PHYKOS
Phycological Society, India

Assesment of the response of planktonic population tabiotic factors in tropical ponds using Factor analysis

M .S. Ragi*, D. S. Jaya, Sheela A.M.[1]

Department of Environmental Sciences, University of Kerala, Kariavattom Campus P.O. Thiruvananthapuram, Kerala, India. PIN-695 581.
[1] Environmental Engineer, Kerala State Pollution Control Board, sheelaamoses@gmail.com
***Corresponding author:** ragims369@gmail.com, +91 9846017369

Abstract

The study was conducted to assess the association of different species of chlorophyceae, cyanophyceae and bacillariophyceae, and zoo plankton namely protozoa, rotifera, cladocera, copepod and ostracoda with water quality characteristics. High level of organic content existed in all three ponds. Alkalinity, organic matter, calcium, magnesium, potassium, phosphate, chloride and sulphate content were high in Urban low land pond. The high level of sodium and silicate content can be found in rural high land pond indicating the pollution due to cloth washing. The study revealed that decomposed products of organic waste are mainly responsible for the replacement of chlorophyceae with cyanophyceae. The prominent factors responsible for the degradation of planktons both phytoplankton and zooplankton have been identified. The association of different factors with different species of phytoplankton has also been delineated. This helps the entrepreneurs to envisage control measures for the protection of these sensitive organisms.

Key Words: Planktonic population, tropical ponds, abiotic factors, Factor analysis, chlorophyceae, cyanophyceae, bacillariophyceae, zooplankton.

Response of plankton to abiotic factors

1. Introduction

Water quality is principally influenced by the natural and anthropogenic processes, particularly in the urban areas and from agricultural farms in the rural areas (Ayeni *et al*., 2011). The biodiversity of marine organisms is at risk due to direct anthropogenic activities like population, fishing, habitat alteration, and introduction of exotic species and indirect effects as global climate change (Flori, 2012). Pollution effects on algae may either inhibit or stimulate growth. Planktons are important part of aquatic life and a good indicator of changes in water quality because they are strongly affected by environmental conditions and respond quickly to changes in environmental quality (Kumar et al., 2012). Phytoplanktons are very sensitive to slight changes in environmental conditions of their habitat (Pamler, 1959). It is located at the base level of energy transfer and hence provides more accurate information on changing habitat characteristics when compared to other aquatic lives (McCormick and Cairns, 1994. Phytoplankton observation has been used as a reliable tool for biomonintoring of pollution in any aquatic bodies (Mathivanan et al., 2007).

Zooplankton occupies a vital role in the trophic structure of an aquatic ecosystem and plays a key role in the energy transfer (Kumar et al., 2012). Thus, planktons are important part of aquatic life and are good indicators of changes in water quality, as they respond quickly both in species composition and densities to a wide range of water conditions due to changes in water quality. Bio monitoring has become an important part of water quality monitoring and pollution in many studies. In the presence of excess nutrients, namely, nitrogen and phosphorus, algae are capable of rapid growth and multiplication, leading to the population shift and the dominance of algal bloom (Kumar and Sahu, 2012). There are many studies on the variation of biodiversity and water chemistry of different water bodies (Verma et al., 2014; Manley et al., 1994; Ifabiyi, 1997; Mazlum *et al*., 1999; Simeonov et al., 2003; Lambrakis et al., 2004; Jaji *et al*., 2007).

The monitoring of water quality and planktons generates voluminous data and application of multivariate statistical techniques facilitates the interpretation of complex data matrices to conceive the know-how to increase the water quality and ecological status of fresh water system (Sheela et al., 2012). It also allows for the identification of possible factors influencing water systems as well as being a valuable tool for facilitating the reliable management of water resources. Hence, the present study is aimed to assess the plankton diversity (phytoplankton and zooplankton) and physico-chemical characteristics of three ponds in a tropical region using multivariate analysis. The possible factors that influence the biodiversity in different ponds have also been identified.

2. Materials and Methods

2.1 Study area

In Thiruvananthapuram district of Kerala state in South India, there are many ponds. Of which three ponds were selected based on its characteristics. The first pond (P1) is located is an urban low land, pond and is a temple pond; the second pond (P2) is a rural lowland pond and the third pond is a rural high land pond. The location map showing the study area and three ponds is shown in Fig.1.

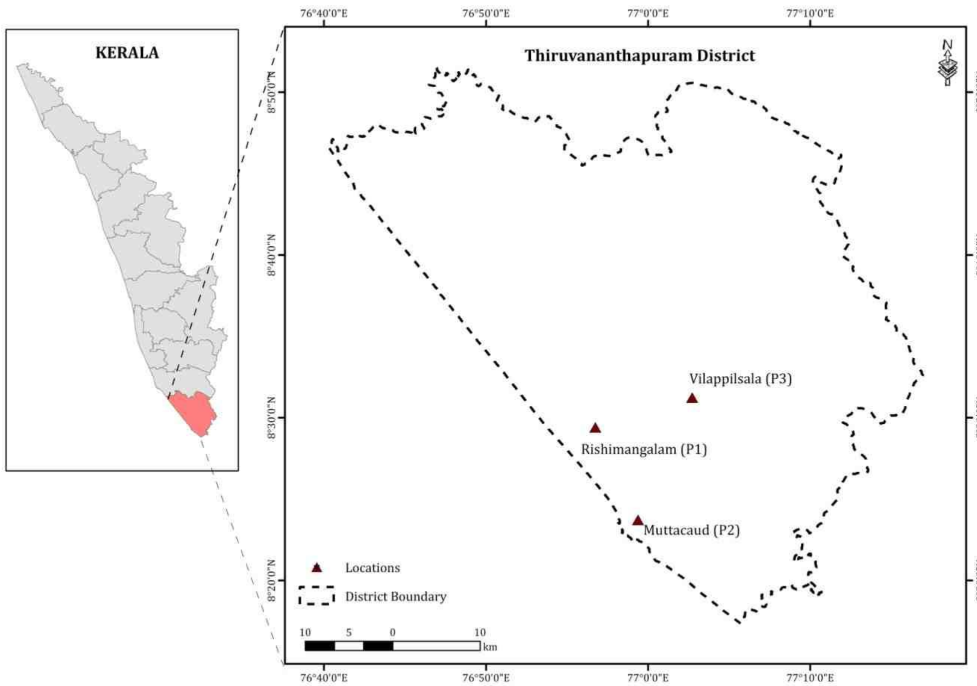

Fig.1 Location Map of selected Ponds in Study area.

Pond 1 is situated near Rishimangalam temple and two public ponds, one situated in Muttacaud (Pond 2) and the other in Vilappilsala (Pond 3).

Pond 1 is located in 8^{0} 29′ 25″N latitude and 76^{0}56′ 45″E longitude, 1.5 km away from Thiruvananthapuram Central Railway station, and in the premises of the Rishimangalam temple (lowland urban pond) with an area of 1100 m^2 and average depth of 200 cm. This pond is located in the midst of Thiruvananthapuram city. This pond is used for bathing and cloth washing. The waste water from nearby hospitals and residences drain into this pond.

Pond 2 is located at 8^{0} 23′44″N latitude and 76^{0}59′ 23″E longitude, 13 km away from Thiruvananthapuram Central Railway station, i.e. in Muttacaud, (lowland rural pond) and with an area of 1400 m^2 and average depth of 225 cm. The residents in the surrounding area use the pond water for irrigation, bathing and other domestic purposes.

Pond 3 is located in 8^{0}31′15″N latitude and 77^{0}02′ 43″E longitude, 19 km away from the Thiruvananthapuram Central Railway station in Vilappil (highland rural pond), covering an area of 1300 m^2 and average depth of 225 cm. This pond is extensively used for irrigation, washing clothes, bathing and for cattle wash.

The climate of Kerala in particular is dominated by the monsoon circulation. Hence samples were collected in the post-monsoon, pre-monsoon, and monsoon seasons from December 2006 to November 2008. The study area enjoys a humid tropical climate with an average annual rainfall of 1823.7 mm, relative humidity of 76.2%, and a temperature of 27.50oC during 2008 as per the records of Indian Meteorological Department.

2.1 Methodology

Water samples from the selected ponds were collected during the post-monsoon, monsoon and pre-monsoon seasons, from December 2006 to 2008. Sampling was done between 6.00 am and 9.00 am. Water samples were collected (1 - 1.5 m depth) in clean plastic bottles for the analysis of physico-chemical parameters. The determination of temperature, pH, dissolved oxygen, colour, conductivity, total dissolved solids, total hardness, potassium, sulphate, chloride, biological oxygen demand (BOD), free carbon dioxide, alkalinity, nitrates, phosphorous, calcium, magnesium, silicates, sodium, transparency was carried out according to the procedures in APHA (1987) and by Trivedy & Goel (1984). Organic carbon, phosphorus, and pH in sediment and primary production and community respiration of lake water were conducted as per Trivedy & Goel (1984). Three litres of water sample were collected for biological study from each sampling site and was sieved using plankton nets for qualitative analysis. The filtered water was concentrated up to 100 ml and preserved in 4% formalin. The identification of different organisms was undertaken with the help of the identification keys given by Ward and Whipple (1918). The separation and counting of plankton were done by taking 1ml of sub-sample into a Sedgwick Rafter (S-R) plankton counting chamber (1ml capacity) under a compound microscope (Olympus, Japan). All organisms were counted according to the procedure described by Welch (1952).

2.2 Factor Analysis

The Factor analysis method is used for determining relationships between features in a dataset(Sheela et al., 2012). It is a useful tool for extracting latent information, including relationships between variables that are not directly evident. The original data matrix is decomposed into the product of a matrix of factor loadings. Because the number of extracted factors is generally less than the number of measured features, the dimensionality of the original data space can be decreased. Factors were extracted using principal component analysis and Varimax rotation with Kaiser Normalization, producing uncorrelated factors. Rotation of factors was necessary for meaningful interpretation of the factors derived. Factor analysis attempts to explain the correlations between the observations in terms of the underlying factors, which are not directly observable. Rotated component matrices of the ponds based on the physico-chemical parameters, sediment parameters and plankton density were arrived.

3. Results and Discussion

3.1 Variation of Water Quality Characteristics in Study Ponds

The physico-chemical characteristics of the water samples from three selected ponds in different seasons during the study period 2006 - 2007 (1^{st} year) and 2007 - 2008 (2^{nd} year) are given in **Tables 1 & 2.**

Table 1 Seasonal concentration of Physico-chemical parameters of Pond water (2006-2007)

Parameters	(Urban low land pond) POND 1	Rural low land pond (POND 2)	Rural high land pond (POND 3)
	Average values	Average Values	Average values
Temperature (^{0}C)	27.3	27	28
Colour (HU)	10	10	5
Conductivity(µmhos)	233.67	186	234.67
Transparency (cm)	62.3	59.33	55
pH	6.1	5.88	6.03
D.O (mg/l**)**	0.68	0.95	0.78

Free CO_2 (mg/l)	28.73	19.33	26.42
B.O.D (mgl)	24	21	20.3
Alkalinity (mg/l as $CaCO_3$)	66.5	52.77	64.67
TDS (mg/l)	208.67	160.67	203.67
Total hardness (mg/l as $CaCO_3$)	76.22	34.92	34.67
Calcium (mg/l as $CaCO_3$)	47.61	16.35	25.53
Magnesium (mg/l as $CaCO_3$)	4.48	3.757	4.31
Nitrates (mg/l)	1.12	0.97	1.05
In. Phosphorous (mg/l)	0.54	0.14	0.15
Potassium (mg/l)	4.985	1.31	4.033
Sodium (mg/l)	14.47	14.76	21.23
Sulphates (mg/l)	3.31	2.30	1.57
Chloride (mg/l)	107.11	109.05	53.004
Silicates (mg/l)	8.46	8.34	13.33

Table 2 Seasonal concentration of Physico-chemical parameters of Pond water (2007-2008)

Parameters	(Urban low land pond) POND 1	Rural low land pond (POND 2)	Rural high land pond (POND 3)
	Average value	Average value	Average value
Temperature (^{0}C)	27.67	27.67	27.33
Colour (HU)	10	10	5
Conductivity (µmhos)	213.33	193.33	232.67
Transparency (cm)	65.33	59.33	55.7
pH	6.13	6.01	6.03
D.O (mg/l)	1.093	1.09	0.93
Free CO_2 (mg/l)	27.57	18.7	26
B.O.D (mg/l)	24.33	20.67	19
Alkalinity (mg/l as $CaCO_3$)	63.33	50.73	62.33
TDS (mg/l)	181.33	162.33	179
Total hardness (mg/l as $CaCO_3$)	57.67	32	44.11
Calcium (mg/l as $CaCO_3$)	45.89	16.63	23.06
Magnesium (mg/l as $CaCO_3$)	4.472	4.49	4.52
Nitrates (mg/l)	0.84	1.01	1
Phosphorous (mg/l)	0.28	0.17	0.24
Potassium (mg/l)	7.98	2.55	5.57
Sodium (mg/l)	13.86	13.92	24.09
Sulphates (mg/l)	1.7057	2.38	1.63
Chlorides (mg/l)	135.74	109.38	56.82
Silicates (mg/l)	7.55	7.81	12.52

Water is slightly acidic in all the ponds. Comparatively lower pH was observed in Pond 2 (lowland rural pond). The colour intensity of water was observed to be high in Pond 1 and Pond 2. Dissolved oxygen (DO) content was found to be very low in all the three ponds. High BOD in all the three ponds is responsible for the lowering of DO in ponds. The contamination of water is due to high organic load. This is further confirmed by the presence of high levels of free CO_2 in all the ponds.

Free carbon dioxide (Table 1a) is high in Pond 1(28.73mg/l) followed by Pond 3 (26.42) and Pond 2 (19.33mg/l). Alkalinity is high in Pond 1 (66.5 mg/l) followed by Pond 3 (64.67) and Pond 2 (52.77mg/l). Potassium is comparatively high in Pond 1 (4.985mg/l) and Pond 3 (4.033mg/l) when compared with Pond 2. Total hardness (76.22mg/l); calcium (47.61mg/l); phosphorus (0.54mg/l) and sulphate (3.31mg/l) are at high level in Pond 1 when compared with Ponds 2 and 3. But sodium (21.23mg/l) and silicate (13.33mg/l) are at high level in Pond 3 when compared to other two ponds. This may be due to cloth washing being done in this high level rural pond as sodium silicate is an ingredient in soap (www.google.com/ptents/US2278352). Chloride level is high in Pond 2 (109 mg/l) and Pond 1 (107.1 mg/l) when compared with Pond 3(53 mg/l). Chloride content is high in lowland ponds.

Comparatively low level of DO and high level of free CO_2, BOD., alkalinity, TDS, total hardness, calcium, magnesium, phosphorus, potassium, nitrate and sulphate exist in the urban lowland pond. This polluted nature of the ponds is mainly due to the different anthropogenic activities as indicated by high BOD, high free carbon dioxide, and higher phosphorus and low values of dissolved oxygen. Comparatively high average mean values for temperature, electrical conductivity, nitrate, sodium and silicate exist in the high land rural pond. The urban lowland pond is more polluted than the other two ponds.

3.2 Variation of Biological Characteristics in Study Ponds

3.2.1 Phytoplankton Density

The seasonal distribution of different species of phytoplankton (No/L) is presented in **Table 3**. In Chlorophyceae, 16 genera namely *Spirogyra* sp., *Scenedesmus* sp., *Cosmarium* sp., *Closterium* sp., *Staurastrum* sp., *Docidium* sp., *Pandorina* sp., *Oedogonium* sp., *Ulothrix* sp., *Paediastrum* sp., *Hyalotheca* sp., *Pleurotaenium* sp., *Euastrum* sp., *Desmidium* sp., *Penium* sp., *Characaeum* sp. were observed in all the three ponds. In the Bacillariophyceae, 8 genera namely *Pinnularia* sp*., Navicula* sp*., Fragilaria* sp*., Melosira* sp*., Diadesmus* sp*., Synedra* sp*., Tabellaria* sp*, Gomphonema* sp were observed. In the Cyanophyceae, 5 genera, namely *Spirulina* sp., *Phormidium* sp., *Oscillatoria* sp*., Anabaena* sp*., Microcoleus* sp. was observed.

Based on the population of phytoplankton in Pond 1, the study revealed that the Cyanophyceae dominated (48%) followed by Bacillariophyceae (33%) and Chlorophyceae (19%). Chlorophyceae can not tolerate pollutants to the same degree as Cyanophyceae and Bacillariophyceae. Cyanophyceae appears as the polluted plankton form after replacing the species of Chlorophyceae. The dominant species representing the class Cyanophyceae were *Oscillatoria princeps*, which was recorded as the highest percentage in the post-monsoon season and the lowest in monsoon season. Among the Bacillariophyceae class, the dominant genus was *Navicula* sp., and which was recorded the highest during pre-monsoon season. According to Palmer (1969), genera like *Scenedesmus*, *Oscillatoria*, *Microcystis*, *Navicula* and *Euglena* are found in organically polluted waters. The dominance of *Oscillatoria* species and *Navicula* species confirms that the urban low land pond is organically polluted.

In Pond 2, phytoplankton community was dominated by Chlorophyceae (38%), followed by Bacillariophyceae (35%) and Cyanophyceae (27%). The dominating species in Chlorophyceae were *Spirogyra ocrugata* which was the highest percentage during pre-monsoon season and the lowest in the post-monsoon season. This is in agreement with the finding of Kagalou *et al.* (2001) that the population of Chlorophyceae increases under high temperature. In Bacillariophyceae, the dominant genera were *Tabellaria* sp. and the highest value was recorded in pre-monsoon season and lower in monsoon season. The dominance of Chlorphyceae indicates comparatively less pollution in the rural lowland pond compared to other ponds.

Table 3. Abundance of phytoplankton (Individuals /L) belonging to different taxonomic groups in the study area

Name of the Phytoplankton	Pond 1						Pond 2						Pond 3					
	(2006-2007)			(2007-2008)			(2006-2007			(2007-2008)			(2006-2007)			(2007-2008)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
CHLOROPHYCEAE																		
Spirogyra ocrugata	0	0	0	0	0	0	112	224	128	112	256	208	0	0	0	0	0	0
Spirogyra kandaensis	112	0	112	144	0	64	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium pyramidatum	0	72	56	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium angulatum	0	0	0	0	0	0	56	0	0	0	48	0	120	112	176	96	160	40
Cosmarium punctatum	0	0	0	0	0	0	0	0	0	0	0	0	0	152	120	64	80	0
Scenedesmus bijuga	0	64	0	0	40	0	0	80	0	0	0	112	0	24	0	0	32	0
Closterium accherianum	64	112	0	48	96	80	64	0	0	0	0	0	0	0	0	0	0	0
Closterium dianae	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0
Pediastrum tetras	0	0	0	0	96	48	0	0	0	0	0	0	0	0	0	0	0	0
Pandorina sp.	0	0	0	0	0	0	0	64	0	112	64	0	0	0	0	0	0	0
Staurastrum sp.	0	0	0	0	0	0	0	64	56	80	48	96	0	0	0	0	0	0
Oedogonium sp.	0	0	0	0	0	0	0	80	0	0	32	0	0	0	0	0	0	0
Ulothrix sp.	0	0	0	0	144	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyalotheca dissilens	0	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurotaenium maculatum	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	40	32
Euastrum anastrum	0	0	0	0	0	0	0	0	0	0	0	0	56	64	104	0	80	48
Desmidium sp.	0	0	40	32	0	0	0	0	0	0	0	0	0	128	80	48	104	72
Penium sp..	0	0	0	0	0	0	0	56	0	64	80	40	0	0	0	0	0	0
Characeum sp.	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0
Docidium sp..	64	0	0	112	0	80	0	0	0	0	0	0	24	0	0	16	0	32
BACILLARIOPHYCEAE																		

Fragilaria pinnata	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0	0
Navicula palea	120	144	128	160	176	168	0	0	0	0	0	0	0	0	0	0	0	0
Navicula chandolensis	0	0	0	0	0	0	16	80	96	48	0	112	0	0	72	0	0	0
Navicula grimmei	0	0	0	0	0	0	0	0	0	0	0	0	0	104	0	120	0	0
Navicula hungarica	128	144	128	144	160	240	0	0	0	0	0	0	0	0	0	0	0	0
Navicula salanarum	0	0	0	0	0	0	64	0	0	96	0	0	0	0	0	0	0	0
Synedra tergestina	0	0	0	0	0	0	0	0	0	0	0	0	56	0	0	24	64	0
Melosira italic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0	0	80
Pinnularia interrupta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	48
Gomphonema acminatum	0	0	0	0	0	0	0	0	40	0	48	0	0	0	0	0	0	0
Diadesmus sp..	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0
Tabellaria sp.	0	0	0	0	0	0	96	160	64	80	48	64	0	0	0	56	0	0
CYANOPHYCEAE																		
Oscillatoria subbrevis	0	0	0	0	0	0	0	112	0	80	0	96	0	0	0	0	0	0
Oscillatotia tenuis	0	0	0	0	0	0	0	0	0	0	0	0	112	160	80	120	144	64
Oscillatoria princeps	280	304	256	304	240	144	0	0	0	0	0	0	0	0	0	0	0	0
Anabaena torulosa	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcoleus chthonplastis	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirulina sp.	0	0	0	0	0	0	48	0	56	0	0	80	0	128	0	0	0	40
Phormidium sp.	0	0	0	0	0	0	32	0	0	0	48	0	0	0	0	0	0	0

In Pond 3, the numerical abundance of phytoplankton was Cyanophyceae (42%), Chlorophyceae (37%) and Bacillariophyceae (21%). In Cyanophyceae, the dominant species recorded was *Oscillatoria tenuis* which recorded the highest percentage during pre-monsoon and lowest during monsoon season. The most pollution tolerant algal species *Navicula*, *Oscillatoria* were recorded in all the ponds in all the seasons, indicating organic pollution, which is in agreement with the views of earlier workers (Nandan and Patel, 1985). But the abundance of *Navicula* sp, *Oscillatoria* sp. and *Euglena* sp. is maximum in the urban low land, pond indicating the highest degree of organic pollution.

The high planktonic population of Cyanophyceae in the lowland urban pond and in the highland rural pond may be due to the variation in abiotic factors, namely anthropogenic factors, sewage discharges, and morphometry of the water body. The dominance of Chlorophyceae in lowland rural pond (Pond 2) might be due to high dissolved content and have observed that green algae prefer water with high concentration of dissolved oxygen. In the present study dissolved oxygen content was comparatively high in P2, correspondingly phytoplankton in the pond was dominated by Chlorophyceae family.

3.2.2 Zooplankton Density

The seasonal distribution of different species of zooplankton (No/L) from the three different ponds during 2006 - 2007 and 2007 - 2008 are presented in **Table 4**.

Table 4 Species distribution and abundance of Zooplankton (No/L) during the period of 2006-2008

Zooplankton	Pond 1						Pond 2						Pond 3					
	(2006-2007)			(2007-2008)			(2006-2007)			(2007-2008)			(2006-2007)			(2007-2008)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
PROTOZOA																		
Euglena sp.	48	144	80	112	160	120	0	128	0	64	0	48	32	0	16	0	0	8
Phacus sp.	0	0	0	0	0	64	0	0	0	0	0	0	56	0	0	0	80	56
Vorticella sp.	0	0	0	0	0	0	0	0	0	0	64	96	0	0	0	0	0	0
Paramecium sp.	0	0	0	0	0	0	120	64	0	0	64	0	0	0	0	0	0	0
Euglypha sp.	0	320	40	16	64	0	112	64	0	80	0	0	0	0	0	0	0	0
Arcella sp.	64	120	128	112	176	80	120	0	0	88	0	0	0	88	48	0	64	0
Didinium sp.	0	64	16	64	0	48	0	0	0	0	0	0	0	0	0	0	0	0
Coleps sp.	0	0	0	0	0	0	0	0	112	0	0	64	40	64	0	40	56	0
Difflugia sp.	128	112	0	0	144	0	0	0	0	0	48	0	0	0	0	0	0	0
ROTIFERA																		
Rotatoria sp.	48	0	56	0	120	0	48	0	64	64	0	64	88	56	0	24	16	0
Keratella sp.	80	64	0	128	0	48	0	120	0	0	64	0	64	0	40	48	0	24
Brachionus sp.	16	0	32	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecane sp.	0	0	0	56	16	0	0	32	48	40	64	80	0	56	0	0	64	0
Mytilina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	56	72	0	0	48
Epiphanes sp.	0	0	0	0	0	0	0	64	0	0	56	0	0	0	0	0	0	0
Platyias sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
Monostyla sp.	0	0	0	0	0	0	0	0	64	0	72	48	0	0	0	0	0	0
CLADOCERA																		
Alona sp.	0	0	0	0	0	0	0	0	64	0	0	48	0	0	0	0	0	0
Bosmina sp.	0	0	0	0	0	0	0	112	64	48	40	0	16	8	16	8	0	16
Ceriodaphnia sp.	0	80	64	64	0	0	48	64	80	64	0	80	0	32	0	16	0	8
Moinadaphnia sp.	0	64	0	0	120	56	0	0	0	0	0	0	32	0	24	0	16	48
Sida sp.	0	0	0	0	40	16	48	64	0	64	48	0	0	24	0	0	8	16
COPEPODA																		
Cyclops sp..	48	64	80	40	0	56	48	96	0	160	64	0	0	32	48	64	80	0

Meso cyclops leuckarti	0	0	0	0	112	0	0	0	0	0	0	0	0	0	0	0	0	0
Limnocalanus sp.	0	0	0	0	0	0	0	0	48	64	0	48	0	0	0	0	0	0
Diaptomus sp.	0	0	0	0	0	0	64	88	64	0	80	0	16	0	0	32	0	48
OSTRACODA																		
Cypris sp.	0	96	0	80	0	48	64	0	40	48	64	80	0	0	48	0	40	72

A= Post-monsoon, B=Pre-monsoon, C=Monsoon

Totally 27 genus of zooplankton were identified from all the studied ponds during the study period. The results showed the presence of zooplankton taxa represented by sixteen (16) species in Pond 1, twenty (20) zooplankton taxa in Pond 2, sixteen (16) zooplankton taxa in Pond 3. The zooplankton diversity was represented by Protozoans (6), Rotifers (4), Cladocerans (3), Copepods (2) and Ostracod (1) in pond 1. In pond 2, Protozoans (7), Rotifers (5), Cladocerans (4), Copepods (3), Ostracod (1) were observed. In pond 3, Protozoans (4), Rotifers (5), Cladocerans (4), Copepods (2) and Ostracod (1) were identified.

In the present investigation, Cladocera, Ostracoda, Copepoda are the orders identified in the crustacean class. *Ceriodaphnia* sp, *Moinadaphnia* sp. and *Sida* sp, *Bosmina* sp, *Alona* sp. are the genus identified in the order Cladocera. *Diaptomus* sp*, Limnocalanus* sp, *Mesocyclops* sp and *Cyclops* sp. come under Copepoda. *Cypris* sp. comes under Ostracoda class. The present investigation showed that in pond 1 among the zooplankton detected, Protozoans was 35% , followed by Ostracods (28%). The dominant genera represented in Protozoa were *Euglena* sp, *Arcella* sp., *Difflugia* sp., *Euglena* and *Arcella* was recorded the highest percentage during the pre-monsoon season. In pond 2, among the zooplankton, Ostracods dominated (31%) followed by Copepods (21%). In pond 3 among the zooplankton detected, Ostracods was 35%, followed by Rotifers (19%).

3.3 Analysis using Factor Analysis

The physic-chemical and biological data on water quality in each pond was evaluated using multivariate statistical techniques namely Factor analysis.

3.3.1 Pond 1 (Urban low land pond)

Factor 1 (F1) explains 25.8% of the total variance (**Table 5**), being mainly contributed to by magnesium (0.847), Secchi disc depth (0.895), nitrate (0.42) and sediment phosphorus (0.48). F1 has negative factor loading with calcium (-0.816), chloride (-0.831). F1 is denoted as Calcium factor. In pond 1, the concentration of calcium and phosphate is high and this may have led to the precipitation of insoluble calcium phosphate thereby increasing sediment phosphorus. The positive factor loading of sediment phosphorus and the negative factor loading of calcium in water confirms this finding. F1 has a positive factor loading with gross primary productivity (0.933) and community respiration (0.903). This shows that Calcium factor has a strong association with primary productivity, which is the radiant energy stored by green plants by photosynthetic activities. This may be the reason for the high diversity of chlorophyceae in Pond 1.

Calcium factor has a positive factor loading with *Scenedesmus bijuga* (0.822); *Closterium accherianum* (0.591); *Pediastrum tetras* (0.595); *Ulothrix* sp. (0.616); *Navicula palea* (0.647); and *Hyalotheca dissilens* (0.616); protozoa namely *Euglena* (0.95); *Euglypha* (0.619); cladocera namely *Moinadaphnia* sp.(0.872) and copepod, namely *Mesocyclops leuckarti* (0.616). According to Ali et al.(2010), calcium is favourable for the growth of green phytoplankton and magnesium is favourable for blooms, colonies, mats etc. This may be the reason for negative factor loading of calcium with the positive factor loading of chlorophceae namely *Scenedesmus bijuga, Closterium accherianum, Pediastrum tetras, Hyalotheca dissilens and Ulothrix sp.* The positive factor loading of protozoa namely *Euglena* shows that it thrives where Chlorophyceae is prominent. (http://webcache.googleusercontent.com/search?q=cache:http://euglenaprotist.wordpress.com/tag/euglena/). Chlorophyceae is present when there is a lot of nitrogen in the water i.e. maximum concentration of 1.12 mg/l of nitrate is available in Pond 1.

According to Shaik et al. (2013) increased dissolved solids, total hardness, calcium and magnesium hardness and ions like chloride and magnesium show deterioration of water quality. The same situation can be observed in the case of Pond 1. Cladocera, codepoda, and rotifers are effective consumers of phytoplankton. *Scenedesmus bijuga* is the dominant pollution tolerant species recorded in the river Pandu having high level of chlorides and calcium (Diwedi, 2010). A similar situation exists in Pond 1 with high calcium, chloride and *Scenedesmus bijuga*. Das and Panda (2010) showed the ability of *Ulothrix* to survive in adverse condition and to adjust with the environment. This is in agreement with the finding of the association of calcium factor with *Ulothrix.* The association of *Closterium* with this calcium factor indicates its association with pollution. This is in conformity with the finding of Singh and Balasingh (2011) that *Closterium* is a pollution tolerant species. The association of *Pediastrum tetras* with Calcium factor which is in conformity with the finding that it is a good indicator of water pollution (Tiwari and Chauhan, 2006).

Table 5. Pond 1 Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Temperature	.323	.482	.578	.514	.253
Electrical Conductivity	-.259	.868	.373	-.005	.200
Secchi Disc Transparency	**.895**	.078	.433	.040	.061
pH	.169	.625	.755	.103	-.005
D.O.	-.143	.333	.562	.025	.743
Free CO_2	.184	.723	.666	-.003	.025
B.O.D.	.238	.650	.703	-.137	.091
Alkalinity	.252	.843	-.116	-.392	-.244
T.D.S.	-.123	.960	.147	.095	.180
Total Hardness	-.064	.947	-.256	.106	-.148
Calcium	-.816	-.328	-.453	-.145	.016
Magnesium	**.847**	.055	-.138	.447	-.246
Nitrates	**.417**	-.340	.024	.307	-.785
Phosphorus	-.295	.233	-.211	-.268	.862
Potassium	.053	-.152	.082	.129	.975
Sodium	.097	.415	.805	.134	-.391
Sulphate	-.403	-.707	-.569	-.057	-.104
Chloride	-.831	-.158	-.514	.128	.062
Silicate	-.970	-.085	-.170	-.064	.135
Spirogyra kandaensis	-.869	.124	-.132	-.104	.448
Cosmarium pyramidatum	.138	.379	-.558	-.704	.177
Scenedesmus bijuga	.822	-.127	-.293	-.155	-.445
Closterium accherianum	.591	-.669	.131	-.117	-.415
Pediastrum tetras	.595	-.262	.377	.639	.164
Ulothrix sp	.616	-.217	-.100	.742	.115
Docidium sp	-.588	-.543	.212	-.288	.481
Navicula palea	.647	-.411	.341	.090	.536
Navicula hungarica	.219	-.230	.924	-.110	.183
Oscillatoria princeps	-.083	-.058	-.963	-.222	-.116
Anabaena torulosa	-.169	.966	-.097	.122	.117
Microcoleus chthonplastis	-.169	.966	-.097	.122	.117
Hyalotheca dissilens	.616	-.217	-.100	.742	.115
Desmidium sp.	-.300	.610	-.355	-.140	.626
Euglena sp.	.950	-.218	.067	-.084	.198
Phacus sp.	-.013	-.103	.973	-.174	.107
Euglypha sp.	.619	.064	-.320	-.511	-.499
Arcella sp.	.779	.208	-.359	.373	.286
Didinium sp.	.190	-.144	.057	-.931	.271

Difflugia sp.	.308	-.413	-.346	.425	-.659
Rotatoria sp.	.260	.111	-.205	.936	-.049
Keratella sp.	-.446	-.602	-.249	-.584	.190
Brachionus sp.	.181	.394	-.213	.875	-.009
Lecane sp.	-.044	-.400	-.425	-.144	.798
Ceriodaphnia sp.	.155	.431	-.544	-.692	.126
Moinadaphnia sp.	.872	-.264	.220	.325	-.127
Sida sp.	.611	-.258	.289	.672	.158
Cyclops sp.	-.381	.646	.129	-.604	-.235
Mesocyclops leuckarti	.616	-.217	-.100	.742	.115
Cypris sp.	.272	-.294	-.079	-.905	.120

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 11 iterations.

The study reveals the association of calcium factor with *Navicula palea* and *Euglena sp.* The is in agreement with the findings of Nandan and Aher (2005) that these species are found in organically polluted water. *Arcella* is one of the most pollution tolerant species (Amer and El-Gawad, 2012) as well as it is one of the most frequently encountered of the testate amoeba, especially in highly organic polluted waters and in the sediments on the pond's bottom where plant materials rot under conditions of low oxygen concentration (http://www.micrographia.com/specbiol/protis/homamoeb/amts0100.htm). The association of *Arcella* with Calcium factor confirms the pollution tolerance.

F2 explains 23.8% of the variance, contributed to by pH (0.785); electrical conductivity (0.86); free carbon dioxide (0.723), BOD (0.65); alkalinity (0.843); T.D.S. (0.96); total hardness (0.947), organic carbon (0.796). This factor is termed as Alkalinity factor. F2 has a negative loading with N.P.P. (-0.56). This shows that Alkalinity factor affects the productivity of the lake system. Alkalinity factor has negative factor loading with *Closterium accherianum* (-0.669); and *Docidium* sp. (0.543), and has a positive factor loading with *Anabaena torulosa* (0.966); and *Microcoleus echthonplastis* (0.966) and *Desmidium* (0.610) and Copepoda namely *cyclops* (0.646). Alkalinity factor has a negative loading with Rotifer species, namely *Keratella species* (-0.602).

Cyanophyceae are highly tolerant organisms and prefer to grow at slightly alkaline condition (Sahu and Kumar, 2012). The higher value of alkalinity is an indication of the polluted nature of the pond and this is in conformity with Chandrasekhar et al. (2003). When comparing with other ponds, alkalinity is high in this pond. This may be the reason for the growth of Cyanophyceae namely *Anabena torulosa* and *Microcoleus chthonplastis* in Pond due to the high value of alkalinity. *Closterium accherianum* is associated with Alkalinity factor. This is in agreement with the finding of Chia et al. (2011) that *Closterium* species is sensitive to alkaline. Cyclops is associated with alkalinity. This is in agreement with the finding of Ferdous et al. (2013) that copepods is resistant to water treatment chemicals causing alkalinity. *Keratella* species are a dominant acidophilic rotifer (Hill and Blaney, 2010) and this may the reason for the reduction with alkalinity factor.

F3 explains 18.8% of total variance, being attributed by sodium (0.805); pH (0.755); free carbon dioxide (0.66), temperature (0.578), BOD (0.703). This may be termed as sodium factor. Sodium and organic factor have negative factor loading with *Cosmarium pyramidatum* (-0.558) and *Oscillatoria princeps* (-0.963) and Cladocera namely *Ceriodaphnia* (-0.544). Sodium factor has a positive factor loading with *Navicula hungarica* (0.924) and Protozoa namely *Phacus* (0.973).

Sodium and organic factor are negatively associated with *Oscillatoria princeps* and Cladocera namely *Ceriodaphnia*. The lower values of sodium may have resulted in the highest concentration of *Oscillatoria princeps* and *Ceriodaphnia*.In the case of diatom namely *Navicula hungarica*, it prefers benthic habitats and it occurs in the planktonic habitat if the waterbody is shallow (Zaim, 2007). The presence of Navicula may be due to the shallow nature of Pond 1. The enriched status of pond 1 due to high calcium, free carbon dioxide and BOD may be the reason for high factor loading of *Navicula hungaria*. This is in agreement with the finding of Kumar et al. (2008).

F4 explains 15.4% of total variance, being attributed by magnesium (0.447), nitrate (0.307) and temperature (0.514). It is termed as Temperature factor. F4 has negative factor loading with phytoplankton namely *Cosmarium pyramidatum* (-0.704); protozoa namely *Euglypha* (-0.511), *Didinum* sp. (-0.931), *Ceriodaphnia* sp. (-0.692), *Cyclops* (-604) *Diaptomus* sp. (-0.905).

The low temperature factor has resulted in high density of protozoa namely *Euglypha*, *Didinum* sp., *Ceriodaphnia* sp., *Cyclops, Diaptomus* sp.. Temperature is a major controlling factor for protozoa as per Laybourn-Parry (1984).,

The temperature has positive factor loading with chlorophyceae namely *Pediastrum tetras* (0.639) *Ulothrix* sp. (0.742) Rotifer namely *Rotatoria* (0.936), *Brachionus* (0.875), Cladocera namely *Sida* sp. and Copepoda namely *Mesocyclops leuckarti* (0.742). Further the inverse relation of Rotifer, Cladocera and Copepoda with protozoa indicates its predation of protozoa. In the case of Chlorophyceae with Protozoa, inverse relation indicates the consumption of Chlorophyceae by Protozoa.

F5 is mainly contributed by phosphorus (0.862) and potassium (0.975) and by negative factor loading of -0.662 of sediment phosphorus; potassium of -703 and total nitrogen in sediment (-0.917). This may be termed as phosphorus factor. *Docidium* sp. (0.481) and *Navicula palea* (0.536). Phosphorus factor has a positive loading with *Desmidium, and* Rotifer namely *Lecane* sp. (0.798). The presence of *Lecane* in tropical aquatic body is in conformity with Verma et al. (2014). Phosphorus factor shows the anaerobic condition exists in the pond.

3.3.2 Pond 2 (Rural lowland Pond)

Factor 1 (F1) explains 31.9% of the total variance (**Table 6**), being mainly contributed to by the BOD (0.934), alkalinity (0.913), total dissolved solids (0.855), free carbon dioxide (0.962), and phosphorus (0.808). F1 has also medium factor loading with organic carbon (0.564). Hence, F1 is denoted as organic factor. Comparatively low level of alkalinity and phosphorus is found in this pond. The reduction of nitrate, magnesium, sulphate, and chloride can be observed as per the negative loading with organic factor.

Table 6. Pond 2. Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Temperature	-.575	.148	.626	-.496	-.095
Electrical Conductivity	.775	-.438	.170	.255	-.339
Secchi Disc Transparency	.547	.805	.194	.127	.009
pH	.741	.519	.417	.024	.084
D.O.	-.893	-.420	.026	-.141	-.080
Free CO_2	.962	.060	.137	.190	.129
B.O.D.	.934	.309	.150	.001	-.099
Alkalinity	.913	.357	.154	.127	.006
T.D.S.	.855	-.269	.363	-.248	.056
Total Hardness	.033	.956	-.032	-.152	.246
Calcium	-.316	.921	.030	-.173	.148
Magnesium	-.600	-.132	.670	.261	.323
Nitrate	-.871	-.100	.385	-.092	-.275
Phosphorus	.808	-.260	.215	.293	-.384
Potassium	.040	.884	.167	-.278	-.336
Sodium	.665	-.325	.153	.617	.219
Sulphate	-.874	-.157	.432	.126	-.092
Chloride	-.794	.484	-.303	.197	-.071
Silicate	-.044	-.990	-.128	.023	.003
Spirogyra ocrugata	.155	.891	.135	.072	-.398
Cosmarium angulatum	-.324	.116	-.586	-.651	-.339
Scenedesmus bijuga	.294	.255	.026	.831	-.396
Closterium accherianum	-.297	-.390	-.845	-.178	-.119
Pandorina sp.	-.723	.274	.580	.017	.254
Staurastrum sp.	.218	.063	.817	.510	-.148
Oedogonium sp.	-.147	.873	-.132	.336	.292
Fragilaria pinnata	.730	-.260	.083	-.289	.556
Navicula chandolensis	.651	-.182	.246	.685	.113

Navicula salanarum	-.762	-.632	.046	-.053	.119
Gomphonema acminatum	.437	.341	.213	-.796	.116
Diadesmus sp.	.730	-.260	.083	-.289	.556
Tabellaria sp.	-.288	.317	-.404	.663	.463
Oscillatoria subbrevis	-.181	.155	.327	.913	-.054
Spirulina sp.	.682	-.539	-.255	.161	-.392
Phormidium sp.	-.274	.326	-.354	-.743	-.375
Penium sp.	-.463	.613	.597	.030	-.229
Characeum sp.	-.297	-.390	-.845	-.178	-.119
Euglena sp.	-.276	.359	.171	.838	.254
Vorticella sp.	.310	.225	.270	.022	-.883
Paramecium sp.	-.401	.269	-.846	-.216	-.067
Euglypha sp.	-.750	-.312	-.486	.200	.252
Arcella sp.	-.680	-.630	-.355	-.120	.030
Coleps sp.	.916	-.338	.174	-.013	.127
Difflugia sp.	-.099	.614	.179	-.688	-.328
Rotatoria sp.	.232	-.946	.195	.100	-.054
Keratella sp.	-.154	.923	-.104	.236	.240
Lecane sp.	.478	.246	.700	.040	-.468
Epiphanes sp.	-.163	.979	-.039	.008	.114
Monostyla sp.	.698	.233	.314	-.531	-.279
Alona sp.	.918	-.342	.190	.065	.001
Bosmina sp.	.006	.558	.184	.245	.771
Ceriodaphnia sp.	.398	-.544	.084	.682	.272
Sida sp.	-.906	.324	-.079	.020	.260
Cyclops	-.879	.084	.330	.106	.315
Limnocalanus sp.	.193	-.654	.706	.181	.061
Diaptomus sp.	.108	.652	-.544	-.323	.404
Cypris sp.	.085	-.436	.059	-.372	-.813

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 11 iterations.

F1 has negative factor loading with phytoplanktons namely *Pandorina* sp. (-0.723) *Navicula* sp*., Salanarum* sp. (-0.762), protozoa namely *Euglypha* (-0.75) and *Arcella* (-0.68), *Cladocera* namely *Sida* sp. (-0.906) and Copepoda namely *Cyclops* (-0.879). This shows the association of organic factor with *Pandorina* sp., *and Navicula* sp*., Salanarum species* of phytoplankton*; Euglypha and Arcella* of protozoa*; Sida* species of Cladocera *and Cyclops* of Copepoda*.* The pollution indicator, namely *Pandorina sp.* (Tiwari and Chauhan, 2006) exists in this pond. *Navicula salanarum* is common in calcareous and slightly alkaline water (Kivrak and Hasan, 2005). The presence of *Arcella* sp. and *Euglypha* sp. indicates that the pond is organically polluted. *Sida* species found in ponds with weeds is in conformity with the finding of Sharma et al. (2012). F1 has a positive factor loading with phytoplankton namely *Fragilaria Pinnata* (0.73), *Navicula chandolensis* (0.651), *Diadesmus* (0.73), and *Spirulina* sp. (0.682), *protozoa* namely *Coleps* sp. (0.916), *rotifiera* namely *Monostyla* sp. (0.698), and *cladocera* namely *Alona* sp. (0.918). This reveals that phytoplanktons namely *Fragilaria Pinnata, Navicula chandolensis, Diadesmus and Spirulina* sp.*; protozoa* namely *Coleps* sp.*; rotifiera* namely *Monostyla* sp., and Cladocera namely *Alona* sp. are associated with organic factor. According to Sharma and Chandrakiran (2011), *Alona* species is associated with macrophytes and its boom due to increased availability of food. This is in conformity with the present association of *Alona* species with organic pollution factor.

Fragilaria Pinnata prefers elevated nitrogen levels and is a strong indicator species of high organic nutrient. The association of *Fraglaria Pinnata* with nitrate agrees with the said finding. According to Khare and Saxena (2013), Spirulina along with Anabena, Navicula, Nosto, Chlorella, Cosmarium are reported from pollution habitats. In the present study, the association of Spirulina with organic factor is in conformity with the above finding.

Factor 2 (F2) explains (27.6%) of the total variance, mainly contributed to by total hardness (0.956); calcium (0.921), potassium (0.884). F2 has a strong factor loading with calcium and is termed as calcium factor. Calcium factor has a strong factor loading with Gross primary productivity (0.934) and community respiration (0.995) and has negative factor loading with net primary productivity (-0.982). Calcium factor has a strong association with gross primary production. Comparatively, low value of calcium content in the pond may affect the gross primary productivity of the pond.

Calcium factor has a positive factor loading with phytoplanktons namely Spirogyra species (0.891), *Oedogonium* species (0.873), and Penium species (0.613); Rotifera namely *Keratella* species (0.923) and *Epiphanes* (0.979); and Cladocera namely *Bosmina* (0.556). Calcium factor has negative factor loading with phytoplankton namely *Navicula salanarum* (0.632), protozoa namely *Arcella* sp. (-0.63); Rotifera namely *Rotatoria* (-0.946) and cladocera namely *Ceriodaphnia* sp*. (-0.544).*

Accroding to Khalif (2014), *Keratella cochiearis*, and *Branchionus* sp. are eutrophic indicator species. *Epiphanes* species also indicate the eutrophic condition. Thus its presence indicates eutrophic condition of pond. The negative relation of calcium factor with Rotatoria and Ceriodaphnia indicates its predation of chlorophyceae due the calcium. Chlorophyceae namely *Spirogyra* species, *Oedogonium species*, and *Penium* species are associated with Calcium factor. This is in agreement with the finding of Ali et al. (2010) that calcium is favourable for the growth of green phytoplankton.

Factor 3 (F3) explains 16.6% of the total variance, being attributed by temperature (0.62), magnesium (0.67) and sediment pH (0.831). Factor 4 (F4) explains 12.7% of total variance, contributed by sodium with a factor loading of 0.617.

3.3.3 Pond 3 (Rural highland Pond)

Factor 1 (F1) explains 28.8% of the total variance (**Table 7**), being mainly contributed by the BOD. (0.960), pH (0.78), electrical conductivity (0.98), total dissolved solids (0.86), free carbon dioxide (0.88), and phosphorus (0.614). F1 is termed as an organic and phosphorus factor.

Organic and phosphorus factor has negative factor loading with phytoplankton namely *Scenedesmus bijuga* (-0.545), *Oscillatotia tenuis* (-0.886); protozoa namely *Coleps* sp (-0.957); Rotifera namely *Rotatoria* sp. (-0.718) and *Lecane* sp. *(-0.568)*. This reveals that organic and phosphorus factor is associated with phytoplankton like *Scenedesmus bijuga* and*, Oscillatotia tenuis;* protozoans namely *Coleps* sp.; Rotifera namely *Rotatoria* species and *Lecane* sp.

F1 has a positive factor loading with phytoplankton namely *Navicula chandolensis* (0.748), *Melosira italica (0.92), Pinnularia interrupta (0.93),* rotifiera namely *Mytilina* sp. (0.585); Ostracoda namely *Cypris* sp. (0.78). This shows the association of organic and phosphorus factor with *Navicula chandolensis*, *Melosira italica, Pinnularia interrupta,* Rotifera namely *Mytilina* sp.; Ostracoda namely *Cypris* sp. Bacillophyceae namely *Navicula* sp., *Melosira* sp., and *Pinnularia interrupta* are indicators of organic and phosphorus factor. *Mytilina* and *Cypris* are also indicators of pollution and eutrophic condition.Organic and phosphorus factor shows the anaerobic condition in the pond.

Factor 2 (F2) has negative factor loading with sulphate (-0.797), silicate (-0.984). F2 has a positive factor loading with calcium (0.783), total hardness (0.945) and magnesium (0.547). Hence, F2 is termed as Calcium silicate factor which has a strong association with gross primary production.

Table 7. Pond 3. Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Temperature	-.213	.124	-.844	-.002	.476
ElectricalConductivity	.983	.017	.102	-.144	.037
Secchi Disc Transparency	.261	.943	-.199	-.015	.059
pH	.777	.613	-.134	-.049	.013
DissolvedOxygen	.916	-.256	.071	.166	-.250
Free CO_2	.877	.439	.012	-.046	.189
B.O.D	.960	-.045	.094	-.193	.177

Alkalinity	.458	.847	-.175	-.029	.203
T.D.S.	.860	.008	-.469	-.187	-.074
Total Hardnes	.147	.945	.225	-.042	-.181
Calcium	-.534	.783	-.300	.080	.067
Magnesium	-.167	.547	-.611	-.073	-.542
Nitrate	.982	.087	-.138	-.077	.047
Phosphorus	.614	.594	.390	.300	.166
Potassium	-.277	-.135	-.091	.862	-.391
Sodium	.156	.532	.063	.813	.169
Sulphate	-.556	-.797	.188	.028	-.142
Chloride	.184	.300	-.183	.168	.903
Silicate	-.070	-.984	.138	-.067	-.056
Cosmarium angulatum	.038	-.005	-.991	.096	-.082
Cosmarium punctatum	-.123	.524	-.594	-.535	-.267
Scenedesmus bijuga	-.545	.715	-.349	.264	-.013
Closterium dianae	-.277	-.725	-.069	.153	.608
Docidium sp	.146	-.460	.819	.182	.252
Navicula chandolensis	.748	-.050	-.594	-.289	-.043
Navicula grimmei	-.537	.031	.189	-.609	-.551
Synedra tergestina	-.480	-.328	-.280	.762	.040
Melosira italic	.922	.185	.284	-.063	.174
Pinnularia interrupta	.930	.181	.263	-.070	.170
Tabellaria sp.	-.192	-.410	.266	-.157	-.836
Oscillatotia tenuis	-.886	.271	-.346	-.065	-.133
Spirulina sp.	-.373	.602	.205	-.611	.288
Pleurotaenium maculatum	-.139	-.182	.147	.797	.540
Euastrum anastrum	.390	.382	-.687	.085	.473
Desmidium sp.	-.050	.949	-.185	-.192	-.162
Euglena sp.	.216	-.700	-.169	.049	.657
Phacus sp.	-.089	.079	.142	.908	.376
Arcella sp.	-.251	.735	-.587	-.222	.057
Coleps sp.	-.957	.163	-.226	.031	-.079
Rotatoria sp.	-.718	-.447	-.095	-.167	.497
Keratella sp.	.219	-.969	.060	-.085	.041
Lecane sp.	-.568	.730	-.335	.180	.010
Mytilina sp.	.585	.461	-.087	-.614	.246
Platyias sp.	-.228	.418	-.356	.786	-.173
Bosmina sp.	.580	-.470	.247	-.381	.486
Ceriodaphnia sp.	-.502	.380	.290	-.704	-.151
*Moinadaphni*a sp.	.600	-.122	.355	.396	.585
Sida sp.	-.271	.797	.355	-.275	.300
Cyclops sp.	-.137	.262	-.513	.223	-.775
Diaptomus sp.	.233	-.254	.926	.103	-.117
Cypris sp.	.789	.427	.197	.382	.103

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Calcium silicate factor has a positive factor loading with phytoplankton namely *Scenedesmus bijuja* (0.72) *and Desmidium* sp. (0.949); protozoa namely *Arcella* sp. (0.735) and Rotifer namely *Lecane* sp. (0.73). It also has negative factor loading with *Closterium dianae*; Protozoa namely *Euglena* sp. (-0.7); Rotifera namely *Keratella* sp.

(-0.969). This shows that calcium factor is associated with *Closterium dianae*; Protozoa namely *Euglena*, Rotifer namely *Keratella*. The growth of Chlorophyceae namely *Scenedesmus bijuja and Desmidium* sp. can be observed with the increase in Calcium factor. Like the other ponds, the presence of *Arcella* indicates high organic pollution in Pond 3. *Euglena* and *Keratella* also indicate the organic nature of water. The increase of *Euglena* and *Keratella* with silicate can also be observed.

Factor 3 (F3) explains 17.9% of the total variance, being attributed by temperature (-0.844), magnesium (-0.61). F3 is termed as Temperature factor. F3 has a direct factor loading with Chlorophyceae of *Cosmarium angulatum* (-0.991), *Euastrum anastrum* (-0.687). and *Cosmarium punctatum* (-0.594); Bacillarophyceae namely *Navicula chandolensis*(-0.594) and with protozoa namely *Arcella* (-0.587). The association of *Cosmarium angulatum, Euastrum anastrum. and Cosmarium punctatum* is due to the presence of chlorophyll-a and thereby associated with temperature and magnesium. Factor 4 (F4) explains 13.3% of total variance, contributed by sodium with a factor loading of 0.813.

4. Conclusion

The study revealed that high level of organic content existed in all three ponds. However, in comparison of the water quality of different ponds, it can be seen that calcium, magnesium, potassium, phosphate, and sulphate content was high in the Urban lowland pond (Pond 1). The high level of sodium and silicate content in Rural highland pond (Pond 3) indicates the pollution due to cloth washing. The diversity of Chlorophyceae was higher than that of Bacillariophyceae and Cyanophyceae in all ponds. While considering the population of phytoplankton, the dominance of Cyanophyceae followed by Bacillariophyceae and Chlorophyceae can be observed at the Urban lowland pond (Pond 1). The organic pollution indicators, namely *Oscillatoria princeps* and *Navicula* species were also observed here. The dominance of Chlorophyeae can be observed at a Rural low land pond (Pond 2) and that of Cyanophyceae in Rural high land pond (Pond 3). The most pollution tolerant species *Navicula* and *Oscillatoria* were recorded in all the three ponds. However, its population was high in the urban lowland pond followed by rural highland pond and rural lowland pond.

In the urban lowland pond, calcium factor, alkalinity factor, sodium and organic factor, temperature factor and phosphorus factor influence planktonic growth. Calcium factor is the reason for the more diversity of phytoplankton in the pond as calcium is favourable for the growth of Chlorophyceae.. The dominant pollution tolerant species, namely *Scenedesmus bujurga Navicula palea, Euglena and Arcella* are related to calcium factor. Alkalinity factor favours the growth of *Anabena torulosa, Microcoleus chthonplastis, Closterium accherianum,* and *Cyclops*. Thus, calcium and alkalinity factors are the decomposed product of biodegradable urban wastes and this in turn has resulted in the abundance of Cyanophyceae. The abundance of Cyanophyceae is also reported in in rural high land pond. Here organic and phosphorus factor, calcium silicate factor, temperature factor are the prominent factors that control planktonic growth. Thus the high level of decomposed organic wastes in these ponds is the main reason for the growth of Cyanophyceae.

In rural lowland pond, organic factor, calcium factor, magnesium factor are the main factors that control the different species. Chlorophyceae is abundant in this pond. This shows that undecomposed organic waste is high when compared with other ponds. This may have resulted in the abundance of Chlorophyceae. The study revealed that waste water disposal has affected the urban lowland pond whereas cloth washing and cattle wash affected the rural highland pond.

The study helps to identify the prominent factors responsible for the degradation of planktons. The association of different factors of water quality with different species of phytoplankton can be clearly identified. Control measures can be accordingly envisaged to control such factors for the protection of sensitive organisms in a water body.

Acknowledgements

The authors gratefully acknowledge Dr. M.V. Nadaraja Panicker, Retd. Professor and Hon. Director of Research, Department of Botany, S.N. College, Kollam for his valuable suggestions for the identification of phytoplankton for this study. Also, thank the Head, Department of Environmental Sciences, University of Kerala, for providing laboratory facilities and support throughout the study.

REFERENCES

Ali, A., Shinwari,Z.K. & Sarim, F.M.,(2010). Contribution to the Algal flow(Chlorophyta) of Fresh waters of districts SWAT.N.N.F.P., Pakisthan. Pakisthan Journal of Botany, 42(5), 3457-3462.

Amer, A.S. & El-Gawad, H.A.(2012). Rapid bio-indicators assessment of macrobiotic pollution on aquatic environment.International water technology journal. 2(3).

Ayeni A.O., Balogun I.I. & Soneye A.S.O. (2011). Seasonal Assessment of Physico-chemical Concentration of Polluted Urban River: A Case of Ala River in South western Nigeria. *Res. J. Environ. Sc*i. 5(1):21- 35.

APHA (1995). Standard methods for the examination of water and waste water, 19th Edn. APHA, AWWA, WEF, Washington DC, USA.

BIS (1991). Drinking water specific IS. 10500: Bureau of Indian Standards, New Delhi.

Chandrasekhar, J.S., Babu, K.L., & Somasekhar, R.K.(2003). Impact of urbanization on Belandur lake, Bangalore – a case study. Journal of Environmental Biology, 24(3), 223-227.

Chia, M.A., Bako, S.P., Alonge, S.O., & Adamu, A.K.(2011). Green algal interactions with physicochemical parameters of some man made ponds in Zaria, northern Nigeria. Revista Brasil Botany, 34(3), 285-295.

Das, M., & Panda, T.(2010). Water quality and phytoplankton population in sewage fed River of Mahanadi, Orissa, India. Journal of Life Sciences, 2(2), 81-85.

Deshmukh, R.N. & Tarar, J.L. (2014). A study of trophic level status of fresh water ecosystems of Bhandara district of Central India. Online International Interdisciplinary Research Journal, 4, March 2014, Special issue.

Diwedi (2010).Pollution induced structural and physic-chemical changes in algal community: A case study of River Pandu in North India. World Academy of Science, Engineering and Technology, 4.

Ferdousm J., Reza, M.S., Khan, M.N.A., Saha, S., Alamgir, M., Akhter, J.N. &Rahman, M.K.(2013). Journal of Agroforestry and Environment, 7(1), 65-70.

Fiori, E. (2012). Phytoplankton response to environmental variables and organic pollutants. Laboratory cultures and numerical simulations experiments. Amsdottorato.unibo.it/5216/2/Fiori_Emanuela_tesi.pdf.

Hill, N.M. & Blaney, C.S.(2010). Assessment of species diversity in the Atlantic Maritime eco zone. NRC Research Press, Canada.

Ifabiyi I.P. (1997). Variation in Water Gravity with Rainfall Incidences: A Case Study of Ogbe Stream Ile-Ife, Ife. Res. Publications Geogr. 6(1&2):139-144.

Jaji M.O., Bamgbose O., Odukoya O.O. & Arowolo T.A. (2007). Water Quality Assessment of Ogun River, South West Nigeria. *Environ. Monitor. Assess*. 133:473-482.

Kagalou, I., Tsimaraki, G., & Patsias, A. Water chemistry and biology in a shallow lake (lake pamvotis-Greece) Present state and perspectives. Global Nest: International Journal, 13, 85-94.

Khalifa, N.(2014). Population dynamics of Rotifera in Ismailia Canal, Egypt. Journal of Biodiversity and Environmental Sciences, 4(2), 58-67.

Khare, P.K., and Saxena, M.(2013). Algal study in relation to tolerating organic pollution of Satri Tank, Chhatarpur(M.P), India. Science Secure Journal of Biotechnology,2(1),1-4.

Kivrak, E., & Hasan, G.R.Z.(2005). The benthi algal flora of Demird, ven Dam Reservoir(Erzurum, Turkey). Turkish journal of Botany, 29,1-10.

Kumar, A., & Sahu, R.(2012). Ecological studies of Cyanobacteria in sewage pond of H.E.C. Industrial area, Ranchi, India. Bioscience Discovery, 3(1), 73-78.

Kumar, A., Sharma, L.L., & Aery, N.C.(2008). Physicochemical characteristics and diatom as indicators of trophic status of Kishore Sagar, Rajasthan. Proceedings of Tal, 2007,The 12th World Lake Conference, 1804-1809.

Kumar, P., Wanganeo, A., Sonaullah, F., & Wanganeo, R. (2012). Limnological study on two high altitude Himalayan Ponds, Badrinath, Uttarakhand. International Journal of Ecosystem, 2(5), 103-111.

Lambrakis, N., Antonakos, A. & Panagopoulos, G. (2004). "The use of multicomponent statistical analysis in hydrogeological environmental research." *Water Research*, Vol.38, pp.1862-1872.

Laybourn-Parry, J.(1984). A functional biology of free-living protozoa.University of California Press.

Manly, B.F.J (1994). Multivariate statistical methods. Chapman and Hall, Newyork, U.S.A.

Mc Carmic P.V., and Cairns, J.J. (1994). Algae as indicators of environmental change. Journal of Applied phycology, 6, 509-526.

Nandan S.N. & Patil S.S (2002). Ecology of polluted waters of three ponds of Khandesh area of Maharashtra. In: Ecology of Polluted waters, pp.140-145.

Nandan, S.N., & Aher, N.H.(2005). Algal community used for assessment of water quality of Haranbaree dam and Mosam river of Maharashtra. Journal of Environmental Biology, 26, 223-227.

Palmer, C.M., 1969. A composite rating of algae tolerating organic pollution. Journal of Phycol., 5, 78-82.

Sahu, R., & Kumar, A.(2012). Ecological studies of cyanobacteria in sewage pond of H.E.C. Industrial area, Ranchi. Bioscience discovery, 3(1), 73-78.

Shaik, I.R., Shaik, P.R., Shaik, R.A., & Shaik, A.A.(2013). Investigation on Eutrophication of Taroda Nala at Nanded(India) through physico-chemical analyses of water and composition of planktonic community within the aquatic ecosystem. International Research Journal of Environmetnal Sciences, 2(6), 39-48.

Sharma & Chandrakiran, S. (2012).Comparative analysis of cladoceran communities from three subtropical freshwater ponds of Jammu: patterns, composition and diversity. Bioscan, 6(2), 233-237.

Sharma, V., Verma, B.K., Sharma, R., Sharma, M.S., & Gaur, K.S.(2012). A report on the fresh water Cladocera(Crustacea:Branchiopoda) of south Rajasthan(India). *International Journal of Environmental Sciences*, 3(1).

Sheela, A. M., Letha, J., Sabu, Joseph, Jobin Thomas, Sanal Kumar, S. P., (2012). Water quality assessment of a tropical coastal lake system usingmultivariate-cluster, principal component and factor analysis. Lakes and Reservoir Management, USA, Taylor and Francis Group 17: 143–159(2012).

Simeonov, V., Stratis, J., Samara, C., Zachariadis, G., Vousta, D., Anthemidis, A., Sofoniou, M. & Kouimtzis, T. (2003). "Assessment of the surface water quality in northern Greece". *Water Research*, Vol.37, pp. 4119-4124.

Singh, R.P., & Balasingh, G.S.P.(2011). Limnological studies of Kodaikanal lake(Dindugal district), in Special reference to Phytoplankton diversity, Indian *Journal of Fundamental and Applied Life Sciences*, 1(3), 112.118.

Tiwari, A., & Chauhan, S.V.S.(2006). Seasonal phytoplanktonic diversity of Kitham lake, Agra. *Journal of Environmental Biology*, 27(1), 35-38.

Trivedy, R.K., & Goel, P.K. (1984). Chemical and Biological Methods for Water Pollution Studies. Environm. Pub.

Verma, D.R., Ahmad, T., & Bajpai, S.(2014). Population dynamics of rotifer fauna in two eutrophic ponds of Bahraich district of Uttar Pradesh. *Cibtech Journal of Zoology*,3(2), 37-42.

Ward H.B., & Whipple C.(1918). Fresh Water Biology: John Wiley & Sons (Pub.), London, Chapman & Hall, Ltd. Inc.,1111.

Welch, P.S. (1952) Limnology. McGraw Hill Book Company, ew York, Toronto and London (IInd Ed) pp. 538.

Yerel S (2010). Water Quality Assessment of Porsuk River. *Turkey E-J. Chem*. 7(2):593-599.

Zaim, E.(2007). Planktonic diatom(Bacillariophyta) composition of lake Kaz(Pazar, Tokat). *Turk Journal of Biology*, 31,203.