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Water quality and conservation management of Ramsagar reservoir, Datia, Madhya Pradesh

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Abstract: *The aim of this study is to assess physico-chemical characteristics, trophic status, pollution studies and macrophytic community of Ramsagar reservoir from April 2003 to March 2005. The range of various parameters of reservoir water (water temperature 15.92-31.87 °C, water depth 2.90-8.25 m, transparency 66.59-116.00 cm, electrical conductivity 108-246.30 µS cm^{-1}, turbidity 2.17-16.72 NTU, total dissolved solids 166.37-239.00 mg l^{-1}, pH 7.41-8.95, dissolved oxygen 6.78-11.59 mg l^{-1}, free carbon dioxide nil-6.32 mg l^{-1}, total alkalinity 64.25-146.25 mg l^{-1}, total hardness 34.00-75.25 mg l^{-1}, chlorides 13.13-22.36 mg l^{-1}, calcium 11.21-33.81 mg l^{-1}, sulphates 1.50-8.87 mg l^{-1}, nitrates 0.011-0.033 mg l^{-1}, nitrites 0.004-0.029 mg l^{-1}, phosphates 0.013-0.054 mg l^{-1}, silicates 0.65-8.42 mg l^{-1}, ammonia nil-0.84 mg l^{-1}, biochemical oxygen demand 0.93-4.68 mg l^{-1}, chemical oxygen demand 3.60-17.40 mg l^{-1}, magnesium 1.17-5.60 mg l^{-1}, sodium 16.75-34.30 mg l^{-1} and potassium 1.97-4.86 mg l^{-1}) exhibit monthly as well as seasonal fluctuations. The nutrients including silicates, sulphates, phosphates, nitrates and potassium are in sufficient quantities for the growth of aquatic plants and animals in the reservoir. In all 13 species of macrophytes were recorded from the reservoir. Macrophytic diversity was higher at the points where nallahas join the reservoir and in the areas where agricultural practices are performed. This was due to allocthonous nutrients brought in to the reservoir from the surrounding catchments area. 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 are very much required.*

Key words: *Water quality, Correlation coefficient, Trophic status, Macrophytes, Reservoir management*
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Introduction

Wetlands comprise only three to six percent of the earth's land surface area, but they provide human populations with a host of goods and services, including water quality maintenance, agricultural production, fisheries, and recreation (Acreman and Hollis, 1996). Due to unplanned management, tremendous development of industry and agriculture and disposal of untreated public sewage water, agricultural run off and other human and animal wastes in to river, lakes, reservoirs and other water bodies are continuously deteriorating their water quality and biotic resources (Venkatesan, 2007; Elmaci *et al.,* 2008). The health of lakes and their biological diversity are directly related to health of almost every component of the ecosystem (Indira and Sivaji, 2006; Krishnan *et al.,* 2007; Shiddamallayya and Pratima, 2008). Human anthropogenic activities are the main causative agents in the increase of nutrients like phosphates, chlorides and calcium and ultimately lead to eutrophication (Chukwu and Odunzeh, 2006; Shekhar *et al.,* 2008).

The performance of trophic status depends on the locality and topography of water bodies. In freshwater bodies, nutrients play a major role as their excessive input leads to eutrophication. Luxuriant growth of macrophytic vegetation is also indicative of eutrophic 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 with an aim to maintain the physico-chemical quality of water. Hence, an attempt has been made to study the physico-chemical parameters of Ramsagar reservoir, Datia, Madhya Pradesh to understand functional aspects of the reservoir and to suggest ways and means for its conservation.

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Materials and Methods

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 and approximately 80 km south of Gwalior. Geographically, it lies between 25°40' N latitude and 78°23' E longitude and at an altitude of 229 m from mean sea level. Reservoir is used for different purposes like drinking water supply, irrigation, fisheries and thus is true a multipurpose tank. Four sampling stations *viz.,* Station-A, B, C and D were established for analysis of physico-chemical characteristics of water covering whole area of reservoir (Fig. 1). The satellite image of the reservoir is in Fig. 2.

Water samples were collected from all four sampling stations from April 2003 to March 2005. Monthly samples of sub-surface water were collected during first week of each month in the early hr of the day (7 to 9 a.m.). Some of the physico-chemical characteristics of water including water temperature, depth, color, transparency, pH, dissolved oxygen, free carbon-dioxide, total alkalinity, total hardness, chlorides, calcium and magnesium, were analyzed at the

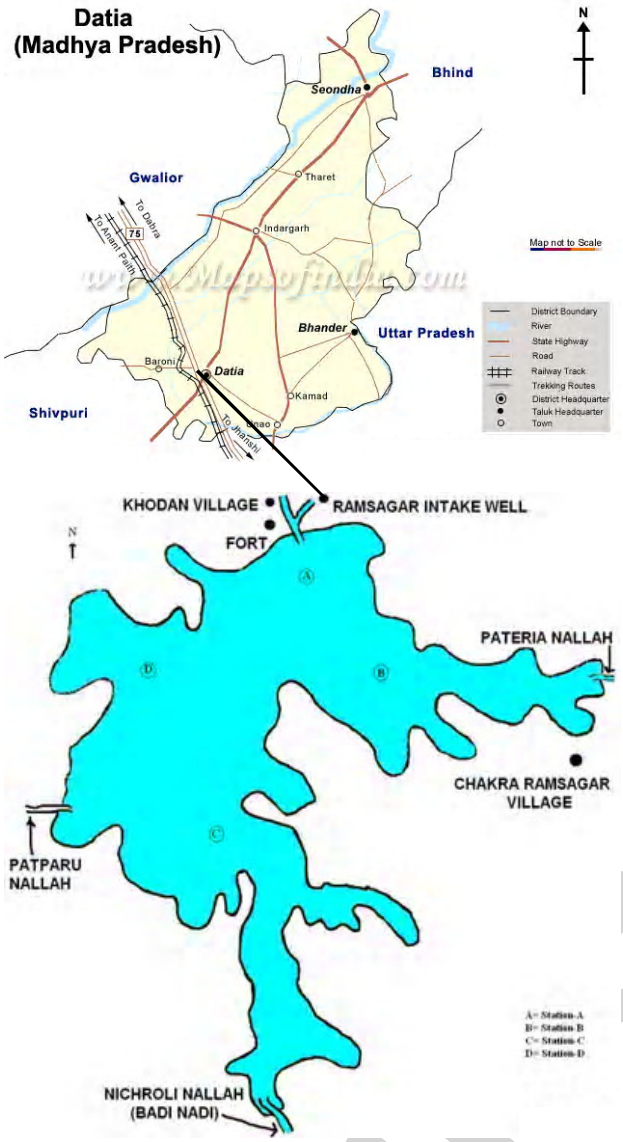

Fig. 1: Location map and the sampling stations in Ramsagar reservoir in Datia district, Madhya Pradesh

sampling stations, while 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 hr following the methods of APHA (1995) and Trivedy and Goel (1986). Macrophytes were collected by hand picking using a metal hooks and were identified by the keys provided by Naskar (1990), Fassette (1992).

Results and Discussion

Range of variation and their annual mean along with standard deviation of various physico-chemical characteristics of water of Ramsagar reservoir have been given in Table 1 and trophic status is shown in Table 2 while correlation coefficient between different parameters is tabulated in Table 3. The distribution of macrophytes and their seasonal abundance have been exhibited in Table 4, 5.

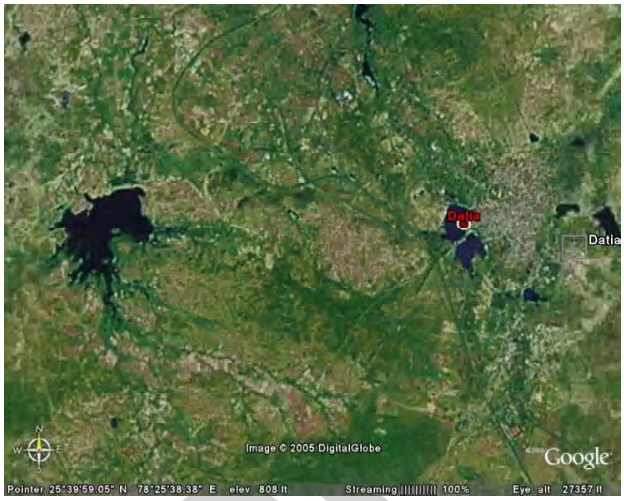

Fig. 2: Remote sensing photograph of Ramsagar reservoir along with Datia city

Water temperature and depth: In Ramsagar reservoir, the water temperature increased during warmer months and decreased during colder months. Similar seasonal variations was also observed by Surve *et al.* (2005). Water level plays an important role in governing the water quality. Like, any other water body, in Ramsagar reservoir, maximum water level was recorded in post-monsoon period while also minimum water level was recorded in summer season during both the years of study.

Colour and transparency: 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 due to 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. Dwivedi *et al.* (2000), 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.,* 2006a).

Electrical conductivity and turbidity: 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^{-1} (September-2004) to 246.30 µS cm^{-1} (May-2004) in this reservoir and falls within the range observed for Indian waters. Olsen (1950) classified water bodies having conductivity values greater than 500.00 µS cm^{-1} 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 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 2.17 NTU

Table - 1: Range of variation, mean and standard deviation of water (twelve samples) quality parameters of Ramsagar reservoir each during 2003-04 and 2004-05

Parameters	Sampling year (2003-2004)			Sampling year (2004-2005)		
	Range of variation		Mean ± SD	Range of variation		Mean ± SD
	Min.	Max.		Min.	Max.	
Water temperature (°C)	17.87	31.87	25.53±4.74	15.92	27.92	22.20±3.95
Water depth (m)	2.90	5.51	4.28±0.84	4.13	8.25	5.09±1.88
Color	Transparent green	Turbid	Transparent green-turbid	Transparent green	Turbid	Transparent green-turbid
Transparency (cm)	66.59	116.00	96.80±13.10	76.25	91.71	85.02±5.50
Electrical conductivity (μS cm^{-1})	140.00	219.04	179.13±30.46	108.00	246.30	183.85±43.77
Turbidity (NTU)	2.17	8.52	6.05±2.49	4.42	16.72	8.60±3.52
Total dissolved solids (mg l^{-1})	166.37	218.00	186.95±18.04	185.00	239.00	206.51±16.32
pH	8.20	8.77	8.40±0.18	7.41	8.95	8.13±0.55
Dissolved oxygen (mg l^{-1})	6.88	10.99	8.67±1.51	6.78	11.59	8.48±1.55
Free carbon-dioxide (mg l^{-1})	Nil	6.32	0.80±2.75	Nil	4.67	1.63±1.32
Total alkalinity (mg l^{-1})	83.87	133.25	104.22±15.27	64.25	146.25	104.65±25.36
Total hardness (mg l^{-1})	34.00	75.25	53.30±13.89	43.50	66.00	53.19±6.49
Chlorides (mg l^{-1})	14.09	17.88	15.98±1.23	13	22.36	17.40±2.57
Calcium (mg l^{-1})	11.21	26.55	17.86±5.49	13.36	33.81	20.32±6.12
Sulphates (mg l^{-1})	1.50	8.87	4.30±2.18	3.57	8.30	5.71±1.52
Nitrate-nitrogen (mg l^{-1})	0.011	0.033	0.019±0.006	0.015	0.032	0.022±0.004
Nitrite-nitrogen (mg l^{-1})	0.004	0.017	0.010±0.003	0.009	0.029	0.016±0.005
Phosphates (mg l^{-1})	0.013	0.054	0.022±0.011	0.015	0.047	0.025±0.009
Silicates (mg l^{-1})	0.65	7.21	3.93±2.03	1.17	8.42	5.82±1.49
Ammonia (mg l^{-1})	0.03	0.65	0.29±0.23	Nil	0.84	0.33±0.27
Biochemical oxygen demand (mg l^{-1})	1.31	2.63	1.93±0.40	0.93	4.68	2.13±1.13
Chemical oxygen demand (mg l^{-1})	3.60	13.00	7.51±2.64	4.70	17.40	9.30±4.26
Magnesium (mg l^{-1})	1.33	3.59	2.19±0.71	1.17	5.60	3.06±1.18
Sodium (mg l^{-1})	21.07	34.30	27.75±3.02	16.75	31.27	24.30±4.69
Potassium (mg l^{-1})	1.97	4.75	3.07±0.65	2.10	4.86	3.25±0.86

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), Bhaumik *et al.* (2003) and Garg *et al.* (2006a) have also reported high turbidity during rainy season.

Total dissolved solids and pH: 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; Garg *et al.,* 2006a, b). The total dissolved solids (TDS) were observed upto 410.00 mg l^{-1} in Kapsi lake (Fokmare and Musaddiq, 2002) and 228.00 mg l^{-1} in Natnagara reservoir (Dhakad and Chaudhary, 2005). In present study, TDS showed highest value of 239.00 mg l^{-1} in the month of June-2004. Similar findings have been reported by Rao *et al.* (2003), Kirubavathy *et al.* (2005), Garg *et al.* (2006a) 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 between 7.41 to 8.95.

Dissolved oxygen and free carbon dioxide: Dissolved oxygen concentration more than 5.00 mg l^{-1} favours good growth of flora and fauna (Das, 2000). The dissolved oxygen ranged from 3.41 to 6.21 mg l^{-1} in Seetadwar lake (Tewari and Mishra, 2005), from 5.30 to 9.00 mg l^{-1} in Deoria tal (Rawat and Sharma, 2005) and from 3.00 to 6.00 mg l^{-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 (June-2004) to 11.59 mg l^{-1} (November-2004) with maximum concentration during winter season. In summer season, dissolved oxygen was decreased due to increased temperature of water (Naz and Turkmen, 2005). Like Harsi reservoir (Garg *et al.,* 2006a), 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 (Sakhre and Joshi, 2002). In Ramsagar reservoir, highest free carbon dioxide was recorded as 6.32 mg l^{-1}. However, its absence or low content was recorded in most of the times due to alkaline nature of reservoir.

Total alkalinity and total hardness: The total alkalinity ranged from 64.25 to 146.25 mg l^{-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

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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

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

Parameters	Water quality of Ramsagar reservoir	Trophic status of Ramsagar reservoir	References
Water temperature (°C)	15.92 - 31.87	Meso-thermal	Lee *et al*. (1981)
Transparency (cm)	66.59 - 116.00	Eutrophic	Lee *et al*. (1981)
Electrical conductivity (μS cm^{-1})	108 - 246.30	Mesotrophic	Olsen (1950)
pH	7.41 - 8.95	Alkaliphilous	Venkateswarlu (1983)
Free carbon-dioxide (mg l^{-1})	Nil - 6.32	Soft	Reid and Wood (1976)
Total alkalinity (mg l^{-1})	64.25 - 146.25	Productive with rich nutrient	Spence (1964)
Total hardness (mg l^{-1})	34.00 - 75.25	Soft water	Sawyer (1960)
Chlorides (mg l^{-1})	13.13 - 22.36	No pollution	Unni (1983)
Calcium (mg l^{-1})	11.21 - 33.81	Medium to rich	Ohle (1938)
Nitrate-nitrogen (mg l^{-1})	0.011 - 0.033	Oligo-mesotrophic	Vollenweider (1968)
Phosphates (mg l^{-1})	0.013 - 0.054	Mesotrophic	Lee *et al*. (1981)

(Pandey, 2008). Sawyer (1960) classified water on the basis of hardness into three categories *i.e.*, soft (0-75 mg l^{-1}), moderately hard (75-150 mg l^{-1}) and hard (151-300 mg l^{-1}). According to this classification, Ramsagar reservoir falls in the category of soft water body with hardness ranging from 34.00 to 75.25 mg l^{-1}.

Chlorides and calcium: The salts of sodium, potassium and calcium contribute chlorides in waters. Large contents of chloride in freshwater is an indicator of organic pollution (Venkatasubramani and Meenambal, 2007). In the present study, chloride concentration varied from 13.13 (August-2004) to 22.36 mg l^{-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 mg l^{-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.

Sulphates, nitrates, nitrites, phosphates, silicates and ammonia: The rich concentration of nutrient such as sulphates (1.50-8.87 mg l^{-1}), nitrates (0.011-0.033 mg l^{-1}), nitrite (0.004-0.029 mg l^{-1}), phosphates (0.013-0.054 mg l^{-1}) and silicates (0.65-8.42 mg l^{-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 Deoria tal 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 mg l^{-1} in June-2003 with higher values in summer season and lower value in monsoon season.

BOD and COD: Biochemical oxygen demand (BOD) is the amount of oxygen utilized by microorganisms in stabilizing the organic matter. BOD in Ramsagar reservoir was recorded in the range of 0.93 mg l^{-1} (September-2004) to 4.68 mg l^{-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 (December-2003) to 17.40 mg l^{-1} (March-2005) with higher values during summer season. Such a seasonal variation was also observed by many workers (Fokmare and Musaddiq, 2002; Chatterjee and Raziuddin, 2003).

Magnesium: 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 number of phytoplanktons population. Dwivedi *et al*. (2000) recorded magnesium content upto 3.27 mg l^{-1} in Naktara reservoir. In the present investigation, the magnesium content upto 5.60 mg l^{-1} was observed with higher concentration during winter season and lower concentration in monsoon season. Similar seasonal variation was reported by Venkateswarlu *et al.* (2002) and Chavan *et al.* (2004).

Sodium and potassium: In the present investigation, sodium content fluctuated between 16.75 (September-2004) to 34.30 mg l^{-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, 2001). In Ramsagar reservoir potassium content varied from 1.97 (September 2003) to 4.86 mg l^{-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

Table - 4: Seasonal variation of macrophytes in Ramsagar reservoir during March-2003 to April-2004

Species	Winter season				Summer season				Monsoon season			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
Nymphaea nouchali	+	+	++	++	+	+	++	++	-	-	-	-
Trapa bispinosa	-	++	+++	+++	-	+	+	++	-	-	-	-
Ipomoea aquatica	++	++	++	+++	+	+++	+++	++++	-	-	+	+
Ipomoea carnea	+	+	++	++++	-	+++	++	++++	-	+	-	+
Ceratophyllum demersum	+	++	+++	++++	++	+++	+++	++++	-	+	+	++
Hydrilla verticillata	++	++	++	+++	+	++	++	+++	+	+	+	++
Vallisneria spiralis	+	+++	+++	++++	++	+++	+++	++++	-	+	+	++
Lemna minor	+	+++	++	++	-	+	++	++	-	-	-	-
Wolffia arrhiza	+	+++	++	+++	+	+++	+++	++++	-	-	-	+
Potamogeton crispus	+	+++	+++	++++	+	+++	+++	++++	+	-	-	+
Najas minor	+	++	++	+++	+	++	+++	+++	-	-	-	+
Aponogeton natans	+	++	+++	++++	++	+++	+++	++++	+	+	+	+
Cyperus articulatus	-	+	+	+	+	+	++	++	-	-	-	-

Table - 5: Seasonal variation of macrophytes in Ramsagar reservoir during March-2003 to April-2004

Species	Winter season				Summer season				Monsoon season			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
Nymphaea nouchali	-	+	++	++	-	+	++	++	-	-	-	-
Trapa bispinosa	-	+	+++	++++	-	+	+	++	-	-	-	-
Ipomoea aquatica	+	++	+++	+++	+	+++	+++	++++	-	-	+	+
Ipomoea carnea	-	++++	++	++++	-	+++	++	++++	-	+	-	+
Ceratophyllum demersum	+	++	+++	++++	++	+++	+++	++++	-	+	+	++
Hydrilla verticillata	+	++	++	+++	+	++	++	+++	-	+	+	+
Vallisneria spiralis	++	+++	+++	++++	++	+++	+++	++++	-	+	+	++
Lemna minor	-	+	++	++	-	+	++	++	-	-	-	-
Wolffia arrhiza	-	+++	++	++++	+	+++	+++	++++	-	-	-	+
Potamogeton crispus	+	+++	+++	++++	+	+++	+++	++++	-	-	-	+
Najas minor	+	++	++	+++	+	++	+++	+++	-	-	-	+
Aponogeton natans	+	++	+++	++++	++	+++	+++	++++	+	+	+	+
Cyperus articulatus	-	+	+	+	+	+	++	++	-	-	+	+

++++ = Dominant, +++ = Sub-dominant, ++ = Common, + = Rare, - = Absent, St = Station

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,b).

Correlation coefficient between different parameters: In the present study, the seasonal variation in ambient temperature shows a direct effect on water temperature and followed an identical pattern. The transparency has been found to show positive correlation 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 the significant negative correlation with silicates. Ammonia and COD showed a highly significant negative correlation with magnesium.

Trophic status: It is suggested 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 and nutrients brought by nallahas joining this reservoir (Spence, 1964; Ohle, 1938; Vollenwelder, 1968).

Macrophytic diversity: Excessive growth of aquatic plants in a water body can cause further deterioration of water quality (Krenkel *et al.*, 1979). In the present study total 13 species of macrophytes were recorded during study period in reservoir. They are *Nymphaea nouchali, Trapa bispinosa, Ipomoea aquatica, Ipomoea carnea, Ceratophyllum demersum, Hydrilla verticillata, Vellisneria spiralis, Lemna minor, Wolffia arrhiza, Potamogeton crispus, Najas minor, Aponogeton natans* and *Cyperus articulatus.* The dominancy of macrophytes was observed in winter and summer season during both years of study period while in monsoon season three macrophytes species *i.e.*, *Nymphaea nouchali, Trapa bispinosa*

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and *Lemna minor* were not observed (Table 4,5). The rich macrophytic community and high biomass was observed in those areas along with which more agricultural practices are being carried out and at the points where the nallahas join the reservoir. This may be due to influx of nutrients from agricultural fields in the catchments area especially during summer season. The excessive growth of aquatic macrophytes in reservoir under study points out towards need for conservation and management of the reservoir.

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 date base, inadequate funding for research, confusions and controversies over area selection for conservation. This has made the task more and more difficult (Garg and Hassan, 2007; Venkatesan, 2007; Krishnankutty and Chandrasekaran, 2007). On the basis of physico-chemical characteristics and macrophytic community, 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 idella.* Since the removal on nutrients in the form of biomass can only check eutrophication, some useful crops such as 'Singhara' (*Trapa bispinosa*) 'Kamal' (*Nelumbo* sp) *etc* may also be planted for some time. 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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