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Research Article

Water quality assessment of Rani Lake of Rewa (M.P.), India

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Abstract

The present study deals with water quality of Rani Lake of Rewa (M.P.), India to assess the impacts of anthropogenic activities. Water samples were collected monthly from the six sampling sites of the lake over two years (Jan. 2008 to Dec. 2009) for analysis of various physico-chemical parameters. Results indicated higher values of electrical conductivity (422mg/l), turbidity (33.9 mg/l), total dissolved solids (673.25 mg/l), total hardness (177.58 mg/l), alkalinity (217.16 mg/l), chlorides (81.52 mg/l), biological oxygen demand (17.47 mg/l), chemical oxygen demand (54.74 mg/l), phosphate (2.35 mg/l) and nitrate (1.46 mg/l) than the prescribed standards. The study revealed low Dissolved Oxygen content than prescribed standards and the water was alkaline and hard. There was seasonal variation in water quality parameters. The results have clearly indicated that this lake is polluted and eutrophic in nature due to discharge of sewage and other anthropogenic activities.

Keywords: Contamination, anthropogenic, eutrophication, osmoregulation, organic matter.

Introduction

Water like other components (air and soil) is equally important for sustenance of life and to maintain ecological progress of the bio-system. But relentless increases in the demand of water for multipurpose brought about by the two interdependent and parallel line of forces *i.e.* industrialization and urbanization, which in one hand usually reflects the all around development and progress but on the other hand posses strong concern about the fate of fresh water habitats. The requirement of water in all lives, from microorganisms to human beings, is increased day-by-day but it is a serious problem to provide a safe drinking water because all water resources have reached to a point of crisis due to unplanned urbanization and industrialization. The aquatic biodiversity are threatened primarily by human abuse and mismanagement of both living resources and the ecosystems that support them.

Several studies have been carried out to assess the water quality of lakes and ponds in India (Jain *et al.*,1996; Sreenivasan *et al.*, 1997; Swarnlatha and Rao, 1998; Maharaj *et al.*, 2000; Srinivasa and Kotaiah, 2000; Thorat and Masarrat, 2000; Duatta and Sharma, 2001; Shastri and Pendse, 2001; Dwivedi and Pandey, 2002; Kumar and Sharma, 2005; Singh and Mathur, 2005; Chaurasia and Pandey, 2007; Bhuiyan and Gupta, 2007; Smitha *et al.* 2007; Mathur *et al.*, 2008; Shiddamallayya and Pratima, 2008; Rajgopal *et al.*, 2010). This study deals with assessment of water quality of Rani lake of Rewa city, where the anthropogenic activities and environmental stress have deteriorated the water quality and accelerated the cultural eutrophication.

The rational behind the study was to assess the status of water pollution of the lake and provide the data to the municipal authority for management because sewage, industrial and municipal waters are being continuously added to the water reservoirs, which affect physico-chemical quality of water making them unfit for use of livestock and organisms. The purposes of this study was also to monitor the physico-chemical parameter of the Rani Lake water and assess the status of the lake and to provide the information to the municipal authority of the Rewa city to take action for management of the lake and prevent the water from deterioration.

Materials and Methods

Study Area

The study site is situated in southern part of the Rewa city, which is a developing city in Northeast Zone of Madhya Pradesh, India. The total area of the lake is appx. 15 ha. It is located at 24°53' N and 81°3' E at 318.5 m from sea level in the subtropical Indian continent and characterized by monsoon type of climate. The city is a part of Vindhya plateau flanked by Vindhya ranges in north and Kaimore ranges in south.

Sampling

Water samples were collected monthly for two years

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(Jan. 2008 to Dec. 2009) in 2 liters sterilized plastic bottles from six sampling sites and taken to the laboratory of School of Environmental Biology, A. P. S. University, Rewa (M.P.) India for analysis. The sampling sites were selected on the basis of magnitude of anthropogenic activities and distribution. Out of six sites, five sites were located on the banks of lake with maximum anthropogenic activities and the rest site was on the centre of the pond.

Analytical Methods

The pH and temperature of water were measured at the sampling sites by using digital pH meter and centigrade thermometer, respectively. Other parameters were analyzed as per methods described by APHA (1992). The results were compared with Indian Standards (IS): 10500 (ISI, 1992).

Statistical Analysis

Interrelationship studies between different variables are very helpful tools in promoting research and opening new frontiers of knowledge. The study of correlation reduces the range of uncertainty associated with decision making. The data were subjected to correlation coefficient analysis among physicochemical parameters using one tailed test at 5% level of significance using SPSS ver. 16.0 software.

Results and Discussion

There were seasonal variations in physicochemical parameters of Rani Lake water for two years (Table 1). Average values of various parameters with respect to six sites are presented in table 2 (2008 and 2009). Table 3 and table 4 represent the correlation coefficient between the physic-chemical parameters. Results revealed marked seasonal differences in various parameters due to climatic conditions and anthropogenic activities. Average water temperatures varied between 21.46°C to 24.72°C (Table 2) and 25.38°C to 25.79°C (Table 2) at six sampling sites, withan annual average of 24.58°C and 25.53°C, during 2008 and 2009, respectively. The water temperature followed the change in solar radiation and ambient air temperature. Maximum water temperature was recorded in summer months and minimum in winter months during both the years. The temperatures are positively correlated to nitrate and negatively correlated to the Dissolved Oxygen (DO) and turbidity. Temperature has been considered as an important factor in aquatic environment (Singh and Mathur, 2005). It plays a critical role in physicochemical and biological behavior of aquatic system (Dwivedi and Pandey, 2002), and has a significant effect on solubility of

Table1: Seasonal Variation (Mean ± SD) in Physico-chemical Characteristics of Rani Lake water, Rewa, during 2008 and 2009

Parameters	Winter		Summer		Rainy		IS:
	2008	2009	2008	2009	2008	2009	10500
	19.45±1.24	20.21±1.87	28.49±1.19	28.49±1.19	25.8±2.60	25.8±2.60	
Temperature	18.28-21.38	17.98-22.46	27.06-30	27.06-30	22.41-28.66	22.41-28.66	-
	7.95±0.24	8.08±0.17	8.58±0.21	8.58±0.21	7.77±0.14	7.77±0.14	
pH	7.61-8.25	7.83-8.28	8.31-8.9	8.31-8.9	7.6-7.98	7.6-7.98	6.5 - 8.5
	403.54±12.91	405.08±16.42	510.38±7.87	510.38±7.87	338.5±6.11	338.5±6.11	
Conductivity	380.83-420	385-426.5	497.66-517.83	497.66-517.83	330.33-346.33	330.33-346.33	-
	30.12±2.63	27.37±3.04	19.58±1.95	19.58±1.95	39.79±2.71	39.79±2.71	
Turbidity	26-32.66	23-30.66	16.66-21.83	16.66-21.83	36-46.33	36-46.33	10
	618.54±20.78	630.46±12.36	622.92±9.66	622.92±9.66	673.08±13.22	673.08±13.22	
TDS	641.16-642.83	613.66-644.66	610.83-635.83	610.83-635.83	657.16-691.83	657.16-691.83	-
Total Hardness	150.38±9.61 137.5-164.62	158.34±9.02 147.83-174.16	195.25±12.88 178.16-212.33	195.25±12.88 178.16-212.33	128.95±8.22 118.16-139.33	128.95±8.22 118.16-139.33	300
Total Alkalinity	167.67±10.06 155.5-181.5	172.59±12.91 156.83-187.66	201.38±8.22 190.5-211.83	201.38±8.22 190.5-211.83	184.58±8.51 173.33-196.33	184.58±8.51 173.33-196.33	200
	51.01±3.57	56.87±0.94	94.54±11.02	94.54±11.02	66.63±5.54	66.63±5.54	
Chloride	46.21-55.78	51.76-64.56	80.38-107.58	80.38-107.58	49.97-73.31	49.97-73.31	250
	6.41±0.41	6.07±0.44	3.17±0.73	3.17±0.73	4.52±0.69	4.52±0.69	
DO	5.95-6.96	5.41-6.58	2.13-4.06	2.13-4.06	3.51-5.35	3.51-5.35	-
	6.18±0.64	7.45±0.37	21.13±1.95	-	14.26±1.82	14.26±1.82	
BOD	4.2-8.31	5.55-9.23	18.63-23.76	-	12.48-15.46	12.48-15.46	-
	26.26±8.0	29.14±6.14	66.46±6.93	66.46±6.93	46.32±5.48	46.32±5.48	
COD	16.01-36.45	20.63-31.11	57.65-76.31	57.65-76.31	40.46-55.01	40.46-55.01	-
	1.20±0.08	1.31±0.12	1.76±0.36	1.76±0.36	1.13±0.30	1.13±0.30	
Phosphate	1.07-1.30	1.15-1.47	1.25-2.22	1.25-2.22	1.23-1.49	1.23-1.49	-
	0.71±0.16	0.85±0.14	1.62±0.27	1.62±0.27	21.13±1.95	1.40±0.10	
Nitrate	14.66-17.66	0.66-1.03	32.66-41.83	32.66-41.83	18.63-23.76	20.83-30.33	45

All the values are expressed in mg/l except Temperature (°C), pH (unit), Conductivity (ì mhos/cm), and Turbidity (N.T.U.)

Table 2: Annual Mean Values of Physico-chemical characteristics of Rani Lake during

			2008				
Parameters	Site-I	Site-II	Site-III	Site-IV	Site-V	Site-VI	Average
Temperature	24.6	24.67	21.46	24.72	24.5	24.2	24.58
pH	8.42	8.05	7.97	8.37	7.96	7.81	8.1
Conductivity	422	421.41	413.91	421.16	412.91	406.66	417.47
Turbidity	33.25	30.83	29.41	32.08	28.16	23.08	29.83
TDS	673.25	635.33	632.5	664.33	625.41	604.33	638.18
TH	169.91	156.25	155.33	168.91	156.16	143.33	158.19
TA	214.41	171.83	173.75	196.58	175	162.33	184.54
Chloride	75.77	69.98	69.54	75.59	68.61	64.94	70.73
DO	3.07	3.71	4.05	3.16	3.84	10.37	4.7
BOD	16.64	14.42	14.03	15.89	14.22	7.72	113.85
COD	53.88	45.11	46.58	52.39	45.97	31.46	46.34
Phosphate	2.23	1.06	1.02	2.13	0.99	0.75	1.36
Nitrate	1.43	1.18	1.17	1.39	1.19	1.07	1.24
			2009				
Temperature	25.38	25.66	25.43	25.79	25.46	25.56	25.53
pH	8.67	8.27	8.1	8.5	8.21	8.04	8.33
Conductivity	421.91	421.16	411.91	424.66	411.75	401.16	415.42
Turbidity	33.9	30.75	29.75	34	30.45	23.08	29.76
TDS	668.33	642.16	637.66	661.16	636.83	615.25	647.43
TH	177.58	164.25	162	176.62	164.41	151.91	166.13
TA	217.16	178.25	178.33	204.75	181.58	164.16	188.79
Chloride	81.52	72.21	72.51	78.8	73.8	70.54	74.73
DO	2.83	3.67	3.92	2.88	3.78	10.14	4.54
BOD	17.47	15.35	14.65	17.11	14.72	8.14	14.57
COD	54.74	49.13	47.82	54.73	47.34	31.89	47.61
Phosphate	2.35	1.16	1.15	2.33	1.07	0.84	1.49
Nitrate	1.46	1.26	1.25	1.46	1.26	1.18	1.31

All the values are expressed in mg/l except Temperature (°C), pH (unit), Conductivity (î mhos/cm), and Turbidity (N.T.U.)

Table 3: Correlation coefficient values among water quality parameters at Rani Lake during 2008

Parameters	Temperature	pH	Conductivity	Turbidity	TDS	TH	TA	Chloride	DO	BOD	COD	Phosphate	Nitrate
Temperature	1	.443	.438	-.191	.060	.380	.957	.891	-.987	.980	.970	.537	.999*
pH	.443	1	1.000**	-.965	-.869	.998*	.685	.801	-.580	.614	.647	.994*	.404
Conductivity	.438	1.000**	1	-.966	-.871	.998*	.681	.798	-.575	.610	.643	.994*	.399
Turbidity	-.191	-.965	-.966	1	.968	-.981	-.469	-.616	.345	-.384	-.424	-.931	-.149
TDS	.060	-.869	-.871	.968	1	-.901	-.234	-.400	.100	-.142	-.185	-.810	.103
TH	.380	.998*	.998*	-.981	-.901	1	.633	.758	-.522	.558	.593	.984	.340
TA	.957	.685	.681	-.469	-.234	.633	1	.985	-.991*	.996*	.999*	.759	.943
Chloride	.891	.801	.798	-.616	-.400	.758	.985	1	-.952	.964	.975	.861	.871
DO	-.987	-.580	-.575	.345	.100	-.522	-.991*	-.952	1	-.999*	-.996*	-.664	-.980
BOD	.980	.614	.610	-.384	-.142	.558	.996*	.964	-.999*	1	.999*	.695	.970
COD	.970	.647	.643	-.424	-.185	.593	.999*	.975	-.996*	.999*	1	.726	.959
Phosphate	.537	.994*	.994*	-.931	-.810	.984	.759	.861	-.664	.695	.726	1	.500
Nitrates	.999*	.404	.399	-.149	.103	.340	.943	.871	-.980	.970	.959	.500	1

Correlation is significant* at 5% level and ** at 1% level

oxygen in water (Joshi and Singh 2001).

The study concluded that Rani Lake water was slightly alkaline where pH varied from 7.81 to 8.42 and 8.04 to 8.67 at sampling sites, with an annual average of 8.10 and 8.33, during 2008 and 2009 respectively. High values of pH were observed during summer months and low during monsoon months of both the years. High water values of pH during summer months may be due to utilization of bicarbonates and carbonates buffer system (Bohra, 1976). The low values obtained during rainy months may be attributed to influence of fresh water influx, dilution of lake water, and organic matter decomposition (Zingde *et al.*, 1987). According to Spence (1967) the pH of a typical eutrophic lake ranges from 7.7 to 9.6. Thus, Rani Lake water is eutrophic on the basis of its pH range, as suggested by Spence (1967). The pH value are positively correlated to conductivity, total hardness and phosphates and negatively correlated with turbidity, total dissolved solids (TDS) and dissolved Oxygen (DO).

Electrical conductivity (EC) values mainly depend on ionic concentration or dissolved inorganic substance. In this study, the water samples exhibited higher values of EC in summer months and lower in monsoon months during both the years. These results are in confirmity with the earlier works elsewhere (Pandey *et al.*, 2003, Chaurasia and Pandey, 2007). The lower values of EC during rainy months were possibly due to rainfall in catchment area, as suggested by Chaurasia and Pandey (2007). In natural water the turbidity is caused by clay, silt, organic matter, phytoplanktons and other microscopic organisms etc. It restricts light penetration for photosynthesis in lake water. The turbidity of Rani Lake water was found to be varied between 23.08 Nephelometric Turbidity Unit (NTU) to 33.25 NTU and 23.08 NTU to 33.9 NTU during 2008 and 2009 respectively. Results evinced higher values of turbidity during monsoon months to be followed by winter and summer months. This is possibly due to influx of surface runoff from catchments area carrying suspended particles, garbage and organic matter etc. during rainy months. As time proceeded there is decomposition of organic matter, hence low turbidity during summer season. The turbidity indicated the negative correlation between most of the parameters. The sum of cations and anions concentration determines total dissolved solids (TDS) of water. A high content of dissolved solids elevates the density of water, influence osmoregulation of fresh water organism, and reduces solubility of gases and utility of water for drinking purposes and results in eutrophication of the aquatic systems. TDS in the present investigation ranged from 604.33 mg/l to 673.25 mg/l and 615.25 mg/l to 668.33 mg/l at six sampling sites, with an average of 638.18 mg/l and 647.43 mg/l, during 2008 and 2009 respectively. Higher TDS values of Rani Lake water are due to contamination of water by wastewater, garbage, mass bathing, offering foods, flowers, garlands and other religious matters. Indeed, high concentrations of TDS enrich the nutrient status of the water body which resulted in to eutrophication of this aquatic ecosystem (Swarnlatha and Rao, 1998, Singh and Mathur, 2005).

Table 4: Correlation coefficient values among water quality parameters at Rani Lake during 2009

Parameters	Temperature	pH	Conductivity	Turbidity	TDS	TH	TA	Chloride	DO	BOD	COD	Phosphate	Nitrate
Temperature	1	.443	.438	-.191	.060	.380	.957	.891	-.987	.980	.970	.537	.750
pH	.443	1	1.000**	-.965	-.869	.998*	.685	.801	-.580	.614	.647	.994*	.925
Conductivity	.438	1.000**	1	-.966	-.871	.998*	.681	.798	-.575	.610	.643	.994*	.923
Turbidity	-.191	-.965	-.966	1	.968	-.981	-.469	-.616	.345	-.384	-.424	-.931	-.793
TDS	.060	-.869	-.871	.968	1	-.901	-.234	-.400	.100	-.142	-.185	-.810	-.616
TH	.380	.998*	.998*	-.981	-.901	1	.633	.758	-.522	.558	.593	.984	.897
TA	.957	.685	.681	-.469	-.234	.633	1	.985	-.991*	.996*	.999*	.759	.910
Chloride	.891	.801	.798	-.616	-.400	.758	.985	1	-.952	.964	.975	.861	.968
DO	-.987	-.580	-.575	.345	.100	-.522	-.991*	-.952	1	-.999*	-.996*	-.664	-.845
BOD	.980	.614	.610	-.384	-.142	.558	.996*	.964	-.999*	1	.999*	.695	.867
COD	.970	.647	.643	-.424	-.185	.593	.999*	.975	-.996*	.999*	1	.726	.888
Phosphate	.537	.994*	.994*	-.931	-.810	.984	.759	.861	-.664	.695	.726	1	.961
Nitrates	.750	.925	.923	-.793	-.616	.897	.910	.968	-.845	.867	.888	.961	1

Correlation is significant* at 5% level and ** at 1% level

The total hardness of this lake water varied from 143.33 mg/l to 169.91 mg/l and 151.91 mg/l to 177.58 mg/l with an annual average of 158.19 mg/l and 166.13 mg/l during 2008 and 2009 respectively, indicating that water was hard. This hardness may be attributed to the presence of high content of calcium and magnesium in addition to sulphate, nitrate and sewage in flow (Patel and Singh, 1998, Angadi *et al.*, 2005). Kannan (1991) classified water on the basis of hardness values as, (i) 0-60 mg/l: soft, (ii) 61-120 mg/l: moderately hard, (iii) 121-160 mg/l: hard, and (iv) > 160 mg/l: very hard. On the basis of above classification, Rani Lake water may be placed under hard to very hard categories. The source of hardness in this lake is mainly due to the addition of calcium and magnesium salts through surface runoff from catchment area during rainy months.

The alkalinity of water is caused due to hydroxyl ion, carbonate ion and bicarbonate ions. Total alkalinity may be used as a tool for measurement of productivity. A range of 162.333 to 214.41 mg/l and 164.16 to 217.16 mg/l has been observed for alkalinity of water samples of Rani Lake during 2008 and 2009, respectively. The average values of alkalinity for two years have been estimated as 184.54 mg/l and 188.79 mg/l respectively, Durrani (1993) has suggested that the withdrawal of CO_2 from the bicarbonates for photosynthesis by algae may increase total alkalinity. Based on alkalinity, Spence (1996) classified the lakes into three categories; (i) 1-15 mg/l is nutrient poor, (ii) 16-60 mg/l is moderately nutrient rich, and (iii) > 60 mg/l is nutrient rich. On the basis of this classification, Rani Lake could broadly be considered as nutrient rich. This may be due to higher input of nutrients in water through anthropogenic activities. The alkalinity shows the positively significant correlation at 5% level with the BOD and COD and negatively correlated to dissolved oxygen.

The chloride status in water is indicative of pollution, especially of human origin. In the present investigation chloride concentration in Rani Lake water was observed to be varied between 64.94 to 75.77 mg/l and 70.54 to 81.52 mg/l during 2008 and 2009 respectively. The water sample indicated average annual chloride concentration as 70.73 mg/l during 2008 and 74.73 mg/l during 2009. There was maximum chloride concentration in summer season samples followed by rainy and winter months. The high content of chloride in Rani Lake water could have resulted due to large amount of organic matter, bathing activities, urination, faces and wastes of animals. These result supported the findings of Mathur *et al.* (2008).

Dissolved Oxygen determines the nature of an aquatic ecosystem to a great extent. The sustenance of living organisms depends on dissolved oxygen content of the water bodies. There are two sources of oxygen for water bodies; (i) directly from the atmosphere and (ii) by the photosynthesis activity of chlorophyll bearing aquatic plants. However, the concentration of dissolved oxygen also depends on surface agitation due to temperature, respiration rate of the aquatic living organisms, and decomposition rate of dead organic matters. The dissolved oxygen, under present investigation, varied from 3.07 to 10.37 mg/l and 2.83 to 10.14 mg/l, with an annual average of 4.70 mg/l and 4.57 mg/l during the year 2008 and 2009, respectively. This study also indicated seasonal variation in DO contents of water, being maximum in winter and minimum in summer months of both the years. The phenomenon of re-oxygenation of water during monsoon months may be due to circulation and mixing by inflow after rains (Hannan, 1979). It further, progressed in winter, may be due to circulation by cooling and draw down of DO in water (Dwivedi and Pandey, 2002). The low DO value has been attributed to the process of decomposition of organic matter involving the utilization of oxygen (Jameel, 1998).

Biological Oxygen Demand (BOD) is the measure of extent of pollution in the water body. It determines the amount of oxygen required for biological oxidation of organic matter with the help of microbial activities. The BOD values of Rani Lake water ranged from 7.72 mg/l to 16.64 mg/l and 8.14 mg/l to 17.47 mg/l during 2008 and 2009, respectively. The annual average BOD for the year 2008 and 2009 was estimated as 13.85 mg/l and 14.57 mg/l respectively. Seasonal variation in BOD values, with higher values during summer months followed by rainy and winter months was recorded. The reason of high content of BOD in summer months could be due to the fact that several microbes accelerated their metabolic activities with concentrated amount of organic matter discharged due to human activities, and hence required more amount of oxygen. The biological oxygen demand shows the positive correlation to total alkalinity and chemical oxygen demand and negatively correlated with the dissolved oxygen. This possibly increased the demand of oxygen during these months (Kumar and Sharma, 2005).

Chemical Oxygen Demand (COD) determines the oxygen required for the chemical oxidation of organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. The values of COD ranged between 31.46 mg/l to 53.88 mg/l and 31.89 mg/l to 54.74 mg/l during the year 2008 and 2009, with an average annual value of 46.34 mg/l and 47.61 mg/l, respectively. The sources of COD in Rani Lake may be due to input of domestic drains and the use of soap and detergents for washing and bathing by common man, as suggested by Mathur *et al.* (2008).

Phosphate content of studied lake water fluctuated between 0.75 mg/l to 2.23 mg/l and 0.84 mg/l to 2.35 mg/l with an annual average of 1.36 mg/l and 1.49 mg/l during the year 2008 and 2009, respectively. The summer months water samples exhibited higher phosphate contents to followed by winter and rainy months samples. Nitrate

contents of the same water samples varied between 1.07 mg/l to 1.43 mg/l and 1.18 mg/l to 1.46 mg/l during the two years, respectively. The annual average contents were exhibited as 1.24 mg/l and 1.31 mg/l for the water samples of the year 2008 and 2009, respectively. Similar seasonal pattern has been observed for the nitrate contents of water samples, as were obtained for phosphate contents. These results of nitrate and phosphate under present investigation are in confirmity with other studies carried out elsewhere by Nawange (1993), Chaurasia and Pandey (2007), Mathur *et al.* (2008), Kumari *et al.* (2008). Basic nutrients, like nitrate and phosphate, determines the productivity of the lake water. Jain *et al.*, (1996) have indicated that any amount in the excess of 0.5 ppm of phosphate is an indicator of pollution. The higher values of nitrate and phosphate of this lake water may be due to high rate of decomposition of organic matter.

Conclusion

This study illustrates that Rani Lake water exhibits low DO, High BOD, COD, turbidity, hardness, TDS, chloride, alkalinity, phosphate and nitrate during 2008 and 2009. The values of these parameters were found to be beyond the permissible limit (IS: 10500). Higher pH value indicates slightly alkaline nature of the water. The findings clearly indicate that this lake is polluted and eutrophic in nature because of discharge of sewage and other anthropogenic activity. All above impacts have resulted in the deterioration of water quality of Rani Lake. It gaves the clue to develop appropriate management strategies by municipal authorities

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