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Water quality assessment of Rajsamand Lake, Rajasthan, India

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Abstract

Rajsamand Lake is situated in the centre of Rajsamand city. Rajsamand district is situated in the southern part of Rajasthan, India and Rajsamand lake lies between 250 3'-0"N and 730 54'-0"E with an altitude of about 559.31 m above the sea level. The WQI was applied to classify water quality as excellent, good, moderately polluted, very poor and unsuitable for drinking purpose. Thirteen physico-chemical parameters were analysed, namely air and water temperature, depth of visibility, pH, dissolved oxygen (DO), electric conductivity (EC), total dissolved solids (TDS), total hardness, total alkalinity, chloride, sulphate, nitrate and phosphate. It was found that the water quality index of Rajsamand lake is 180.105033 which corresponds to "unsuitable for drinking purpose". This study revealed that the water quality index of Rajsamand lake is polluted and thus requires sufficient treatment, conservation and management.

Keywords: Rajsamand lake, Physico-chemical Parameters, Eutrophic, Permissible limits, Water Quality Index.

Introduction

Approximately 70% of the Indian water becomes polluted due to the discharge of domestic sewage and industrial effluents into freshwater bodies[1]. According to WHO, life of 0.4 million people is lost in India due to the lack of uncontaminated and hygienic water[2].

Water quality is shifting continuously and leads to eutrophication by deteriorating domestic sewage and industrial effluents into freshwater bodies[3]. Globally, the demand of water is rapidly increasing due to extensive increase in population, industrialization and urbanization. The availability of excellent quality of water is required for prevention of diseases and improving quality of life on earth[4].

Water quality assessment is required for the management of water bodies. The WQI is applied to assess the quality of major water supply sources representing the level of pollution[5]. The use of WQI in the first instance was used by Horton R.K.[6] and Brown R.M. et al.[7]. Since then, diverse methods for the calculation of WQI have been evolved till date. The water quality criteria, on the basis of WQI, have been prescribed as excellent, good, medium, bad, and unsuitable for drinking or very bad[8]. The scientific evaluation of the water quality for any water sources is necessary for the assessment of surface water used for human consumption.

Various literatures on WQI have been studied in reference to comparative evaluations and water quality management[9-13].

Rajsamand lake is one of the significant lake situated in the southern part of the Rajasthan state in India. The water in this lake comes through the rain run-off from surrounding hill areas, Khari feeder and main supplier of water is Gomti River. The lake water is also a source of drinking water supply and irrigation.

There has been no recent literature related to water quality and numerical expression of water quality in the form of WQI of Rajsmand lake till date. Significant contribution on water quality status of the Southern Rajasthan was given by so amny researchers[14-19].

Materials and methods

Study area: Rajsamand Lake is situated in Rajsamand district. The Rajsamand district is situated in the southern part of Rajasthan, India and Rajsamand lake lies between 25^0 3'-0"N and 73^0 54'-0"E with an altitude of about 559.31 m above the sea level. Rajsamand lake was constructed by Maharana Raj Singh, ruler of Mewar during 17 th centuary. The main source of water in Rajsamand lake from Khari feeder of Nandsamand dam and Gomti River. Huge embankment of white marble is present on the southern end of the lake which is called as Nauchowki (nine ghats). This lake was declared the religious lake in 2009 by Govt. of Rajasthan hence fishing is banned in this Reservoir. Water spread area of the lake is 18.10 km2with Catchment area of 522.93 sq km wherever maximum length and depth are 2.8 Km and 18.71 m respectively.

Collection and analysis of water samples: To assess the water quality status of Rajsamand lake, samples were collected at seasonal intervals (summer, monsoon and winter) from Monsoon 2013 to Summer 2015. Air temperature, water temperature, depth of visibility, pH, dissolved oxygen (DO) and

total dissolved solid (TDS) were examined in the field. Air and water temperature were examined by thermometer (modal LCD portable digital multistem of (-50°C to 150°C). Electric conductivity was measured by Systronic' direct reading conductivity meter (308). Depth of visibility was analyzed by Secchi disc, pH through digital pH meter (HANNA pH ep), and total dissolved solid (TDS) was measured by digital (Hold) TDS meter. DO was measured according to Ellis[20]. Chloride, total alkalinity, total hardness and phosphate were analyzed from surface water samples collected seasonally in polyethylene bottles and further analysis was done by APHA method[21].

Water Quality Index (WQI): For the WQI, seasonal (winter, summer and monsoon) water samples were collected and studied. Out of 13 physico-chemical parameters, 11 parameters were under taken for computing water quality index. WQI is a numerical expression used to transform large number of variable data into a single number, which represent the water quality level[22]. The weighted arithmetic index method has been used to calculation of WQI of the water body[7].

The WQI is derived from the following formula : $W_i = K/S_i$

Where: W_i - Unit weight of chemical factor, K - Constant of proportionality, S_i - standard value of i^{th} parameter (i= 1, 2, 3, 4……10) refers to water quality, Calculation of Water Quality Index involves two fundamental steps: i. Each chemical factor has been assigned a water quality rating to calculate WQI and ii. Aggregation of these sub-indices into overall index.

The water quality rating q_i is corresponding to the parameters. q_i is a number reflecting the relative value of this parameter in the polluted water with respect to its standard or permissible value. Water quality rating may be obtained from following:
$q_i = 100\ [(V_i-V_{io})/(S_i-V_{io})]$

Where: V_i : average of measured values in the water sample for two years (season wise) at one place, S_i : standard value i^{th} of parameter, V_{io} - ideal value for pure water (0 for all parameters except pH and DO).

The above equation becomes: $qi = 100\ (V_i/S_i)$.

But there are the following two exceptions: i. For dissolved oxygen (D.O.): The ideal value = 14.6 mg/l; permissible value = 6 mg/l, $q_{D.O.} = 100\ [(V_{D.O.}-14.6)/(6-14.6)]$. ii. For pH: The ideal value = 7.0; Max. Permissible value = 8.5,

$q_{pH} = 100\ [(V_{pH}- 7.0)/(8.5-7.0)]$

The overall WQI is calculated as: $WQI = \sum_{i=1}^{N} q_i W_i \Big/ \sum_{i=1}^{N} W_i$

Water quality parameters namely pH, dissolved oxygen, Total Alkalinity, Hardness, Electrical Conductivity, TDS, Chloride, Nitrate, and Phosphate were measured for calculating WQI and unit weight (W_i) of every parameters is obtained depending upon its weightage.

The word weighting implies relative significance of each factor in the overall water quality and it depends on the permissible limit in drinking water, as suggested by World Health Organization (WHO) and Bureau of Indian Standard (BIS). Using the WQI, all the water bodies were categorized as shown in Table-1[23].

Table-1: Water Quality Index (WQI) showed quality of water[23]

WQI	Status of water body
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor/ Moderately polluted water quality
76-100	Very poor water quality
101 and above	Unsuitable for Drinking Purpose

Results and discussion

The Water quality index was applied to integrate various water quality parameters and their aspect into a single frame showing a clear image of water quality of Rajsamand lake. The variation in WQI in monsoon 2013 and 2015 was noticed.

Table-2 indicates season-wise water quality data and WQI values among all the seasons, the high value of WQI was observed during Monsoon 2013 (230.6461) which indicates that water is unsuitable for drinking purpose and it is due to the high concentration of Total Alkalinity (235 mg/l) and high Total Hardness (242 mg/l). The lowest value of WQI reported in monsoon 2014 as compared to other seasons because of low value of TDS (293 ppm) and nitrate (4.682 mg/l) and Electric Conductivity (0.458 µS/cm). Therefore, it can be concluded that the water quality of the Rajsamand lake is not acceptable for drinking and bathing purpose.

The interpretation of data of physico-chemical characteristics of the Rajsamand lake has been made with the help of statistical tools (Table-3).

Most of the chemical reactions and biological processes in any water bodies is regulated by the Temperature[24]. Average value of air temperature of Rajsamand lake of varied between 18.9°C to 42°C. During the study period highest temperature (42°C) was recorded during the summer of 2015 whereas the air temperature (18.9°C) was lowest during the winter 2014. Temperature of water ranged between 17.9°C to 35.6°C. Minimum temperature (17.9°C) was found during the winter 2014 and maximum temperature (35.6°C) during the summer 2015.

The variation in pH regulates most of the chemical and biochemical processes in aquatic ecosystem[25]. During the study period, water of Rajsamand lake was mostly alkaline and the values of pH fluctuated between 6.7 to 10.8. The minimum value of pH 6.7 was recorded during the summer 2014 however maximum value of pH was observed during monsoon 2013 as well as winter 2014. In India many small confined water pockets are particularly alkaline in nature[15]. During the study pH showed more significant positive correlation with depth of visibility (r=0.3422), while it had negative relation with Water temperature (r=-0.3388) and Air temperature (-0.5391). Sharma found positive relation of pH with alkalinity, hardness, chloride, nitrate, phosphate, silicate and productivity[26].

Dissolved oxygen is essential for direct need of many organisms, it affects the solubility of the majority of the nutrients and periodicity in aquatic ecosystem[27]. The present study showed that maximum peak value of dissolved oxygen was analyzed 4.8 mg/l during the winter 2014 because of low temperature and the least value recorded in the summer 2015 which may be due to the eutrophication and microbial load in the lake[28]. Throughout the study dissolved oxygen showed significant correlation with depth of visibility and pH while significant negative correlation was displayed with Water temperature and Alkalinity (Table-4). Dissolved oxygen confirmed positive correlation with temperature, chlorides, hardness, nitrate, phosphate, and pH[26].

Depth of visibility of any water body gives a clear picture of the water quality[29]. The visibility of water is directly associated to the turbidity, it determines the degree of light penetration in water and depth of euphotic zone in the water body. In the present study, depth of visibility varied between of 70 cm to105 cm at Rajsamand lake.

Alkalinity is an estimate of the ability of water to oppose change in pH upon accumulation of acid. It is composed mainly of carbonate (CO_3^{2-}) and bicarbonates (HCO_3^-), acting as a stabilizer for pH. Total alkalinity in Rajsamand lake ranged between 172 mg/l to 235 mg/l. Total alkalinity variation between 84 to 282 mg/l at the Udaisagar dam[13]. Alkallinity above 40 ppm has been considered as good sign of productivity, further total alkalinity above 60 ppm are indication of nutrient rich condition, which is good for the production of fish food organisms[30].

The statistical computation showed positive correlation of alkalinity with depth of visibility (r=0.1792) and pH (r=0.6636). Total alkalinity displayed positive significant correlation coefficient with EC, TDS, nitrate and phosphate.

Total hardness is an important limnological parameter indicating level of water quality and organic production in the lake[28]. Total hardness ranged between 175 mg/l to 242 mg/l at Rajsamand lake. In this study hardness values were found within permissible limits in all seasons (Table-3). In Chambal river total hardness between 175 mg/l and 242 mg/l[24]. During this study, total hardness showed positive correlation with depth of visibility (r=0.3257), pH(r=0.6685), Alkalinity (r=0.8545) and dissolved oxygen (r=0.01885). Total hardness showing positive relation with visibility, phosphate, nitrate and pH[27].

In Rajsamand lake TDS value found between 293 mg/l and 386 mg/l. Indian Standards prescribed the desirable limit of TDS as 500 mg/l in drinking water. However, TDS values were found beneath the desirable limits (Table-3). The minimum value (293 mg/l) was recorded in monsoon of 2014 and maximum (386 mg/l) during the winter of 2014. TDS analysis also has great involvement in the control of biological and physical waste water treatment processes[31]. Density of water and osmoregulation of aquatic organisms is raised by high content of dissolved solids[32]. The statistical computation indicated significant positive correlation of TDS with electrical conductance (r=0.9106), pH (r=0.0972), water temperature (r=0.1141). In Mahi dam positive relationship of TDS with visibility, conductivity, nitrate, phosphate, pH and alkalinity[33].

In turn, conductivity provides a rapid mean of obtaining approximate knowledge of total dissolved solids concentration and salinity of water sample[34]. During the present study conductivity values ranged between 833 µS/cm to 1460 µS/cm. The highest value of conductance as 884 µS/cm at Chambal River[35]. In Rajsamand lake electrical conductance demonstrated negative relation with dissolved oxygen, total hardness and phosphate. Chambal river also found negative relation of conductivity with pH, hardness and nitrate[24].

Nitrate is one of the most stable forms of nitrogen. Nitrate is the final product of the biochemical oxidation of ammonia [26]. Nitrate is acting a significant role in the process of eutrophication, it is enhanced by domestic sewage and agricultural runoff in the water bodies[33]. High concentration of nitrate beyond 40 ppm is toxic in the water body[36]. Nitrate is essential for many photosynthetic activities and also identified as the growth limiting nutrient[37]. The value of nitrate in the Rajsamand lake varied between 4.682 mg/l to 10.786 mg/l. In the present study nitrate showed significant positive correlation with electrical conductance, water temperature and TDS. Nitrate showed positive correlation with pH, alkalinity, total hardness, chloride, phosphate and negative relation with dissolved oxygen, TDS and conductivity[38].

Phosphorous is generally recognised as a key nutrient in the fertility of fish pond. Moderate amount of phosphate is suitable for growth of plankton[33]. In the water of Rajsamand lake phosphate fluctuated between 0.0673 mg/l to 0.63 mg/l. During present study maximum phosphate was found during the summer 2015 while minimum value was recorded in winter 2015. In the present study phosphate showed negative correlation with Hardness, Alkalinity, TDS and Chloride.

Table-2(a): Computed Seasonal Water Quality Index (WQI) of Rajsamand lake.

Parameter	Standard permission Limit	Ref.	Monsoon 2013			Winter 2014		Summer 2014	
			W_i	q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i
pH	6.5-8.5	WHO	0.1176	253.3333	29.7914	253.3333	29.7919	23.4667	2.7596
Chloride (mg/l)	250	ICMR/ BIS	0.004	61.912	0.247648	48.776	0.195104	43.104	0.172416
Hardness (mg/l)	300	WHO	0.003	80.6666	0.2419998	71.6666	0.2419998	63.6666	0.1909998
Alkalinity (mg/l)	120	ICMR	0.008	195.8333	1.566664	169.1666	1.3533328	143.3333	1.1466664
D.O. (mg/l)	6	WHO	0.1666	127.9069	21.3092	113.9534	18.9846	123.2558	20.5344
Nitrate (mg/l)	20	ICMR	0.05	26.44	1.322	32.16	1.608	45.81	2.2905
Phosphate (mg/l)	0.1-1	WHO	1	256.1	256.1	178.4	178.4	236.4	236.4
T.D.S. (mg/l)	500	ICMR/ BIS	0.002	67.6	0.1352	77.2	0.1544	75	0.15
Electric conductivity (µS/cm)	250	WHO	0.004	464.4	1.8576	584	2.336	333.2	1.3328
∑			1.3552		312.5717		233.0653		264.9773
	WQI=		230.6461			171.9785		195.5263	

Table-2(b): Computed Seasonal Water Quality Index (WQI) of Rajsamand lake.

Parameter	Standard permission Limit	Ref.	Monsoon 2014		Winter 2015		Summer 2015	
			q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i
pH	6.5-8.5	WHO	66.6666	7.8399	46.6666	5.4879	33.3333	3.9199
Chloride (mg/l)	250	ICMR/ BIS	64.856	0.259424	51.272	0.205088	40.752	0.163008
Hardness (mg/l)	300	WHO	70.3333	0.2109999	75.6666	0.2269998	58.3333	0.1749999
Alkalinity (mg/l)	120	ICMR	166.6666	1.3333328	184.1666	1.4733328	145.8333	1.1666664
D.O. (mg/l)	6	WHO	113.9534	18.9846	120.9302	20.1469	129.0697	21.5030
Nitrate (mg/l)	20	ICMR	23.41	1.1705	29.405	1.47025	53.93	2.6965
Phosphate (mg/l)	0.1-1	WHO	1.661	166.1	179.5	179.5	2.135	2.135
T.D.S. (mg/l)	500	ICMR/ BIS	58.6	0.1172	69.6	0.1392	74	0.148
Electric conductivity (µS/cm)	250	WHO	472	1.888	354.8	1.4192	536	2.144
∑				197.9039		210.0688		245.4160
	WQI=		146.3569		155.0094		181.0920	

Table-2(c): Computed Seasonal Water Quality Index (WQI) of Rajsamand lake.

Parameter	Standard permission Limit	Reference	Monsoon 2013			Winter 2014		Summer 2014		Monsoon 2014		Winter 2015		Summer 2015	
			W_i	q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i	q_i	W_iq_i
Average WQI =		180.101533													

Table-3: Water quality data summary of Rajsamand lake.

Parameters	Monsoon 2013	Winter 2014	Summer 2014	Monsoon 2014	Winter 2015	Summer 2015	Min	Max	Mean	Standard deviation
Air Temperature (°C)	34.9	18.9	41.2	29.5	24.9	42	18.9	42	31.9	9.17888882
Water Temp (°C)	33.4	17.9	34.2	25.7	20.4	35.6	17.9	35.6	27.866667	7.61988626
Depth of Visibility (cm)	76	99	72.5	105	84.5	70	70	105	84.5	14.5396011
pH	10.8	10.8	6.7	8.2	7.7	7.5	6.7	10.8	8.6166667	1.75888222
DO (mg/l)	3.6	4.8	4	4.8	4.2	3.5	3.5	4.8	4.15	0.56480085
Total Alkalinity (mg/l)	235	203	172	200	221	185	172	235	202.66667	22.9840524
Hardness (mg/l)	242	215	189	211	227	175	175	242	209.83333	24.5146215
E Conductivity (µS/cm)	1161	1460	833	1180	887	1340	833	1460	1144.25	75.7507
Total dissolved solid (mg/l)	338	386	375	293	348	370	293	386	351.66667	33.7678348
Chloride (mg/l)	154.78	121.94	107.76	162.14	128.18	101.88	101.88	162.14	129.44667	24.4900753
Nitrate (mg/l)	5.288	6.432	9.162	4.682	5.881	10.786	4.682	10.786	7.0385	2.403248
Phosphate (mg/l)	2.561	1.784	2.364	1.661	1.795	2.315	1.661	2.561	2.08	0.21085531
Sulphate	26.9	20.0	15.4	14.8	18.5	22.0	14.8	26.9	19.6	4.49666543

Table-4: Correlation coefficient results between limnological parameters of Rajsamand Lake.

	Air temperature	Water temperature	Depth of visibility	pH	Alakalinity	DO	Hardnesss	EC	TDS	Chloride	Nitrate	Phosphate	Sulphate
Air temperature	1.	*	*	*	*	*	*	*	*	*	*	*	*
Water temperature	0.9741	1.	*	*	*	*	*	*	*	*	*	*	*
Depth of visibility	-0.7811	-0.7656	1.	*	*	*	*	*	*	*	*	*	*
pH	-0.5391	-0.3388	0.3422		*	*	*	*	*	*	*	*	*
Alakalinity	-0.4673	-0.327	0.1792	0.6636	1.	*	*	*	*	*	*	*	*
DO	-0.7704	-0.803	0.9413	0.1842	-0.0354	1.	*	*	*	*	*	*	*
Hardnesss	-0.5681	-0.4342	0.3257	0.6685	0.9256	0.01885	1.	*	*	*	*	*	*
EC	0.068	0.0344	-0.4729	0.0145	-0.3649	-0.2649	0.3853	1.	*	*	*	*	*
TDS	0.1132	0.1141	-0.6541	0.0972	-0.0428	-0.5029	-0.1082	0.9106	1.	*	*	*	*
Chloride	-0.3346	-0.211	0.565	0.4588	0.6603	0.3405	0.7344	-0.8636	-0.7213	1.	*	*	*
Nitrate	0.6708	0.5738	-0.6985	-0.5374	-0.7353	-0.5563	-87199	0.668	0.5356	-0.8996	1.	*	*
Phosphate	0.35	0.3846	0.1036	0.0101	-0.6179	0.0861	-0.6089	0.057	-0.25	-0.131	0.3805	1.	*
Sulphate	0.1022	0.2742	-0.4254	0.637	0.61	-0.619	0.3924	0.1962	0.1962	0.0932	-0.0067	-0.1329	1.

Conclusion

Water quality parameters of the Rajsamand lake were not found within the permissible limits as shown in (Table-1) so water of Rajsamand lake is "unsuitable for drinking purpose". Present study results clearly revealed that water of Rajsamand lake is polluted and should not be used for drinking, irrigation, domestic as well as fish culture without any scientific treatment. Therefore, regular assessments of water quality parameters are required to further management and conservation of Rajsamand lake.

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