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ASSESSMENT OF SURFACE WATER QUALITY IN RELATION TO WATER QUALITY INDEX OF TROPICAL LENTIC ENVIRONMENT, CENTRAL GUJARAT, INDIA

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Abstract

The present study involved the determination of surface water quality index of tropical sacred wetland *viz*. Dakor Pilgrimage Wetland (DPW), Central Gujarat, India. The main aim of the study was to evaluate various water quality parameters to draw-out the water quality index for an assessment of a tropical aquatic body. The monthly values of pH, Dissolved Oxygen (DO), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total alkalinity (TA), Total Hardness (TH), Calcium Hardness (Ca), Magnesium Hardness (Mg), Chloride, Sulphate, Phosphate, Sodium, and Potassium, were analyzed to compute water quality index (WQI). The results manifest that WQI at site 1 (D1) was maximum (161.74), followed by D2 (159.96), and minimum at site 3 (D3) (157.19). The values clearly depicts that quality of water is completely unfit for human consumption unless and until strict and mandatory steps are taken to rejuvenate it. The suggestive measures to improve the overall health of an aquatic body is also discussed herewith alongwith conservation measures and management strategies.
Key Words: Surface water quality, Water quality index, Tropical lentic environment, conservation measures, management strategies

Introduction

Wetland is collective term for ecosystems, whose formation has been dominated by water, and whose processes and characteristics are largely controlled by water (Maltby, 1986).The wetlands located in different physiographic, climatological and geological regions, are major sources of drinking water, irrigation, recreation and fishing (Attri and Santvan, 2012). A surface water supply primarily surface runoff, which indirectly plays an important role in the recycling process, replenishes groundwater; creates the landscape by eroding topography and transporting the material elsewhere. Increased human activities influencing adversely on hydro-biological regime as well as aquatic habitats; and are uncontrollably deteriorating or even drying at some places.

The rationale of a water quality index is to transform the huge amount of data into information, which can be easily interpreted. Water quality index exhibits the overall water quality at a specific location and specific time based on several water quality parameters. WQI is a set of standards used to measure and compare changes in water quality in a particular aquatic body over time (Akkaraboyina and Raju, 2012). This index is employed to a general analysis of water quality at different levels that affect a stream's ability to host the life, and also to investigate the overall quality of water body facing potential threats. The present paper is to investigate the suitability of the surface water of tropical sacred wetland *viz*. Dakor Pilgrimage Wetland (DPW), Central Gujarat, India, for the human consumption for drinking as well as domestic purposes. The suggestive measures to improve the overall health of an aquatic body are also discussed herewith along with conservation measures and management strategies.

Materials and Methods

Study Area

Dakor Pilgrimage Wetland (DPW)

Dakor Pilgrimage Wetland (DPW), District Anand, Central Gujarat, India, is located at 22.75^0 N latitude and 73.15 ^{0} E longitude, with an average elevation of 49 meters (~160 feet) above mean sea level; temperature ranges from lowest 12 ^{0}C (Winter) to highest 34 ^{0}C (Summer) (World Weather Online, 2008). Based on 2001 census, the human inhabitants of DPW are around 23,784 with an average literacy rate of 76%, which is well-blessed with 70-80 lakhs devotees per year (Census Commission of India, 2004). The study area is neighbouring to one of the most sanctified temple of Deity Lord Krishna, and has also become the source of attraction for the people not only from India but from every corners of the world (Figure 1).

Figure 1. Holistic View of Dakor Pilgrimage Wetland (DPW), Central Gujarat, India

Surface Water Sampling

Prior to selection of the study sites, the entire study area was inspected with cautious observations aided either by walk or a canoe. After selecting the permanent sampling stations, the surface water samples were collected systematically from the specified sampling sites. The surface water samples were collected on monthly basis for a time period of nine months (December 2012 to August 2013) for three consecutive distinct seasons (Winter, Summer, Monsoon). The collected samples were stored in pre-cleaned two litre plastic bottles, and brought to the laboratory with precautions for further analysis. The samples were then filtered using 0.45 micron millipore filter and preserved hygienically **(Trivedy and** Goel, 1986; Maiti, 2003; Gupta, 2004; APHA, 2012). The physico-chemical parameters such as pH, Dissolved Oxygen (DO), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total alkalinity (TA), Total Hardness (TH), Total Hardness, Calcium Hardness (Ca), Magnesium Hardness (Mg), Chloride, Sulphate, Phosphate, Sodium, and Potassium, were analyzed following standard protocols as mentioned above. Of the aforesaid physico-chemical parameters, pH and DO were recorded on-site using Freshwater Aquaculture Test Kit Manual, Model FF-2, Kit No. 2430-01, whereas rest of the parameters was analyzed in laboratory. On the basis of the obtained values, the water quality index (WQI) was calculated for the sampling sites and the entire study area using standard literatures (Munawar, 1970; Naik *et al.*, 1998).

Water Quality Index (WQI)

The water quality index was first developed by Horton in the early 1970s, which is basically a mathematical means of calculating a single value from multiple test results. The results of an index represents the level of water quality in a given water basin, such as lake, river or stream, and ponds too (Akkaraboyina and Raju, 2012). Basically, WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Miller *et al.*, 1986). In this study, thirteen important parameters were chosen to calculate the water quality index, using the standards of drinking water quality recommended by WHO (1993), BIS (1993) and ICMR (1975) (Table 1). Further, WQI was obtained as a standard of quality rating or sub index (q_n) using the following equation:

$$q_n = 100\,(V_n – V_{io}) / (S_n – V_{io})$$

(Let there be n water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of a particular parameter in the polluted water with respect to its standard permissible value).

q_n = Quality rating for n^{th} water quality parameter

V_n = Estimated value of n^{th} parameter at a given sampling station

S_n = Standard permissible value of n^{th} parameter

V_{io} = Ideal value of n^{th} parameter in pure water

(*i.e.* 0 for all other parameters except pH and DO (7.0 and 14.6 mg/L, respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value (S_n) of the corresponding parameter (Table 1), as

$$W_n = K / S_n$$

W_n = Unit weight for n^{th} parameter

S_n= Standard value for n^{th} parameter

K= Constant for proportionality

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating with the unit weight linearly (Table 2), as

$$WQI = \sum qnWn / \sum Wn$$

Table 1. Drinking Water Standards

Sr. No.	Parameters	Standard Value (S_n)	Units	Recommended	Unit weight (w_n)
1	pH	6.5-8.5	-	ICMR / BIS	0.219
2	DO	4.0-6.0	mg/L	WHO	0.004
3	TSS	75	mg/L	ICMR / BIS	0.025
4	TDS	1000	mg/L	WHO	0.002
5	TA	200	mg/L	ICMR / BIS	0.009
6	TH	300	mg/L	WHO	0.006
7	Ca	75	mg/L	BIS	0.025
8	Mg	30	mg/L	BIS	0.062
9	Chloride	45	mg/L	ICMR / BIS	0.041
10	Sulphate	5.99	mg/L	ICMR	0.311
11	Nitrate	150	mg/L	ICMR	0.012
12	Sodium	200	mg/L	WHO	0.009
13	Potassium	10	mg/L	WHO	0.186

Table 2. Water Quality Ratings

Standard Water Quality Index	
Value of WQI	*Quality of Water*
0-25	Excellent
26-50	Good
51-75	Poor
75-100	very-poor
>100	Unsuitable for drinking

Source: Chaterjee (1992), Chaterjee and Raziuddin (2002)

Conservation Measures and Management Strategies

Since the studied wetland is inundated by recurrent anthropogenic loads at all the sampling sites, site-specific conservation, and management strategies are demanded as an urgent need of an hour. Such stratagem can be achieved by involving Gujarat State Forest Department (GSFD), semi-government and autonomous bodies, local NGOs, and native populace of the area. Moreover, prudent recommendations from regional wetland experts should also be implied to maintain the integrity of an entire aquatic ecosystem as a whole in terms of its ecology, biota, and hydrological quality. Hydrological study of DPW in past also reveals the waterbody to be a eutrophic by identified anthropogenic sources (Soni and Thomas, 2013a). Thus, spatio-temporal analysis alongwith systematic studies are needed for an in-depth monitoring of water quality of study area. Besides, manipulative methods such as removal of obnoxious aquatic weeds, installation of filtration plants and refining filters, etc. become essential components to recycle and reuse the water for drinking and domestic purposes. In addition, legal rules and regulations must be imposed for the visiting devotees restraining them to devoid of any unnatural activities for better sustenance of prevailing biota therein. Different types of domestic wastes are also get drained into the water body from adjacent areas. Such wastes should be channelized through a proper underground canal, and then be released after an appropriate pre-treatment. As being a pilgrimage spot, dumping of idols, plastics, cloths, papers, irons, rubbers, etc. by devotees should be strictly prohibited in the form of a legal mandate. Cleaning of bank by local authorities should be done on timely basis to prevent inorganic pollution to its fullest extent. Recreational activities such as boating and canoeing should be regularized by restricting number of boats and passengers. Dumping of solid and non-biodegradable garbage into waterbody by local people should be prevented on urgent basis. The central area should be properly fenced with barbed wires to restrict the entry of unauthorized persons, and be declared as *Sanctum sanctorum* to prevail the sanctity of the wetland (Soni *et al*., 2013b). Fishermen should be advised to use fishnet of definite mesh size during especially the breeding season of fish in order to avoid growing fingerlings. Overall, systematic study and monitoring of hydro-biological aspects on regular basis are advised to protect, manage, and conserve the sacredness of Dakor Pilgrimage Wetland (DPW), Central Gujarat, India.

Results and Discussion

The water quality index (WQI) of surface water of all the study sites at Dakor Pilgrimage Wetland (DPW), Central Gujarat, India, indicates the high amount of anthropogenic pollution. The results obtained clearly reveals the water as an unfit entity for human consumption in terms of drinking as well as domestic purposes (ICMR, 1975; BIS, 1993; WHO, 1993). Among the studied sites, D1 showed maximum value (161.75 mg/L of WQI, followed by 159.96 mg/L at D2, and the least at D3 (157.20 mg/L) (Tables 3, 4, 5). Similar trend was obtained by Yadav *et al.* (2010). The high values of WQI at these stations have been found to be mainly from the higher seepage of nitrate, total dissolved solids, hardness, bicarbonate and chloride in the groundwater (Ramakrishnaiah *et al.,* 2009; Soni and Thomas, 2013b). Besides, the overall water quality index of entire study area was obtained (159.64 mg/L) (Table 6). Such peak values clearly interprets that the water of DPW is completely unfit for human consumption for drinking as well as domestic uses. As the study area is a sacred destination visited by innumerable devotees every month, the mounting pollution of surface water might be due to high degree of unrestrained anthropogenic interventions (Soni and Thomas, 2013a). The water quality index was also determined in surface waters of selected waterbodies at regional and national levels by Yogendra and Puttiah (2007), Chandaluri *et al*. (2010), Sundara *et al*. (2010), Bharti and Katyal (2011), Pogpan and Yuwadee *et al*. (2011), Akkaraboyina and Raju (2012), Abbasi *et al*. (2013) and Kotadiya *et al*. (2013).

Table 3. Water Quality Index of D1 (DPW)

Parameters	Estimated Value (V_n)	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	Multiple Value (W_nq_n)
pH*	8.54	6.5-8.5	0.219	102.660	22.483
DO	4.28	4.0-6.0	0.004	0.099	0.000
TSS	741.00	75	0.025	988.000	24.502
TDS	214.00	1000	0.002	21.400	0.040
TA	161.60	200	0.009	80.800	0.751
TH	322.20	300	0.006	107.400	0.666
Ca	185.01	75	0.025	246.680	6.118
Mg	13.96	30	0.062	46.535	2.885
Chloride	82.96	45	0.041	184.356	7.620
Sulphate	13.45	5.99	0.311	224.617	69.747
Nitrate	30.21	150	0.012	20.142	0.250
Sodium	61.05	200	0.009	30.527	0.284
Potassium	6.47	10	0.186	64.735	12.041
			0.911#	2117.950#	147.387#
Water Quality Index (D1) = 161.7451 mg/L					

** Except pH, all the values are expressed in mg/L; # Sum of Values*

Table 4. Water Quality Index of D2 (DPW)

Parameters	Estimated Value (V_n)	Standard Value (S_n)	Unit Weight (W_n)	Quality Rating (q_n)	Multiple Value (W_nq_n)
pH*	8.54	6.5 – 8.5	0.219	102.660	22.483
DO	4.66	4.0-6.0	0.004	0.232	0.001
TSS	692.00	75	0.025	922.667	22.882
TDS	283.00	1000	0.002	28.300	0.053
TA	163.00	200	0.009	81.500	0.758
TH	301.20	300	0.006	100.400	0.622
Ca	146.79	75	0.025	195.720	4.854
Mg	13.35	30	0.062	44.515	2.760
Chloride	80.69	45	0.041	179.313	7.412
Sulphate	14.06	5.99	0.311	234.709	72.881
Nitrate	25.54	150	0.012	17.028	0.211
Sodium	59.31	200	0.009	29.655	0.276
Potassium	5.68	10	0.186	56.841	10.572
			0.911#	1993.541#	145.765#
Water Quality Index (D2) = 159.9647 mg/L					

** Except pH, all the values are expressed in mg/L; # Sum of Values*

Table 5. Water Quality Index of D3 (DPW)

Parameters	**Estimated Value (V_n)**	**Standard Value (S_n)**	**Unit Weight (W_n)**	**Quality Rating (q_n)**	**Multiple Value (W_nq_n)**
pH*	8.52	6.5 – 8.5	0.2190	101.330	22.191
DO	4.58	4.0-6.0	0.0037	0.204	0.001
TSS	637.20	75	0.0248	849.600	21.070
TDS	306.00	1000	0.0019	30.600	0.057
TA	159.60	200	0.0093	79.800	0.742
TH	301.40	300	0.0062	100.467	0.623
Ca	138.18	75	0.0248	184.240	4.569
Mg	13.46	30	0.0620	44.882	2.783
Chloride	84.09	45	0.0413	186.877	7.724
Sulphate	13.69	5.99	0.3105	228.563	70.973
Nitrate	22.64	150	0.0124	15.093	0.187
Sodium	60.32	200	0.0093	30.162	0.281
Potassium	6.47	10	0.1860	64.735	12.041
			0.9112#	1916.552#	143.241#
Water Quality Index (D2) = 157.1953 mg/L					

** Except pH, all the values are expressed in mg/L; # Sum of Values*

Table 6. Overall Water Quality Index (DPW)

Study Sites	**mg/L**
D1	161.75
D2	159.96
D3	157.20
Study Area	
DPW	159.64

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