH of water is a measure of hydrogen ion activity in water. It indicates nature of water such as acidic, neutral or alkaline. The pH of 6.5 to 8.5 considered as ideal for aquatic ecosystem as per the guidelines of WHO and Indian Standards. In the present study average pH with standard deviation was 8.5±0.1. The average value of Electrical conductivity (EC) with standard deviation was 1761±106 µS/cm. EC value depends on the amount of dissolved solids, which determines the amount of dissolved material in the water. Generally EC has lower values in unpolluted waters than polluted water. The higher values of conductivity may be due to mixing of industrial effluents, dissolution of wastewater from sewage, fertilizers and soil erosion etc.

The total dissolved solid (TDS) consists of carbonate, bicarbonate, sulphate, nitrates, chloride, and other substances. The average TDS value with was 1056.6±63.3 mg/L. The quantity of suspended material in water is measured in terms of turbidity. The consumption of highly turbid water may cause health risks as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants. The average turbidity with standard deviation was 5.38±5.6 NTU. The higher turbidity may be due to mixing of industrial wastes or suspended particles in water. The principle source of alkalinity is dissolved carbon dioxide in natural waters. The average value of alkalinity was 364.8±75 mg/L.

Table 5 Phytoplankton genera and their occurrence in Purna River

Genera	Sampling location				
	PR-1	PR-2	PR-3	PR-4	PR-5
Chlorophyceae					
Ankistrodesmus sp.	+	+	+	+	+
Chlamydomonas sp.	-	+	-	+	+
Chlorella sp.	+	-	+	+	+
Chlorococcum sp.	-	-	-	+	-
Coelastrum sp.	+	+	+	+	+
Cosmarium sp.	-	+	-	-	-
Crucigenia sp.	+	-	-	-	-
Gloeocystis sp.	+	+	+	-	+
Pediastrum sp.	+	+	+	-	+
Scenedesmus sp.	+	+	-	-	-
Schroederia sp.	+	-	-	-	-
Staurastrum sp.	-	-	-	-	+
Cyanophyceae					
Merismopedia sp.	+	+	+	+	+
Microcystis sp.	+	+	+	+	+
Oscillotoria sp.	+	-	-	-	+
Bacillariophyceae					
Achnanthes sp.	+	-	+	+	+
Cymbella sp.	-	-	-	+	-
Fragilaria sp.	-	+	+	-	-
Navicula sp.	+	-	+	+	+
Staroneis sp.	-	+	+	+	-

+: Presence of genera concerned -: Absence of genera concerned

IJASRM

International Journal of Advanced Scientific Research and Management, Volume 4 Issue 1, Jan 2019

www.ijasrm.com

ISSN 2455-6378

Table 6 Zooplankton genera and their occurrence in Purna River

Genera	Sampling location				
	PR-1	PR-2	PR-3	PR-4	PR-5
Protozoa					
Arcella sp.	+	+	+	+	+
Rotifera					
Asplanchna sp.	+	+	+	+	+
Brachionus sp.	+	+	+	+	+
Filinia sp.	+	+	-	-	+
Keratella sp.	-	-	+	-	-
Notholca sp.	+	+	-	-	-
Trichocerca sp.	+	+	-	-	+
Cladocera					
Moina sp.	+	+	-	-	+
Copepoda					
Cyclops sp.	+	+	+	+	+
Diaptomus sp.	+	-	-	-	+
Nauplius larva	+	+	+	+	-

+: Presence of genera concerned -: Absence of genera concerned

The total hardness was 340±22.8 mg/L. This may be due to calcium and magnesium ions as carbonates, bicarbonates, chlorides and sulphates. Calcium and magnesium content in water ranged between 30–52 and 52–69 mg/L, respectively. The calcium concentration is found to be lower than magnesium concentration in all the samples. Naturally chloride ions are found in surface and ground waters. High concentrations of chloride in freshwater affects water quality and aquatic environments. Chloride rich effluent of sewage and municipal wastes can be responsible for high chloride content in water. The chloride content is well within the desirable limits and varying from 240 to 395 mg/L. The high content of sodium and potassium may be due to enriched sewage content. Sodium is the major cation in all the rivers which can be attributed to the type of soil forming materials in catchment (Khadse et al. 2008). The nitrates in water are found mainly due to human and animal wastes, industrial effluents, fertilizers, chemicals, and silage through drainage system. The average value with standard deviation was 95.2±7.8 mg/L which is within the standard limits of BIS and WHO. The water became unsuitable for bathing when phosphate is increased in water because it is responsible for algal growth. The major sources of phosphate include domestic sewage, detergents, agricultural effluents, fertilizers and industrial waste water. COD is the amount of oxygen required to carry out oxidation of organic waste by using strong oxidizing agent (Durmishi et al. 2014). COD measure the amount of organic and oxidisable inorganic compounds in water. Higher COD may be due to chemical pollution load, fertilizers, domestic and industrial wastes. The average BOD value with standard deviation was 18±8mg/L indicating microbial pollution in water. This may be related to wastewater from Amravati city flowing through Amba nalla. Anthropogenic activities specially domestic, industrial and agricultural discharges, also may be responsible for deterioration of Purna river water quality and its tributaries. Therefore the water is not suitable for drinking water supply. Dissolved oxygen (DO) concentration is indicator of water pollution and is important for survival of fishes and other aquatic animals. The average DO values were maximum at all locations promoting the planktonic growth in river water.

The phytoplankton diversity was maximum at sampling location PR-5 and minimum at sampling location PR-3. The members of chlorophyceae, cyanophyceae and bacillariophyceae were most common. The group chlorophyceae was represented by 12 genera viz. *Ankistrodesmus*, *Coelastrum*, *Chlorella*, *Scenedesmus*, *Chlamydomonas*, *Cosmarium*, *Chlorococcum*, *Crucigenia*, *Gloeocystis*, *Schroederia*, *Pediastrum* and *Staurastrum*. Cyanophyceae was represented by 3 genera viz. *Merismopedia*, *Microcystis* and *Oscillotoria*. The group bacillariophyceae was represented by 5 genera viz. *Achnanthes*, *Cymbella*, *Fragilaria*, *Navicula* and *Staroneis*. Phytoplankton size and morphology determine the ecosystem variability in different environmental conditions (Aktan et al. 2009). Most of the limnological studies of lakes and rivers are based on appropriate biological monitoring, physico-chemical and hydrological characteristics (Akindele and Adeniyi 2013). Water temperature and nutrients are key factors for increasing the phytoplankton abundance and diversity (Nowrouzi and Valavi 2011). High species diversity, richness and moderate to high

individual counts are characteristics of undisturbed environments. Generally a large value of Shannon-Wiener Diversity Index represents the high species diversity. Shannon-Wiener Diversity Index (SWI) varied from 3.42 to 3.66 (Table 3) indicates good level of phytoplankton diversity. According to Palmer (1969), a total score of 20 or more in a sample is an indicator of organic pollution. The PPI values ranged between 7 and 18 indicates less evidence of organic pollution (Table 3).

Among the zooplankton, protozoa and cladocera comprise of single species, rotifera 6 species and copepoda 2 species with single larval Nauplius stage. The zooplankton density was maximum at sampling location PR-5 and minimum at PR-3. The average community composition of zooplankton in was protozoa (10%), rotifera (64%), cladocera (3%) and copepoda (23%). Among the zooplankton, rotifera was the most dominant group followed by copepoda with respect to community composition. *Asplanchna sp. Brachionus sp., Filinia sp.* and *Trichocerca sp.* were most common rotifers. *Keratella sp.* and *Notholca sp.* were observed with less count. All these rotifer genera are widely distributed in the world (Segers 2007; Ozge et al. 2010). Copepoda was the second dominant group with respect to community composition. The major constituents of this group were *Cyclops, Diaptomus* and Nauplius stages. *Cyclops* and Nauplius stages were most common while *Diaptomus* was observed with less count (Tables 4 & 6). The abundance of copepods may be related to water quantity, water movement, food availability, suitable environmental conditions for their growth and development. They found in almost all water bodies and play an important role in ecological pyramids serving as food for fishes (Patel et al. 2013). Protozoa and cladocera were very rarely present which are represented by single genera viz. *Arcella* and *Moina* respectively. Protozoa was most common in all sampling locations and cladocera was common in few locations only (Tables 4&6). Zooplankton play principal role in aquatic food chain for recycling and nutrients transfer from primary producers to secondary consumers. Therefore their quality and diversity are useful for assessing the health status of an aquatic ecosystem and used as bio-indicators. The zooplankton biodiversity and distribution mainly depends on physico-chemical properties of water in an aquatic ecosystem. Zooplanktons of all major groups were observed. The summer population maxima of zooplankton may be due to higher temperatures, lower transparency, and a high standing crop of primary producers (phytoplankton) leading to greater availability of food. During summer presence of good levels of DO and hard water favoured the production of zooplanktons (Joshi et al. 1996a, b). Increases in zooplankton population summer might also be due to high photosynthetic activities in aquatic ecosystem.

Generally Shannon Wiener Index (SWI) values between 1 and 3 are believed to indicate semi productivity of the water body, while the values above 3 are considered to represent lowest or minimum impact of pollution or adverse factors. SWI is directly related to the number, uniform distribution and total abundance of species in a sample. Large value of Shannon-Wiener Diversity Index reflects the high species diversity. In the present study, the average value of SWI with standard deviation was 2.63±0.2 indicated moderate to good levels of zooplankton diversity (Table 4). This may be related to more favourable climatic conditions such as moderate water temperature, water quality, optimum productiveness and abundance of food organisms in the river water.

5. Conclusions

Study revealed that the physicochemical parameters of Purna River were found within the limits for irrigation water quality standards. BOD and COD were exceeding the limits of drinking water standards indicating microbial pollution in water. Therefore the water is not suitable for drinking water supply directly however it is suggested that the river water is useful for drinking purpose only after proper conventional treatments. An average value of Shannon-Wiener Diversity Index (SWI) for both phytoplankton and zooplankton indicated moderate to good level of diversity of plankton. The phytoplankton and zooplankton densities were in moderate levels. This study also showed that the average value of Palmer's Pollution Index (PPI) was 11 indicated less evidence of organic pollution. Thus the river water can be useful for domestic use and irrigation purposes. The data from this study can be used as a baseline for future conservation and management plan of river water quality.

Acknowledgements

Authors thank to the Director, CSIR- National Environmental Engineering Research Institute (NEERI), Nagpur 440 020, India for his valuable guidance. We gratefully acknowledge support from the staffs in Water Technology and Management Division (WTMD), CSIR-NEERI, Nagpur.

References

[1] Akindele EO and Adeniyi IF, A study of the physico-chemical water quality, hydrology and zooplankton fauna of Opa Reservoir catchment area, Ile-Ife, Nigeria. African Journal of Environmental Science and Technology, 7: 192-203, (2013).

[2] Aktan Y, Gurevin C and Dorak Z, The effect of environmental factors on the growth and size structure of two dominant phytoplankton species in Buyukcekmece reservoir (Istanbul, Turkey). Turk J Biol, 33:335-340, (2009).
[3] APHA Standard method for the examination of water and waste-water. 22nd Edn, APHA, Washington DC, USA, (2012).
[4] BIS, Drinking water standards of BIS (IS: 10500), Bureau of Indian Standards, New Delhi, (1991).
[5] CPCB, Guidelines for water quality monitoring, Central Pollution Control Board, Delhi, (2007).
[6] Chaturvedi RK, Sharma KP, Sharma K, Bharadwaj SM and Sharma S, Plankton community of polluted water around Sanganer, Jaipur. Jour of Environ and Pollu, 6: 77-84, (1999).
[7] Dadhick N and Saxena MM, Zooplankton as indicators of trophical status of some desert waters near Bikaner. J Environ Pollut, 6: 251-254, (1999).
[8] Durmishi BH, Arianit RA, Murtezan I and Shabani A, Physico-Chemical Quality of Drinking Water in the Autumn Season of Tetova City, Macedonia. Universal Journal of Environmental Research and Technology, 3: 407-414 (2014).
[9] Edmondson WT, Freshwater biology, 2nd Edn, John Wiley & Sons, New York, U.S.A, (1992).
[10] Joshi BD, Bisht RCS and Joshi N, Planktonic population in relation to certain physico-chemical features of Ganga canal at Jwalapur (Hardwar). Him J Environ Zool, 10: 75-77, (1996a).
[11] Joshi BD, Bisht RCS, Joshi N and Singh R A, study of planktonic and benthic components of three selected tributaries of River Ganga between Devprayag and Rishikesh. Him J Environ Zool, 10: 23-26, (1996b).
[12] Joshi PS, Studies on zooplanktons of Rajura Lake of Buldhana district, Maharashtra India. Science Research Reporter, 1: 132 -137, (2011).
[13] Kadiri MO, Seasonal changes in the phytoplankton biomass of a shallow tropical reservoir. Nig J Bot, 6: 167 – 175, (1993).
[14] Kemdirim EC, Checklist of phytoplankton of Shedam reservoir in Plateau State, Nigeria. J Aqua Sci, 16: 61-63, (2001).
[15] Khadse GK, Patni PM, Kelkar PS and Devotta S, Qualitative evaluation of Kanhan river and its tributaries flowing over central Indian plateau. Environ Monit Assess, 147:83–92, (2008).
[16] Krishnan RR, Dharmaraj K and Kumari BDR, A comparative study on the physicochemical and bacterial analysis of drinking, borewell and sewage water in the three different places of Sivakasi. J En Biol, 28: 105-108, (2007).
[17] Mengzhen XW, Zhaoyin DX and Baozhu P, Effects of pollution on macro invertebrates and water quality bio-assessment. Hydrobiologia, 729: 247–259, (2014).
[18] Nowrouzi S and Valavi H, Effect of environmental factors on phytoplankton abundance and diversity in Kafter lake. J Fish Aquat Sci, 6: 130-140, (2011).
[19] Palmer C, A composite rating of algae tolerating organic pollution. Journal of Phycology, 5: 78-82, (1969).
[20] Person JL, Use of algae to determine water quality. Environmental science investigations, 131, (1989).
[21] Pennak RW, Freshwater invertebrates of United States, 2nd Edn, John Willey Sons Inc., New York, (1978).
[22] Prescott GW, The Fresh Water Algae, Brown Company Publishers, Dubuque, Iowa, (1973).
[23] Shannon CE and Weaver W, The mathematical theory of communication, University of Illinois Press, Urbana, (1949).
[24] Sharapova TA, Spatial Structure of Zooperiphyton in a Small River (West Siberia). Inland Water Biology, 3: 149–154, (2010).
[25] Sinha B and Islam MR, Seasonal variation in zooplankton population of two lentic bodies and Assam State Zoo cum Botanical garden, Guwahati, Assam. Eco Environ Cons, 8: 273-278, (2002).
[26] Tiwari A and Chauhan SVS, Seasonal phytoplanktonic diversity of Kitham lake, Agra. Journal of Environ Biology, 27: 35-38, (2006).
[27] Ward HB and Whipple GC, Freshwater Biology, John Wiley and Sons, USA, (1992).