An Active Biological Food Chain can Restrict Eutophication : Case Study of a Pond Ecosystem

Priyanka Singh[1], AK Haritash[2]

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Abstract

In the present study, an attempt has been made to investigate the seasonal and temporal change in the quality of water and to find out better utilisation of present lentic system. Water Quality Index (WQI) and productivity of a pond ecosystem have been determined. The Water quality Index (WQI) facilitates to evaluate surface water quality for protection of aquatic life with specific guidelines. Water quality was investigated for four months (from January, February, March and April of 2015). The index calculated in this work is composed of nine parameters which are significant for aquatic life. Water quality index were observed to be 483, 478, 469, and 487 during January, February, March, and April respectively. Water quality was found as poor for the aquatic life based on the water quality index. Total phosphate (TP) was observed to be 9.3 mg/l, 13.7 mg/l, 9.5 mg/l and 14.3 mg/l, during the month of January, February, March, and April, respectively classifying the water as high-strength w.r.t. phosphate. Chlorophyll a was found to be 17.9 μg/ml, 20.9 μg/ml, 13.3 μg/ and 32.8 μg/ml during the four samplings. The productivity (as gross primary productivity) was observed as 245 mgO2/l/hr. High value of the TP, Chla, and GPP indicate that water body was hypereutrophic. Despite being hypereutrophic water body, no algal bloom was observed. Apart from it, temporal variation for Chlorophyll a was observed. During spring (March) the concentration was minimum because of the high growth of *Ceriodaphnia Spp*. and maximum in summer due to high intra-species competition, and stress due to high temperature. High concentration of total suspended solid (TSS) was also one of the reason leading to supress the growth of phytoplanktons/algae. During the study period, thermal stratification was also observed which restricted the mixing of the water body, therefore pollutant entering as domestic waste water discharge from the surroundings of the pond get trapped in the epilimnion due to less or no mixing. Recapitulating the above, despite of the poor water quality, presence of active biological food chain can result in no significant adverse effects over the aquatic life.

Keywords: Water quality index; Eutrophication; Thermal stratification; Epiliminion; Gross primary productivity; *Ceriodaphnia spp*.

Introduction

Pond ecosystem plays a crucial role in the biosphere, as it supports aquatic life within and isalso an important sink of untreated waste discharge (domestic, industrial, and agricultural). Nutrient losses from domestic and agricultural area are a significant cause of degradation of quality in surface water bodies (Kadlec 2010; Gupta *et al.* 2016). Excessive discharge of nutrients into the water body can cause eutrophication, which is a worldwide problem. It has been reported that 54% of the lakes in Asia are eutrophic (ILEC 1988-93). There are number of adverse effects of eutrophication including high turbidity, depletion of oxygen,

Author's Affiliation: [1,2]Department of Environmental Engineering, Delhi Technological University, Bawana Road, Shahbad Daulatpur, Delhi 110042, India.

Correspondence and Reprint Requests: AK Haritash, Department of Environmental Engineering, Delhi Technological University, Bawana Road, Shahbad Daulatpur, Delhi 110042, India.

E-mail: akharitas@dce.ac.in

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and it can finally results in major extinction events in aquatic ecosystems (Wetzel 2001). Tropical countries like India have suitable climate for microbial growth, and majority of surface water bodies in these regions arefacing the problemof eutrophication because of algal blooms (Bhagowati and Ahamad 2019).

Classification with respect to trophic status is an important step before providing the conservation plan for awater body (Carlson 1991). There are various physical, chemical and biological factors that affect the quality of water, based on which the water body is classified. Assessment of water quality is a subjective term and is relevant when there is a need to balance ecological and socio-economic interests (El-Serehy *et al.* 2018). Different approaches have been adopted to assess the water quality in past decades *i.e.* water quality index (Hortan 1965) ranging from 0-100 which classifies water body as excellent, good, intermediate, bad, and poor; tropic state index (Carlson 1977) classifies surface water body as oligotrophic, mesotrophic, eutrophic, and hypertrophic; transition water quality index (Giordani *et al.* 2009) ranging from 0 as worst to 100 as best conditions, and many others. The water quality index (WQI) allows the reduction of large amounts of physical, chemical and biological variables into a single number. So, it is a helpful tool for stake holders (water body manager, policy maker, public etc.) to enumerate the water quality (El-Serehy *et al.* 2018). On the other hand, trophic status of a water body indicates the level of biological productivity,phosphate concentration, and light penetration (Carlson 1977).

Eutrophication is one of the very harmful and long lasting threats to the health of an aquatic ecosystem. Algal blooms have number of adverse effects on water users ranging from poor aesthetics to toxicity (Bormans *et al.* 1997). It is reported that phytoplankton growth is primarily controlled by nutrients (phosphorous and nitrogen) (Gagliardi *et al.* 2019). If the concentration of nitrogen and total phosphate present in the water is or above 20 µg/L and 300 µg/L, respectively, then eutrophication may occur. Algal biomass (chlorophyll 'a') is used to observe the response of a lake with variations in nutrient. However, the nutrient–chlorophyll a (Chl a) relationship is generally nonlinear, and suggests that other factors, e.g., physical (water level, color, wind speed) and biotic (predation, competition) also limit algal growth (Carlson 1991). One of the necessary conditions for algal bloom formation is thermal stratification (Sherman *et al.* 1994), as it restricts the vertical mixing of nutrients within the water body, and benthic layer get isolated. Wind speed can overcome the effects of thermal stratification as wind speed higher than 3 ms^{-1} result in complete mixing which may inhibit the growth of algae (Bormans *et al.* 1997). Growth of phytoplankton can also be regulated by zooplankton grazing (Vanni and Temte 1990, Vollenweider *et al.* 1992). All these factors (nutrient loading, wind, thermal stratification, zooplankton grazing etc.) change seasonallyand hence the metabolic process in epilimnion vary with weather conditions (Gigliardi *et al.* 2019).

Materials and Methods

This study was conducted in a pond ecosystem having surface area of 9468 m^2 and average depth of 1.8 meters, located inside the campus of Delhi Technological University, Delhi (28°44'58.55"N, 77°0.6'46.75"E). The study was undertaken from January'15 to April'15. It was a shallow water body and thermally stratified along its depth. It receives wastewater from neighbouring residential colony; and partially from a University hostel.

Water quality analysis

The pond was divided into grids of 100 m^2 each, and in order to deduce water quality a representative sample was collected from each grid to evaluate the spatial variations, if any. The samples were collected in pre-rinsed PET bottles and were immediately transported to laboratory (within 10 minutes) for its characterisation. The samples was characterised for pH, Electric conductivity (EC), temperature, total dissolved solids (TDS), total suspended solids (TSS), dissolve oxygen (DO), oxidation reduction potential (ORP), cations (sodium, potassium, calcium and magnesium), anions- (carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride(Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), total and available phosphate, biochemical oxygen demand (BOD_5), total Kjeldahl's nitrogen (TKN), andchlorophyll a (Chl'a'), as per standard methods in triplicates using analytical grade (AR) chemicals and ultrapure (type I) water. The parameters like pH, EC (µS/cm), temperature (^{0}C), DO (mg/l), TDS (mg/l), and ORP (mV) were measured on the site using Orion make Star A329 model multiparameter meter. Extraction and determination of chlorophyll a was performed according to the method prescribed by Arnon (1949). Gross primary productivity (GPP) of the pond was also dtermined for the month of April by measuring DO in dark and light bottle as prescribed by Garder and Gran (1927). Other parameters were determined within 24 hours using standard methods as prescribed by APHA (1995).

To determine representative status of the water quality in the pond, values recorded as the physico-chemical parameters which are pH, temperature (^{0}C), total dissolved solids (mg/l), dissolve oxygen (mg/l), biochemical oxygen demand (mg/l), sulphate (mg/l), chloride (mg/l), total Kjeldahl nitrogen (TKN), and nitrate (mg/l) were mathematically transformed into a single number that represents water quality as water quality index (WQI) as prescribed by Horton (1965).

The WQI is calculated by using the expression given in equation (i),

$$WQI = \sum Q_n W_n / \sum W_n \quad \text{(i)}$$

Where, Q_n = Quality rating of n^{th} water quality parameter which is calculated as,

$$Q_n = [(V_n - V_{id}) / (S_n - V_{id})] \times 100 \quad \text{(ii)}$$

Where,

V_n = Estimated value of n^{th} water quality parameter at a given sample location.

V_{id} = Ideal value for n^{th} parameter in pure water.

(V_{id} for pH = 7 and 0 for all other parameters)

S_n = Standard permissible value of n^{th} water quality parameter (CONAMA 2005).

W_n= Unit weight of n^{th} water quality parameter.

Results and Discussion

Based on the analysis of samples collected, water quality in the pond was observed to be polluted. The pH varied from 7.8 to 8.7, indicating that the water was almost neutral in February and shifted to slightly alkaline in March. pH governs solubility of most of the elements in a water body, as pH moves above 9.0 dissolve phosphate present in the water will react with calcium and get precipitated (Cerozi and Fitzsimmons 2016). Electrical conductivity and total dissolve solids are the measure of ions present in the system and can significantly alter the suitability of the water body (Alobaidy *et al.* 2010). In the present study, EC and TDSwere observed to vary from 1534 to 1706 μS/cm and 753 to 837 mg/l, respectively. Presence of TSS in the water body affects the light penetration, and the rate of photosynthesis in hypolimnion (Carlson 1977). TSS in this study varied from 734 to 1533 mg/l, indicating high turbidity of water in the pond. It was reported by Cao et al. (2016) that TSS has major role in controlling growth of phytoplankton as they occupy the space available. Significant change in mean temperature was also observed from January being coldest (14^{0}C) to April as warmest (29^{0}C). The mean value of DO in the surface water was above its critical value (5 mg/l, CANOMA 2005) during the study except in February (0.8 mg/l), this can directly be correlated with the value of ORP which was negative (reducing potential) in the same month. BOD_5 and COD of the water were found to be very high varying from 17.6 to 40 mg/l; and 78 to 178 mg/l during the study, respectively, indicating high organic loading in the water body.

Nutrients in a surface water body are the major cause of eutrophication (Yang *et al.* 2008, Bhagowati 2019, Gagliardi 2019). Among the all nutrients, nitrogen and phosphate are limiting ions which can restrict the growth of phytoplanktons (Wetzel 2001). Nitrogen was calculated as nitrate and total Kjeldahl's nitrogen and was found to be varying from 1.1 to 16.9 mg/l; and 9.6 to 25 mg/l, respectively. Nitrate is the final end product of biological activity in the presence of oxygen, which is directly correlated with DO. DO and nitrate were minimum during February, and ammonical nitrogen (as TKN) was maximum with negative ORP of the water. It may be attributed to reduction of nitrogen to ammonia/ammonium ions under prevailing reducing conditions. Phosphorous was measured as available and total phosphorous and was observed from 2.1 to 10.3 mg/l and 9.3 to 14.3 mg/l, respectively. Both nitrogen and phosphorous were present above the threshold limit to cause eutrophication (Yang *et al.* 2008). Domestic waste water has substantial concentration of ions like sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, sulphate etc. These ions are responsible for imparting hardness to water which may have associated adverse effects on the aquatic life. Carbonate was observed only in March (42 mg/l) when pH rose to basic (as 8.7) which is suitable for the precipitation of cations present in the water. Chloride and sulphate was observed to be varying from 175 to 247 mg/l and 47 to 90 mg/l, respectively, which is above the standard limit (250 mg/l for aquatic organisms).

To obtain WQI values for the water body, mean values of 09 parameters (Table 1) were used. WQI values were 135, 172, 282 and 240 in the months of January'15, February'15, March'15, and April'15, respectively. Based on the WQI, the water body was classified as significantly polluted. Productivity was also calculated in April as gross primary productivity (GPP) and was observed as 245 mgO_2/l/hr. High productivity and high phosphate concentration classify the water body as hypereutrophic (Sharma and Giri 2018). High productivity indicates high algal biomass in the water body (Mathur *et al.* 2015), but the chlorophyll concentration (13.3 to 32.8 mg/l) in the present study was very less as compared to a eutrophic water body. The limited algal growth may be affected by zooplankton grazing, which in turn is affected by physico-biochemical changes. Maximum growth of zooplankton biomass can be obtained in spring, whereas Daphnia which is the most influential grazer attains maximal biomass in late spring (Vanni and Tempte 1990). Chlorophyll was found to be varying from 13.3 (March) to 32.8 µg/l (April). During spring (March) the concentration was minimum because of the high growth of zooplankton (Ceriodaphnia Spp.) present in the water body, and maximum in summer due to high intra-species competition, and stress due to high temperature (Zao *et al.* 2008). The studied system was thermally stratified, as change in temperature with depth was found above 0.10C/m. Minimum chlorophyll in March was observed which could be result of complete mixing between weak stratification (January and February) and strong stratification (April), as algal bloom do not form in complete mix condition (Bormans *et al.* 1997).

Table 1: Physicochemical characterisation and water quality Index (WQI) of the pond water

Period (no. of samples) / Parameters	January'15 (n=10) (mean±SD)	February'15 (n=09) (mean±SD)	March'15 (n=09) (mean±SD)	April'15 (n=09) (mean±SD)
pH*	8.1 ±0.12	7.8 ±0.16	8.7 ±0.16	8.3 ±0.09
EC (µS/cm)	1616 ±5.8	1706 ±5.7	1534 ±18.9	1664 ±13.6
TDS*	773 ±58.9	837 ±2.5	753 ±9.1	816 ±6.7
TSS	734 ±319	895 ±602	1154 ±182	1533 ±570
Temperature (°C)*	14 ±0.5	21 ±1.3	26 ±0.9	29 ±0.6
DO*	9.5 ±2.4	0.8 ±1	17.9 ±8.3	10 ±6.8
ORP (mV)	108 ±48	-246 ±51	137 ±26	120 ±74
Na^+	212 ±5	219 ±3	206 ±2.5	185 ±9.7
K^+	43 ±3	42 ±0.7	44 ±0.9	44 ±1.5
Ca^{2+}	51 ±4	80 ±2	85 ±3	90 ±2
Mg^{2+}	61 ±13	36 ±2	24 ±4	67 ±7.3
CO_3^{2-}	0	0	42 ±10	0
HCO_3^-	616 ±46	1148 ±174	236 ±42	773 ±33
Cl-*	175 ±6	247 ±6	210 ±10	182 ±11
SO_4^{2-}*	90 ±6	61 ±7	47 ±17	64 ±5
NO_3^-*	3.2 ±0.5	1.1 ±1.02	16.9 ±0.8	2 ±0.4
AP	8.4 ±0.2	10.3 ±2.3	2.1 ±0.9	8.6 ±1.7
TP	9.3 ±2	13.7 ±1.9	9.5 ±1.6	14.3 ±1.9
BOD5*	17.6 ±8.5	36 ±2.8	40 ±8.2	40 ±6.2
COD	109 ±50	178 ±29	78 ±25	96 ±26
TKN*	13 ±4.5	25 ±6.7	16 ±4.2	9.5 ±2.1
Chl'a' (µg/l)	17.9 ±5.6	20.1 ±8.9	13.3 4.6	32.8 ±10.2
WQI	135	172	282	240

Note: all the values are given in 'mg/l' unit except pH; EC (µS/cm); Temperature (°C); Redox potential (ORP) (mV); and chlorophyll 'a' content (µg/l); *parameters used to calculate WQI.

Conclusion

Based on the physico-chemical characteristics and WQI, the water body was classified as highly polluted. Despite having poor water quality and being hypereutrophic, limited algal growth was observed during the study. Biomass count was represented by chlorophyll 'a' concentration in water which was varying from 13.3 to 32.8 µg/l in March and April 2015, respectively. Restricted growth of phytoplankton during March was observed due to high growth of zooplankton (Ceriodaphnia sp.) in late spring, which resulted in high grazing rate. Thermal stratification was also observed during the study. As the water undergo mixing due to the shift from weak stratification to strong stratification, phytoplankton growth was restricted. The study concludes that an active food-chain complemented with limited vertical mixing in a thermally stratified aquatic ecosystem can limit the growth of phytoplanktons despite high concentration of nutrients.

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