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ASSESSMENT OF SEASONAL VARIATIONS OF WATER QUALITY PARAMETERS OF SAVITRI RESERVOIR, POLADPUR, RAIGAD DISTRICT, MAHARASHTRA

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ABSTRACT

The present study assessed the seasonal variations of the selected water quality parameters of Savitri reservoir from February, 2012 to January, 2013. The range of the selected water quality parameters were observed to have a seasonal significant difference for temperature (24-33.66ºC), alkalinity (34-76.66 mg/L), hardness (36.67-62.67 mg/L), dissolved oxygen (6.4-9.47 mg/L), carbon dioxide (0-8.93 mg/L), phosphate (0.011-0.04 mg/L), ammonia (0.026-0.182 mg/L), nitrate (0.058-0.315 mg/L) and silicate (8.59-23.06 mg/L), whereas no significant seasonal variations were observed on pH (7.3-7.8), chloride (5.57-10.3 mg/L) and nitrite (0.006-0.093 mg/L). Temperature, dissolved oxygen, alkalinity, hardness, chloride and phosphate were observed to be maximum in summer; pH, nitrite and nitrate in monsoon; carbon dioxide, ammonia and silicate in winter. Factor analysis showed that most of the selected water quality parameters except chloride are significant to water quality variations in all seasons. The present study clearly evidenced that Savitri reservoir is suitable for fisheries, irrigation and drinking purposes.

INTRODUCTION

Water quality is the characteristics of water which influence its beneficial use as well as the sustainability of ecosystem. Water resources are of critical importance to both natural ecosystem and human development. The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem and the suitability for human use. Good quality of water resources depends on a large number of physicochemical parameters and biological characteristics. The reservoir serves as a rich source of water supply for irrigation, drinking, hydroelectric power generation and fish culture. The water of the reservoir should fulfill the quality required for human use as well as for the sustainability of the ecology.

Many researchers assessed the water quality parameters in order to draw out the baseline information for utilization, management and conservation of reservoir for fisheries, irrigation and drinking purposes (Ahamed and Krishnamurthy, 1990; Chavan *et al*., 2004; Kirubavathy *et al*., 2005; Surve *et al*., 2005; Garg *et al*., 2006; Mustapha, 2008; Narayana *et al*., 2008; Gonjari and Patil, 2008; Garg *et al*., 2009; Prabhakar *et al*., 2012; Saxena and Saksena, 2012).

Aquatic pollution is a global concern, but even so, huge pollution loads are still producing due to human population growth and unscientific management and the trends are expected to increase. Due to unplanned management, industrial developmental work, agricultural activity, public sewage and other anthropogenic activity, water quality and biotic resources of river, lakes, reservoirs and other water bodies are continuously deteriorating (Venkatesan, 2007; Elmaci *et al*., 2008). As the aquatic pollution is drastically increasing, it has become essential to assess the water quality parameter of reservoirs and identify the various sources of contaminants in order to provide scientific basis for finding appropriate remedies to the situation and to provide good water quality for drinking, irrigation and fisheries. Therefore, the assessment of the variation of water quality parameter is the first and foremost task for the scientific management of reservoir and to find out the suitability of the water for multipurpose. It is in this light that the present study was undertaken to assess the seasonal variations of water quality parameters of Savitri reservoir which is located on Savitri river near Poladpur, Raigad district, Maharashtra, India.

MATERIALS AND METHODS

Sampling

Water sample was collected monthly for a period of 1 year from February, 2012 to January, 2013 to cover three seasons of summer (February-May), monsoon (June-September) and winter (October-January). The water was collected from three stations which are having a coordinate of 17º58' 40.1" N and 73º28' 54.2" E, 17º58' 51.6" N and 73º29' 8.7" E and 17º 58' 40.3" N and 73º29' 37.1" E for station 1, station 2 and station 3, respectively. Water was collected from 0.5 meter depth from each station with 1 liter plastic bottle. The water samples were brought immediately to the laboratory for analysis.

Water quality parameter analysis

Temperature and pH were measured *in situ*, using mercury-in-glass thermometer and portable pH meter (Eutech, Malaysia), respectively. Total alkalinity, total hardness, chloride, dissolved oxygen (DO), free carbon dioxide (CO_2), phosphate (PO_4-P), ammonia (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N) and silicate (SiO_2) were analyzed using standard methods of APHA (2005). Wavelength measurement was done using DR 5000 UV-Vis Spectrophotometer (Hach, USA).

Statistical analysis

Data collected were subjected to proper statistical analysis. One-way analysis of variance (ANOVA) was used to test seasonal variation of the water quality parameters. Pearson correlation coefficient was calculated to test the degree of relationship between the water quality parameters. Factor analysis was carried out for each season to extract and recognize the factors or origins responsible for water quality variations in each season. All the statistical analysis was carried out using software packages SPSS 16.

RESULTS AND DISCUSSION

Seasonal range of variation, mean and standard error of water quality parameters of Savitri reservoir are summarized in Table 1. Correlation coefficients between different water quality parameters are tabulated in Table 2.

Temperature

Temperature is one of the most important parameter of water as it affects the biotic as well as abiotic component of the ecosystem. In the present study the surface water temperature ranged between the lowest value of 24°C obtained in January, 2013 and the highest of 33.66ºC obtained in May, 2012. There was a significant difference ($P < 0.05$) in temperature among the seasons, the temperature value was maximum during summer and minimum during winter. Low temperature recorded in winter was due to lesser solar radiation and low atmospheric temperature. Similar pattern of temperature fluctuation was also seen in many water bodies (Narayana *et al.,* 2008; Garg *et al.,* 2009; Verma *et al.,* 2011; Prabhakar *et al.,* 2012). The temperature showed strong positive correlation with hardness, DO, and phosphate, whereas it showed strong negative correlation with ammonia.

pH

The pH indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in the solution. In the present study the pH fluctuated between the lowest monthly mean of 7.3 obtained in January, 2013 and the highest monthly mean of 7.8 obtained in September, 2012 which clearly indicated that the waters are slightly alkaline in nature and are good for fish culture, irrigation and other purposes. There was no significant difference in pH ($P > 0.05$) among the seasons. Alkaline pH was also reported in many water bodies by different authors (Dagaonkar and Saksena, 1992; Sinha and Biswas, 2011; Saxena and Saksena, 2012). The correlation coefficient analysis indicated that pH had no strong positive correlation with most of the observed water quality parameters, whereas it showed a strong negative correlation with ammonia.

Alkalinity

Alkalinity of surface water is primarily a function of carbonate, hydroxide content and also includes the contributions from borates, phosphates, silicates and other bases. In the present study, the alkalinity ranged between the lowest value of 34 mg/L obtained in July, 2012 and the highest value of 76.66 mg/L obtained in May, 2012. Statistical difference at $P < 0.05$ was noticed in the alkalinity among the seasons with the maximum in summer and the minimum in monsoon. Similarly, maximum alkalinity in summer was also observed by Garg *et al*. (2006), Verma *et al*. (2011) and Verma *et al*. (2012). Alkalinity showed a strong positive correlation with hardness and phosphate, whereas it showed a strong negative correlation with nitrate and silicate.

Hardness

The total hardness of water is the sum total of alkaline metal cations present in it. In the present study the total hardness ranged from the lowest value of 36.67 mg/L obtained in both July and August, 2012 to the highest of 62.67 mg/L obtained in May, 2012. There was a significant difference in hardness ($P < 0.05$) among the seasons with the highest in summer and the lowest in winter. Total hardness with its maximum value in summer and minimum in winter season was also observed by Sinha and Biswas (2011) and Khan *et al*. (2012). Higher values of hardness during summer might be due to the increased in evaporation during this period. Total hardness showed a strong positive correlation with temperature, alkalinity and phosphate, but a strong negative correlation with silicate.

Chloride

Chloride is a ubiquitous aqueous anion in all natural waters, the concentrations varying very widely and reaching a maximum in sea water. In the present study chloride fluctuated between the minimum value of 5.57 mg/L obtained in January, 2013 and the maximum value of 10.3 mg/L obtained in March, 2012. There was no significant difference in chloride ($P > 0.05$) among the seasons, however the chloride content was highest in summer. Mahajan (1996), Sinha and Biswas (2011) and Verma *et al*. (2012) also found that the chloride content was highest during summer in different water bodies. Higher content of chloride during summer might be due to the higher rate of evaporation during this period. Chloride showed neither strong positive nor strong negative correlation with any of the water quality parameters.

Dissolved Oxygen (DO)

DO is a very important parameters of water quality and is an index of physical and biochemical processes occurs in water. The dissolved oxygen play a role of regulator of metabolic

activities of organisms and thus governs metabolism of the biological community as a whole and used as an indicator of trophic status of the water. It may be present in water due to direct diffusion from air and photosynthetic activity of autotrophs. DO in the present study fluctuated between the lowest monthly mean of 6.4 mg/L recorded in December, 2012 and the highest monthly mean of 9.47 mg/L recorded in April, 2012 which clearly indicated that the water is suitable for fish culture as well as for other purposes. Statistical difference at $P<0.05$ was noticed in the DO concentration among the seasons with the highest concentration in summer and the lowest concentration in winter. Highest value of DO in summer may be due to the photosynthetic activity of autotrophs during this period. Similarly, Ahamed and Krishnamurthy (1990) and Gonjari and Patil (2008) also recorded maximum DO during summer. Correlation coefficient analysis showed that the DO had a strong positive correlation with temperature, but it showed a strong negative correlation with CO_2, ammonia and silicate. The strong positive correlation between DO and temperature might be due to the higher photosynthetic activity as the temperature rises.

Free carbon dioxide (CO_2)

The free carbon dioxide level in water is decreased due to photosynthesis by algae and macrophytes and increased due to the respiration of all aquatic organisms. The presence or absence of the free carbon dioxide in surface water is mostly governed by its utilization by algae during photosynthesis and also through its diffusion from air. In the present study the free CO_2 ranged between the lowest value of 0 mg/L obtained both in March and April, 2012 and the highest value of 8.93 mg/L obtained in November, 2012. Saxena and Saksena (2012) observed free carbon dioxide to be in the range of 0 to 9.30 mg/L in Raipur reservoir which is in accordance with the present study. Similar to the present study, seasonal variation of free carbon dioxide was also observed in Oyun reservoir by Mustapha (2008). Lower CO_2 during summer might be due to the increased photosynthetic activity of the autotrophs during this period. Statistical difference at $P<0.05$ was noticed in free CO_2 among the seasons with the highest concentration in winter and the lowest in summer. CO_2 showed no strong positive correlation with any of the observed water quality parameters, whereas it showed a strong negative correlation with DO, ammonia and silicate.

Phosphate (PO_4-P)

Phosphorous is considered to be the most significant component among the nutrients responsible for eutrophication of a water body. Phosphate is the most important nutrient for the production of phytoplankton in freshwater which is the primary food for many of the commercial fishes. In the present study phosphate ranged between the minimum of 0.011 mg/L obtained in both November and December, 2012 and the maximum of 0.04 mg/L obtained in May, 2012. The phosphate value of the present study is in accordance with the phosphate value observed by Garg *et al*. (2009) and Saxena and Saksena (2012). The observed value of phosphate indicated that the reservoir is productive enough to support good fisheries. Statistical difference at $P<0.05$ was noticed in the phosphate among the seasons with the highest concentration in summer and the lowest in winter. Higher concentration of phosphate during summer was also observed by Vetriselvi *et al*. (2011) which might be due to the low level of water because of higher evaporation rate during this period. Phosphate showed a strong positive correlation with temperature, alkalinity and hardness, but it showed a strong negative correlation with silicate.

Ammonia (NH_3-N)

The most important source of ammonia in water bodies is the ammonification of organic matter. In higher concentrations ammonia becomes harmful to fishes and other biota. In the present study ammonia fluctuated between the lowest value of 0.026 mg/L obtained in August, 2012 and the highest value of 0.182 mg/L obtained in January, 2013. The Savitri reservoir is suitable for fisheries as the ammonia content was lower than the maximum limit of ammonia for fish suggested by Boyd and Tucker (1998). Garg *et al*. (2009) observed ammonia in the range of 0 to 0.84 mg/L in Ramsagar reservoir which is in accordance with the present study. Statistical difference at $P<0.05$ was noticed in ammonia concentration among the seasons with the highest concentration in winter and summer with the lowest concentration. The high ammonia content during winter might be due to the decomposition of organic matter which was accumulated during the rainy seasons from the catchment area. Ammonia did not show a strong positive correlation with any of the water quality parameters, but it showed a strong negative correlation with temperature, pH, DO and CO_2.

Nitrite (NO_2-N)

Nitrite represents an intermediate form during de-nitrification and nitrification reactions in nitrogen cycle. It is a very unstable ion and gets converted into either ammonia or nitrate depending upon the conditions of the water. In the present study nitrite ranged between the lowest value of 0.006 mg/L obtained in November, 2012 and the highest value of 0.093 mg/L obtained in June, 2012. Garg *et al*. (2009) observed nitrite in the range of 0.004 to 0.029 mg/L in Ramsagar reservoir which is in agreement with the present study. There was no significant difference in nitrite ($P>0.05$) among the seasons, however the nitrite content was highest in monsoon which might be due to influx of nitrite from the watershed areas along with runoff water in monsoon. Maximum nitrite concentration in monsoon was also observed by Patil *et al*. (2011). Nitrite showed a strong positive correlation with nitrate, but no strong negative correlation with any of the water quality parameters.

Nitrate (NO_3-N)

Nitrate is one of the most important nutrient which accounts for the productivity in water. In the present study nitrate ranged from the lowest value of 0.058 mg/L obtained in May, 2012 to the highest of 0.315 mg/L obtained in June, 2012. . The observed nitrate value evidenced that the water is productive to support good fisheries as higher nitrate value enhances the plankton production. There was a significant difference in nitrate ($P<0.05$) among the seasons with the highest in monsoon. Similar pattern of nitrate fluctuation with the present study was observed by other researchers (Gohram, 1961; Rajashekhar, 2007; Pawar and Shembekar, 2012). Mustapha

Table 1: Seasonal range of variations, mean and standard error of water quality parameters with a sample size (n) = 3 of Savitri reservoir (February, 2012 to January, 2013)

Parameter	Summer			Monsoon			Winter		
	Min.	Max.	Mean ± SE	Min.	Max.	Mean ± SE	Min.	Max.	Mean ± SE
Temperature (ºC)	25.33	33.66	30.16 ± 1.96	29	30	29.25 ± 0.25	24	28	25.75 ± 0.85
pH	7.5	7.7	7.59 ± 0.04	7.47	7.8	7.62 ± 0.05	7.3	7.66	7.51 ± 0.09
Alkalinity (mg/L)	53.33	76.66	60.58 ± 5.42	34	43.66	37.75 ± 2.14	40.66	44.33	43.08 ± 0.83
Hardness (mg/L)	44.67	62.67	51.84 ± 4.27	36.67	45.67	39.75 ± 2.12	38.33	40	39.25 ± 0.34
Chlorides (mg/L)	5.73	10.3	7.44 ± 1.04	5.8	10	7.14 ± 0.99	5.57	7.17	6.02 ± 0.38
DO (mg/L)	7.73	9.47	8.53 ± 0.36	7.73	7.87	7.8 ± 0.04	6.4	7.6	6.77 ± 0.28
CO_2 (mg/L)	0	4.8	2.12 ± 1.24	3.8	8.27	6.72 ± 1.04	6.13	9.6	8.23 ± 0.75
PO_4-P (mg/L)	0.018	0.04	0.028 ± 0.005	0.013	0.02	0.016 ± 0.001	0.011	0.016	0.013 ± 0.001
NH_3-N (mg/L)	0.033	0.041	0.037 ± 0.002	0.026	0.093	0.052 ± 0.015	0.057	0.182	0.117 ± 0.026
NO_2-N (mg/L)	0.007	0.009	0.008 ± 0.001	0.008	0.093	0.035 ± 0.020	0.006	0.008	0.007 ± 0.001
NO_3-N (mg/L)	0.058	0.067	0.062 ± 0.002	0.142	0.315	0.198 ± 0.040	0.089	0.205	0.149 ± 0.030
SiO_2 (mg/L)	8.59	14.04	11.18 ± 1.28	17.65	21.92	19.71 ± 1.13	16.54	23.06	20.67 ± 1.55

Table 2: Correlation matrix of the water quality parameters of Savitri reservoir

	Temperature	pH	Alkalinity	Hardness	Chloride	DO	CO_2	PO_4-P	NH_3-N	NO_2-N	NO_3-N	SiO_2
Temperature	1											
pH	0.166	1										
Alkalinity	0.494	0.047	1									
Hardness	0.720**	-0.097	0.886**	1								
Chloride	0.303	-0.095	0.170	0.330	1							
DO	0.631*	0.329	0.360	0.473	0.157	1						
CO_2	-0.509	-0.120	-0.510	-0.516	-0.290	-0.828**	1					
PO_4-P	0.801**	-0.104	0.833**	0.965**	0.270	0.556	-0.552	1				
NH_3-N	-0.610*	-0.703*	-0.323	-0.298	-0.128	-0.759**	0.600*	-0.347	1			
NO_2-N	0.187	-0.243	-0.394	0.015	0.542	0.049	0.126	0.013	0.114	1		
NO_3-N	-0.038	0.127	-0.673*	-0.410	0.183	-0.273	0.456	-0.438	0.164	0.702*	1	
SiO_2	-0.532	0.264	-0.783**	-0.853**	-0.308	-0.582*	0.661*	-0.884**	0.252	0.025	0.657*	1

** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level

Table 3: Varimax rotated factor loadings value and explained variance of water quality parameters

Parameter	Summer			Monsoon			Winter		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
Temperature	0.991	0.121	0.064	0.920	-0.337	-0.200	0.818	-0.061	0.573
pH	-0.936	0.330	-0.124	-0.388	0.872	0.299	0.878	-0.449	0.168
Alkalinity	0.618	0.784	0.056	-0.018	0.991	0.130	-0.102	0.959	0.265
Hardness	0.858	0.495	-0.137	1.000	-0.018	-0.017	-0.148	0.987	-0.056
Chloride	-0.033	0.041	0.999	0.988	-0.122	-0.093	0.224	0.711	-0.666
DO	0.144	-0.918	-0.370	-0.367	0.168	0.915	0.459	0.111	0.882
CO_2	-0.120	0.919	-0.376	0.196	-0.001	0.981	-0.214	-0.016	-0.977
PO_4-P	0.921	0.378	-0.094	0.900	-0.309	0.308	-0.824	0.029	0.566
NH_3-N	0.985	-0.174	-0.008	0.869	-0.485	0.103	-0.923	-0.189	-0.335
NO_2-N	-0.492	-0.869	-0.054	0.843	-0.532	-0.076	-0.589	0.806	-0.052
NO_3-N	-0.978	-0.188	0.091	0.975	-0.149	-0.162	0.773	-0.497	0.395
SiO_2	-0.974	-0.226	0.030	-0.377	0.903	-0.208	0.946	-0.300	0.121
Variance (%)	62.92	25.96	11.12	66.06	18.31	15.63	42.89	24.83	20.01

(2008) also observed seasonal difference of nitrate among the seasons which is in accordance with the present study. High value of nitrate during monsoon might be due to the run-off from the catchment and low value during summer might be due to the assimilation by algae. Nitrate showed a strong positive correlation with nitrite, whereas it showed a strong negative correlation with alkalinity.

Silicate (SiO_2)

Silica occurs mainly as orthosilicate in an undissociated condition. Dissolved silica is assimilated in large quantities by diatoms in the synthesis of their cell walls. Since diatoms are major component in many lakes, diatom utilization can modify greatly the conditions and flux rates of dissolved silica in lakes and streams (Wetzel and Likens, 1991). In the present study, the silicate concentration ranged between the lowest value of 8.59 mg/L obtained in May, 2012 and the highest value of 23.06 mg/L obtained in both October and November, 2012. Silicate concentration which was observed to be the highest among the ions studied is in agreement with the observation of other authors (Talling and Talling, 1965; Mustapha, 2008). Statistical difference at $P<0.05$ was noticed in the silicate concentration among the seasons with winter having the highest concentration and summer with the lowest concentration. Mustapha (2008) also observed significant

statistical difference of silica among the seasons. High concentration during monsoon and winter might be due to the catchment runoff. Low concentration of silicate during the summer might be due to the assimilation of silicate by diatoms during this period. Silicate showed a strong positive correlation with CO_2 and nitrate, whereas it showed a strong negative correlation with alkalinity, hardness, DO and phosphate.

Factor analysis of the water quality parameters

Factor analysis (FA), which includes principal components analysis (PCA), enables us to explain the relationships among numerous important variables with a smaller set of independent variables well. Factor analysis was executed on water quality parameters in three seasons in order to identify the parameters which are significantly important for seasonal variation of water quality parameters. The PCA/FA results are shown in Table 3. Classification of factor loading is 'strong', 'moderate' and 'weak', corresponding to absolute loading values of > 0.75, 0.75-0.50 and 0.50-0.30, respectively (Liu *et al.,* 2003).

In summer Factor 1, Factor 2 and Factor 3 included 62.92%, 25.96% and 11.12% of the total variance, respectively. In Factor 1, strong positive loading was observed in temperature, hardness, phosphate and ammonia, whereas strong negative loading was observed in pH, nitrate and silicate. In Factor 2 strong positive loading was observed in alkalinity and CO_2, whereas DO and nitrite showed strong negative loading. In Factor 3 chloride showed strong positive loading, but no strong negative loading was observed.

During monsoon period Factor 1, Factor 2 and Factor 3 included 66.06%, 18.31% and 15.63% of the total variance, respectively. A strong positive loading was observed in temperature, hardness, chloride, phosphate, ammonia, nitrite and nitrate, whereas no strong negative loading was observed in Factor 1. In Factor 2 a strong positive loading observed in pH, alkalinity and silicate, but no strong negative loading was observed. A strong positive loading was observed in DO and CO_2, but no strong negative loading was observed in Factor 3.

In winter Factor 1, Factor 2 and Factor 3 included 42.89%, 24.83% and 20.01% of the total variance, respectively. In Factor 1 a strong positive loading was observed in temperature, pH, nitrate and silicate, whereas a strong negative loading was observed in phosphate and ammonia. A strong positive loading was observed in alkalinity, hardness and nitrite, but no strong negative loading was observed in Factor 2. In Factor 3 a strong positive loading was observed in DO, whereas CO_2 was observed to have a strong loading.

Result of PCA/FA indicated that most of the selected water quality parameter showed a strong factor loading in each season except for chloride. The present study clearly indicated that most of the selected water quality parameters are significant to water quality variations throughout the seasons of the year. Pejman *et al*. (2009) also extracted the most significant parameters in water quality variations in each seasons using PCA/FA.

The ANOVA and Correlation coefficient analysis of the water quality parameters in the present study clearly showed seasonal variations and the degree of relationship of the water quality parameters which are the baseline information for the management of the reservoir. Factor analysis also clearly showed the parameters responsible for water quality variations in each season which is very important to find out the parameter that has to be monitored in different seasons. Most of the water quality parameters were in the permissible range for fisheries, irrigation and drinking purposes. The findings clearly proved that the reservoir water is suitable for multipurpose.

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