Goyal, V.C.; Singh, Omkar; Singh, Rajesh; Chhoden, Kalzang; Kumar, Jhalesh; Yadav, Sandeep; Singh, Nihal; Shrivastava, N.G.; Carvalho, Laurence. 2021.
Ecological health and water quality of village ponds in the subtropics limiting their use for water supply and groundwater recharge.

The definitive version was published in *Journal of Environmental Management*, 277, 111450. https://doi.org/10.1016/j.jenvman.2020.111450

The definitive version is available at https://www.elsevier.com/

Research Highlights

- Water quality of village ponds in sub-tropical India is severely degraded
- High nutrient and organic loadings resulted in hypertrophic and anoxic conditions
- Poor water quality status impacts freshwater biodiversity and limits pond use
- Dissolved oxygen concentrations <4 mg/l prevents development of fisheries
- Electrical conductivity >1500 µs/cm limits their use for irrigation
- Decentralised wastewater treatment is needed to restore ponds as a water resource

Ecological health and water quality of village ponds in the subtropics limiting their use for water supply and groundwater recharge

V. C. Goyal[1], Omkar Singh[1], Rajesh Singh[1]*, Kalzang Chhoden[1], Jhalesh Kumar[2], Sandeep Yadav[1], Nihal Singh[1], N. G. Shrivastava[1], Laurence Carvalho[3]

[1]National Institute of Hydrology, Roorkee, Uttarakhand, India

[2]NSV College of Agricultural Engineering and Technology & Research Studies, IGKV, Raipur, Chattisgarh, India

[3]UK Centre for Ecology & Hydrology, Penicuik, United Kingdom

Abstract

Ponds are a typical feature of many villages in the subtropics, and have been widely used as important sources of water for agriculture, aquaculture and groundwater recharge, as well as enhancing village resilience to floods and drought. Currently many village ponds are in a very poor state and in dire need of rejuvenation. This paper assesses the current water quality status and ecological health of twelve sub-tropical village ponds, situated in western Uttar Pradesh, India. This assessment is used to evaluate their wastewater treatment needs in relation to potential village uses of the water. Physico-chemical (Secchi depth, Total phosphorus and Total nitrogen) and biological (Phytoplankton chlorophyll-a) indicators highlight hypertrophic conditions in all the ponds. The study indicates that the status of village ponds requires significant investments in wastewater treatment to restore their use for many purposes, including aquaculture, although some may still be acceptable for irrigation purposes, as long as pathogenic bacteria are not abundant. We propose increased implementation of decentralised systems for wastewater treatment, such as septic tanks and constructed wetlands, to reduce the

organic and nutrient loads entering village ponds and allow their use for a wider range of purposes.

Keywords: Phytoplankton; Trophic Status; Wastewater treatment, Water resources; Aquaculture

1. Introduction

Villages in sub-tropical countries are facing stagnation of drains and choked ponds, which are in dire need of renovation so that the ponds can be effectively utilized as a source of water for agriculture, aquaculture and potentially even bathing and drinking. Village ponds can also reduce flood impacts during monsoon seasons and facilitate groundwater recharge, enhancing the availability of water throughout the year. Village ponds also support biodiversity, cultural services, and carbon sequestration (Moore and Hunt, 2012). Currently, however, many village ponds in these regions are filled with domestic wastewater and solid waste. Disposal of wastewater in village ponds is a major public health concern as the stagnant water smells bad and leads to the spread of many diseases (Shukla et al. 2020). As a result, village ponds have become dumps for solid waste and are not used for any useful purpose. The groundwater recharge from these polluted ponds can also contaminate the local aquifer. There is, therefore, an urgent need for protection, conservation and rejuvenation of such village ponds. Initially this requires an assessment of their trophic condition and ecological health to assess their current status in relation to relevant use-based indicators. Here, we focus particularly on their status in relation to indicators for irrigation water and groundwater recharge and then consider what management interventions may be needed to restore village ponds to these standards.

Human activities in the catchment around a pond change the nutrient inputs which then lead to changes in the ponds' trophic state, biotic assemblages and physico-chemical conditions (Li et al. 2019). Ecological health assessment essentially require evaluation of the trophic status to classify ponds in terms of the productivity of the system. The trophic state is functionally defined by factors related to nutrients, algal biomass and water transparency (Wetzel 1975; Ayoade et al. 2019). Algal community characteristics reflect a pond's trophic dynamics, which are related functionally to phosphorus, nitrogen, water transparency, chlorophyll, oxygen depletion and nutrient loading (Osgood 1984). The trophic condition of a water body can be expressed using a Trophic State Index (TSI), which is derived from multiple parameters (e.g. chlorophyll, phosphorus, Secchi depth, nitrogen).

An action plan for pond management requires defining the problems, identifying causes, examining feasible management alternatives, and implementing remedial measures to achieve the desired results. An integrated assessment approach using a TSI, phytoplankton community index and water chemistry characteristics, therefore, can effectively represent the waterbody status and can be the basis to develop a robust management plan. The success of any water body rejuvenation depends on converting it into a resource for the people residing in its catchment, and putting efforts into public participation to achieve this goal. Village ponds can be used for recreational activities, irrigation, fisheries, and groundwater recharge requiring improvement in the pond water quality by treating the inflowing water.

The Government of India is supporting a programme of rejuvenation of village ponds and other water bodies for water sustenance. There is, however, limited information available on the water quality, ecological health and trophic status of village ponds in India and elsewhere. Thus, the objective of this study was to assess the ecological health of village ponds in western Uttar Pradesh using water chemistry and biological characteristics. This assessment will underpin the preparation of an action plan for the rejuvenation of pond health in India, to enhance water resources, but is also highly relevant to rural pond management in other tropical and sub-tropical countries.

2. Study Area

Twelve ponds from the identified villages of Muzaffarnagar and Meerut districts of western Uttar Pradesh (India), located at 77°02′-78°07′E and 28°44′-29°44′E, were selected for the study (Fig. 1). The details of these ponds are given in Table 1. The study area is located in the Doab region of Indo-Gangetic Plain, with monsoon influenced humid subtropical climate. The summer season during early April to late June, are extremely hot, with temperatures reaching up to 49 °C. The monsoon arrives in late June and continues until the middle of September. The average annual rainfall is 929 mm and 845 mm in Muzaffarnagar and Meerut district, respectively. The soil in the area is unconsolidated alluvial deposits. Land is very fertile for growing crops, especially wheat, sugarcane and vegetables.

The ponds receive wastewater from the nearby habitation and storm water from the surrounding areas during monsoon. Wastewater generated from households in the catchment area of a pond reaches the ponds through naturally defined channels. The majority of ponds are surrounded by rural habitation and all kinds of waste material, including grit, silt, dairy-waste, etc. enter into the ponds. In a few ponds, runoff from the nearby agricultural fields also brings residues of fertilizers, pesticides, etc. The ponds generally constitute a landlocked water body as the outlets are blocked for most of the ponds. Depth of the ponds generally varies between 3-4 m. The storage capacity of the study ponds varied between 80,208 m^3 and 6,062 m^3 for the largest pond (MN-4) and the smallest pond (MN-8), respectively. The ponds are a source of groundwater recharge in these areas as the depth of groundwater varies between 5-8 m (b.g.l.) at MN-8 to 38 m (b.g.l.) at MN-1.

3. Materials and Methods

3.1. Use-based Indicators

The poor status of the ponds are due to neglect from society as a result of their limited or no use in present times. Therefore, to avoid deterioration, the value of these water bodies should be recognised and they should be designated for some specific use(s). The indicator parameters for different uses (Table 2) were considered and for setting the target values for management strategies.

3.2. Sample Collection & Analysis

Pond water samples were collected from 15-20 cm below the surface in the month of June 2017. The samples were preserved and analyzed for pH, EC, major ions, DO, BOD, COD, and Chlorophyll-a as per standard methods (APHA 2012) in triplicates. Water temperature, pH, EC and DO were recorded onsite using SENSOREX AQUACHEM digital meter. DO in the water samples were also fixed in the field for analysis in the laboratory by Azide-Winkler titration method. COD of the samples was estimated using dichromate reflux titrimetric method. BOD was analyzed using manometric respirometric method. Chlorophyll-a (Chl-a), total phosphorus (TP) and total nitrogen (TN) were analyzed by spectrophotometric methods. For determining the transparency of pond water a Secchi disc was used. Plankton samples were sampled by filtering pond water through a plankton net of 33mm mesh size and preserving the filtrate in 1% Lugol's solution. The samples were examined using an inverted microscope (Digi –

LaboMat) and the phytoplankton taxa were identified using standardized databases for phytoplankton taxonomy.

3.3. Trophic State Determination Using Different Trophic Indices

The trophic status of a water body is calculated by a combination of water quality parameters like Secchi depth (SD) denoting water transparency, chlorophyll-a concentration for algal productivity and nutrients (N & P) concentration, and are classified as eutrophic, mesotrophic or oligotrophic (Carlson 1977; Taylor et al. 1980; Carlson and Simpson 1996). Due to the dynamic nature of pond productivity and eutrophication as a result of natural and anthropogenic factors, no single assessment variable can be considered as a true measure of eutrophication status (Xu et al. 2001; Padisak et al. 2009) and a combination of physical and chemical parameters are widely used in determining the health of an aquatic ecosystem (Phillips et al. 2013). The health of water body can also be assessed using biological indicators, with phytoplankton considered a reliable measure of the health of a water body depicting different levels of eutrophication (Carvalho et al., 2013; Xu et al., 2001).

3.4. Trophic Status Index

Carlson's trophic status index (Carlson 1977) has been widely used to estimate the trophic condition of water bodies. This method is based on three parameters namely Chl-a, SD and TP in a water body. Kratzer & Brezonik (1981) concluded that the total nitrogen (TN) content of the water body also impacts the productivity and incorporated TN in the composite trophic status index (CTSI). In the present work, the Kartzer & Brezonik (1981) approach was adopted using the following equation:

$$CTSI = \frac{TSI(SD)+TSI(Chl-a)+TSI(TP)+TSI(TN)}{4} \quad (1)$$

Where

$$TSI(SD) = 60 - 14.41\ln(SD)$$

$$TSI(Chl-a) = 9.81\ln(Chl-a) + 30.6$$

$$TSI(TP) = 14.42\ln(TP) + 4.15$$

$$TSI(TN) = 14.43\ln(TN) + 54.45$$

TP and Chlor-a are in µg/l, and SD transparency in meters. Based on the values of CTSI, the ponds are classified as oligotrophic, mesotrophic, eutrophic, and hypertrophic (USEPA 1979).

3.5. Nygaard's Algal Index

Nygaard's index (1949) evaluates the productivity of water bodies based on the ratios of different algal groups (Eq. 2-5). The combination of four indices is used to calculate a Compound Quotient Index (CQI) (Eq. 6).

$$\text{Cyanophycean index} = \frac{Cyanophyceae}{Desmidaceae} \quad (2)$$

$$\text{Chlorophycean index} = \frac{Chlorococcales}{Desmidaceae} \quad (3)$$

$$\text{Bacillariohycean index} = \frac{Centric\ diatoms}{Pennate\ diatoms} \quad (4)$$

$$\text{Euglenophycean index} = \frac{Euglenophyceae}{Cyanophyceae + Chlorococcales} \quad (5)$$

$$CQI = \frac{Cyanophyceae + Chlorophyceae + Bacillariophyceae + Euglenophyceae}{Desmidaceae} \quad (6)$$

3.6. Shannon-Wiener Diversity Index

Shannon-Wiener Index (*H*) accounts for both abundance and evenness of species present and is commonly used to characterize the species diversity in a community (Shannon and Weaver 1964). The following equation is used to calculate the Shannon-Wiener Index:

$$H = -\sum[(pi).\ln(pi)] \quad (7)$$

Where

pi is the proportion of individuals of one particular species observed divided by the total number of species.

3.7. Statistical Analysis

The relationship between the physico-chemical parameters and biological parameters pertaining to the trophic status of a water body was investigated by Pearson's correlation coefficient (r) using SPSS version 16.0. The correlation coefficient ranges from -1 to 1. A positive correlation indicates that both the variables increase or decrease together, whereas a negative correlation indicates that as one variable increases, the other decreases and vice versa.

4. Results and Discussion

4.1. Physico-chemical Characteristics

The physico-chemical characteristics of the ponds are given in Table 3. Water temperature ranged from 25 to 35 ºC. The pH of the ponds varied from 7.2 to 9.3. Samples from 25% of the ponds had pH levels >8. High pH in the ponds during the daytime is likely due to the uptake of CO_2 by algae and plants for photosynthesis. Moreover, the high pH values may also be due to the influents from agricultural fields, addition of soap and other household ingredients into water (Mohammad et al. 2015). The Electrical conductivity (EC) of the ponds ranged from 1303 to 2280 µS/cm. The higher values of EC in ponds are likely to be due to the discharge of salts from the households and agricultural field (Ekhalak et al. 2013) as well as evaporation of water. These levels were largely above the acceptable level of 1500 µS/cm outlined by BIS (1984) for irrigation water but mostly below a later CPCB (2019) standard of 2500 µS/cm. Dissolved oxygen (DO) varied from non-detectable (ND) to 3.1 mg/l. These low DO concentrations clearly reflect the impact of high organic loadings to the ponds (Bhattacharyya & Ghosh 2018) and are all lower than the target values for fisheries of 4 mg/l (CPCB, 2019). Human and animal activities around the pond e.g. washing, defecation etc. leads to a high concentration of organic load, and a high Biochemical oxygen demand (BOD) with levels varying from 16 to 90 mg/l in the ponds, indicating highly polluted water. The optimum value of BOD for drinking, irrigation and fishery is less than 6 mg/l (Khanom et al. 2014). Further, Chemical oxygen demand (COD) was 56 to 380 mg/l in ponds, indicating that organic waste is entering into ponds, whose probable sources include sewage discharges, agricultural runoff and runoff from livestock kept in the villages. Total nitrogen (TN) concentrations ranged from 410 to 514 mg/l and total phosphorus (TP) concentrations ranged from 0.65 to 9.79 mg/l. Concentrations of phosphorus in the ponds were much higher than 0.05 mg/l, confirming hypertrophic condition, as reported by Kilpimaa et al. (2014) and Mor et al. (2016). The excessive amounts of nutrients lead to dense blooms of phytoplankton, reduced water clarity, shading of plants, and foul odour. ME-1, MN-4, MN-7, MN-8 and MN-9 had especially high values of TP. The TN and TP ratio can be used to indicate which nutrient is limiting the growth of algae in ponds.. The high TN/TP ratio (42.6 to 772.3) in all the ponds, indicates phosphorus is the limiting nutrient for algal growth, but this assumes bioavailable forms of these nutrients are not in excess. Given the very high concentrations of TP and TN it is likely that algal growth is not limited by either nutrient, but analysis of bioavailable forms is really needed to confirm this (Maberly et al., 2020). Strong ($p < 0.01$), significant ($p < 0.05$) and moderate ($p < 0.1$) correlations were observed among several physico-chemical parameters (Table 4). COD had a strong positive correlation with EC (0.708), BOD (0.949), and total phosphorus (0.622). These correlations may reflect common input sources from the villages of high conductivity, and high organic and nutrient loading. The microbial oxidation of organics taking place in the ponds also leads to increases in conductivity and available nutrients for algal production (El-serehy et al. 2018). Secchi depth, which is typically related with phytoplankton growth in lakes was very low at 0.04 to 0.16 m. Suspended sediment loads were high and appear to be the main cause of such low Secchi depths, preventing too much plankton development (Kumar 2012). In summary, it can be seen that the organic and nutrient loading into the ponds is exceptionally high resulting in very low dissolved oxygen concentrations, hypertrophic conditions and very poor water clarity.

4.2. Phytoplankton Characteristics

In aquatic ecosystems, phytoplankton are important primary producers and an indicator of the health and productivity of the water body (Ekhalak et al. 2013). In the present study, green algae (Chlorophyceae), desmids (Desmidiaceae), Euglenophytes (Euglenophyceae), cyanobacteria (Cyanophyceae) and diatoms (Bacillariophyceae) were all well represented in the ponds (Table 5 & 6). The cyanobacteria namely *Dolichospermum* and *Microcystis* were dominant in all the ponds. Blooms of cyanobacteria are an indicator of eutrophic waters (Carvalho et al., 2013). The large number of Euglenophytes are a characteristic indication of organic pollution, as these genera can survive without light on a diet of organic matter, taking in nutrients by osmotrophy (Leadbetter et al. 2002). Chlorophyceae were also abundant in all the ponds and many genera recorded are also characteristic of waters rich in nutrients (Thakur et al. 2014). More surprisingly was the frequency of desmids like *Cosmarium*, *Closterium* which were observed in all the ponds and are typically indicators of more mesotrophic or oligotrophic waters (Nygaard, 1949; Round 1957; Rawson 1956; Palmer 1969; Garg et al. 2006; Tiwari et al. 2006). It has, however, been observed that in shallow water bodies these desmid genera can grow well (Coesel et al. 1978; Taylor et al. 1980; Dembowska et al. 2018). The high diversity of diatoms also included many genera associated with plants and sediments rather than true planktonic genera.

4.3. Trophic Status

The CTSI of the ponds were in the range of 104 to 115 indicating the hypertrophic nature of the ponds (USEPA 1979) (Table 3). This is due to the high loading of organic matter and nutrients from domestic wastewater and run-off from agricultural fields and livestock, which results in poor water clarity and high TP and phytoplankton productivity in the ponds (Gupta et al. 2014; Sharma and Gupta 2013). TP had a strong positive correlation with SD (0.725) and significant correlation with chlorophyll-a (0.612). The strong correlation with SD is most likely due to TP largely being in the form of suspended solids. The correlation of TP concentrations with chlorophyll-a reflects the widely-recognised importance of phosphorus in influencing phytoplankton abundance (Carvalho et al., 2013).

Further, the decomposition of the organic matter by bacteria are likely to lead to anoxic conditions as observed in the present study. Because of the anoxic conditions, fish are absent and zooplankton are reduced, resulting in an imbalanced trophic structure within these pond ecosystems.

The trophic status was further evaluated using Nygaard's indices (1949) based on phytoplankton community composition and a Compound Quotient Index (CQI) was used to get a meaningful evaluation of the extent of pollution in the water. The CQI value less than 0.24 indicates ultraoligotrophic nature, 0.24-1.8 oligotrphic, 1.8-3.0 oligomesotrophic. 3.0-4.2 mesotrophic, 4.2-5.4 mesoeutrophic, 5.4 – 10 eutrophic, and greater than 10 hypertrophic. The CQI values in the present study ranged from 4.5 to 6.89 (Table 7), indicating all the ponds as meso-eutrophic, except one, which was identifed as eutrophic (Yang 1990). Results showed that chlorophyceae and cyanobacterial groups dominated, indicators of more polluted eutrophic or hypertrophic waters (Kumar 2014).

The CTSI had a positive correlation with CQI indicating both chemical and biological indices are interrelated. Despite this, the water quality based indices showed the ponds in a much more eutrophic state than the phytoplankton-based Nygaard Index. This was most likely due to the presence of floating macrophytes, water hyacinth and duckweeds, in the ponds, affecting Nygaard's Index. The floating plants enhance the diversity of plant-associated desmid and diatom species, that appear in the plankton samples. The macrophytes can also significantly influence the phytoplankton community and species composition by shading the water column, releasing organic compunds, and competing for nutrients (Van Donk and van de Bund 2002; Celewicz-Gołdyn 2010; Mohamed 2017; Dembowska et al. 2018). Our study highlights that the Nygaard Index, developed for lakes, is not appropriate for shallow ponds. The mismatched trophic status calls for further development of phytoplankton based indices that are suitable for small and shallow water bodies.

4.4. Management Options for Water Quality Improvement

The results clearly highlight that the water quality of the ponds is not suitable for sustaining a healthy biodiversity-rich ecosystem. Furthermore, many of the water quality parameters indicated the ponds cannot be used for many economical activities, like pisciculture, due to the high organic loads and consequent low DO levels. Usage of this water for irrigation activities is also not advisable due to high electrical conductivity and coliform counts. The high coliform counts could also contaminate the shallow groundwater which can be a primary source of drinking water in many villages. The groundwater recharge of polluted water through ponds could catalyse the mobilisation of contaminants, like Arsenic, Uranium and Fluoride, through microbial action and/or dissolution of aquifer minerals. In order to make village ponds beneficial for the environment and society, it is essential to reduce the contaminated organic loadings. This can be achieved by treating point sources of wastewater pollution in the village, such as through increasing numbers of septic tanks and other forms of decentralised wastewater treatment. It has been demonstrated by Monzo et al. (2020) that ponds receiving treated wastewater low in organics and nutrients can support a rich biodiversity. Considering the limitations related to power supply, operation and maintenance costs, and land availability in India, constructed wetlands offer a promising nature-based solution for decentralised treatment of inflowing contaminated village wastewater (Monzo et al., 2020; Olguin et al., 2017). The silt that may escape from decentralized wastewater treatment systems needs to be removed in a sedimentation chamber before entering a pond. This will help in reducing the clogging of pond bed surfaces for infiltration and eliminate a large part of the particulate organic load and forms of nutrients entering ponds. However, it is to be expected that nutrients and some organic load will still reach ponds through diffuse surface run-off from agricultural fields, resulting in occassional high nutrient loading events. Therefore, provison for in-pond treatments, such as aeration and harvesting of floating-leaved macrophytes may be required. In addition, periodic sediment dredging can be practiced to mitigate internal loading from nutrient-rich sediments. Decentralised wastewater treatment in combination with some active pond management, should be sufficient to restore village ponds in sub-tropical countries to make them suitable for groundwater recharge, irrigation, and pisciculture, once again, making these water bodies a useful resource (Chen et al., 2019).

5. Conclusions

In developing countries, like India, traditional sources of surface water, such as village ponds, have deteriorated. This study was conducted to evaluate the status of a number of village ponds to evaluate their restoration needs and potential for water use. The following conclusions are drawn from this study:

i. The common measures of trophic state of the ponds (TP, TN, Secchi depth, Chlorophyll-a) indicated hypertrophic status and consequently poor ecosystem health.

ii. The ponds were all rich in organic matter and nutrients due to loadings from domestic wastewater, livestock waste and village surface run-off. Because of this ponds were mostly anaerobic/anoxic due to microbial degradation of the organic matter preventing establishment of fisheries. Electrical conductivity was also generally high, limiting use for irrigation water.

iii. These indicators highlight currently the ponds offer little value as a village resource and decentralised wastewater treatment options are needed to restore their potential use for groundwater recharge, irrigation and other uses.

The management strategies in these ponds could include harvesting of floating macrophytes to remove nutrients from the system, but ultimately some form of decentralised wastewater treatment, such as constructed wetlands, are needed to reduce the loads of organic matter and nutrients entering from the villages and surrounding land. The study highlights the value of baseline monitoring for formulating the rejuvenation strategies for village ponds in India and other countries in the sub-tropics.

6. Acknowledgements

This work was funded by Indian National Committee on Surface Water (INCSW), Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Govt. of India and the authors gratefully acknowledge the support. Laurence Carvalho was supported by the Natural Environment Research Council award number NE/R000131/1 as part of the SUNRISE programme delivering National Capability.

7. Data Sharing

The data that support the findings of this study are available from the corresponding author upon reasonable request.

8. References

Alcalde-Sanz, L., & Gawlik, B. M. (2017). Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge - Towards a water reuse regulatory instrument at EU level, EUR 28962 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-77176-7, doi 10.2760/887727, PUBSY No.109291.

APHA (2012). Standard Method of Water and Waste Water Examination, American Public Health Association, 22nd Edition, Washington DC.

Ayoade, A. A., Osuala, B. O., & Adedapo, T. A. (2019). Physico-chemical parameters, chlorophyll a and phytoplankton community as trophic state indices of two tropical lakes, Southwestern Nigeria. EurAsian Journal of Bio Sciences, 13, 15-22.

Bhattacharyya, B., & Ghosh, N. (2018). Physicochemical analysis of pond water in Purba Barddhaman , West Bengal. International Research Journal of Environmental Sciences, 7(2), 54–59.

BIS (1986). Indian standard: Guideline for the quality of irrigation water (IS: 11624-1986; Reaffirmed 2001). Bureau of Indian Standards, New Delhi.

Bonachela, S., Acuña, R. A., & Casas, J. (2007). Environmental factors and management practices controlling oxygen dynamics in agricultural irrigation ponds in a semiarid Mediterranean region: Implications for pond agricultural functions. Water Research, 41(6), 1225–1234.

Carlson, R. E. (1977). A Trophic state index for lakes. Limnology and Oceanography, 22, 363–369.

Carlson, R. & Simpson J. (1996). A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society, Alachua, FL, USA.

Carvalho L., Poikane S., Lyche Solheim A., Phillips G., Borics G., Catalan J., De Hoyos C., Drakare S., Dudley B., Jarvinen M., Laplace-Treyture C., Maileht K., McDonald C., Mischke U., Moe J., Morabito G., Nõges P., Nõges T., Ott I., Pasztaleniec, A., Skjelbred B. & Thackeray S. (2013). Strength and uncertainty of lake phytoplankton metrics for assessing eutrophication impacts in lakes. Hydrobiologia, 704, 127-140.

Celewicz-Gołdyn, S. (2010). Influence of Ceratophyllum demersum L. on phytoplankton structure in a shallow eutrophic lake. Oceanological and Hydrobiological Studies, 39(3), 121-128.

Central Pollution Control Board (2019) Water Quality Standards. Available at: https://cpcb.nic.in/wqstandards/ (Accessed: 20 September 2020).

Chen, W., He, B., Nover, D., Lu, H., Liu, J., Sun, W., & Chen, W. (2019). Farm ponds in southern China: Challenges and solutions for conserving a neglected wetland ecosystem. Science of The Total Environment, 659, 1322-1334.

Coesel, P. F. M., Kwakkestein, R., & Verschoor, A. (1978). Oligotrophication and eutrophication tendencies in some Dutch mooreland pools, as reflected in their desmid flora. Hydrobiologica, 61(1):21-31.

Dembowska, E. A., Mieszczankin, T., & Napiórkowski, P. (2018). Changes of the phytoplankton community as symptoms of deterioration of water quality in a shallow lake. Environmental Monitoring and Assessment, 190, 95.

Ekhalak, A., Mohini, G., & Ranjana, S. (2013). Phytoplanktonic studies of village pond with reference to water quality. International Journal of Innovative Research in Science

Engineering and Technology, 2(9), 4458–4466.

El-serehy, H. A., Abdallah, H. S., Al-misned, F. A., Irshad, R., Al-farraj, S. A., & Almalki, E. S. (2018). Aquatic ecosystem health and trophic status classification of the Bitter Lakes along the main connecting link between the Red Sea and the Mediterranean. Saudi Journal of Biological Sciences, 25(2), 204–212.

Gupta, M. (2014). A New Trophic state index for lagoons. Journal of Ecosystems, 2014, 1-8.

Garg, R. K., Saksena, D. N., & Rao, R. J. (2006). Studies on nutrients and trophic status of Ramsagar reservoir, Datia, Madhya Pradesh. Nature, Environment and Pollution Technology, 5(4), 545-551.

Khanom, U. S., Sharmeen, S., Ferdouse, J., Shumi, W., Abdu, A., Hamid, H. A., & Hossain M. A. (2014). Determination of pond water quality for aquaculture and ecosystem management. Journal of Food, Agriculture & Environment, 12, 389-394.

Kilpimaa, S., Runtti, H., Kangas, T., Lassi, U., & Kuokkanen, T. (2014). Removal of phosphate and nitrate over a modified carbon residue from biomass gasification. Chemical Engineering Research and Design, 92(10), 1923–1933.

Kratzer, C. R., & Brezonik, P. L. (1981). A Carlson-type trophic state index for nitrogen in Florida lakes. Journal of the American Water Resources Association, 17(4), 713–715.

Kumar, A., & Sharma, M. P. (2014). Application of water quality index and diversity index for pollution assessment of Kankaria lake at Ahmedabad , India. Journal of Civil &

Environmental Engineering, 4(3), 1-4.

Leadbeater, Barry S. C.; Green, John C. (2002). Flagellates: Unity, Diversity and Evolution. CRC Press. ISBN 9780203484814

Li, W. (1998). A conceptual model for predicting and managing vegetative types in shallow lakes. Ecological Engineering, 10(2), 165–178.

Li, Y., Wright, A., Liu, H., Wang, J., Wang, G., Wu, Y., & Dai, L. (2019). Land use pattern, irrigation, and fertilization effects of rice-wheat rotation on water quality of ponds by using self-organizing map in agricultural watersheds. Agriculture, Ecosystems & Environment, 272, 155–164.

Lv, J., Wu, H., & Chen, M. (2011). Effects of nitrogen and phosphorus on phytoplankton composition and biomass in 15 subtropical, urban shallow lakes in Wuhan, China. Limnologica, 41(1), 48–56.

Maberly S.C., Davies P.S., Pitt J.-A. & L. Carvalho L., 2020. Nitrogen and phosphorus limitation and the management of small productive lakes. Inland Waters, Online early 23 March 2020. https://doi.org/10.1080/20442041.2020.1714384

Manzo, L. M., Epele, L. B., Horak, C. N., Kutschker, A. M., & Miserendino, M. L. (2020). Engineered ponds as environmental and ecological solutions in the urban water cycle: A case study in Patagonia. Ecological Engineering, 154, 105915.

Mohammad, M. J., Krishna, P. V, Lamma, O. A., & Khan, S. (2015). Analysis of water quality using limnological studies of Wyra Reservoir, Khammam District, Telangana, India. International Journal of Current Microbiology and Applied Sciences, 4(2), 880–895.

Mohamed M. J., (2017). Macrophytes-cyanobacteria allelopathic interactions and their implications for water resources management - a review. Limnologica, 63, 122–132.

Moore, T. L. C., & Hunt, W. F. (2012). Ecosystem service provision by stormwater wetlands and ponds – A means for evaluation? Water Research, 46(20), 6811–6823.

Mor, S., Chhoden, K., & Khaiwal, R. (2016). Application of agro-waste rice husk ash for the removal of phosphate from the wastewater. Journal of Cleaner Production, 129, 673–680.

Nygaard, G. 1949. Hydrobiological studies on some Danish ponds and lakes II. The quotient hypothesis on some new or little known phytoplankton organisms. Det Kongelige Danske Videnskabernes Selskab 7: 293 pp.

Olguín, E. J., Sánchez-Galván, G., Melo, F. J., Hernández, V. J., & González-Portela, R. E. (2017). Long-term assessment at field scale of Floating Treatment Wetlands for improvement of water quality and provision of ecosystem services in a eutrophic urban pond. Science of The Total Environment, 584-585, 561–571.

Osgood, R. (1984). Who needs trophic state indices? Lake and Reservoir Management, 1(1), 431-434.

Padisak, J., Crossetti, L. O. & Naselli-Flores, L. (2009). Use and misuse in the application of the phytoplankton functional classification: a critical review with updates. Hydrobiologia, 621, 1-19.

Palmer, C. M. (1969). A composite rating of algae tolerating organic pollution. Journal of Phycology, 5(1), 78-82.

Phillips, G., Lyche-Solheim, A., Skjelbred, B., Mischke, U., Drakare, S., Free, G., Järvinen, M., de hoyos, C., Morabito, G., Poikane, S. & Carvalho, L. (2013). A phytoplankton trophic index to assess the status of lakes for the water framework directive. Hydrobiologia, 704, 75-95.

Rawson D. S. (1956). Algal indicators of trophic lakes types. Limnology and oceanography, 1(1), 18-25.

Round, F. E. (1957). The Diatom community of some bryophyte growing on sandstone. Botanical Journal of Linnean Society, 55(3), 657-661.

Sager, L. (2009). Measuring the trophic status of ponds: Relationships between summer rate of periphytic net primary productivity and water physico-chemistry. Water Research, 43(6), 1667–1679.

Sandgren, C. D. (1988). The ecology of Chrysophyte Flagellates: Their growth and perennation strategies as freshwater phytoplankton. In: C. D. Sandgren (ed.), Growth and Reproductive Strategies of Freshwater Phytoplankton. Cambridge University Press, California.

Sharma, D. K. & Singh, R. P. (2013). Correlation between physico-chemical parameters and phytoplankton of Tighra Reservoir, Gwalior, Madhya Pradesh. International Journal of

Science and Nature, 4(1), 90-95.

Shukla, B. K., Gupta, A., Sharma P. K. & Bhowmik A. R. (In press). Pollution status and water quality assessment in pre-monsoon season: A case study of rural villages in Allahabad district, Uttar Pradesh, India, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.03.823

Taylor, W. D., Lambou, V. W., Williams, L. R., & Hern, S. C. (1980). Trophic state of lakes and reservoirs (Technical Report: E-80-3). Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Las Vegas, USA.

Thakur, R. K., Jindal, R., Singh, U. B., & Ahluwalia, A. S. (2013). Plankton diversity and water quality assessment of three freshwater lakes of Mandi (Himachal Pradesh, India) with special reference to planktonic indicators. Environmental Monitoring and Assessment, 185, 8355–8373.

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

USEPA (1974). The relationship of phosphorus and nitrogen to the trophic state of northeast-central lakes and reservoirs. Working paper no. 23, National Eutrophiction Survey, Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

USEPA (1979). Lake and reservoir classification system (Ed. Maloney T. E.), EPA-600/3-79-074, Coravallis Evironemental Research Laboratory, U. S. Environmental Protection Agency, Oregon.

Van Donk, E., & van de Bund, W. J. (2002). Impact of submerged macrophytes including charophytes on phyto- and zooplankton communities: allelopathy versus other mechanisms. Aquatic Botany, 72(3-4), 261–274.

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

Xu, F., Tao, S., Dawson, R. W. & Li, B. (2001). A GIS-based method of Lake Eutrophication assessment. Ecological Modelling, 144, 231-244.

Yang, C. (1990). Diatoms as Indicators of Lake Trophic Status, M.Sc. Thesis, Brock University, St. Catharines, Ontario.

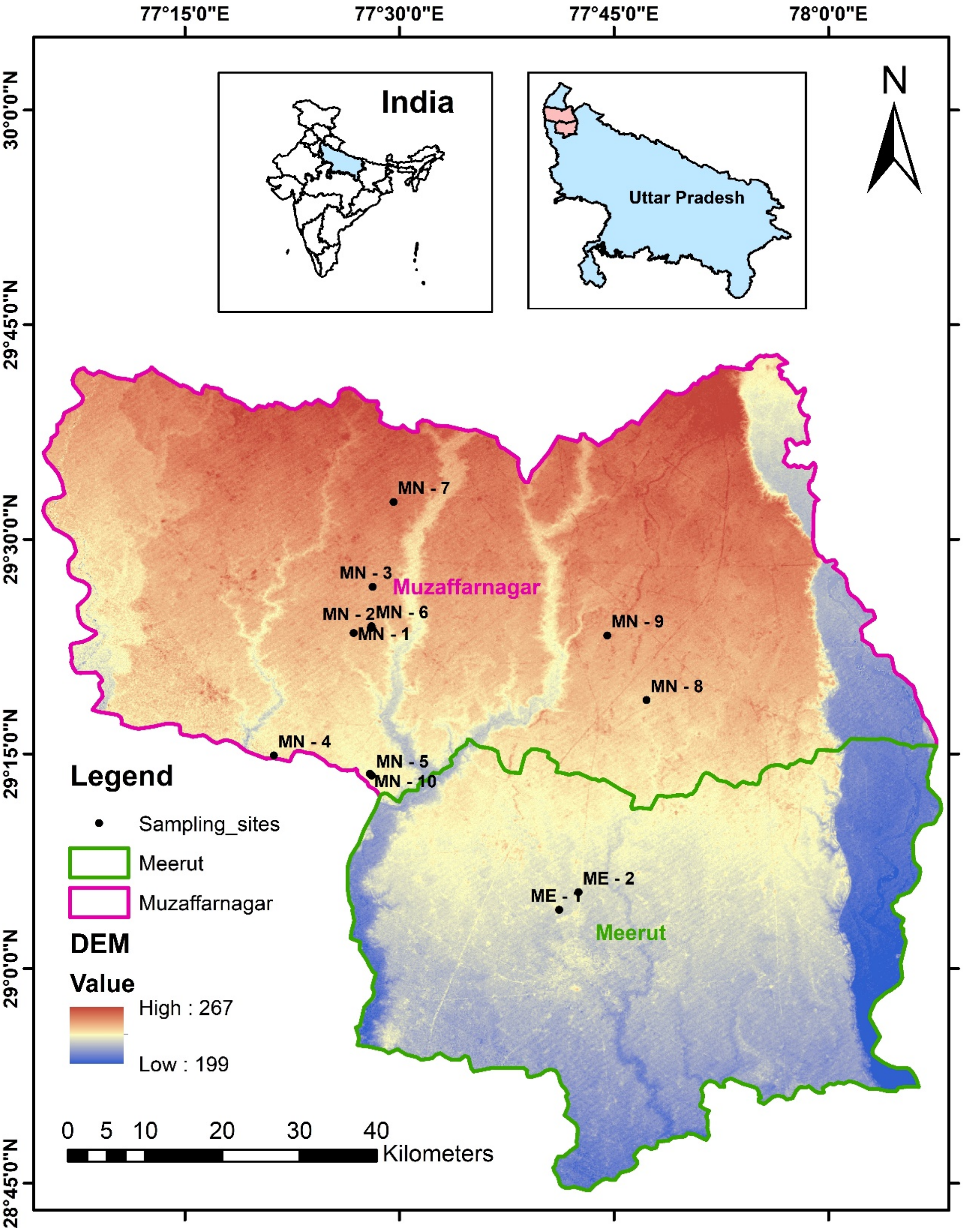

Fig. 1 Study area (Muzaffarnagar & Meerut) showing pond location

Table 1: Features of identified village ponds

Sr. No.	Village	Village ID	Block & District	Co-ordinates	Pond Area (m^2)	Perimeter (m)	Capacity (m^3)	Catchment Area (m^2)
1	Pavli Khas	ME - 1	Daurala, Meerut	29.068355°; 77.686094°	10600	445	30,655	924,785
2	Siwaya Jamalullapur	ME - 2	Daurala, Meerut	29.088818°; 77.708742°	7400	354	17,242	325,030
3	Bhora Kalan	MN - 1	Shahpur, Muzaffarnagar	29.390714°; 77.446661°	8500	348	23,710	463,727
4	Bhora Khurd - 1	MN - 2	Shahpur, Muzaffarnagar	29.396421°; 77.466515°	9400	417	15,787	474.836
5	Mohammadpur Madan	MN - 3	Baghra, Muzaffarnagar	29.444523°; 77.468680°	2900	355	14,053	366,866
6	Biral	MN - 4	Budhana, Muzaffarnagar	29.247980°; 77.353848°	18500	935	80,208	616,818
7	Itawa -2	MN - 5	Budhana, Muzaffarnagar	29.224812°; 77.467710°	3600	482	17,830	337,895
8	Bhora Khurd - 2	MN - 6	Shahpur, Muzaffarnagar	29.398626°; 77.467483°	7900	441	37,036	540,128
9	Roni Hazipur	MN - 7	Charthwal, Muzaffarnagar	29.543380°; 77.493092°	6800	352	20,736	540,128
10	Antwara	MN - 8	Khatauli, Muzaffarnagar	29.312605°; 77.787791°	3500	222	6,062	335,336
11	Munnawarpur Kalan	MN - 9	Khatauli, Muzaffarnagar	29.387868°; 77.742046°	2700	265	10,727	324,648
12	Itawa - 1	MN - 10	Budhana, Muzaffarnagar	29.226693°; 77.465664°	6900	306	10,065	159,207

Table 2: Water quality indicator parameters for different use

Indicator	Indicator Use Value	Target for Use
Nitrate	Groundwater recharge	<45 mg/L NO_3
Electrical Conductivity (EC)	Agriculture	<1500 µS/cm* <2500 µS/cm***
E. coli	Agriculture[#]	≤1000 cfu/100 ml**
	Agriculture[##]	≤100 cfu/100 ml**
Carlson TSI / Phosphate / Nitrate	Biodiversity / Ecosystem Health	mesotrophic
Nygaard's Index	Biodiversity / Ecosystem Health	mesotrophic
Dissolved Oxygen (DO) / Biochemical Oxygen Demand (BOD) / Chemical Oxygen Demand (COD)	Fisheries	DO > 4 mg/L*** BOD < 5 mg/L*** COD < 10 mg/L***

[#]Sprinkler irrigation methods for food crops consumed raw, where edible portion is not in direct contact with reclaimed water, and processed food crops.

[##]All irrigation methods for food crops consumed raw, where edible portion is not in direct contact with reclaimed water, and processed food crops

*BIS (1986); **Alcalde-Sanz and Gawlik (2017); *** CPCB (2019)

Table 3: Water quality and trophic status of identified ponds

Sr. No.	Village ID	pH	EC (µS/cm)	Temp. (ºC)	DO (mg/l)	COD (mg/l)	BOD (mg/l)	Chlorophyll-a (mg/l)	TP (mg/l)	TN (mg/l)	TN/TP	Secchi Depth (m)	Composite TSI (CTSI)	Trophic Status
1	ME - 1	8.1	1647	32	ND	180	48	0.33	9.63	410	42.6	0.16	113	Hypertrophic
2	ME - 2	7.7	1675	28	2.2	150	60	0.18	0.65	502	772.3	0.11	104	Hypertrophic
3	MN- 1	9.3	1303	34	ND	102	30	0.29	1.40	412	294.3	0.11	107	Hypertrophic
4	MN - 2	7.6	1660	30	ND	220	65	0.31	2.04	416	203.9	0.04	112	Hypertrophic
5	MN - 3	7.5	1483	33	0.2	56	16	0.18	1.04	474	455.8	0.06	107	Hypertrophic
6	MN - 4	8.2	1735	33	1.1	260	70	0.30	4.54	512	112.8	0.15	111	Hypertrophic
7	MN - 5	7.7	2170	35	ND	220	60	0.45	2.28	432	189.5	0.06	112	Hypertrophic
8	MN - 6	7.4	1770	30	ND	68	20	0.30	1.71	433	253.2	0.10	108	Hypertrophic
9	MN - 7	7.6	2280	30	ND	380	90	0.48	9.17	452	49.3	0.13	115	Hypertrophic
10	MN - 8	7.6	1909	33	3.1	200	50	0.31	4.49	514	114.5	0.12	112	Hypertrophic
11	MN - 9	7.4	1645	25	ND	220	54	0.49	9.79	487	49.7	0.15	115	Hypertrophic
12	MN - 10	7.2	1540	35	ND	160	50	0.40	1.47	426	289.8	0.04	112	Hypertrophic

Table 4: Pearson's correlation matrix of physico-chemical and biological parameters

	pH	EC (µs/cm)	Temp (ºC)	DO (mg/l)	COD (mg/l)	BOD (mg/l)	Chl a (mg/l)	TP (mg/l)	TN (mg/l)	SD (m)	Plankton Density	CTSI	CQI
pH	1												
EC (µs/cm)	-0.372	1											
Temp (ºC)	0.297	-0.04	1										
DO (mg/l)	-0.046	0.113	-0.032	1									
COD (mg/l)	-0.108	**0.708****	-0.173	0.028	1								
BOD (mg/l)	-0.114	**0.634***	-0.195	0.124	**0.949****	1							
Chl a (mg/l)	-0.220	0.537	-0.118	-0.412	**0.653***	0.511	1						
TP (mg/l)	-0.056	0.352	-0.418	-0.146	**0.622***	0.452	**0.612***	1					
TN (mg/l)	-0.217	0.153	-0.293	**0.754****	0.167	0.19	-0.217	0.073	1				
SD (m)	0.329	0.108	-0.397	0.231	0.317	0.221	0.138	**0.725****	0.374	1			
Plankton density	0.402	0.087	-0.079	-0.549	0.223	0.079	0.277	0.455	**-0.605***	0.339	1		
CTSI	-0.282	0.487	-0.09	-0.277	**0.723****	0.552	**0.856****	**0.766****	-0.113	0.222	0.272	1	
CQI	-0.079	-0.077	-0.527	-0.137	0.265	0.126	0.531	**0.605***	0.22	0.394	0.002	**0.587***	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5: Number of species identified and distribution of phytoplankton density in ponds

Village ID	Chlorophyceae	Desmidiaceae	Euglenophyceae	Cyanophyceae	Bacillariophyceae		Total Number of Species	Phytoplankton density (cells/l)
					Pennals	Centrales		
ME-1	39	16	11	28	29	19	142	$25x10^7$
ME-2	24	8	3	20	27	11	93	$67x10^6$
MN-1	36	14	10	27	29	18	134	$24x10^7$
MN-2	31	12	9	26	28	16	122	$17x10^7$
MN-3	29	10	8	25	28	15	115	$10x10^7$
MN-4	28	9	4	23	27	14	105	$12x10^7$
MN-5	28	9	4	23	27	14	105	$10x10^7$
MN-6	34	12	9	27	29	15	126	$21x10^7$
MN-7	37	15	10	28	29	19	138	$28x10^7$
MN-8	29	12	3	25	28	13	110	$82x10^6$
MN-9	25	7	2	19	26	11	90	$13x10^7$
MN-10	28	9	4	23	27	14	105	$10x10^7$

Table 6: Common identified phytoplankton species in ponds

	Chlorophyceae		***Desmidiaceae***		***Euglenophyceae***		***Cyanophyceae***		***Bacillariophyceae***
1	*Ankistrodesmus falcatus*	*1*	*Closteridium tetani*	*1*	*Euglena elongata*	*1*	*Dolichospermum aequalis*		***Pennals Diatoms***
2	*Arthrodesmus icus*	*2*	*Closteridium acerosum*	*2*	*Euglina gracilus*	*2*	*Dolichospermum affinis*	*1*	*Amphora bitumida*
3	*Chalodomonas reinhardtii*	*3*	*Closteridium ehrenbergii*	*3*	*Euglina viridis*	*3*	*Anacystis cyanea*	*2*	*Asterionella formosa*
4	*Chlorella Pyrenoidosa*	*4*	*Cosmarium biratum*	*4*	*Euglena sanguine*	*4*	*Aphonacapsa montana*	*3*	*Caloneis amphisbaena*
5	*Chlorella vulgaris*	*5*	*Cosmarium vexatum*	*5*	*Phacus acuminatus*	*5*	*Aphanizomenon flos-aquae*	*4*	*Cocconeis scutellum*
6	*Chlorococcum botryoides*	*6*	*Cosmarium granulatum*	*6*	*Phacus oribicularis*	*6*	*Arthospira maxima*	*5*	*Cymbella cistula*
7	*Chlorococcumhumicola*	*7*	*Desmidium grevillea*	*7*	*Phacus curvicauda*	*7*	*Chrococcus turgidus*	*6*	*Cymbella laceolata*
8	*Cladophora aegagropila*	*8*	*Echinella oblonga*	*8*	*Phacus curvicauda*	*8*	*Chroococcus minor*	*7*	*Cymbella timudula*
9	*Cladophora glomerata*	*9*	*Euastrum angulatum*	*9*	*Petalomonas abcissa*	*9*	*Chroococcus minutus*	*8*	*Diatoma elongatum*
10	*Coelastrum microsporum*	*10*	*Gonatozygon monotium*	*10*	*Trachelomonas volvocina*	*10*	*Gloeothece linearis*	*9*	*Diatoma vulgare*
11	*Eudorina elegans*	*11*	*Netrium digitus*	*11*	*Euglena elongata*	*11*	*Gleotrichia echinulata*	*10*	*Egleana rubra*
12	*Glaucocystis nostochinearum*	*12*	*Pleurotaenium trabecula*			*12*	*Gomphosphaeria lacustris*	*11*	*Eunotia ridon*
13	*Gonium pectorale*	*13*	*Staurastrum gracilie*			*13*	*Lyngbya spiralis*	*12*	*Fragillaria rhmboides*
14	*Hydrodictyon reticulatum*	*14*	*Staurastrum paradoxum*			*14*	*Merismopedia glauca*	*13*	*Fragillaria vaucherias*
15	*Microspora mononucleata*	*15*	*Sphaerozosma granulatum*			*15*	*Merismopedia punctata*	*14*	*Fragillaria construens*
16	*Microspora bunucleata*	*16*	*Staurastrum leptocladium*			*16*	*Merismopedia tennuissima*	*15*	*Gomphonema acuminatum*
17	*Mougeotia scalaris*					*17*	*Merismopedia eleganse*	*16*	*Gomphonema olivaceum*
18	*Oedogonium macrandrous*					*18*	*Microcystis aeruginosa*	*17*	*Gomphonema subtile*
19	*Pediastrum boryanum*					*19*	*Microcystis flos-aquae*	*18*	*Navicula cuspidata*
20	*Pandestrum duplex*					*20*	*Nostoc azollae*	*19*	*Nitzschia acicularis*
21	*Pediastrum biradiatum*					*21*	*Nostoc commune*	*20*	*Nitzschia apiculata*
22	*Pandorina morum*					*22*	*Oscillatoria annae*	*21*	*Nitzschia longissima*
23	*Protocussus viridis*					*23*	*Oscillatoria limnosa*	*22*	*Nitzschia palea*
24	*Scenedesmus quadricanda*					*24*	*Oscillatoria princeps*	*23*	*Plnnularia gibba*
25	*Scedesmus dimorphus*					*25*	*Oscillatoria tennuis*	*24*	*Surirella ovata*
26	*Secenedesmus obliques*					*26*	*Phormidium kuetzing*	*25*	*Suriella elegans*
27	*Scenedesmus incrassatulus*					*27*	*Rivularia haematites*	*26*	*Synedra ulna*
28	*Scenedesmus opoliensis*					*28*	*Spirulina turpin*	*27*	*Synedra capitata*
29	*Scenedismus bijugatus*					*29*	*Dolichospermum aequalis*	*28*	*Tabllearia flocculosa*
30	*Spirogyra occidentalis*					*30*	*Dolichospermum affinis*	*29*	*Stauroneis acuta*
31	*Tribonema minus*					*31*	*Anacystis cyanea*		
32	*Tetraspora gelitinosa*					*32*	*Aphonacapsa montana*		***Centrals Diatom***
33	*Ulotrix zonata*					*33*	*Aphanizomenon flos-aquae*	*30*	*Aulacoseira islandica*
34	*Ulothrix aequalis*					*34*	*Arthospira maxima*	*31*	*Actinocyclus normanii*
35	*Volvox tertius*					*35*	*Chrococcus turgidus*	*32*	*Cheatocertos abnormis*

36	*Volvox aureus*					*36*	*Chroococcus minor*	*33*	*Coscinodiscus granii*
37	*Zygonema spiralis*					*37*	*Chroococcus minutus*	*34*	*Cyclotella catenata*
38	*Zygnema insigne*							*35*	*Cyclotella striata*
39	*Zygogonium ericetorium*							*36*	*Gallionella crenata*
								37	*Lysigonium crenulatum*
								38	*Melosira granulata*
								39	*Melosira aequalis*
								40	*Melosira elegans*
								41	*Melosira varians*
								42	*Melosira ambigua*
								43	*Melosira distans*
								44	*Pleurosira laevi*
								45	*Stephanocyclus meneghiniana*
								46	*Cheatocertos abnormis*
								47	*Gallionella crenata*
								48	*Pleurosira laevi*
								49	*Pleurosira indica*

Table 7: Algal coefficient and trophic status of identified ponds

Ponds ID	Algal coefficient						Trophic status as per Nygaard's (1949) index
	Chlorophyceae	Desmidiaceae	Euglenophyceae	Cyanophyceae	Bacillariophyceae	CQI	
ME-1	1.59	1.44	1.47	2.50	1.79	5.10	Mesoeutrophic
ME-2	0.46	0.62	0.32	1.44	0.58	4.52	Mesoeutrophic
MN-1	1.51	1.43	1.42	2.65	1.79	5.15	Mesoeutrophic
MN-2	1.06	1.08	0.98	2.30	1.37	5.29	Mesoeutrophic
MN-3	0.89	0.98	0.75	2.05	1.12	4.91	Mesoeutrophic
MN-4	0.73	0.93	0.96	2.19	1.05	5.30	Mesoeutrophic
MN-5	0.71	0.87	0.78	1.89	0.91	4.93	Mesoeutrophic
MN-6	1.30	1.40	1.30	2.53	1.66	4.85	Mesoeutrophic
MN-7	1.73	1.63	1.70	2.83	2.00	5.07	Mesoeutrophic
MN-8	0.50	0.60	0.57	1.44	0.70	5.35	Mesoeutrophic
MN-9	0.42	0.37	0.41	1.20	0.52	6.89	Eutrophic
MN-10	0.71	0.87	0.78	1.89	0.91	4.93	Mesoeutrophic

Table 8: Diversity index of identified ponds

	ME - 1	ME - 2	MN - 1	MN - 2	MN - 3	MN - 4	MN - 5	MN - 6	MN - 7	MN - 8	MN - 9	MN - 10
Chlorophyceae	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	-0.35	-0.36	-0.35
Desmidiaceae	-0.25	-0.21	-0.24	-0.23	-0.21	-0.21	-0.21	-0.22	-0.24	-0.24	-0.20	-0.21
Euglenophyceae	-0.20	-0.11	-0.19	-0.19	-0.19	-0.12	-0.12	-0.19	-0.19	-0.10	-0.08	-0.12
Cyanophyceae	-0.32	-0.33	-0.32	-0.33	-0.33	-0.33	-0.33	-0.33	-0.32	-0.34	-0.33	-0.33
Bacillariophyceae	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37
Total Value	-1.49	-1.37	-1.47	-1.47	-1.44	-1.39	-1.39	-1.46	-1.48	-1.40	-1.33	-1.39
Shannon's index	**1.49**	**1.37**	**1.47**	**1.47**	**1.44**	**1.39**	**1.39**	**1.46**	**1.48**	**1.40**	**1.33**	**1.39**