Water Quality Assessment of Futala Lake, Nagpur (Maharashtra, India): A Case Study

Kirti Y. Lanjewar and Prajakta V. Harkare

[1]*Project Assistant, Geo-Environment Management Division, NEERI, Nehru Marg, Nagpur, India*
e : mail: kirti_lanjewar@yahoo.co.in

ABSTRACT

Futala lake is one of the prime lake of Nagpur. The lake is a rainwater impoundment with a water spread area of 37.58 hectares and average depth of 4.5 meters during monsoon. Due to increase in population at the vicinity, the lake aesthetics has deteriorated gradually resulting in heavy weed growth and bad odour all around the year. Water quality assessment studies on the Futala lake were conducted by NEERI on the request of Nagpur Improvement Trust (NIT), Nagpur during 2003 - 2004 to assess the condition of the lake. The condition of the lake is observed to be mesotrophic heading towards eutrophic condition. The study report discusses about the analysis of the water quality of the lake and suggests the means to improve it through eco-remediation measures.

INTRODUCTION

Futala Lake and its environs, near Telankhedi garden on Amravatı road, Nagpur, in the central India is a picnic spot. It is a rainwater impoundment, with an area of 26.3 ha and with maximum water depth of 4-5 meters during monsoon. It is used as a stocking tank for the major carps and other fishes and for recreational fishing activity. The lake aesthetics deteriorated gradually due to pollution load resulting in heavy weed growth and bad odour all around the year. The environmental status of the Futala Lake has been assessed to suggest appropriate interventions to improve the water quality of the lake and beautify the surrounding.

Eutrophication is often discussed in terms of lake history. Active biological communities are developed and lake basins become shallower and more eutrophic as decaying plant and animal material accumulate at the bottom. Shallow lakes tend to be more productive than deep lakes because they do not stratify, thereby, allow nutrients to remain in circulation and accessible to plants. However, lakes may be culturally eutrophied due to the acceleration of nutrient inflow (Raevie, 2005). This occurs through poor management of the watershed and introduction of anthropogenic activities. Such changes may occur over periods of only decades and are reversible if anthropogenic nutrient loading can be controlled.

WATER QUALITY IMPACTS ASSOCIATED WITH EUTROPHICATION

Assimilative capacity is the limiting concentration of a substance or mixtures of substances that will cause no deleterious effects upon the receiving ecosystem (Campbell, 1981). The ecosystems (water bodies) have certain assimilative properties regarding anthropogenic wastes. Anthropogenic wastes may be of non-point sources or point sources, e.g. from upstream tributaries after rainstorms, from die-off of aquatic plants, from pulses of urban storm water and direct runoff of agricultural lands. Significant amounts of phosphorous and available nitrogen may be deposited during rainfall (wet deposition) and during the less obvious deposition of aerosols and dust particles (dry deposition). Water quality of eutrophic lake is highly affected by increasing nutrient loading. Profuse algal growth cause bad taste and odour. Excessive macrophytes growth leads to the loss of open water zone and hence with increased turbidity secchi depth goes down. Dissolved oxygen becomes a limiting factor for the survival of fish and fish food. Blue green alga is inedible by some zooplanktons and hence food chain efficiency reduces. In the bottom of the lake production of toxic gases e.g. ammonia (NH4), hydrogen sulphide (H2S), methane (CH4) cause loss of fish habitat. Also, some blue green algae synthesize possible toxins harmful to fish habitat. Aquatic organisms influence the chemistry of the surrounding environment. Phytoplankton extract nutrients from the water and zooplankton feed on phytoplankton. Nutrients are redistributed from the lake's upper water to the bottom as the dead plankton gradually sinks to lower depths and decompose. The redistribution is partially offset by the active vertical migration of the plankton.

In contrast to DO, essential nutrients, such as, the bioavailable forms of phosphorous and nitrogen (dissolved phosphate, nitrate and ammonium) typically increase in the winter by the mixing of accumulated nutrients from the bottom. Concentrations of nutrients decrease in the epilimnion during summer stratification as nutrients are taken up by algae and eventually transported to the hypolimnion when the algae die and settle at the bottom. During this period any "new" input of nutrients into the upper water may trigger a "bloom" of algae (Harkare, et. al. 2005).

The limiting nutrient concept is based on the assumption that under given cell stoichiometry of aquatic plants, the nutrient rate will control the maximum amount of plant biomass. In freshwater systems, the limiting nutrient is usually phosphorous and studies have mostly been concentrated on indices of limitation (Organization for Economic Cooperation and Development (OECD), 1982; Perkins, et. al. 2000). In a phosphorous limited condition, algae have been observed to use phosphatase enzyme to utilize the organic phosphorous (Whitton, et. al. 1996). Phosphorous, especially when in the form of orthophosphate (PO42+), is widely accepted as being the critical nutrient in determining the degree of lake eutrophic conditions. In some cases inorganic nitrogen (NH4 or NO3) can be the limiting nutrient. The significance of phosphorous is evident from the fact that 1 g of phosphorous can give rise to at least 100 g of algae, which in turn require 150 g of oxygen for aerobic degradation (Campbell, 1981). A lake's biological characteristics are determined in large part by physical characteristics including temperature, light, transparency and abundance of inorganic nutrients [N, P, C], which results into the enrichment of periphyton standing crop, species composition and primary production in an oligotrophic water lake.

METHODOLOGY

The Futala Lake water quality with respect to physico-chemical and biological aspects has been evaluated for two years to assess the status of the lake. The samples were collected once in a month from ten locations at surface and depth for physico-chemical and biological analysis (Figure-1). Water quality assessment was carried out as per standard methods (APHA, AWWA & WEF, 2005). The physico-chemical parameters studied for the lake water are Temperature, pH, Conductivity, Turbidity, Hardness, Dissolved oxygen (DO), Phosphates (PO4), Nitrate nitrogen (NO3-N), Sulphate (SO4), Total Kjeldahl Nitrogen (TKN), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD). Lacky's microsect drop method was used for quantitative

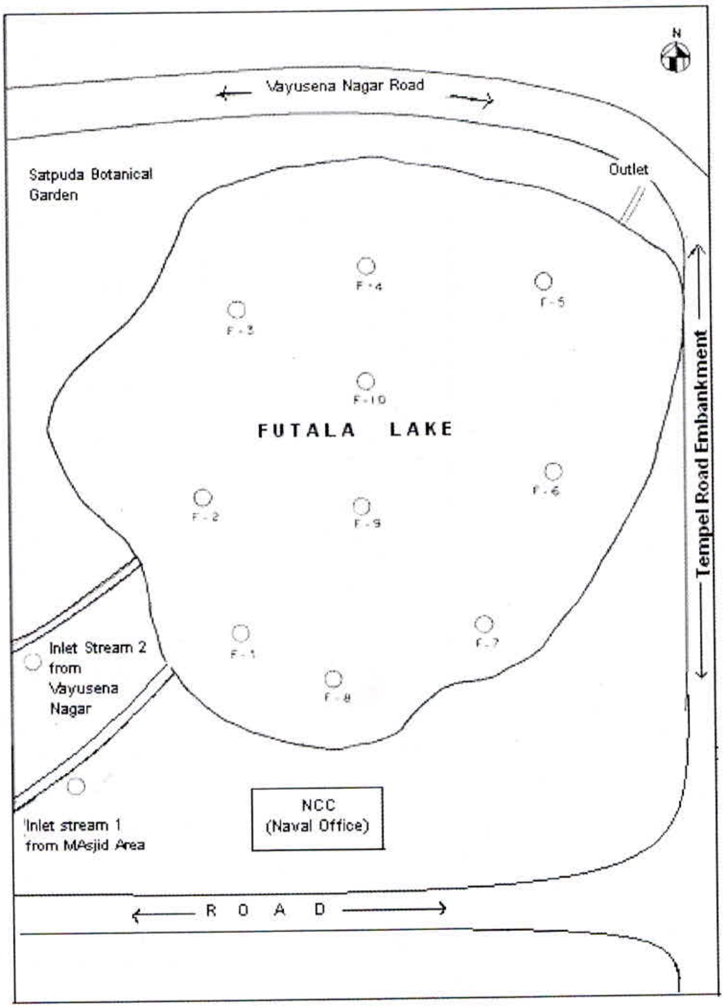

Fig. 1 : The index plan showing the Futala lake and the inlet streams and locations locations

estimations of phytoplankton. Water samples were also filtered through conical plankton net (number 25) for estimation of zooplankton. Quantitative estimation was carried out with the help of Sedgwick-Rafter cell. Shannon Wiener Diversity Index (SWI) values were assigned to the organisms in order to decide the trophic status of the water body.

OBSERVATIONS AND DISCUSSIONS

Physico-chemical Quality

The water quality analysis shows (Table-1) that all the samples of both surface and depth water zones are well saturated with dissolved oxygen (7 mg/L to 9 mg/L for surface water and 5.3 mg/L to 6 mg/L for depth water). The pH, at all sites, was in the range 7.5 to 7.8 and turbidity varied between 5 and 9 NTU. The sample from third location (code no. F3B) has high turbidity (53 NTU), due to sewage pollution through inlet stream. BOD was in the range 2 mg/L to 7 mg/L. COD was in the range 4.8 mg/L to 16 mg/L in surface water and 7.2 mg/L to 30 mg/L in depth water samples. Nitrate and phosphate was in the range 2 mg/L to 4 mg/L and 0.02 mg/L to 0.16 mg/L in surface water and 2 mg/L to 4 mg/L and 0.03 mg/L to 0.23 mg/L in depth water respectively. This indicates that the nutrients concentration is high and sufficient enough for the growth of algal blooms.

Statistical analysis (Figures-2 and 3) showed significant coefficient of determination (Line of fit curve) and positive correlation of coefficient between N:P and Phosphate (R2=0.978 and r=0.998) and N:P and Nitrate-nitrogen (R2=0.970 and r=0.989). As the nitrogen concentration increases, the N:P ratio increases whereas the phosphate increase results into the decrease in N:P ratio. Lake water, with phosphate more than 0.05 mg/L and nitrates more than 0.5 mg/L, is eutrophic and highly polluted. Based on the relationship between phosphorous concentration and algal bloom frequency, observed in lakes, the desired phosphorous limit in lake water is recommended as 0.02 mg/L (Kulkarni, et. al. 2005). The frequencies of algal blooms increase sharply as lake phosphorous concentrations increase above 0.02 mg/L (Figure-4). Studies further gave a correlation between algal count and phosphate concentration (R2=0.979 and r=0.98943) through the same year in different seasons. This criterion is also supported by the fact that the lakes with long term average phosphorous concentrations less than 0.02 mg/L generally comply with quality standards and are not considered impaired by nutrients, at least for recreational uses. Vollenweider (1983) identified that ratio between the total nitrogen to total phosphorous to be 9:1 for proper growth of phytoplankton. Seasonal variation in Nitrogen to phosphorous ratio was found in the lake water (Figure-5). The ratio was greater than 9 during the winter season and was decreased during summer, monsoon and postmonsoon. The trend in algal growth in different seasons (Figure-6) indicates that algal growth decreases the phosphate concentration and the lake become phosphorous limited. According to the boundary conditions for classification of lakes and reservoirs, as defined by the OECD, the status of Futala Lake is in mesotrophic condition and is progressive towards eutrophication.

Table 1 : Water Quality of Futala Lake

Sl. No.	Sample Code	Turb. (NTU)	pH	Cond. □S/cm	TDS (mg/L)	Total Alkal (mg/L)	Total Hard (mg/L)	Ca (mg/L)	Mg (mg/L)	F (mg/L)	Cl (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	Na (mg/L)	K (mg/L)	TKN (mg/L)	DO (mg/L)	BOD (mg/L)	COD (mg/L)
1	F1A	3.48	7.8	452	271.2	180	220	44	27	0.6	62	4	12	0.06	30	4	2	6.0	6.0	15.2
2	F1B	45.50	7.4	453	271.8	172	219	43	27	0.8	64	5	15	0.07	32	5	6	3.6	11.0	32.0
3	F2A	5.50	7.6	452	271.2	188	224	58	19	0.6	54	4	30	0.10	30	4	4	6.2	7.0	14.4
4	F2B	88.20	7.5	454	272.4	180	197	49	18	0.8	56	5	34	0.19	36	6	9	3.6	8.0	32.8
5	F3A	3.79	7.2	464	278.4	184	193	52	15	1.0	56	5	21	0.09	32	3	1	6.7	6.5	16.0
6	F3B	14.88	7.4	476	285.6	172	187	50	15	1.0	60	6	32	0.11	36	5	4	3.6	9.0	24.0
7	F4A	3.47	7.7	453	271.8	188	189	58	11	0.8	56	6	9	0.12	33	3	1	6.7	6.0	32.0
8	F4B	141.76	7.5	465	279	180	176	48	14	0.9	58	7	15	0.13	35	4	3	2.6	9.5	44.8
9	F5A	3.57	7.6	454	272.4	192	195	47	19	1.0	58	5	8	0.07	33	4	3	6.8	6.0	19.2
10	F5B	56.09	7.1	468	280.8	180	156	45	11	1.0	68	6	9	0.09	37	7	5	3.0	7.5	30.4
11	F6A	3.09	7.7	454	272.4	192	188	56	12	0.8	56	4	8	0.07	33	3	2	7.5	4.5	16.8
12	F6B	32.08	7.4	464	278.4	180	146	49	6	0.8	56	7	10	0.09	35	4	6	3.5	9.5	31.2
13	F7A	1.65	7.6	461	276.6	188	188	51	15	0.9	56	5	10	0.06	33	3	1	6.0	4.5	16.0
14	F7B	18.93	7.4	482	289.2	180	132	46	4	0.8	56	5	20	0.09	35	6	3	3.6	7.0	78.4
15	F8A	1.40	7.5	451	270.6	192	146	50	5	0.7	54	3	9	0.06	33	3	2	6.6	8.5	13.6
16	F8B	49.34	7.4	465	279	180	131	47	4	0.8	56	6	10	0.08	37	4	2	2.6	13.5	29.6
17	F9A	1.75	7.7	450	270	188	150	46	9	0.9	58	4	15	0.06	34	3	2	6.6	9.5	15.2
18	F9B	186.72	7.4	455	273	180	136	34	13	0.9	60	6	17	0.08	38	4	2	3.6	12.0	30.4
19	F10A	1.85	7.5	451	270.6	188	171	46	14	0.9	54	4	8	0.01	33	3	4	6.6	9.5	28.0
20	F10B	16.37	7.4	464	278.4	164	158	41	14	0.9	56	6	11	0.05	34	6	4	2.4	11.0	43.2
21	IS 1	3.00	7.5	494	296.4	208	160	36	17	1.2	56	6	9	1.30	38	4	7	4.5	7.0	22.4
22	IS 1-Con	4.55	7.5	452	271.2	180	147	42	10	1.0	54	8	11	3.60	37	5	8	6.0	10.5	24.0
23	IS 2	1.44	7.4	445	267	172	153	38	14	1.0	54	7	11	2.30	39	8	7	4.9	3.5	32.0
24	IS 2-Con	3.83	7.5	453	271.8	184	151	36	15	0.9	54	7	13	6.34	40	8	7	5.5	9.0	12.0

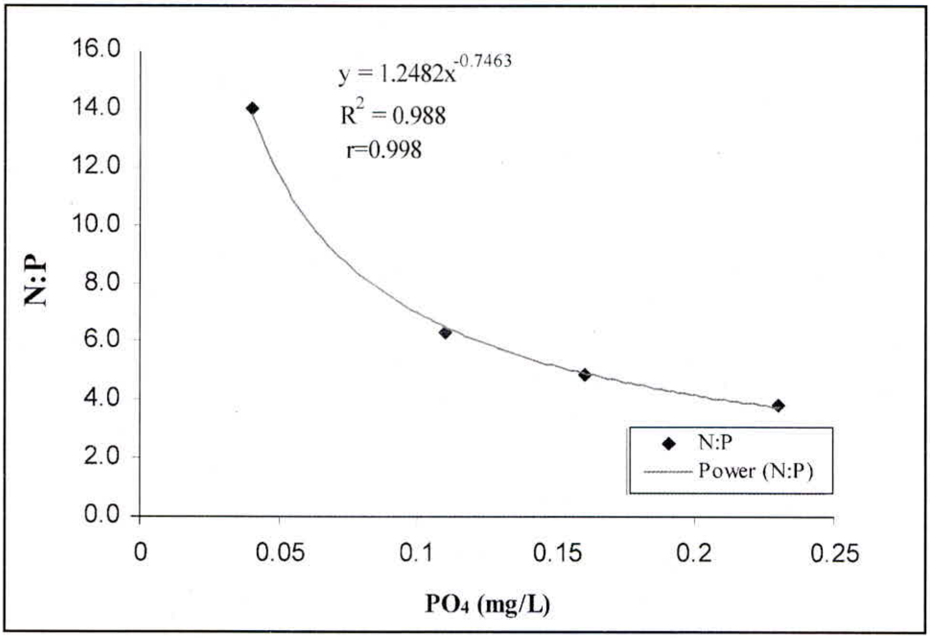

Fig. 2 : Nitrogen phosphorous ratio and phosphate content in the lake water

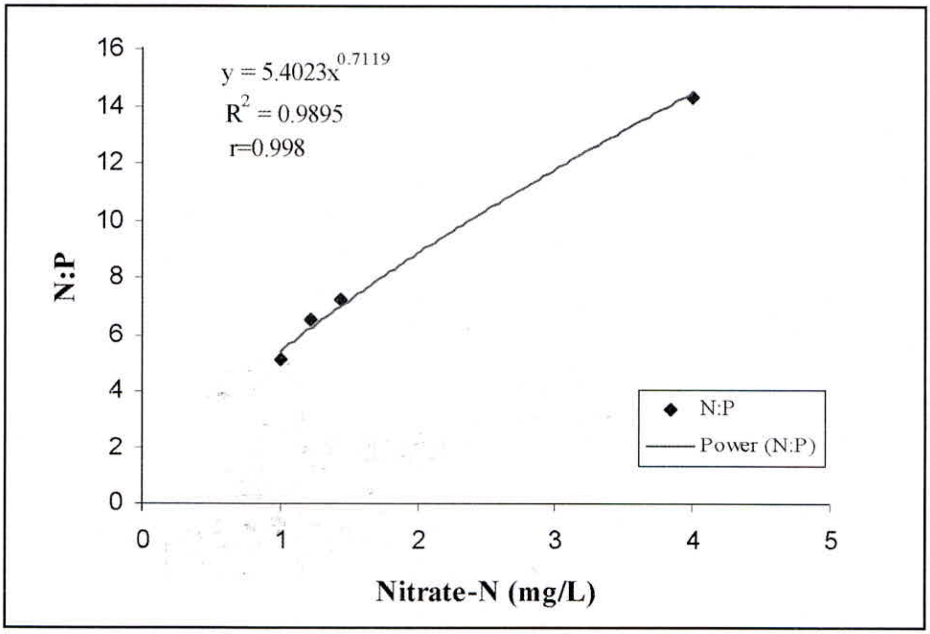

Fig. 3: Nitrogen phosphorous ratio and Nitrate nitrogen content in the lake water

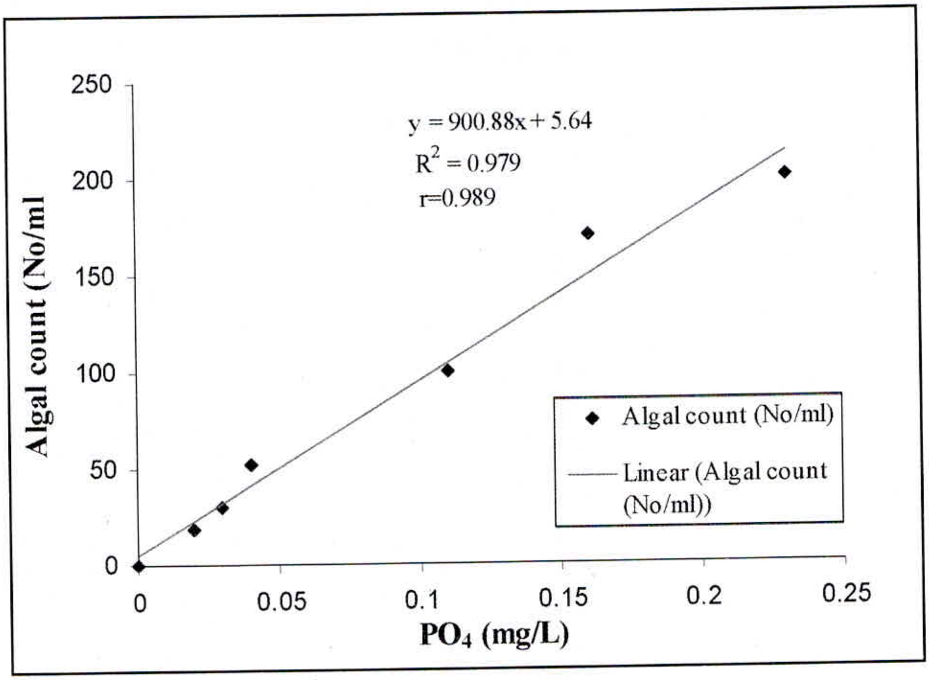

Fig. 4: Correlation of Algal count and phosphate in the lake water

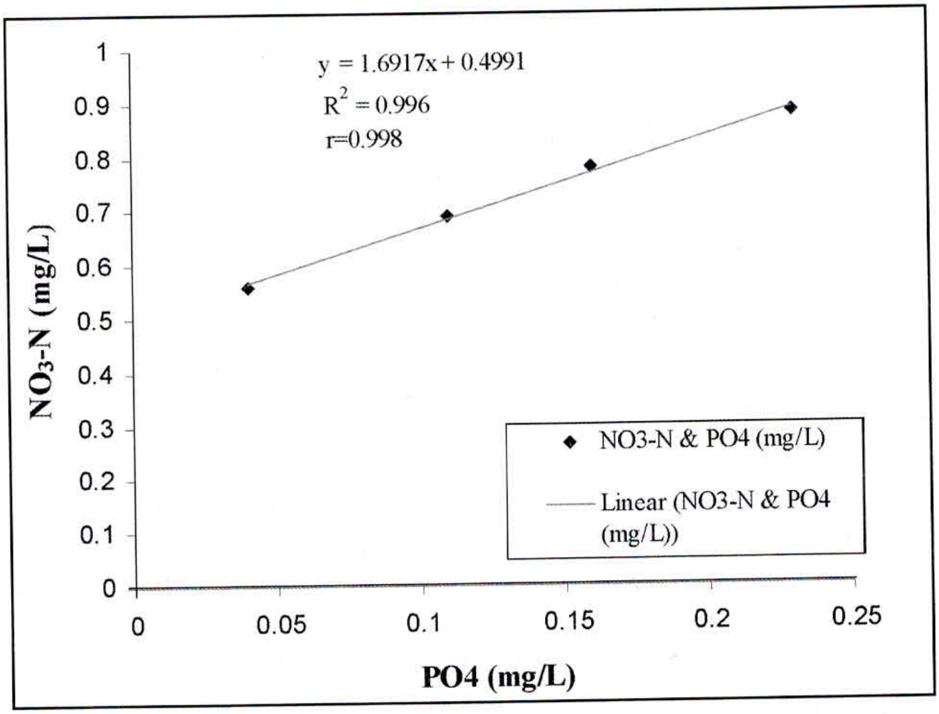

Fig. 5: Correlation of in Nitrogen and phosphorous ratio with lake water

Samples from all locations were analysed for heavy metals like, Arsenic, Aluminium, Lead, Cadmium, Zinc, Cadmium, Cobalt, Manganese, Iron and Chromium by inductive coupled plasma (ICP) and the results are presented in Table-2. Arsenic and lead were present in the range 0.005 mg/L to 0.108 mg/L and 0.005 mg/L to 0.04 mg/L respectively. The heavy metal concentration is 0.05 mg/L as prescribed by the IS 10500. Cadmium, chromium, zinc, cobalt and copper were below detectable limits while iron, manganese and aluminium were found in higher concentration as 1.2 mg/L to 10.5 mg/L, 0.02 mg/L to 0.88 mg/L and 0.02 mg/L to 4.316 mg/L respectively.

BIOLOGICAL ANALYSIS

Biological species in a water body are not only dependent on its physico-chemical characteristics but also on its nature, such as stagnant lakes or moving water (river). Diversity of plankton depends on the physico-chemical characteristics of water. The general trend of phytoplankton growth showed that the maximum count was observed in postmonsoon season attributed to the observed nutrient status (Figure-7). In oligotrophic water, diversity of plankton is high with increasing levels of pollution. Under mesotrophic and eutrophic condition, diversity of plankton decreases (Rolland, 2005). The water bodies receiving organic pollution, normally showing index values below 1 can be devoted as eutrophic. While values between 1 and 3 and above 3 may indicate mesotrophic and oligotrophic respectively (Trivedi 1980)

The biological analysis results are presented in Table-4 and 5. Futala Lake has a stone embankment on one side only and hence there is a lot of submerged, floating and emergent macrophytic vegetation such as *Ceratophyllum, Lemna, Azola, Potamogeton, Sagittaria, Eloidiea* etc. Phytoplankton studies revealed the presence of Chlorophyceae, Euglenophyceae, Bascillariophyceae and Cyanophyceae. Inspite of the large number of species of Chlorophyceae, most of the time Cyanophyceae was dominant. Algal bloom due to *Oscillatoria sp., Spirulina sp., Scenedesmus sp., Euglena sp., along with Anacystes sp.*, existed, which is characteristic of nutrient enriched waters (Salmaso, 2003). SWI of phytoplankton was in the range 1.84 to 2.84. Among the zooplankton, 4 groups were present in the sample. Out of the 4 groups, Cladocera was the dominating group, followed by Rotifera, Copepoda and Ostracoda. Species like *Brachionus, Keratella, Rotatoria, Lecane* existed in the lake water indicates that the lake, under mesotrophic status, is shifting towards eutrophic conditions (Takamura et al., 1986). SWI of zooplankton was in the range 1.82 to 2.1. The nutrient load, diversity indices and species composition ndicate that the lake is in mesotrophic condition.

ECORESTORATION OF LAKE

Ecotechnological measures are suggested for rejuvenation of the lake. Floating fountains are installed in the lake for hypolimnetic aeration to make up for the depleted oxygen level. The sediment basins should be construction to trap sediment load from

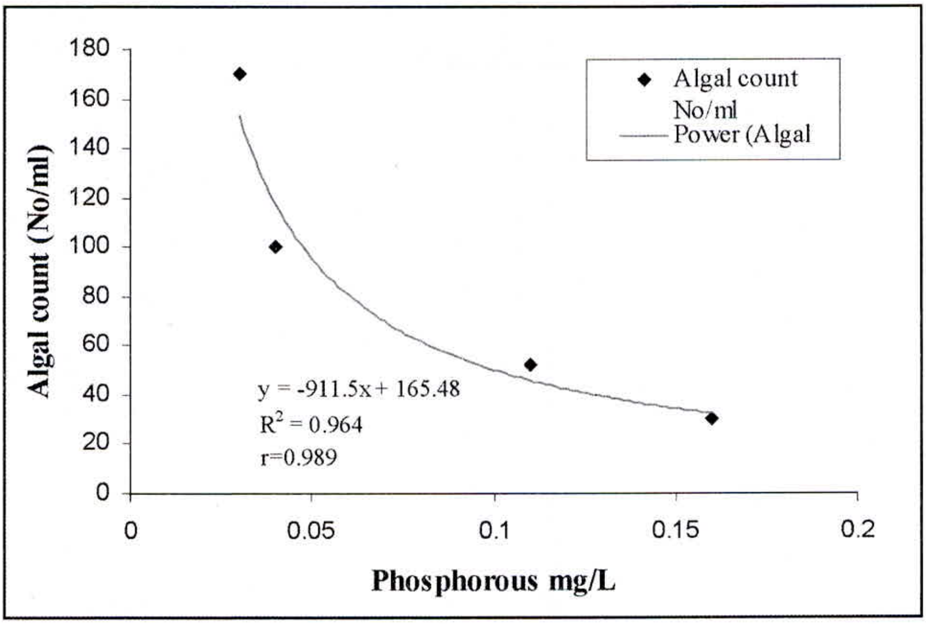

Fig. 6: Relationship in phosphate concentration and algal growth in the lake water

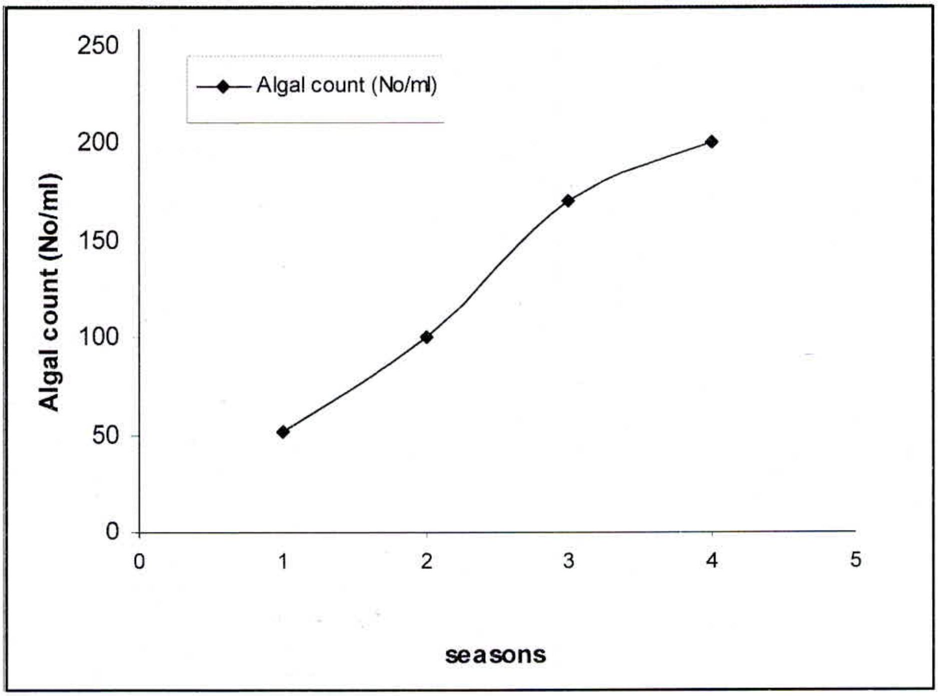

Fig. 7: Seasonal variation in algal growth

Table 2 : Heavy Metal Analysis of Futala Lake Water

Sample ID	Iron as Fe (mg/L)	Manganese as Mn (mg/L)	Zinc as Zn (mg/L)	Copper as Cu (mg/L)	Aluminium as Al (mg/L)	Chromium as Cr (mg/L)	Cadmium as Cd (mg/L)	Cobalt as Co (mg/L)	Lead as Pb (mg/L)	Arsenic as As (mg/L)
F1A	ND	0.097	ND	ND	0.156	ND	ND	ND	0.031	0.022
F2B	4.721	0.426	ND	ND	2.26	ND	0.003	0.047	0.048	0.07
F2A	ND	0.071	ND	ND	0.011	ND	0.002	ND	0.049	0.029
F2B	13.371	0.993	0.019	ND	6.26	0.003	0.006	0.126	0.063	0.042
F3A	ND	0.086	ND	ND	0.101	ND	0.003	ND	0.055	0.043
F3B	0.861	0.286	0.032	ND	0.64	ND	0.003	0.012	0.047	0.046
F4A	ND	0.1	ND	ND	ND	ND	0.002	ND	0.035	0.023
F4B	4.731	0.581	ND	ND	2.308	ND	0.003	0.049	0.052	0.074
F5A	ND	0.09	ND	ND	0.015	ND	0.002	ND	0.038	0.035
F5B	6.771	0.872	ND	ND	3.148	ND	0.004	0.072	0.059	0.092
F6A	ND	0.118	ND	ND	0.047	ND	0.002	ND	0.043	0.033
F6B	2.641	0.31	0.049	ND	1.498	ND	0.004	0.028	0.066	0.07
F7A	ND	0.139	ND	ND	0.088	ND	0.002	ND	0.007	0.026
F7B	2.789	0.272	0.005	ND	1.556	ND	0.002	0.025	0.043	0.067
F8A	4.739	0.517	0.007	ND	2.166	ND	0.004	0.047	0.046	0.028
F8B	ND	0.111	ND	ND	ND	ND	0.003	0.003	0.026	0.071
F9A	ND	0.133	ND	ND	ND	ND	0.002	ND	0.022	0.032
F9B	17.539	1.532	0.031	ND	8.316	0.011	0.009	0.163	0.087	0.052
F10A	ND	0.132	ND	ND	ND	ND	0.002	ND	0.029	0.023
F10B	1.829	0.272	0.013	ND	0.901	ND	0.002	0.016	0.031	0.041
IS1	0.26	0.129	0.305	ND	0.079	ND	0.003	0.005	0.052	0.05
IS1-Con	ND	0.111	ND	ND	ND	ND	0.002	ND	0.031	0.026

Table 3 : Diversity and Composition of Zooplankton in Futala Lake

Sl. No.	Sampling Code	Observation No/m3	SWI	Percentage Composition in Groups			
				Rotifer	Cladocera	Ostracoda	Copepoda
1	F1A	3250	1.89	29	33	13	25
2	F2A	3000	1.82	16	65	6	13
3	F3A	2120	1.84	20	60	10	10
4	F4A	3216	1.84	20	50	20	10
5	F5A	1020	2.1	18	22	30	30
6	F6A	4405	1.98	30	20	30	20
7	F7A	3125	1.99	25	25	25	25
8	F8A	3600	2.1	30	30	20	20
9	F9A	5689	1.8	50	20	15	15
10	F10A	3785	1.82	20	20	30	30
11	IS1	7050	1.96	30	30	20	20
12	IS1-Con	7500	1.5	36	25	20	19

Table 4 : Diversity and Composition of Phytoplankton in Futala Lake

Sl. No.	Sampling Code	Counts / ml	SWI	Percentage Composition in Groups				Palmer's Pollution Index
				Cyanophyceae	Chlorophyceae	Bacillariophyceae	Euglenophyceae	
1	F1A	60	2.55	30	40	20	10	15
2	F2A	73	2.48	18.85	78.28	2.87	-	14
3	F3A	36	1.9	18	74.5	7.5	0.85	16
4	F4A	12	2	10	80	-	10	16
5	F5A	20	2	20	36	25	19	17
6	F6A	66	2.84	24	66	10	-	18
7	F7A	50	2.88	10	78	10	2	19
8	F8A	46	3	5	91	4	-	19
9	F9A	60	3.1	26	55	91	8	19
10	F10A	55	2.9	6	78	10	6	15
11	IS1	76	2.9	10	78	8	4	20
12	IS1-Con	80	2.45	19	62	15	4	19
13	IS2	70	2.7	6	82	8	4	20
14	IS2-Con	86	2.69	16	63	19	2	19
A: Surface water		IS1: Inlet stream		SWI : Shannon Wiener's Diversity Index				
B: Depth water		IS2: Inlet stream						

the surface run-off. Root zone culture is being adopted to reduce the nutrient levels in the incoming wastewater to the lake. Alum treatment is suggested for turbidity removal and phosphorous inactivation without altering the aesthetic quality of lake water. The wastewater before entering into the lake body should be treated by different species of aquatic weeds suitable for tropical condition and then allowed to flow into the lake. Species for tropical environment like Eichornia (water hyacinth), Typha, Juccia, Phragmitis, Hydrilla, Lotus, Elodea, Duckweeds are suggested for wetland development. These species may also remove heavy metals from water such as Cadmium, Nickel, Lead, and Chromium along with Iron and Manganese. Green belt development is under consideration to avoid excessive soil erosion from the catchment of the lake.

CONCLUSION

Overall parameters for both physico-chemical and biological analysis indicate mesotrophic condition of the Futala Lake, Nagpur (India) is proceeding towards eutrophic conditions. The lake is polluted and rich in nutrients like carbon, nitrogen and phosphorous. To avoid the aging of lake, it is essential to minimize the ingress of pollutants and sewage into the lake water and removal of macrophytes to reduce the organic load. The water quality and sediment analysis for Futala Lake shows nutrient enrichment in the lake. Statistical analysis of nitrogen, phosphorous and algae count in the water indicates positive correlation. The relationship is linear for algae count and phosphate content. The year long study shows increasing trend for algae count in surface water of the lake from winter to postmonsoon season. Biological species, namely, phytoplankton and zooplankton, specific for a particular environmental condition are the best indicators of environmental quality. SWI of zooplankton and phytoplankton indicates mesotrophic condition of the lake. Ecotechnological measures like aeration, sediment traps, phosphorous precipitation and inactivation, land management, control of macrophyte biomass by mechanical removal are the methods to be adopted to rejuvenate the lake to oligotrophic conditions. The ecorestoration measures adopted will improve the lake condition. The water and sediment quality is periodically analysed to establish the ecorestoration of the lake.

ACKNOWLEDGEMENT

The authors thank the cooperation and assistance rendered by the staff of Nagpur Improvement Trust and NEERI, Nagpur for the completion of this assignment.

REFERENCES

1. APHA, AWWA & WEF. 2005. Standard Methods for the Examination of Water and Wastewater, 21th Edition.
2. Campbell IC Commentary. 1981. A Critique of Assimilative Capacity. Journal of Water Pollution Control Federation, 53: 604-607.

3. Harkare P. V., Kelkar P.S., Madan Nanoti. 2005. A Review of Lake Eutrophication. Proceedings on Hydrogeological Aspects of Rejuvenation of Urban Lakes, Udaipur, Vol.1, pp 58.
4. Kulkarni A.V., Ghosh TK and Chakraborty T. 2005. Assessment of Phosphorous Linked Assimilative Capacity of Selected Water Bodies in Nagpur District through Mathematical Model. Proceedings of National Conference on 'Frontiers in environmental Sciences and Engineering in India', Coimbatore.
5. OECD – Organisation for Economic Cooperation and Development. 1982. Boundary values of lake classification.
6. Perkins R. G. and Underwood GJC. 2000. Gradients of Chlorophyll- a and Water Chemistry along a Eutrophic Reservoir with Determination of the Limiting Nutrient by in Situ Nutrient Addition. Water research, 34: 3: 713-724.
7. Salmaso N. 2002. Ecological patterns of phytoplankton assemblages in Lake Garda: seasonal, spatial and historical features, Journal of Limnology, 61:1:95-115.
8. Takamura K.Y., Sugaya Y, Takamura N., Hanazato T., Yasuno M. and Iwakuma T. 1986. Primary Production of Phytoplankton and Standing Crops of Zooplanktons and Zoo-Benthos in Hypertrophic Lake Teganuma. Hydrobiologia, 173:173-184.
9. Trivedi R.C., CPCB. 1980. Biological Indicators and Indices of Environmental Pollution, Proceedings of the Workshop held at Osmania University, Hyderabad, India.
10. Reavie E. D., Neil K. E., Smol J. P., Little J. 2005. Cultural Eutrophication Trends in Three Southeastern Ontario Lakes: A Paleolimnological Perspective, Journal of Lake and Reservoir Management.
11. Vollenweider R. A. 1983. Eutrophication Notes Contributed during II Meeting of the Regional Projects on the Eutrophication of Tropical Lakes.
12. Rolland A., David F. B., Giani A. 2005. Seasonal Changes in Composition of the Cyanobacterial Community and the Occurrence of Hepatotoxic Blooms in the Eastern Townships, Quebec, Canada, Journal of Phytoplankton Resaerch, 27: 7: 683-694.
13. Whitton B. A., Yelloly J.M. 1996. Seasonal Changes In Ambient Phosphate and Phosphates Activities of the Cyanobacterium Rivularia Atra in Intertidal Pools of Tyne Sandsm Scotland. Hydrobiologia, 325: 201 – 212.