A Study on Hydrochemical Characteristics of Fresh Water Lentic Ecosystems in Chavara Industrial Area-South West Coast of India

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Abstract- The pollution status of freshwater ponds in Chavara, an industrial area in Kollam district, south west coast of India was studied seasonally for a period of one year from January 2014 to December 2014. The parameters determined for the study were pH, conductivity, total dissolved solids, alkalinity, total hardness, Chloride, Dissolved oxygen (DO), Biological oxygen demand (BOD), Chemical oxygen demand (COD), sulphate and nitrate concentrations. The study revealed that maximum conductivity, TDS, Chloride, Total Hardness, BOD, sulphate and COD were recorded during summer and minimum during the monsoon season. pH and total alkalinity was found to be high in post monsoon period and low on summer. Maximum DO was recorded during monsoon and minimum on summer. Highest value of Nitrate was observed during pre monsoon and lowest value on summer. The study indicated that the waste water from the industrial area is deteriorating the water quality of nearby water bodies.

Index Terms- Physico-chemical Parameters, Chavara industrial area, Pollution status, COD, DO.

I. INTRODUCTION

Fresh water availability is the most important criteria for the survival of life on earth. Without water, life will not exist in this planet. Ponds, lakes, rivers and reservoirs form the important fresh water bodies on earth. Ponds and lakes are lentic water bodies and have tremendous capacity to retain water in an ecosystem .They play a chief role in maintaining the water balance in the ecosystem. Even though water is that much vital for life, fresh water bodies are not getting hold of great botheration. Rapid industrialization always leads to waste disposal issues. Most of the industries are to be found on the banks of aquatic water bodies and consider them as easiest and cheapest place for disposing their waste products. Such indiscriminate disposal of toxic industrial effluents always leads to severe environmental problems. So it is important to monitor the water quality profile of aquatic ecosystem using Physico-chemical Parameters and pollution status of aquatic ecosystems can be monitored time to time for proper utilization of water bodies.

In Kerala as per Kerala State Pollution Control Board (KSPCB), 423 hazardous waste generating units were present. Kerala Minerals and Metals Ltd (KMML) is one such public sector, sited at Chavara, Kollam District, Kerala produces 40,000 MT waste product (sludge) per annum during the production of titanium dioxide pigment. (Jayasree *et al*., 2009). Accidental leakage of this industrial effluent has led to the degradation of adjacent area of industry along with surrounding aquatic ecosystems. Compared to other water bodies less research work have been carried out related to the conservative status of pond ecosystem. (Linton *et al*., 2000). In the recent years several studies have been made on KMML related issues (Humsa *et al*., 2015; Krishnan *et al.*, 2013; Shaji *et al*., 2009 and Divakaran *et al*., 2013) but not much information is available on Physico-Chemical parameters of the pond water bodies in this area.

MATERIALS AND METHODS

The sites selected for the study include seven naturally occurring fresh water ponds from Chavara taluk, an industrial area in Panmana panchayat where KMML, one of the few profit-making public sector units in Kerala, situated in the south west coast of India. Seven sampling stations (S1 to S7) were preferred for this study based on the requirement of this investigation. For analysing the physic-chemical properties, water samples were collected from selected stations for a period of one year from January 2014 to December 2014. For analysis, the samples were collected in clean polyethylene, white two litre cans. After proper labelling, the samples were brought to the laboratory for further analysis of various physico-chemical parameters. The physico-chemical characteristics of water was analysed using standard methods of (APHA, 2008).

RESULT AND DISCUSSION

The values of each parameter during different seasons (pre monsoon, monsoon, post monsoon and summer) and different stations (seven pond ecosystem in Chavara industrial area) during Jan-2014 to Dec 2014 are given in different Tables (1 to 11. The result obtained was compared and discussed with other water quality standards and also with other works related to this study.

pH

In the present investigation the pH in different pond ecosystem (Table 1) varied between 3.1 (S7) summer and 8.4 (S4) Post monsoon. Seasonal average showed a high pH in the post monsoon and low in the summer in the study period. The station average showed a very low pH in station S7 where pH dropped to highly acidic nature. The (WHO, 1993) and (BIS, 1991) recommendation of pH is 6.5- 8.5. Minimum value of 3.1 recorded at S7 representing good evidence on the effect of the

industrial effluent at this site. Variation in pH will be affect the metabolic activities of aquatic organisms .The analysis of variance (ANOVA) of pH revealed a significant variation between station and between seasons at P<0.05 level.

Electrical conductivity

High concentration of acid, base or salt in water results in increase of Electrical Conductivity (EC) of that water (Ramesh, 2014). Electrical conductivity (EC) of different pond ecosystem showed that the highest EC was noticed in station S4 (1951.33 µS.) during summer season and minimum value obtained during monsoon season in S1 (345.33 µS) (Table-2). Due to greater evaporation, concentration of salts gets increased so as to show a higher EC in summer; during monsoon due to precipitation results in dilution makes value reduced (Trivedy *et al.*, 1984). Similarly high E.C. was reported from Bandematta Hosakere Lake during the summer season and low during monsoon season (Bheemappa, 2015). ANOVA showed highly significant variation between seasons and between stations at 0.05 % level.

Total Dissolved Solids

In the present investigation the seasonal mean concentration of total dissolved solid were shown in Table 3. The TDS of the stations ranged from 234.66 mg/L (S1) in monsoon to 1298 mg/L (S4) in summer. The highest seasonal average for TDS was 768.04 mg/L for summer and the minimum 363.6667 mg/L for monsoon and this may be due to dilution effect of rainy season (Manosathiyadevan , 2009). Compared with other stations, in monsoon the highest value (490 mg/L) was for S7. This high value of TDS may be due to the leaching of various pollutants into the groundwater (Jothivel *et al.*, 2014). Water having value more than 500 mg /l cannot be used for drinking purpose. (Kamble *et al.*, 2013). High level of dissolved solids inversely affect the gas solubility, hence reduces usability for water for drinking, irrigation and industrial purposes (Saxena, 1994). The analysis of variance (ANOVA) of TDS shown highly significant variation between stations and between seasons at P<0.05 level.

Total Alkalinity

In the present study, total alkalinity values ranged from 48.33 mg/L (S7) to 148 mg/L (S6) were shown in Table 4. Zero value for alkalinity was observed in S7 for all the seasons. It may be due to highly acidic disposal of effluent from nearby industry. Highest seasonal average for alkalinity was observed in post monsoon (107.66 mg/L) and lowest for summer 60.19 mg/L). This was also supported by Choudhary *et al.*, in 2014. During post monsoon periods water input is high and dissolution of calcium carbonate may occur hence result in increase in total alkalinity (Padma and Periakali, 1999). The analysis of variance (ANOVA) showed that the variation between station and months with in the station were significant at 0.05 level.

Total Hardness

Hardness of water is mainly due to the presence of Calcium and Magnesium ions. Hardness of water indicates about the consistence of water, whether it is soft, moderately hard, hard or very hard (above 300 mg/L) (Dutta *et al.*, 2013). In the current study the hardness values ranged from 95.66 mg/L (S1) in monsoon to 474.33 mg/L (S6) in the summer season were shown in Table 5. Highest seasonal average of total hardness is 364.52 mg/L for summer season and lowest for monsoon. This result was also supported by the studies of (Hoare, 2008). In summer excluding S5 and S7 all station values ranges above 300 mg/L. Domestic and industrial effluents also impart high hardness to water (Singh *et al.*, 1999). Ca and Mg salts get solubilise faster in summer due to increase in temperature, hence high hardness can be noticed during these seasons (Kalpana *et al.*, 2014; Shivayogimath *et al.*, 2012; Mumtazuddin *et al.*, 2012). The analysis of variance (ANOVA) showed a significant variation between season and between stations at 0.05 levels.

Chloride

Chloride occurs in all type of water and is one of the important parameter for determining the quality of water. In this study lowest value obtained was 76.66 mg/L (S1) in monsoon and highest value in summer (700 mg/L in S4), (Jain 2008), (Dhanapakiam *et al* ., 1999) also reported that lower value of chloride was recorded in rainy season (Manjare *et al.*, 2010), (Swaranlatha and rao,1998) reported that highest chloride value was obtained in summer. Highest seasonal mean is observed in summer (357.71 mg/L) and lowest in monsoon (147.38 mg/L).This was shown in Table 6. The annual average is highest in S4 (419.08 mg/L). These elevated levels of the chlorides may be endorsed of the industrial discharge or accidental leakage of Titanium Tetra Chloride. This was supported by Humsa *et al.*, (2015). The maximum annual average of chloride was in the station S4 (419.08mg/L). ANOVA showed highly significant variation between seasons (P<0.05) and between stations (P<0.05).

Dissolved Oxygen

The value of DO varies from 2.1 mg/L to 6.8 mg/L (Table 7). Low DO may indicate the presence of higher organic matter (Solanki *et al.*, 2007). The maximum value (6.8 mg/l) was recorded in site-3 in Monsoon and minimum values (2.1 mg/l) in site- 7 in summer. When comparing the seasonal mean values highest dissolved oxygen was noticed during the monsoon and lowest in summer which agrees with the observation of Baskar *et al.*, (2013), Singh *et al., (*2010). Reduction of organic matters needs a large amount of DO, so usually low DO may obtain in summer (Mamta and Ranga, 2012). In monsoon, heavy rainfall result in influx of water causes dilution results in increase of DO (Koshy, 2013). ANOVA showed that variations in concentration of DO between stations and seasons were significant at P<0.05 level

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD) can be explained as the amount of available oxygen utilized by the microbes for decomposing the organic matter through biological oxidation process. Seasonal variation in BOD is shown in Table 8. In the present study highest BOD value was obtained in the station seven (9 mg/L) in summer season and lowest value 2.2 mg/L in Station six during monsoon season. Seasonal average also shows that summer season obtained maximum value (5.97 mg/L)) and minimum (2.77 mg/L) in monsoon season. High value of BOD in summer may be due to higher rate of organic decompositi (Abdar**,** 2013). Station average showed that highest BOD value

was in S2 (4.7 mg/L) and lowest in S6 (4.075 mg/L). The analysis of variance (ANOVA) showed a significant variation between season and between stations at P<0.05 level

Chemical Oxygen Demand

Chemical oxygen demand (COD) is an important parameter for studying the pollution status of a water body. Table 9 shows the seasonal variation in COD in different seasons. The highest seasonal average for COD value was obtained in summer (59.41 mg/L) and lowest for monsoon (24.85 mg/L). Compared to all other stations S2 had highest COD value for all seasons. High COD values may be due to the presence of non biodegradable oxygen demanding pollutants in the water. Mainly industrial effluents or sewage contribute the high COD content in an aquatic ecosystem (Elayaraj and Selvaraju, 2015). The analysis of variance (ANOVA) showed a significant variation between seasons and between stations at P<0.05 level.

Nitrate

The seasonal variations of nitrate in different stations are presented in Tables 10. Nitrogen generally occurred as nitrate in most of the aquatic ecosystems. Amount and rate of supply of nitrate mostly depend on the land use practices of nearby water bodies. (Hulyal and Kaliwal, 2011). Usually fertilizers, municipal and industrial waste waters, agricultural wastes may contribute major source of nitrogen in an aquatic ecosystem. Highest seasonal average was observed in pre monsoon (5.64 mg/L) followed by monsoon and post monsoon and lowest in summer (1.81 mg/L). Nitrate value ranged from 0.55 mg/L (S6 in summer) to 15.80 mg/L (S7 in pre monsoon).Generally in rainy season highest nitrate concentration was observed due to influx of water and greater surface runoff (Shai and Sinha, 1969), (Yadav *et al.*, 2013). This is in agreement with the present study except S5 and S7 where high concentration of nitrate was found in all of the seasons. This may be due to the influence of industrial discharge that increases high nutrient content in the pond ecosystems.

Sulphate

In this study sulphate value ranged from 4.40 mg/L (S2) in monsoons to 53.62 mg/L (S4) in summer,(Table11) which are within permissible limits according to WHO (1984). Highest seasonal average (32.73) was shown in summer and lowest (13.01) for Monsoon season. Compared to other sites S4, S5 and S6 showed high sulphate values in all the seasons. The analysis of variance showed significant variation between seasons (P<0.05) and between stations (P<0.05)

REFERENCES

[1] M. R. Abdar, "Physico-chemical characteristics and phytoplankton of Morna lake, Shirala (M.S.) India,"Biolife., 2nd ed. Vol. 1 , 2013 pp.1-7

[2] APHA, Clescerl, Leonore S. (Editor), Greenberg, Arnold E. (Editor), Eaton, Andrew D.(Editor). "Standard Methods for the Examination of Water and Wastewater," (20th Ed.) American Public Health Association, Washington, DC, 2008.

[3] S. Baskar, N.Narasimhan, G. Swamidass Daniel, R. Ravichelvan, M.Sukumaran, and T.Anandaraj. "Seasonal Variations in physico-chemical parameters of river Cauveri, Thanjavur, Tamil Nadu, India," International Journal of Research in Biological Sciences., 1st ed. Vol. 3, 2013, pp. 8-11

[4] K.Bheemappa, "Temporal Variation in Water Quality Parameters of Bandematta Hosakere Lake – Peri Urban Area of Bengaluru, Karnataka, India," International Journal of Advanced Research., 7th ed. Vol. 3, 2015, pp.1283-1291

[5] BIS, Indian standard specification for drinking water. IS: 10500, Indian Standard Institute, 1991.

[6] P. Dhanapakiam, V. Sampoorani, and R. Kavitha, "Assessment of water quality of the river Cauveri," J. Environ. Bio., 4th ed. Vol. 20, 1999, pp. 342-350.

[7] B. Elayaraj, and M. Selvaraju, "Seasonal Variations in Physico-Chemical Parameters of Sri Kamatchiamman Temple Pond Chidambaram Taluk, Tamilnadu,"J. Environ. Treat. Tech., 2nd ed. Vol. 3, 2015, pp. 126-133

[8] M. S. Hujare, "Seasonal variation of physico-chemical parameters in the perennial tank of Talsande, Maharashtra," Ecotoxicology and Environmental Monitoring", 3rd ed. Vol 18, 2008, pp. 233-242

[9] S. B. Hulyal, and B.B Kaliwal, "Seasonal Variations in Physico-Chemical Characteristics of Almatti Reservoir of Bijapur district, Karnataka State," International Journal of Environmental Protection., 1st ed. Vol. 1, 2011, pp. 58-67 .

[10] Jaya Divakaran, Sarasamma, and Beena Kochuraman Narayanan. "Air quality assessment in the surroundings of KMML industrial area, Chavara in Kerala, South India,"Aerosol and Air Quality Research., (1-10), 2013, pp. 2071 – 1409. Online.

[11] P. K. Jayasree, Y. Sheela Evangeline, and K. J. Sudhir, "Remediation of hazardous solid waste from titanium industries. Indian geo technical society. Guntur, India," 2009, pp. 296- 300

[12] N.Jothivel, N. and V.I.Paul, " Comparative physico-chemical profiling of two coastal water bodies from south east coast of india with special reference to their pollution status," Int. J. Modn. Res. Revs., 12th ed. Vol. 2, 2014, pp. 544-553.

[13] Jyoti Choudhary, S. N. Singh, and Sunita Singh. 2014. "Physico-chemical and biological parameters of the three rural ponds of Sasaram of Bihar," Int J Appl Sci Biotechnol., 1st ed. Vol. 2, 2014, pp. 206-210.

[14] N. A. Kamble. And S. S. Sakhare, "Pollution Status of Freshwater Bodies from Gadhinglaj Tahsil, District Kolhapur," Biological Forum – An International Journal., 1st ed. Vol. 5, 2013 pp. 50-61.

[15] P. M. Koshy ," Environmental stress studies with reference to the pollution in the Vattakayal backwaters near the industrial area of Chavara, Kollam district, Kerala,"Ph.D. Thesis, School of environmental sciences, Mahatma Gandhi University.,Kottayam,India. 2013, pp. 59

[16] S. Linton and R. Goulder, "Botanical conservation value related to origin and management of ponds," Aquatic Conserv: Mar. Freshw. Ecosyst., Vol. 10, 2000, pp. 77–91

[17] S. A. Manjare, S. A.Vhanalakar, and D. V. Muley, 2010. "Analysis of water quality using physico-chemical parameters Tamdalge tank in Kolhapur district, Maharashtra,"International Journal of Advanced Biotechnology and Research., 2nd ed. Vol. 1(2), 2010, pp. 115-119.

[18] M. Manosathiyadevan, "Studies on the impact of Paravanar river Pollulants on the adult male freshwater prawn Macrobrachium malcolmsonii (H. Milne Edwards)," Ph.D. Thesis. Annamalai University, 2009, 1-22 pp.

[19] S. Mumtazuddin, A. K. Azad, Bharti Prabhat and Ranjan Rakesh. "Physico-chemical analysis of groundwater of the Budhi Gantak belt in Muzaffarpur district, India," I. Res.J.Environme Sci., 1st ed. Vol 1, 2012, pp. 7-11.

[20] S. Padma, and Periakali, " Physicochemical and geochemical studies in Pulicat Lake, east coast of India," Indian J. Mar.Sci., Vol. 28, 2013, pp. 434-437.

[21] Priyanka Yadav, V. K. Yadav, A. K. Yadav, and P. K. Khare, "Physico-Chemical Characteristics of a Fresh Water Pond of Orai, U. P., Central India," Octa. J. Biosci., 2nd ed. Vol. 1, 2013, pp. 177-184.

[22] N. Ramesh, "Assessment of Physico-Chemical Parameters of Bellandur Lake, Bangalore, India," International Journal of Innovative Research in Science, Engineering and Technology. 3rd ed. Vol. 3, 2014

[23] R. Rathod Kalpana, R. P. Chavan, and R. S. Lokhande, " Assessment on pollution impact and correlation study of lake water from Thane region of Maharashtra, INDIA,"Int. Res. J. Environment Sci., 12th ed. Vol. 3, 2014, pp. 44-51.

[24] Remya Krishnan and D. S. Jaya, "Impact of industrial effluents on the hydrochemical characteristics of Kayamkulam estuary, south west coast of India," Journal of Industrial Pollution Control., 2013.

[25] Renu Jain, 2008. "Physico-chemical seasonal analysis of singwasa reservoir Guna, M.P. (India) ," Journal of Environmental Research And Development ., 1st ed. Vol. 3 (1) 191pp.

[26] R. Sahai, and A. B. Sinha, "Investigation on bio-ecology of inlands water of Gorakhpur (U.P.), India," I. Limnology of Ramgarh Lake. Hydrobiol., Vol 34(3), 1969, pp. 143-447.

[27] M. M. Saxena, "Environmental analysis- water, soil and air," Agrobotanica publishers,India. 1994, pp.185

[28] C. Shaji, H. Nimi, and L. Bindu, "Water quality assessment of open wells in and around Chavara industrial area, Quilon Kerala," Journal of Environmental Biology., 5th ed. Vol. 30, 2009, pp. 701-704

[29] C. B. Shivayogimath, P. B. Kalburgi, U. B. Deshannavar, and D. B. M. Virupakshaia, "Water Quality Evaluation of River Ghataprabha (India)," I. Res.J.EnvironmeSci., 1st ed. Vol. 1, 2012, pp. 12-18

[30] M. R. Singh, A. Gupta, S. Asha, and K. H. Beeteswari, "Physico - chemical properties of water samples from Manipur river system, India," J.Appl.Sci.Environ Manage., 4th ed. Vol. 14, 2010, pp. 85 – 89

[31] H. P .Singh, L. R. Mahaver, and J. P. Mishra. "Impact of industrial and sewage wastes on water qualities in middle stretch of river Ganga from Kanpoor to Varanasi," J.Environ.Biol., Vol. 3, 1999, pp. 279-285.

[32] V. R. Solanki, S. S. Murthy, Amarjit Kaur, and S. Sabita Raja, "Variation in dissolved oxygen and biological oxygen demand in two fresh water lakes of Bodhan, Andhra Pradesh, India,"Nature,Environ. Pollution Techno., 4th ed. Vol. 6, 2007, pp. 623-628

[33] S. Swaranlatha and A. Narsingrao, "Ecological studies of Banjara lake with reference to water pollution," J. Envi. Biol., 2nd ed. Vol. 19, 1998, pp. 179-186.

[34] Tapas kumar Dutta, and C. Bidhan Patra, "Biodiversity and seasonal abundance of Zooplankton and its relation to physico –chemical parameters of Jamunabundh, Bishnupur, India," International Journal of Scientific and Research Publications., 8th ed. Vol. 3, 2013.

[35] Tekedil Zeenat Humsa, and R. K. Srivastava, "Impact of Rare Earth Mining and Processing on Soil and Water Environment at Chavara, Kollam, Kerala: A case Study,"Procedia Earth and Planetary Science., Vol. 11, 2015, pp. 566 – 581

[36] Tiwari Mamta, and.M. M. Ranga, "Assesment of Diurnal Variation of Physico Chemical Status of Khanpura,"Res. J. Chem. Sci., 7th ed. Vol. 2, 2012, pp. 69-71.

[37] R. K. Trivedy, and P. K.Goel, "In Chemical and biological methods for water pollution studies. Environmental Publication, Karad, Maharashtra (India)," 1984.

[38] WHO, "Guidelines for drinking water quantity" 2nd Ed., 1993, World Health Organization, Geneva

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Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	6.96±0.08	7.70±0.09	8.07±0.17	6.70±0.25	7.36±0.18
S2	6.87±0.08	7.40±0.09	7.93±0.08	6.80±0.08	7.25±0.14
S3	6.93±0.08	7.83±0.02	7.43±0.02	6.80±0.08	7.25±0.12
S4	7.13±0.18	6.93±0.08	8.43±0.20	6.40±0.20	7.22±0.23
S5	6.87±0.08	7.20±0.02	8.06±0.08	6.33±0.12	7.12±0.19
S6	6.73±0.08	7.57±0.02	8.13±0.02	6.33±0.08	7.19±0.21
S7	3.43±0.08	4.00±0.02	3.76±0.08	3.16±0.02	3.59±0.09
mean	6.42±0.49	6.95±0.5.	7.40±0.61	6.07±0.48	6.71±.51

Table 1. Seasonal variations of pH in different stations in the pond systems with during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	838.67±0.32	345.33±1.76	457.33±2.90	956.33±0.32	649.41±76.78
S2	1114.67±0.32	615.67±1.44	781.66±1.2	1399±0.57	977.75±91.17
S3	1001±0.57	455±2.64	573.33±1.2	1160.33±0.32	797.42±87.98
S4	1559±0.57	618±1.15	788.33±1.76	1951.33±0.87	1229.16±165
S5	818.33±0.32	494±2.30	645.66±2.02	961.33±0.87	729.83±53.11
S6	763±0.57	555.33±3.47	642±2.30	1112.33±1.44	768.16±63.91
S7	679.33±0.32	411±0.57	501.33±2.90	841.67±0.66	608.33±49.97
mean	967.71±113.0	499.19±39.11	627.09±48.3	1197.47±142.93	822.86±81.27

Table 2. Seasonal variations of in (E C) of different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	582.33±2.72	234.66±2.40	303.66±5.92	636.33±3.27	439.25±51.96
S2	635.00±2.88	368.66±5.92	428.66±3.75	784.33±3.27	554.16±49.95
S3	656.00±1.52	286.66±3.52	323.33±1.76	730.33±2.60	499.08±59.18
S4	965.00±2.64	439.33±5.80	490.33±0.87	1298±0.99	798.16±106.73
S5	525.00±3.78	344.33±2.60	376±2.30	623.33±13.01	467.16±34.21
S6	489.66±3.75	382.00±2.30	425±2.64	741.67±1.2	509.58±44.63
S7	407.66±4.09	490.00±0.57	455±2.88	562.33±1.85	478.75±17.04
mean	608.66±67.64	363.66±32.72	400.28±25.98	768.04±93.07	535.16±45.9

Table 3. Seasonal variations of Total Dissolved Solids in different stations in the pond system during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	91.33±1.85	88.33±0.87	110.33±1.20	55±2.30	86.25±6.03
S2	124.00±2.08	155.66±0.33	161.00±1.52	75.33±2.71	129.00±10.27
S3	107.00±1.52	127.66±0.87	136.00±2.30	85.66±2.02	114.08±5.92
S4	73.00±1.52	86.33±0.87	70.333±0.88	48.33±1.76	69.50±4.15
S5	122.00±1.52	111±0.57	127.33±1.76	74.00±2.30	108.58±6.31
S6	115.33±1.20	140.33±0.87	148.66±2.02	85.00±0.99	121.83±7.49
S7	0	0	0	0	0
mean	90.38±16.54	101.33±19.46	107.67±21.1	60.19±11.31	89.89±16.89

Table 4. Seasonal variations of Total alkalinity (mg/L) in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	239.66±2.18	95.66±2.84	139.66±1.66	300.33±4.97	193.83±24.2
S2	352.66±2.33	200.66±2.90	288.33±1.85	412.33±1.45	313.50±23.69
S3	283.33±2.90	124.00±2.08	202.00±4.04	353.00±2.51	240.58±25.94
S4	380.66±2.40	209.00±4.50	275.66±3.17	458.66±5.90	331.00±28.91
S5	239.00±2.08	142.00±3.05	199.33±4.09	284.00±4.35	216.08±15.81
S6	300.66±8.25	168.00±1.52	225.00±6.08	474.33±2.33	292.00±34.84
S7	235.33±0.66	107.66±3.17	170.66±2.90	269.00±5.29	195.66±18.71
mean	290.19±22.05	149.57±16.8	214.38±20.23	364.52±32.02	254.66±21.57

Table 5. Seasonal variations of Total Hardness in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	247.00±2.081	76.66±2.40	113.33±1.20	288.00±1.52	181.25±26.66
S2	262.00±1.99	126.00±3.46	156.33±2.60	386.66±0.88	232.75±30.83
S3	281.66±1.66	233.66±1.85	247.33±1.20	310.33±2.60	268.25±9.06
S4	427.00±3.21	265.00±2.64	284.33±2.33	700.00±0.57	419.08±52.42
S5	184.67±2.90	90.00±3.21	116.00±3.05	231.66±0.66	155.58±16.89
S6	188.33±1.66	123.33±1.92	131.66±0.33	300.66±0.33	186.00±21.35
S7	223.33±2.66	117.00±0.99	180.00±2.88	286.66±1.20	201.75±18.68
mean	259.14±31.12	147.38±27.39	175.57±25.22	357.71±59.62	264.14±36.86

Table 6. Seasonal variations of Chloride in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	3.93±0.52	5.90±0.20	4.90±0.23	3.25±0.57	4.49±0.34
S2	4.00±0.58	5.80±0.15	4.76±0.32	3.73±0.17	4.57±0.28
S3	4.33±0.67	6.80±0.28	6.23±0.18	3.76±0.33	5.28±0.41
S4	4.16±0.65	6.33±0.29	5.70±0.15	3.20±0.30	4.85±0.40
S5	4.13±0.43	5.93±0.29	5.26±0.17	3.90±0.17	4.80±0.27
S6	4.23±0.82	6.23±0.25	5.96±0.29	4.66±0.33	5.27±0.32
S7	2.60±0.11	4.00±0.26	2.70±0.49	2.13±0.08	2.85±0.24
mean	3.91±0.22	5.85±0.33	5.07±0.44	3.52±0.29	4.59±0.3

Table 7 Seasonal variations of Dissolved Oxygen in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	5.33±0.81	2.43±0.20	3.46±0.35	5.33±0.35	4.14±0.42
S2	5.86±0.70	3.20±0.23	4.40±0.23	5.40±0.30	4.71±0.35
S3	5.46±1.09	2.33±0.56	3.06±0.35	5.73±0.35	4.15±0.52
S4	4.80±1.05	2.40±0.23	3.23±0.25	6.40±0.69	4.20±0.53
S5	5.46±0.48	2.93±0.35	3.86±0.35	4.66±0.13	4.23±0.32
S6	5.60±1.28	2.26±0.35	3.13±0.17	5.46±0.35	4.11±0.52
S7	6.26±0.35	4.00±0.92	7.06±1.13	9.06±0.81	6.59±0.65
mean	5.53±0.17	2.79±0.23	4.02±0.53	6.00±0.54	4.59±0.34

Table 8. Seasonal variations of Biochemical Oxygen Demand in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	42.00±1.15	25.33±1.32	34.00±1.15	51.66±1.20	43.87±2.97
S2	98.66±1.76	41.66±1.2	51.60±0.87	124.6±2.40	96.62±10.26
S3	36.00±0.57	18.33±1.2	26.33±1.45	43.00±1.73	36.5±2.87
S4	27.33±0.66	20.33±0.87	25.66±1.20	37.33±1.33	30.87±1.9
S5	45.66±1.2	29.66±0.87	34.66±1.32	61.66±1.20	48.75±3.73
S6	55.33±0.87	25.00±1.52	31.66±.87	68.33±1.20	54.25±5.3
S7	23.00±0.57	13.66±1.20	19.00±.57	29.33±1.32	24.37±1.77
mean	46.85±8.86	24.85±3.17	31.85±3.6	59.42±11.12	47.89±9.00

Table 9. Seasonal variations of Chemical Oxygen Demand in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	1.43±0.01	2.67±0.06	2.13±0.02	0.86±0.01	1.79±0.21
S2	2.20±0.02	5.02±0.09	4.26±0.03	1.33±0.02	3.23±0.46
S3	3.23±0.04	4.13±0.15	2.40±0.20	1.45±0.01	2.73±0.27
S4	3.05±0.01	3.98±0.15	2.09±0.03	1.61±0.01	2.64±0.25
S5	12.50±0.04	7.13±0.02	8.26±0.03	3.55±0.02	7.87±0.96
S6	1.27±0.03	$2.09\pm7.50x10^{-3}$	1.29±0.06	0.55±0.01	1.30±0.16
S7	15.80±0.06	9.34±0.02	8.36±0.08	3.35±0.03	9.22±1.32
mean	5.64±2.11	4.91±0.96	4.11±1.1	1.81±0.44	3.11±1.17

Table 10. Seasonal variations of Nitrate in different stations in the pond systems during 2014

Station	Pre monsoon M±SE	Monsoon M±SE	Post monsoon M±SE	Summer M±SE	Mean
S1	13.61±0.02	7.89±0.03	10.23±0.12	15.38±0.06	11.78±0.87
S2	$8.53\pm7.21x10^{-3}$	4.40±0.13	7.46±0.10	10.43±0.09	7.70±0.65
S3	14.54±0.05	10.60±0.03	12.81±0.30	16.840.11	13.70±0.69
S4	30.55±0.10	22.57±0.07	27.13±0.42	53.620.09	33.46±3.61
S5	30.50±0.07	18.90±0.04	28.76±0.35	50.310.09	32.12±3.43
S6	30.14±0.08	15.36±0.08	30.16±0.46	63.230.15	34.72±5.28
S7	16.49±0.06	$11.36\pm6.35x10^{-3}$	13.42±0.08	19.360.12	15.16±0.91
mean	20.62±3.57	13.01±2.39	18.57±3.66	32.74±8.31	21.23±4.4

Table 11. Seasonal variations of Sulphate in different stations in the pond systems during 2014