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Full Length Research Paper

Seasonal variations in water quality and major threats to Ramsagar reservoir, India

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Ramsagar reservoir, a small inland reservoir located in Datia district, Madhya Pradesh is constructed over Nichroli nallah, in the basin of Sindh River. The physico-chemical characteristics, trophic status and pollution studies of Ramsagar reservoir have been studied from April, 2003 to March, 2005. The nutrients including silicates (0.65 - 8.42 mgl^{-1}), sulphates (1.50 - 8.87 mgl^{-1}), phosphates (0.013 - 0.054 mgl^{-1}), nitrates (0.011 - 0.033 mgl^{-1}) and potassium (1.97 - 4.86 mgl^{-1}) are in sufficient quantities for the growth of aquatic animals in the reservoir. The above study indicated that the Ramsagar reservoir is under the category of mesotrophic water body slightly inclined towards eutrophication. Therefore, the conservation and management of this water body is very much required.

Keywords: Water quality, trophic status, threats of reservoir degradation.

INTRODUCTION

India is facing a serious problem of natural resource scarcity, especially that of water in view of population growth and economic development. Water is a prime natural resource, a basic human need and a precious national asset and hence its use needs appropriate planning, development and management. However, studies related to ecology and environment are often perceived as ‘anti-development and detrimental to the overall growth and welfare of human beings and are viewed with suspicion and generally considered as nuisance. The trophic status of a water body depends on the locality and its topography. Of all renewable resources of planet, water has the unique place. It is essential for sustaining all forms of life, food production, economic development and for general well being. Due to tremendous development of industry and agriculture, the water ecosystem has become perceptibly altered in several respects in recent years and as such they are exposed to all local disturbances regardless of where they occur (Venkatesan, 2007).

The increasing industrialization, urbanization and developmental activities, to cope up the population explosion have brought inevitable water crisis. The health of lakes and their biological diversity are directly related to health of almost every component of the ecosystem (Ramesh et al., 2007). In freshwater bodies, nutrients play a major role as their excesses lead to eutrophication. Excessive macrophytic vegetation is indicative of the eutrophication status of any water body. Monitoring of water quality is the first step that can lead to management and conservation of aquatic ecosystems. It is also true that the management of any aquatic ecosystem is aimed to the conservation of its habitat by suitably maintaining the physico-chemical quality of water within acceptable levels. Hence, in the present study, an attempt has been made to study the physico-chemical parameters of Ramsagar reservoir situated in Datia district, Madhya Pradesh to arrive at certain conclusions on the structural and functional aspects of the reservoir and to suggest ways and means for its conservation.

MATERIALS AND METHODS

Study area

Ramsagar, a small man-made reservoir with 140.097 ha water spread area, was built over a Nichroli Nallah in the basin of Sindh River. The reservoir is located approximately 8 km northwest of Datia city in Madhya Pradesh, India and approximately 80 km south of Gwalior. Geographically, it lies near 25°40’ N latitude and 78°23’ E longitude and at an altitude of 229 m from mean sea level. This reservoir is a multipurpose tank used for different activities like drinking water supply, irrigation, fisheries etc. Four sampling station

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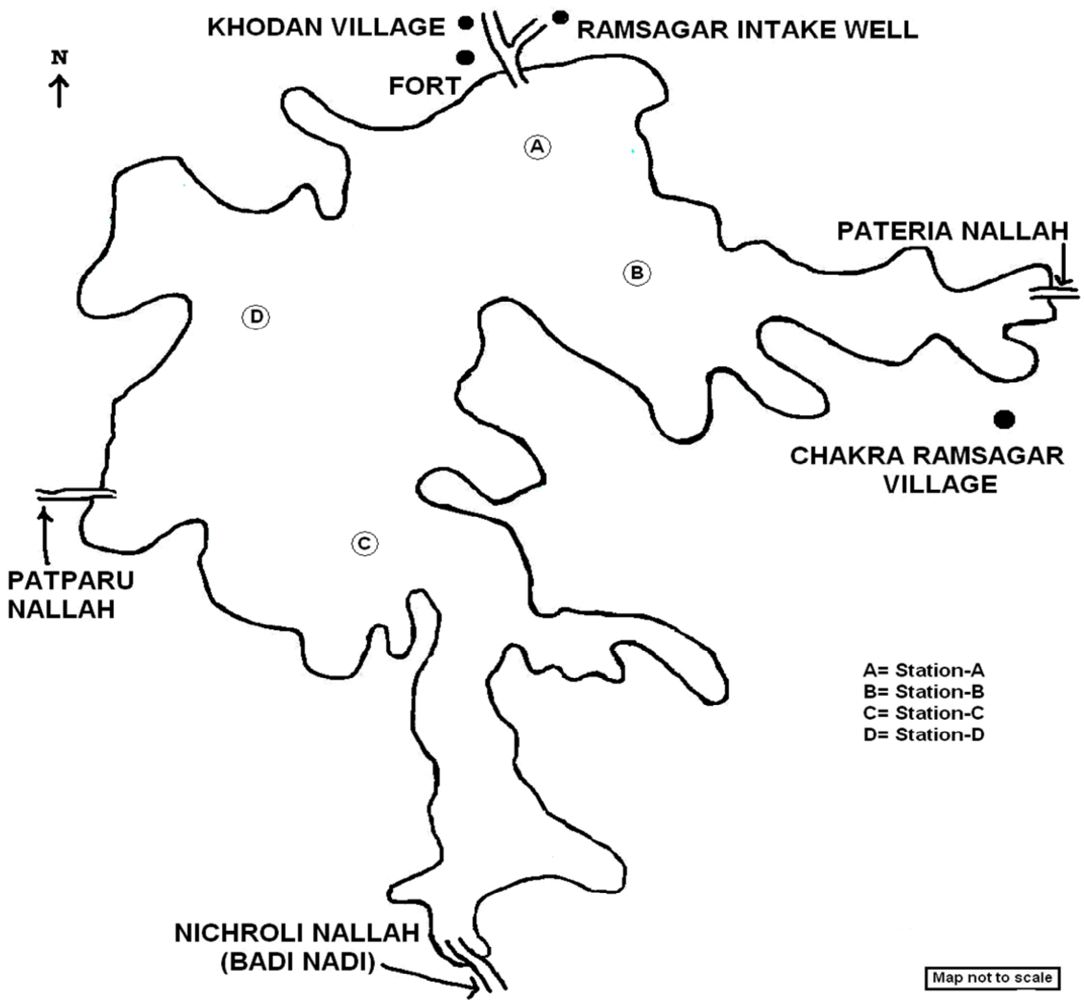

Figure 1. Map of Ramsagar reservoir showing sampling stations.

stations, namely, station-A, B, C and D were selected for analysis of physico-chemical characteristics of water covering whole area of the reservoir (Figure 1).

Sampling procedure and laboratory analysis

Water samples were collected from all four sampling stations from April, 2003 to March, 2005. Monthly samples of sub-surface water in triplicate were collected during first week of each month in the early hours of the day (7 a.m. to 9 a.m.). Iodine treated double stoppard polyethylene bottles were used for collection of water samples. Bottles were kept in ice bucket and brought to the laboratory for analysis. Some of the physico-chemical characteristics of water including water temperature, depth, color, transparency, pH were determined using mercury thermometer, graduated string, visual, Sechi disc, digital pH meter, respectively. While dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, chlorides, calcium and magnesium, were analyzed using titrimetric method at the sampling stations. Other parameters including turbidity, electrical conductivity, total dissolved solids, nitrate-nitrogen, nitrite-nitrogen, sulphates, phosphates, silicates, biochemical oxygen demand, chemical oxygen demand, ammonia, sodium and potassium were analyzed in the laboratory within the 6 to 8 h following the methods of APHA (1995) and Trivedy and Goel (1986).

RESULTS AND DISCUSSION

Range of variation and their annual mean along with standard deviation of various physico-chemical characteristics of water of Ramsagar reservoir is given in Table 1 and trophic status is shown in Table 2. Monthly variations in water quality are depicted in Figures 2 - 25, while correlation coefficients between different parameters are tabulated in Table 3.

Water quality of the reservoir

In Ramsagar reservoir, the water temperature increased during warmer months and decreased during colder months. Similar seasonal variations were also observed by Surve et al. (2005). Water level plays an important role in governing the water quality. Like any other water

Table 1. Range of variation, mean and standard deviation of water quality parameters of Ramsagar.

S/No.	Parameters	2003 - 2004			2004 - 2005		
		Range of variation		Mean and Standard deviation	Range of variation		Mean and standard deviation
		Minimum	Maximum		Minimum	Maximum	
1.	Water temperature, °C	17.87	31.87	25.53 ± 4.74	15.92	27.92	22.20 ± 3.95
2.	Water depth, m	2.90	5.51	4.28 ± 0.84	4.13	8.25	5.09 ± 1.88
3.	Color	Transparent	Turbid	Transparent	Transparent	Turbid	Transparent
4.	Transparency, cm	66.59	116	96.80 ± 13.10	76.25	91.71	85.02 ± 5.50
5.	Electrical conductivity, µS/cm	140.00	219.04	179.13 ± 30.46	108.00	246.30	183.85 ± 43.77
6.	Turbidity, NTU	2.17	8.52	6.05 ± 2.49	4.42	16.72	8.60 ± 3.52
7.	Total dissolved solids (mgl^{-1})	166.37	218	186.95 ± 18.04	185.00	239.00	206.51 ± 16.32
8.	pH	8.20	8.77	8.40 ± 0.18	7.41	8.95	8.13 ± 0.55
9.	Dissolved oxygen(mgl^{-1})	6.88	10.99	8.67 ± 1.51	6.78	11.59	8.48 ± 1.55
10.	Free carbon dioxide (mgl^{-1})	Nil	6.32	0.80 ± 2.75	Nil	4.67	1.63 ± 1.32
11.	Total alkalinity (mgl^{-1})	83.87	133.25	104.22 ± 15.27	64.25	146.25	104.65 ± 25.36
12.	Total hardness (mgl^{-1})	34.00	75.25	53.30 ± 13.89	43.50	66.00	53.19 ± 6.49
13.	Chlorides (mgl^{-1})	14.09	17.88	15.98 ± 1.23	13.13	22.36	17.40 ± 2.57
14.	Calcium (mgl^{-1})	11.21	26.55	17.86 ± 5.49	13.36	33.81	20.32 ± 6.12
15.	Sulphates(mgl^{-1})	1.50	8.87	4.30 ± 2.18	3.57	8.30	5.71 ±1.52
16.	Nitrate-nitrogen (mgl^{-1})	0.011	0.033	0.019 ± 0.006	0.015	0.032	0.022 ± 0.004
17.	Nitrite-nitrogen (mgl^{-1})	0.004	0.017	0.010 ± 0.003	0.009	0.029	0.016 ± 0.005
18.	Phosphates (mgl^{-1})	0.013	0.054	0.022 ± 0.011	0.015	0.047	0.025 ± 0.009
19.	Silicates (mgl^{-1})	0.65	7.21	3.93 ± 2.03	1.17	8.42	5.82 ± 1.49
20.	Ammonia (mgl^{-1})	0.03	0.65	0.29 ± 0.23	Nil	0.84	0.33 ± 0.27
21.	BOD (mgl^{-1})	1.31	2.63	1.93 ± 0.40	0.93	4.68	2.13 ± 1.13
22.	COD (mgl^{-1})	3.60	13.00	7.51 ± 2.64	4.70	17.40	9.30 ± 4.26
23.	Magnesium (mgl^{-1})	1.33	3.59	2.19 ± 0.71	1.17	5.60	3.06 ± 1.18
24.	Sodium (mgl^{-1})	21.07	34.30	27.75 ± 3.02	16.75	31.27	24.30 ± 4.69
25.	Potassium (mgl^{-1})	1.97	4.75	3.07 ± 0.65	2.10	4.86	3.25 ± 0.86

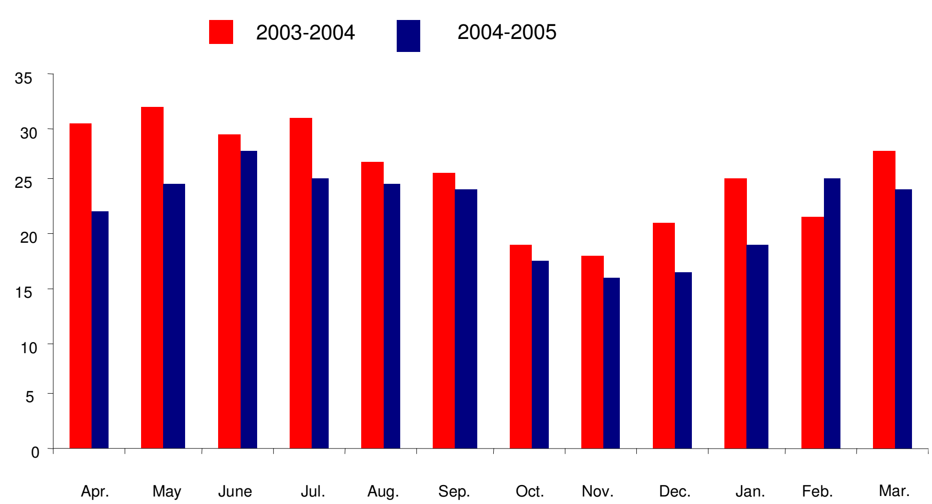

Figure 2. showing monthly variations in water temperature.

Table 2. Correlation Coefficient (r) amongst physico-chemical parameters of the Ramsagar reservoir.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1.00																							
2	0.933	1.00																						
3	-0.223	-0.391	1.00																					
4	0.605	0.386	0.418	1.00																				
5	-0.132	0.038	-0.239	-0.477	1.00																			
6	0.333	0.514	-0.026	0.879	0.315	1.00																		
7	0.513	0.628	-0.347	0.367	-0.071	0.671	1.00																	
8	-0.084	-0.081	-0.114	-0.009	-0.528	-0.233	-0.004	1.00																
9	-0.381	0.191	-0.854	-0.405	0.364	0.901	0.997	-0.316	1.00															
10	0.431	0.458	0.046	0.473	-0.547	0.415	0.546	0.145	0.743	1.00														
11	-0.401	-0.531	0.138	0.011	-0.401	-0.724	-0.564	0.534	0.075	-0.161	1.00													
12	0.064	0.071	-0.226	-0.072	0.032	0.134	0.367	0.031	0.358	0.325	-0.269	1.00												
13	-0.281	-0.401	0.036	0.023	-0.452	-0.718	-0.466	0.592	0.191	-0.032	0.973	-0.141	1.00											
14	-0.021	0.013	0.459	0.041	0.441	0.496	-0.127	-0.516	-0.632	0.028	-0.359	-0.119	-0.443	1.00										
15	0.242	0.345	-0.196	0.106	0.044	0.549	0.641	0.276	-0.317	0.065	-0.502	0.091	-0.508	-0.007	1.00									
16	-0.123	0.055	-0.126	-0.315	0.201	0.365	0.291	0.322	-0.535	-0.185	-0.354	-0.039	-0.378	0.124	0.833	1.00								
17	0.376	0.102	0.141	0.548	-0.448	-0.203	0.165	-0.262	-0.981	0.103	-0.156	0.116	-0.166	-0.175	0.011	-0.323	1.00							
18	-0.361	-0.151	-0.251	-0.641	0.453	0.371	0.153	0.065	0.201	-0.211	-0.464	0.365	-0.486	0.221	0.571	0.766	-0.372	1.00						
19	0.193	0.377	-0.411	0.077	-0.048	0.445	0.783	-0.033	0.782	0.538	-0.541	0.567	-0.408	-0.093	0.461	0.361	0.013	0.424	1.00					
20	0.211	-0.049	0.406	0.724	-0.548	-0.081	0.064	-0.217	0.286	0.397	0.133	0.027	0.096	-0.039	-0.295	-0.673	0.726	-0.636	-0.185	1.00				
21	0.603	0.633	-0.328	0.011	0.291	0.309	0.141	-0.298	-0.092	0.287	-0.495	0.368	-0.394	0.298	0.022	-0.128	0.031	0.126	0.204	-0.065	1.00			
22	-0.538	-0.627	0.461	-0.068	0.205	-0.107	-0.499	-0.201	-0.317	-0.604	0.192	-0.555	-0.038	0.353	-0.016	0.097	0.043	0.076	-0.632	0.137	-0.456	1.00		
23	0.155	0.181	0.211	0.421	0.118	0.532	0.576	-0.463	0.881	0.447	-0.408	0.429	-0.372	0.196	-0.003	-0.271	0.139	-0.114	0.421	0.403	0.032	-0.222	1.00	
24	0.354	0.316	0.433	0.574	-0.401	0.552	0.516	0.078	-0.996	0.691	-0.441	0.278	-0.406	0.261	0.491	0.228	0.255	0.104	0.409	0.35	0.193	-0.195	0.432	1.00

Data is the mean value of monthly collected samples. The values (r) ranged from 0.400 to 0.52 and 0.53 to above are significant at $P < 0.05$ and $P < 0.01$ respectively. 1 = Ambient temperature, 2 = water temperature, 3 = Transparency, 4 = electrical conductivity, 5 = turbidity, 6 = TDS, 7 = pH, 8 = dissolved oxygen, 9 = CO_2, 10 = total alkalinity, 11 = total hardness, 12 = chlorides, 13 = calcium, 14 = sulphates, 15 = nitrates, 16 = nitrites, 17= phosphates, 18 = silicates, 19 = ammonia, 20 = BOD, 21= COD, 22 = magnesium, 23 = sodium and 24 = potassium.

Table 3. Trophic status of the Ramsagar reservoir on the basis of different indices

S/No.	Parameters	Water quality of Ramsagar reservoir	Trophic status of Ramsagar reservoir	References	Overall trophic status of Ramsagar reservoir
1.	Water temperature (^{0}C)	15.92 - 31.87	Meso-thermal	Lee et al. (1981)	Mesotrophic
2.	Transparency, cm	66.59 - 116.00	Eutrophic	Lee et al. (1981)	
3.	Electrical Conductivity (µS/cm)	108 - 246.30	Mesotrophic	Olsen (1950)	
4.	pH	7.41 - 8.95	Alkaliphilous	Venkateswarlu (1983)	
5.	Free carbon dioxide (mgl^{-1})	Nil - 6.32	Soft	Reid and Wood (1976)	
6.	Total alkalinity (mgl^{-1})	64.25 - 146.25	Productive with rich nutrient	Spence (1964)	
7.	Total hardness (mgl^{-1})	34.00 - 75.25	Soft water	Sawyer (1960)	
8.	Chlorides (mgl^{-1})	13.13 - 22.36	No Pollution	Unni (1983)	
9.	Calcium (mgl^{-1})	11.21- 33.81	Medium to rich	Ohle (1934)	
10.	Nitrate-nitrogen (mgl^{-1})	0.011- 0.033	Oligo-mesotrophic	Vollenweider (1968)	
11.	Phosphates (mgl^{-1})	0.013 - 0.054	Mesotrophic	Lee et al. (1981)	

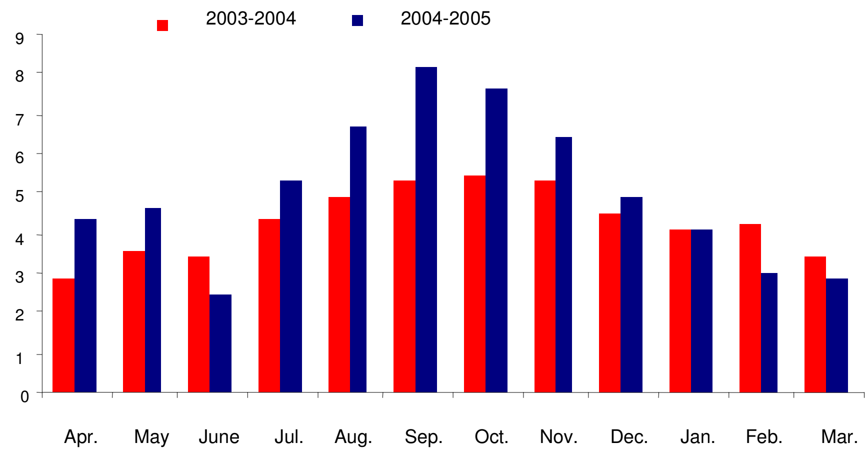

Figure 3. showing monthly variations in depth of water.

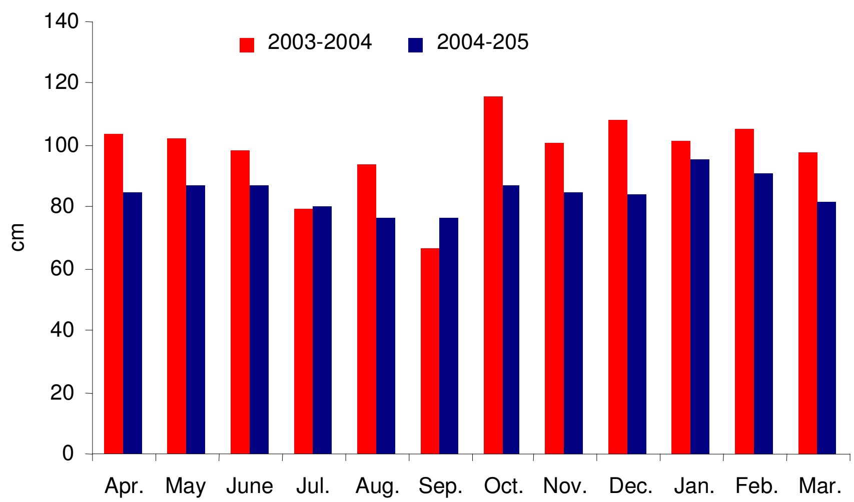

Figure 4. showing monthly variations in transparency of water.

bodies, in Ramsagar reservoir, maximum water level was recorded in post-monsoon period while minimum water level was recorded in summer season during both the years of study.

Water was turbid in monsoon season with yellow brown colour, while green colour in winter and transparent green colour was observed in summer season. The transparency of water is mainly affected by factors such as biological productivity, suspended particles and water colour. The transparency in Ramsagar reservoir ranged from 66.59 - 116.00 cm with low value during monsoon season. Settlement of sand, silt and clay result in a higher transparency from the post-monsoon period reaching a maximum of 116.00 cm in October 2003 marks the highest transparency in this reservoir. Devaraju et al. (2005) have reported transparency ranging from 36.00 to 55.00 cm in Naktara reservoir and from 131.86 to 339.66 cm in Maddur lake, respectively and in Harsi reservoir this reported from 48.75 to 114.25 cm (Garg et al., 2006b).

Conductivity measures the capacity of a substance or solution to conduct electrical current. The electrical conductivity was found to fluctuate between 108.00 µS/cm (September, 2004) and 246.30 µS/cm (May, 2004) in this reservoir and that falls within the range observed for Indian waters. Olsen (1950) classified the name for water bodies having conductivity values greater than 500.00 µS/cm as eutrophic. According to this criteria, Ramsagar reservoir water falls under the category of mesotrophic water body. Clay, silt, organic matter, plankton and other microscopic organisms cause turbidity in natural waters (Kishor et al., 2005). This has been recognized as a valu-

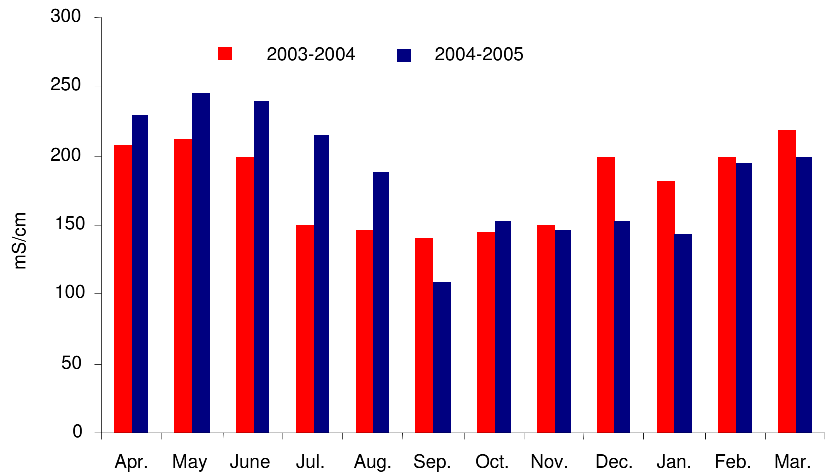

Figure 5. showing monthly variations electricity conductivity of water.

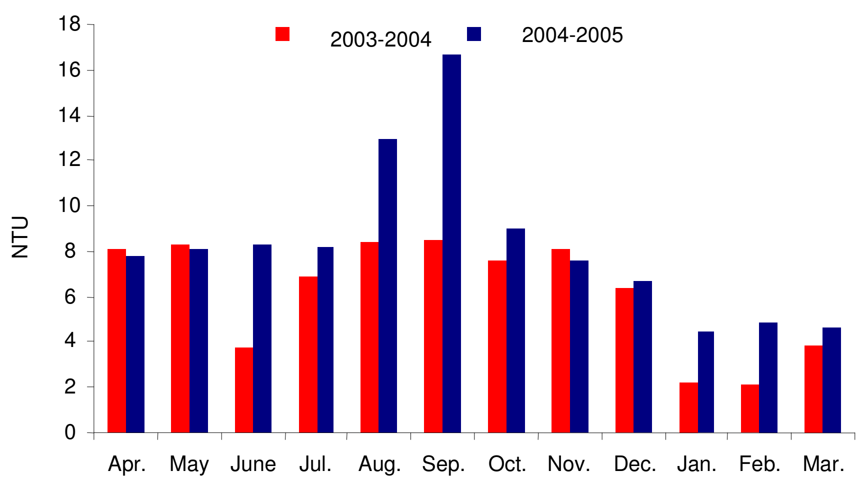

Figure 6. showing monthly variations in turbidity of water.

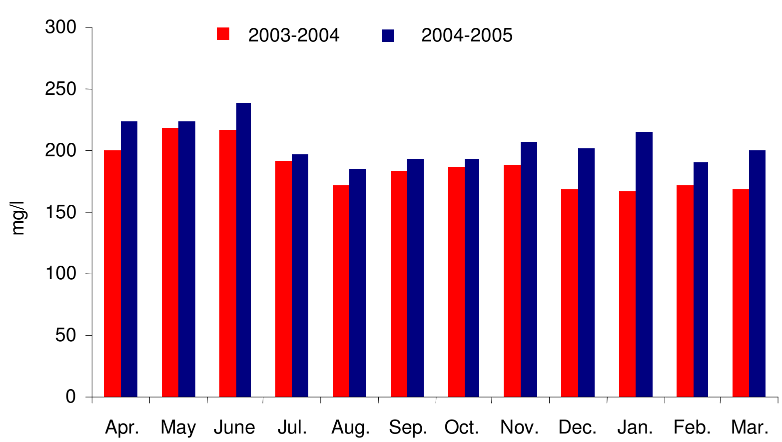

Figure 7. showing monthly variations in T.D.S of water.

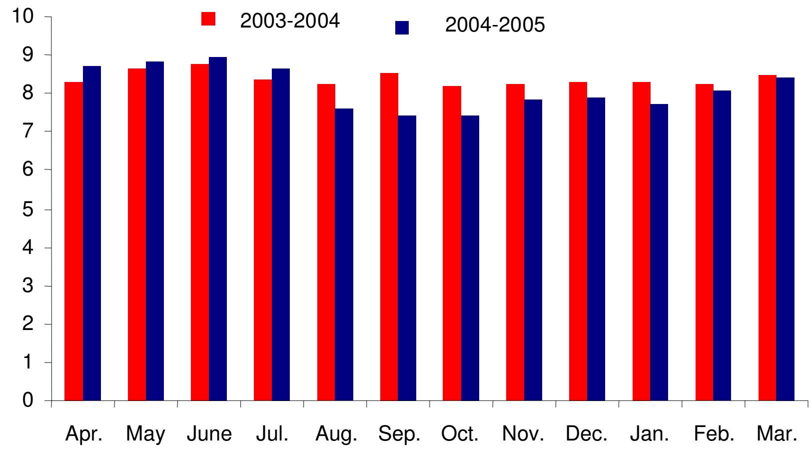

Figure 8. showing monthly variations in p^{H} of water.

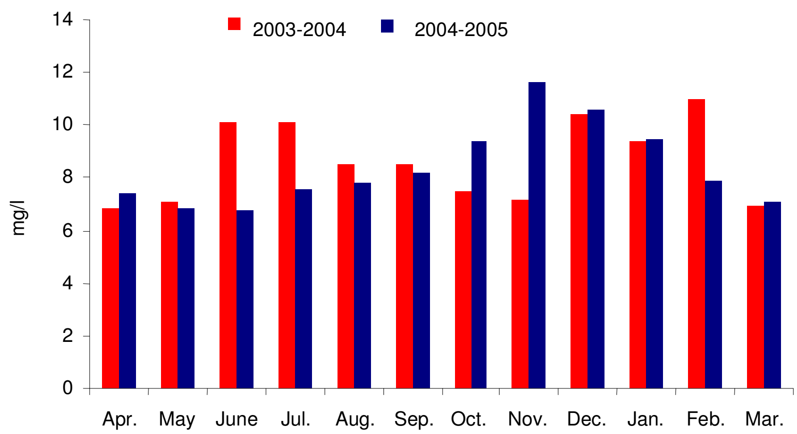

Figure 9. showing monthly variations in dissolved oxygen.

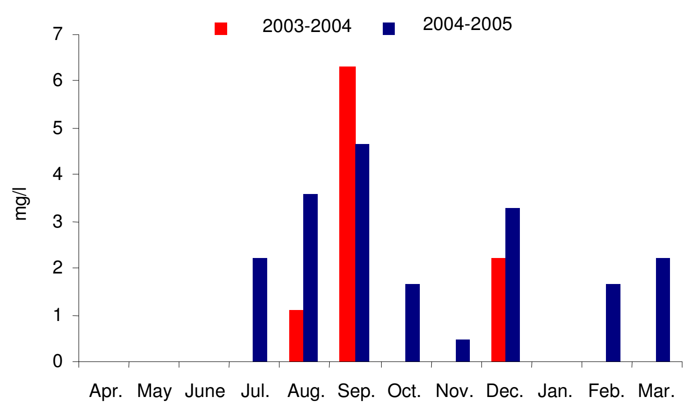

Figure 10. showing monthly variations in free carbon dioxiode.

valuable limiting factor in the biological productivity of the water bodies. In the present study, maximum turbidity was recorded as 16.72 NTU in September, 2004 during monsoon season, while minimum value was recorded as

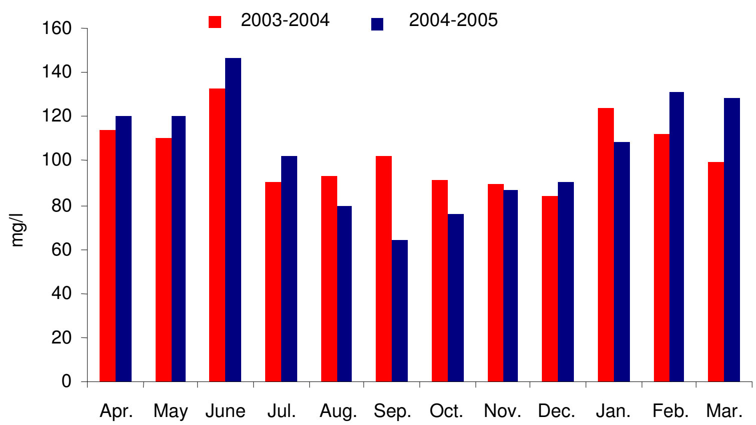

Figure 11. showing monthly variations in total alkalinity.

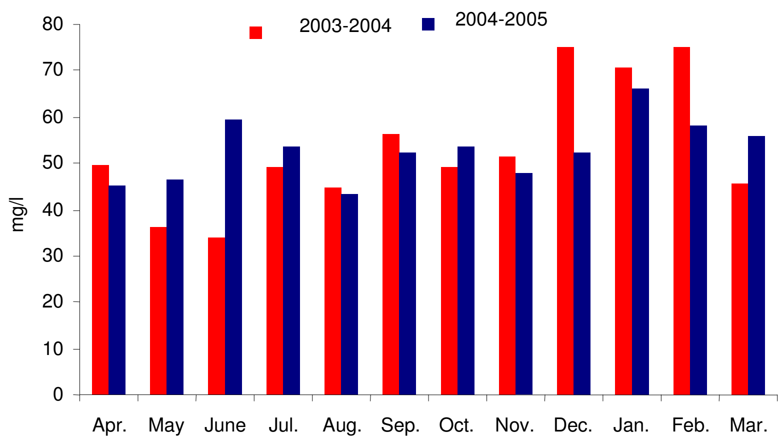

Figure 12. showing monthly variations in total hardness.

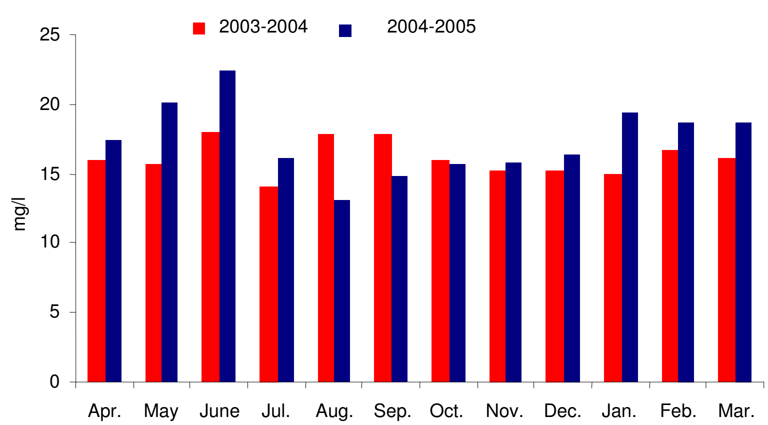

Figure 13. showing monthly variations in chlorides.

2.17 NTU in February, 2004 during winter season. During monsoon season, silt, clay and other suspended particles contribute to the turbidity values, while during winter season settlement of silt, clay resulting low turbidity. Dagaonkar and Saksena (1992) and Garg et al. (2006b) have also reported high turbidity during rainy season.

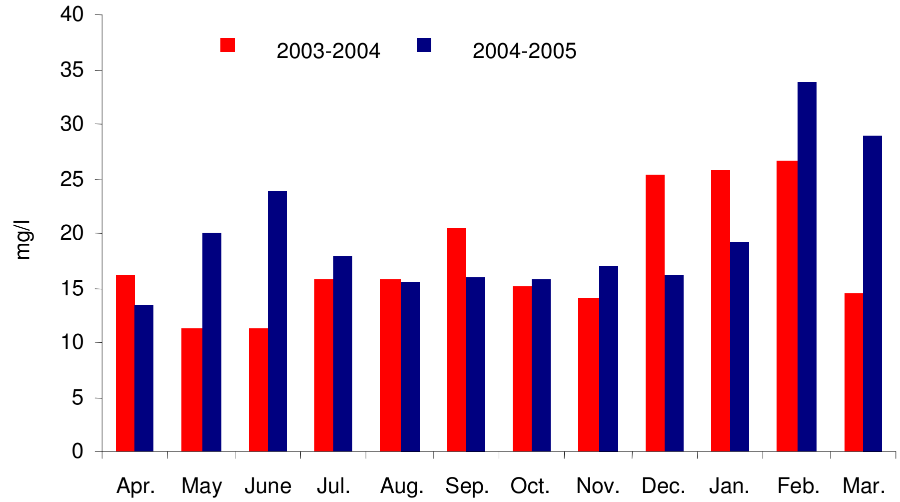

Figure 14. showing monthly variations in calcium.

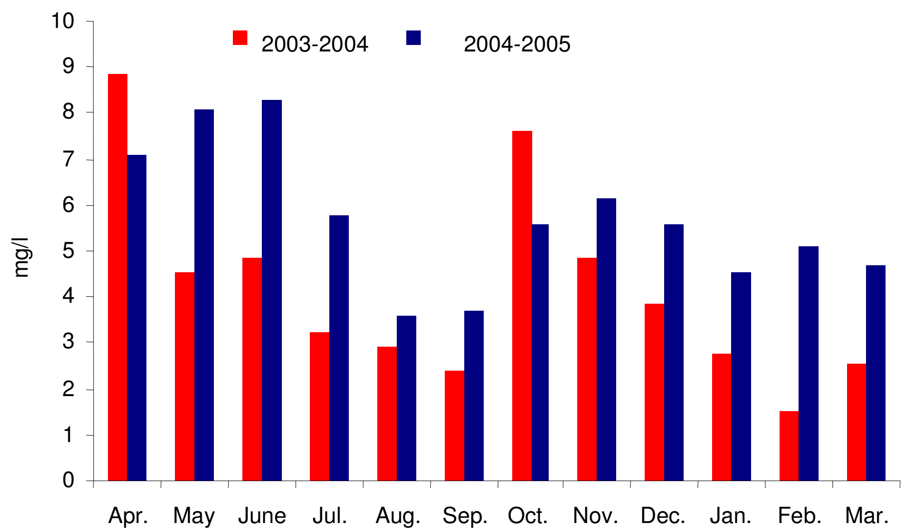

Figure 15. showing monthly variations in sulphate.

In natural waters, dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron and manganese etc (Esmaeili and Johal, 2005). The total dissolved solids (TDS) were observed upto 410.00 mgl^{-1} in Kapsi lake (Fokmare and Musaddiq, 2002) and 228.00 mgl^{-1} in Natnagara reservoir (Dhakad and Chaudhary, 2005). In present study, TDS showed highest value of 239.00 mgl^{-1} in the month of June, 2004. Similar findings have been reported by Rao et al. (2003), Kirubavathy et al. (2005) and Garg et al. (2006b) with regards to seasonal variations of TDS. Klein (1972) has reported that the excess amount of TDS in waters disturbed the ecological balance and caused suffocation of aquatic fauna. Sreenivasan (1976) has demonstrated that a large variation in pH of water is an indication of a highly productive nature of the water body. The variation in pH in Ramsagar reservoir was in the range 7.41 to 8.95.

Dissolved oxygen concentration more than 5.00 mgl^{-1} favours good growth of flora and fauna (Das, 2000). The dissolved oxygen ranged from 3.41 to 6.21 mgl^{-1} in Seetadwar lake (Tewari and Mishra, 2005), from 5.30 to 9.00 mgl^{-1} in Deoria tal (Rawat and Sharma, 2005) and from 3.00 to 6.00 mgl^{-1} in Kandhar dam (Surve et al., 2005). Thus, the dissolved oxygen varies greatly from one water body to the other. In the present investigation, however, the dissolved oxygen was found to vary from 6.78 mgl^{-1} (June, 2004) to 11.59 mgl^{-1} (November, 2004)

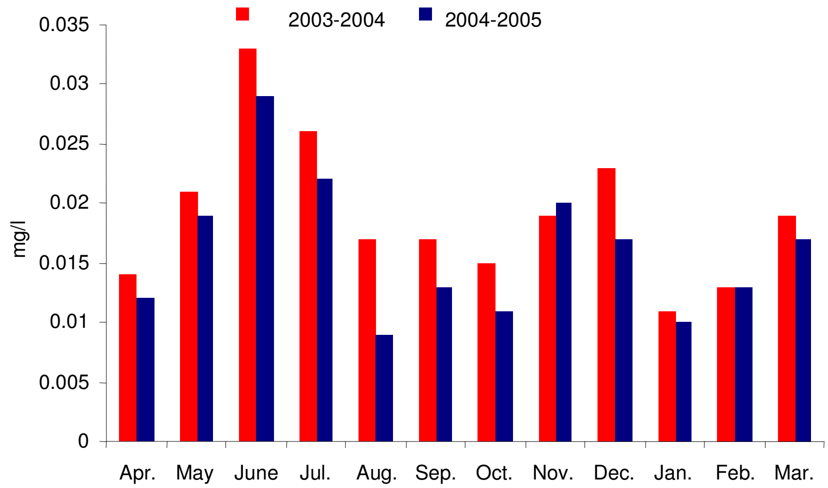

Figure 16. showing monthly variations in nitrate-nitrogen.

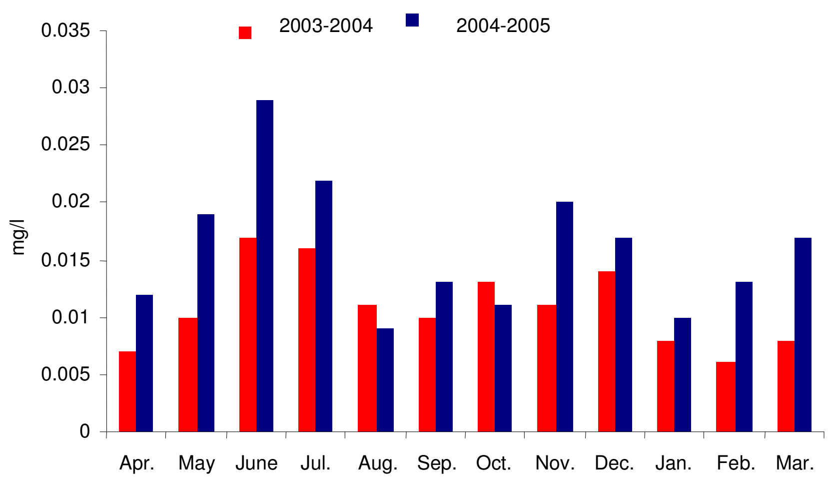

Figure 17. showing monthly variations in nitrate-nitrogen.

with maximum concentration during winter season. In summer season, dissolved oxygen decreased due to increased temperature of water (Naz and Turkmen, 2005). Like Harsi reservoir (Garg et al., 2006b), the dissolved oxygen in this reservoir also was quite enough to support biological life. Free carbon dioxide liberated during respiration and decay of organic matter is highly soluble in natural waters. The carbon dioxide content of water depends upon the water temperature, depth, rate of respiration, decomposition of organic matter, chemical nature of the bottom and geographical features of the terrain surrounding the water body (Sakhare and Joshi, 2002). In Ramsagar reservoir, highest free carbon di-oxide was recorded as 6.32 mgl^{-1}. However, its absence or low content recorded in most of the times was due to alkaline nature of reservoir.

The total alkalinity ranged from 64.25 to 146.25 mgl^{-1}, which makes the reservoir as nutrient rich and highly productive water body as suggested by Munawar (1970). High hardness of aquatic ecosystem points out towards eutrophication (Rai, 1971). Sawyer (1960) classified water on the basis of hardness into three categories that is, soft (0.00 - 75 mgl^{-1}), moderately hard (75.00 - 150.00 mgl^{-1}) and hard (151.00 -300.00 mgl^{-1}). According to this classification, Ramsagar reservoir falls in the category of soft water body with hardness ranging from 34.00 to 75.25 mgl^{-1}.

The salts of sodium, potassium and calcium contribute chlorides in waters. Large contents of chloride in fresh-water is an indicator of organic pollution (Venkatasubramani and Meenambal, 2007). In the present study, chloride concentration varied from 13.13

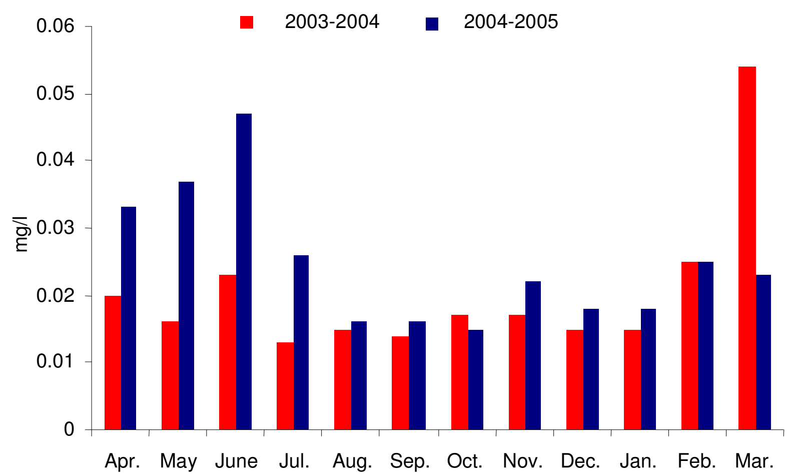

Figure 18. showing monthly variations in phosphates.

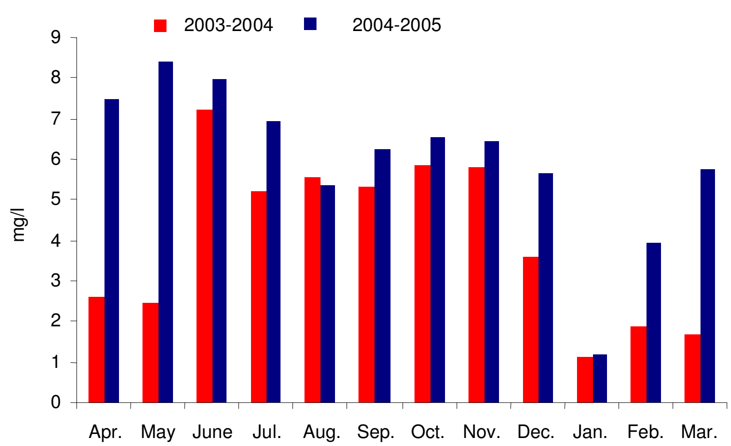

Figure 19. showing monthly variations in silicate.

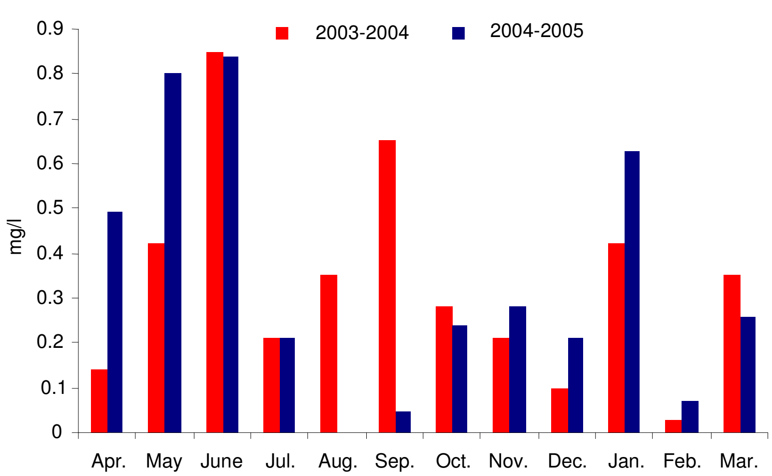

Figure 20. showing monthly variations in ammonia.

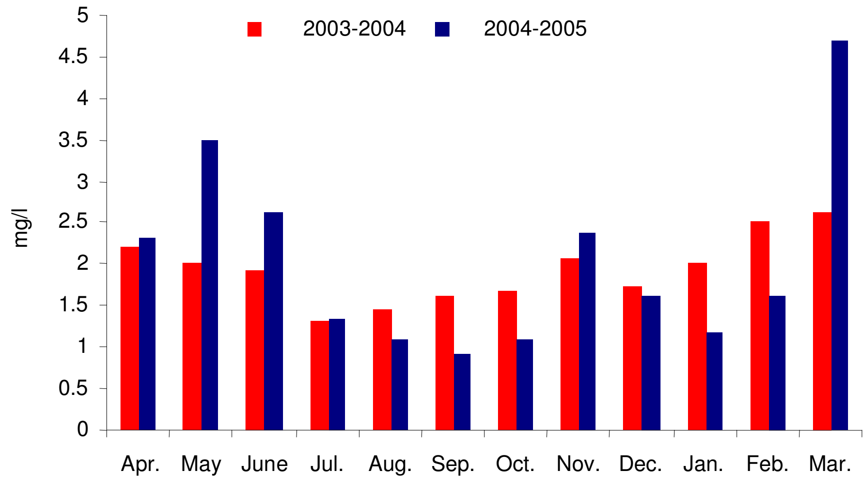

Figure 21. showing monthly variations in B.O.D.

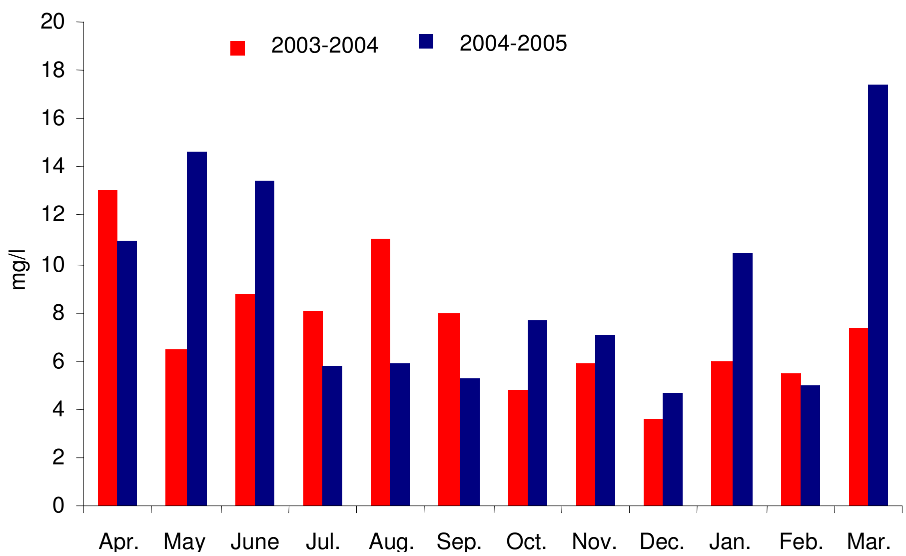

Figure 22. showing monthly variations in C.O.D.

(August, 2004) to 22.36 mgl^{-1} (June, 2004) with the concentration higher in summer season and lower in monsoon season. In aquatic environment, calcium serves as one of the micronutrients for most of the organisms. The calcium contents in Ramsagar reservoir varied from 11.21 (June, 2003) to 33.81 mgl^{-1} (February, 2005). On the basis of calcium richness, Ohle (1938) classified water bodies into: (i) poor (ii) medium and (iii) rich water body with regard to calcium content. According to this classification Ramsagar reservoir falls under the category of medium to rich calcium in water.

The rich concentration of nutrient such as sulphates (1.50 - 8.87 mgl^{-1}), nitrates (0.011 - 0.033 mgl^{-1}), nitrite (0.004 - 0.029 mgl^{-1}), phosphates (0.013 - 0.054 mgl^{-1}) and silicates (0.65 - 8.42 mgl^{-1}) has been observed in Ramsagar with greater concentration during summer season due to evaporation. The pattern of nutrient concentration in this reservoir was quite similar to that observed by Rawat and Sharma, (2005) in Deoriatal and Thilaga et al. (2005) in Ooty lake. Ammonia in higher concentration is harmful to fishes and other life. The toxicity of ammonia increases with the pH because at higher pH most of the ammonia remains in the gaseous form. At low pH due to conversion of ammonia into ammonium ions (which are much less toxic than the gaseous form) decreases its toxicity. In the present study, the ammonia content varied from its absence in August, 2004 to 0.85 mgl^{-1} in June, 2003 with higher values in summer season and lower value in monsoon season.

Biochemical oxygen demand (BOD) is the amount of

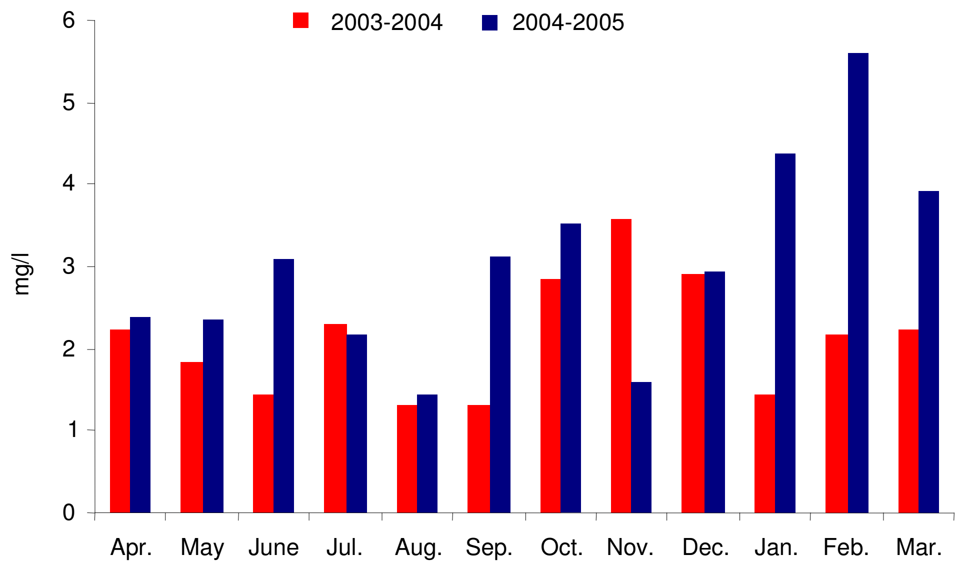

Figure 23. showing monthly variations in magnesium.

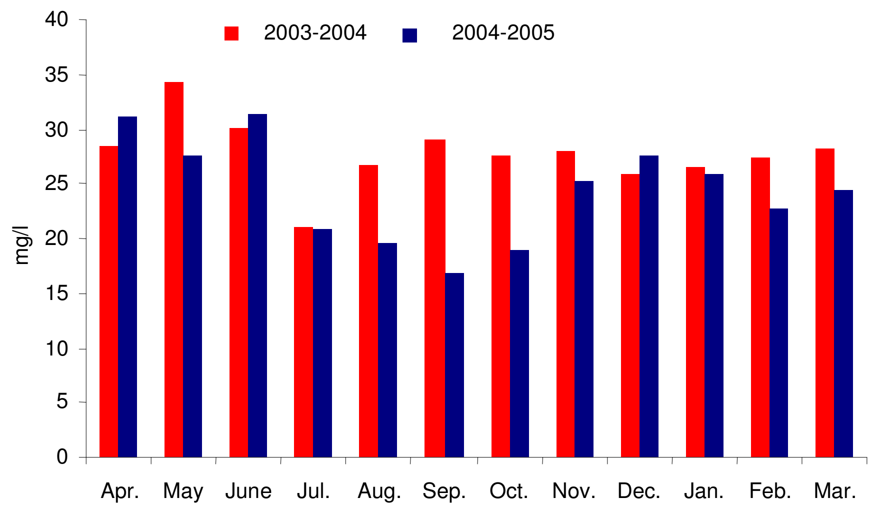

Figure 24. showing monthly variations in sodium.

oxygen utilized by microorganisms in stabilizing the organic matter. BOD in Ramsagar reservoir was recorded in the range of 0.93 mgl^{-1} (September, 2004) to 4.68 mgl^{-1} (March, 2005) with low values in monsoon and high values in summer season. Devaraju et al. (2005) has made similar observations in Maddur lake. Chemical oxygen demand (COD) is a measure of the oxygen equivalent of the organic matter content of water that is susceptible to oxidation by a strong chemical oxidant. Thus, COD is a reliable parameter for judging the extent of pollution in water (Amirkolaie, 2008). The COD of water increases with increasing concentration of organic matter (Boyd, 1981).

In the present study, COD ranged from 3.60 mgl^{-1} (December, 2003) to 17.40 mgl^{-1} (March, 2005) with higher values during summer season. Such a seasonal variation was also observed by many workers (Fokmare and Musaddiq, 2002).

Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium (Venkatasubramani and Meenambal, 2007). Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton (Dagaonkar and Saksena, 1992). Therefore, depletion of magnesium reduces the phytoplankton population. Dwivedi et al. (2000) recorded magnesium content upto

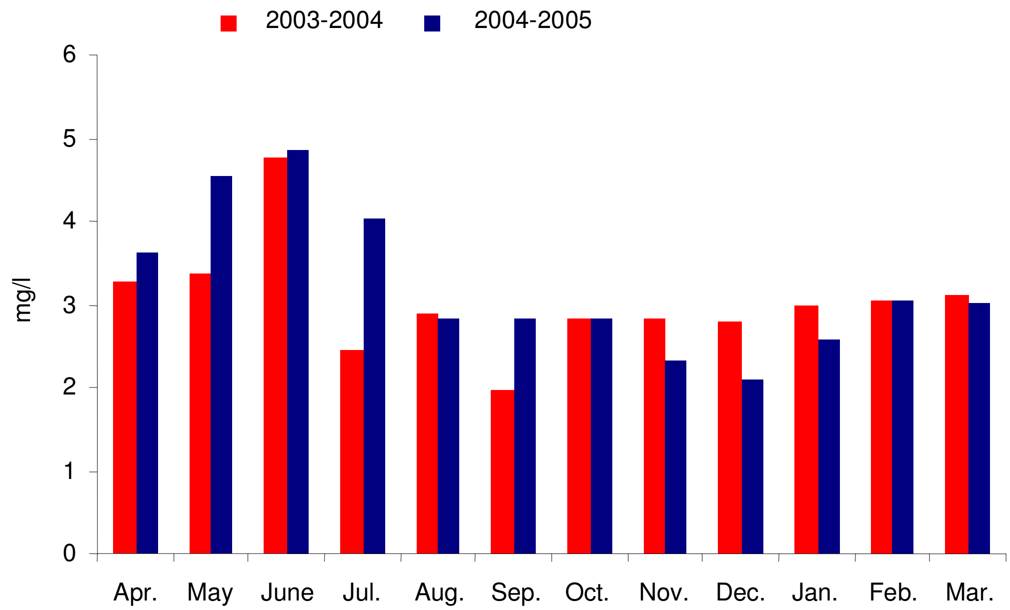

Figure 25. showing monthly variations in potassium.

3.27 mgl^{-1} in Naktara reservoir. In the present investigation, the magnesium content upto 5.60 mgl^{-1} was observed with higher concentration during winter season and lower concentration in monsoon season. Similar seasonal variation was reported by Venkateshwarlu et al. (2002).

In the present investigation, sodium content fluctuated between 16.75 (September, 2004) to 34.30 mgl-1 (May, 2003). A higher value of sodium during summer season and lower value in monsoon season was recorded. Evaporation of water is a significant factor in increasing sodium level during summer season. Like, sodium, potassium is also a naturally occurring element, but the concentrations in freshwater bodies remain quite lower than the sodium and calcium. Under low potassium concentration, the growth rate and photosynthesis of algae especially blue green algae becomes poor and respiration is increased (Wetzel, 1983). In Ramsagar reservoir, potassium content varied from 1.97 (September, 2003) to 4.86 mgl-1 (June, 2004). Higher concentration of potassium was recorded in summer season during second year of the study and lower concentration was recorded in monsoon season during first year of the study period while second year of the study period, lower potassium content was recorded in winter season. Sedimentation and utilization of potassium by biota caused decrease in its content during winter season (Garg et al., 2006a and b).

Correlation coefficient between different parameters

In the present study, the seasonal variation in ambient temperature shows a direct effect on water temperature followed an identical pattern. The transparency has been found to show positive correlations with electrical conductivity, sulphates, biochemical oxygen demand, magnesium and potassium while, free carbon dioxide negatively correlated with transparency. The strong positive correlation between electrical conductivity and total dissolved solids ($r = 0.879$, $P < 0.01$) has been observed in the present study. A positive correlation between turbidity with sulphates and silicates has been observed in the present study. pH exhibited high positive correlated with free carbon dioxide ($r = 0.997$, $P < 0.01$). Dissolved oxygen showed significant positive correlation with total hardness and calcium. The nitrates were positively correlated with nitrites ($r = 0.883$, $P < 0.01$) while phosphates showed significant positive correlation with biochemical oxygen demand and biochemical oxygen demand shows significant negative correlation with silicates. Ammonia and COD showed a highly significant negative correlation with magnesium.

Trophic status

From the range of various water quality parameters and values of various indices like transparency (Lee et al., 1981), electrical conductivity (Olsen, 1950), total alkalinity (Spence, 1964), Calcium (Ohle, 1934), nitrate-nitrogen (Vollenweider, 1964) and phosphates (Lee et al., 1981) with suggested trophic status, it is concluded that the Ramsagar reservoir is considered as mesotrophic water body with slightly rich amount of nutrients which may be due to agricultural practices being done by farmers in surrounding catchments area of this reservoir.

Threats to the reservoir ecosystem

Some of the major threats to the decrease in reservoir area and ecology are discussed: 1. Large-scale deforestation around the reservoir causes severe soil erosion in the catchments area; 2. Heavy siltation has reduced the erstwhile lake to a shallow wetland. Major amount of silt is deposited in the monsoon season when heavy rains wash down the soil from the surrounding area; 3. Nutrients through fertilizers, toxic pesticides and other chemicals mainly from agricultural run-off causing water pollution and eutrophication; 4. Intensive spreading of common aquatic macrophytes; 5. Over-exploitation of fish resources and poaching of water birds by local villagers.

All these threats have resulted not only in shrinking of the lake area but also deteriorated the natural environment for the survival of aquatic animals. The situation might have further worsened subsequently, as the lake reclamation for fishing and agriculture is going unhindered. Therefore, some urgent conservation measures are required to save the wetland ecosystem.

Conservation measures of the reservoir and conclusion

Conservationists are meticulously attempting to conserve the biodiversity from anthropogenic erosion and 'pre-natural' extinction. The major barriers in conservation of biodiversity for sustainable life in future include inadequate data base, inadequate funding for research, confusions and controversies over area selection for conservation. This has made the task more and more difficult (Pattanaik and Reddy, 2007; Krishnankutty and Chandrasekaran, 2007). On the basis of physico-chemical characteristics it may be said that the Ramsagar reservoir is a mesotrophic water body, which is slightly inclined towards eutrophication. The trophic status of reservoir warrants a proper conservation and management strategy. In order to have proper management and best possible use of the reservoir, the macrophytes will have to be controlled. This can be achieved by mechanical removal or by biological means using grass carp, *Ctenopharingodon idell.*, since the removal of nutrients in the form of biomass can only check eutrophication. The nallahs, streams and rivulets joining the reservoir should be obstructed by constructing stop and check dams. This will not allow the siltation in reservoir.

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