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Application of Water Quality Index and Diversity Index for Pollution Assessment of Kankaria Lake at Ahmedabad, India

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Abstract

Kankaria Lake, the biggest artificial lake of Ahmedabad located in south-eastern part of the city is studied based on the data of water quality parameters and phytoplankton collected from the literature over one year. The data was categorized into summer, monsoon and winter seasons of the year. The available data is transformed into National Sanitation Foundation Water Quality Index (NSFWQI) and Shannon Diversity Index (SDI) using mathematical equations. The NSFWQI ranges from 70-80 for all the seasons while SDI in the range of 3.4-3.5 indicates the slight pollution level and good water quality of the lake. Through NSFWQI and SDI, it can also be concluded that physicochemical and biological characteristic of Kankaria lake water shows sign of further improvement somewhere between summer and monsoon. The Naviculla Species is found to be dominant among the investigated phytoplankton genera and has great impact on the lake water quality. Further, it is suggested to do an extensive study of Naviculla Species in summer and monsoon for further improvement of lake water quality in future.

Keywords: National sanitation foundation water quality index (NSFWQI); Shannon diversity index (SDI); Water pollution assessment

Introduction

Lakes are either formed by variety of geomorphic processes (tectonic, volcanic, glacial, fluvial, aeolian and coastal) or man-made efforts (excavation of earth or obstruction of flow). World's lakes contain about four times freshwater than rivers thereby showing their importance as a potential water resource [1]. India is endowed with large number of shallow natural lakes, most of which are in Himalayan belt. In recent times, large reservoirs are constructed on practically all the rivers. With fast growing industrialization and urbanization, the demand of fresh water has increased tremendously in recent years ultimately putting huge pressure on water resources. The problems of siltation, tourism, discharge of domestic and industrial sewage, dumping of solid waste, encroachment are becoming the common serious problems of rivers, lakes, wetlands etc [1-4].

Literature reveals that Dal Lake in Kashmir has shrinked from 40to 20 km2 in 20 years [1]. Lake Renuka located in Himalayan region is filled up with sediment [1]. Upper Lake in Bhopal, Poondi, Red Hills in Madras and Osmansagar in Hyderabad have shrunk considerably in the recent past while 40% area of the Powai Lake is filled by the builders [1]. Kankaria Lake, an urban lake located in south-eastern part of Ahmedabad with geographical location 23.006°N, 72.601°E, is a major centre for public functions and recreational activities in the city. Despite the large population pressure, industrialization and visitors, the Lake Management Authority (LMA) has ensured its existence and regulation of public functions in a sustainable way which can be a model for conservation and management of urban lakes in developing countries. Looking at the importance of the Kankaria Lake for tourism and recreation, the water quality and biodiversity has been studied as indicators of lake health. Based on the data of the phytoplankton and water quality parameters, Shannon Diversity Index (SDI) and National Sanitation Foundation Water Quality Index (NSFWQI) are applied to assess the Pollution status of Kankaria Lake.

The paper reports the assessment of Pollution status of Kankaria Lake based on SDI and NSFWQI calculated on the basis of one year data of phytoplanktons and water quality parameters obtained from Verma et al. [5]. The results indicated that NSFWQI from 70-80 while SDI from 3.4-3.5 for summer, monsoon and winter season is indication of slight pollution of the lake. Through NSFWQI and SDI, it is concluded that physicochemical and biological characteristic of Kankaria lake water shows sign of further improvement somewhere between summer and monsoon.

About Kankaria Lake

Kankaria Lake is located in 23.006°N, 72.601°E in densely populated south-eastern part (Maninagar) of Ahmedabad city in western Gujarat (India).It is also known as "Qutub Hojj" or "Hauj-e-Kutub" and was created by Sultan Qutub-ud-Din in the year 1451 A.D [6]. It is a multisided (polygonal) artificial lake with thirty four sides. There is an island-garden with a summer palace (known as Nagina Wadi) in the centre of lake. Kankaria lakefront development project was completed in December, 2008 with an outlay of 30 crores. Two trains named 'Atal Express' (imported from London) circles the lake on a 4.5 km track at a speed of 10 km/h with capacity of 150 passengers. The lake is a popular recreational centre surrounded by parks, children's gardens, a boat club, natural history museum, tethered balloon complex, gymnasium, open air theatre and a zoo. The salient features of Kankaria Lake are given in Table 1.

Since the catchment area of the lake is totally urban, water supply to the lake is ensured from storm water drains of the catchment. There are seven main channels connected to the lake from the surrounding areas. To revive the lake and to ensure the availability of water, Ahmedabad Urban Development Authority (AUDA) had initiated the Interlinking of Lakes (IOL) in 2004 which is still under progress. AUDA has identified 630 small lakes in its jurisdiction and notified 79 lakes as urban lakes. Out of the 79 urban lakes, 33 lakes are identified for storm water networking with total lake area of 15,63,638 m^2 with an estimated cost of 132 crores. 35% of the total cost will be provided by Government of India (GOI) as Jawaharlal Nehru National Urban Renewal Mission

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City	Ahmedabad (Gujarat)
Catchment area (m^2)	$64X10^4$
Water spread area (m^2)	$32X10^4$
Average depth (m)	6 to 7 m
Shore length (km)	2.25
Island	Nagina Wadi
Shape	Soccer shaped
Tourists visiting the lake	13000-15000 /day
Input source	Storm water
Sides	Multi-sided (Polygonal) with 34 sides
Source of Revenue	Entry fee, Gymnasium, Tethered balloon, Toy train, Zoo, Natural history museum, Children park, Water balloon, Speed boat, Open air theatre etc.

Table 1: Salient Features of Kankaria Lake.

(JnNURM), 15% by the state Government and 50% by urban local body like Ahmedabad Municipal Corporation (AMC).

Background

The physicochemical data and phytoplankton data collected by Verma et al. [5] on Kankaria Lake from March 2009 to February 2010 issued for the assessment of water quality. The assessment is done in terms of seasonal variation in water quality index and phytoplankton diversity index. Apart from these assessments, the importance of lake water to the people is also studied.

NSFWQI

Water quality index (WQI) is a number to express the overall water quality of a certain location and transforms the complex physicochemical parameters into information that is usable and understandable by general public. It is one of the most effective tools to communicate the water quality information between policy makers and general public. National Sanitation Foundation Water Quality Index (NSFWQI) of USA is one of the most acceptable and convenient WQI, proposed by Horton in 1965 [7]. The NSFWQI, which is used for the assessment of water quality of Kankaria Lake, is expressed as following equation:

$$WQI = \sum_{i=1}^{n} W_i Q_i$$

Where Q_i: Sub index for i^{th} water quality parameter;

W_i: Weight associated with water quality parameter;

n: Number of water quality parameters

The water quality data of seven parameters like pH, total solids (mg/l), turbidity (NTU), D.O (mg/l), B.O.D (mg/l), nitrate (mg/l), and total phosphate (mg/l)for the period March 2009 to February 2010 is categorized into three season namely summer, monsoon and winter. NSFWQI for these seasons is calculated using standard software [8] and reported in Table 2.

SDI

Diversity index is the mathematical tool to express number of species in a biological community i.e. to understand community structure. It provides more information about community composition than simply species richness by taking the relative abundances of different species into account [9]. A widely used diversity index is the Shannon-Weiner Diversity Index (SDI). The mathematical expression of SDI is expressed as follows:

$$H = \sum_{i=1}^{S} P_i In\,(Q_i)$$

Where p_i: proportional abundance of each species which is expressed as n_i/N (i.e. abundance of species/ total abundances)

Phytoplankton data of class Cyanophyceae (13 genera), Chlorophyceae (17 genera), Bacillariophyceae (6 genera) and Euglenophyceae (3 genera) for the period March 2009 to February 2010 is categorized into three season namely summer, monsoon and winter. On the basis of these data, their respective abundance ratio is computed in Table 3. These abundance ratios are further used for the computation of final SDI which is tabulated in Table 2.

S.No.	Parameters	Season		
		Summer	Monsoon	Winter
1	NSFWQI	73	80	70
2	Water Quality	Good	Good	Good
3	SDI	3.5	3.4	3.4
4	Pollution Level	Slight	Slight	Slight

Table 2: Seasonal Variations in NSFWQI, Pollution Level and SDI.

Results and Discussions

The results of NSFWQI between 70-90 are indications of good water quality in the lake throughout the year which is attributed to the diversion of sewage away from the lake as well as the suitable lake management adopted or strategies being adopted. In winter season, the WQI is between good and medium water quality which is an alarming signal for lake management authority (LMA) to take preventive measures to improve the quality. However, the overall water quality trend shows relatively better trend in monsoon compared to other seasons which might be due to the inflow of storm water to the lake, thereby diluting the pollutant concentration. Evident from the Indian standard of lake water quality, the lake water if found within the limit.

National Lake Conservation Plan (NLCP) in India recommends Class-B criteria of Designated Best Use (DBU) system of CPCB for lake water quality [10,11]. If lake water quality parameters are found within the limit then it is recommended for outdoor bathing. In case of Kankaria Lake water quality, parameters like pH DO and BOD are found well within the limit (Table 4). As far as concentration of faecal coliform is concerned, it is not tested by Verma et al. [5]. Therefore, source of faecal coliform is studied. Faecal pollution in water bodies is mainly attributed by animal and human excreta or by bathing [12]. In our case, LMA of Ahmedabad has ensured the diversion of incoming sewage towards the lake and only storm water is allowed from the highly paved catchment area. If chances exist for faecal pollution, it is only possible through storm water drains which are not found evident from the result of NSFWQI or SDI of monsoon season. NSFWQI value for monsoon (i.e. 80) is found more than the summer (i.e. 73) and winter (i.e. 70) which is attributed due to dilution of pollutants by storm water.

The SDI of phytoplanktons of lake water is found within the range of 3.4-3.5 Table 2 which shows slight pollution level in lake water (Table 5). SDI for 39 genera of phytoplanktons calculated as 3.5, 3.4 and 3.4 for summer, monsoon and winter seasons respectively. The result shows that genera diversity in summer is more than the monsoon and winter seasons. Overall abundance of phytoplankton in all the three season as a whole depicts that Naviculla Species holds dominance followed by Synedra Species, Cymbella species and Cosmarium Species. It means Naviculla Species has great impact on Kankaria Lake water quality. The NSFWQI for monsoon holds maximum score followed by summer and winter. At the same time, SDI for summer holds the maximum score. Therefore, it can be concluded that good water quality among three seasons vary somewhere between summer and monsoon. The abundance ratio of dominant genera i.e. Naviculla Species also shows

S.No	Class	Genera	Sampling Season					
			Summer		Monsoon		Winter	
			Mean (Number of Phytoplankton/ml)	Abundance Ratio	Mean (Number of Phytoplankton/ml)	Abundance Ratio	Mean (Number of Phytoplankton/ml)	Abundance Ratio
1	Cyanophyceae	Anabaena sp.	5	0.02	8	0.04	5	0.03
2	Chlorophyceae	Spirulinasp.	4	0.02	2	0.01	0	0
3		Aphanocapsa sp.	0	0	3	0.02	0	0
4		Aulosira sp.	3	0.01	4	0.02	0	0
5		Calothrix sp.	2	0.01	4	0.02	0	0
6		Phormidium sp.	9	0.04	7	0.04	10	0.05
7		Microcystis sp.	8	0.04	6	0.03	8	0.04
8		Oscillatoriasp	5	0.02	7	0.04	4	0.02
9		Nostoc sp.	4	0.02	7	0.04	0	0
10		Nodularia sp.	2	0.01	4	0.02	4	0.02
11		Cylinderospermum sp.	5	0.02	8	0.04	9	0.05
12		Gomphosphaeria sp.	2	0.01	0	0	3	0.02
13		Lyngbya sp.	4	0.02	0	0	2	0.01
14		Closterium sp.	4	0.02	3	0.02	6	0.03
15		Pediastrum sp.	8	0.04	5	0.03	10	0.05
16		Stigeoclonium sp.	4	0.02	0	0	2	0.01
17		Chlorella sp.	6	0.03	4	0.02	7	0.04
18		Ankistrodesmus sp.	7	0.03	4	0.02	9	0.05
19		Tetraedon sp.	4	0.02	2	0.01	5	0.03
20		Palmella sp.	7	0.03	4	0.02	7	0.04
21		Cosmarium sp.	10	0.05	6	0.03	12	0.06
22		Scendesmus sp.	7	0.03	4	0.02	7	0.04
23		Zygnema sp.	6	0.03	3	0.02	7	0.04
24		Mieospora sp.	4	0.02	2	0.01	6	0.03
25		Desmidium sp.	7	0.03	4	0.02	5	0.03
26		Pandorina sp.	2	0.01	0	0	4	0.02
27		Euastrum sp.	0	0	4	0.02	0	0
28		Cladophora sp.	3	0.01	2	0.01	4	0.02
29		Sphaerocystis sp.	3	0.01	6	0.03	4	0.02
30		Volvoxareus	2	0.01	1	0.01	2	0.01
31	Bacillariophyceae	Cymbella sp.	13	0.06	11	0.06	9	0.05
32		Fragillaria sp.	7	0.03	8	0.04	5	0.03
33		Navicula sp.	16	0.08	13	0.07	10	0.05
34		Pnnularia sp.	6	0.03	9	0.05	8	0.04
35		Melosira sp.	4	0.02	6	0.03	2	0.01
36		Synedra sp.	11	0.05	9	0.05	15	0.08
37	Euglenophyceae	Euglena sp.	4	0.02	3	0.02	3	0.02
38		Peranema sp.	2	0.01	2	0.01	3	0.02
39		Phacus sp.	2	0.01	4	0.02	0	0
	TOTAL		202		179		197	

Table 3: Seasonal Variation of Phytoplankton Abundance in Kankaria Lake.

S.No.	Parameters	Sampling Season			Indian Standard of Lake Water Quality
		Summer	Monsoon	Winter	Class-B of DBU System of CPCB
		Mean	Mean	Mean	
1	pH	8.3	7.9	8.2	6.5-8.5
2	D.O (mg/l)	5.6	6.8	6.2	>5.0
3	B.O.D (mg/l)	2.1	1.3	1.8	<3.0

Table 4: Physicochemical Data of Kankaria Lake.

Diversity Level	Shannon Diversity Index	Pollution Level
High	3.0–4.5	Slight
Moderate	2.0–3.0	Light
Less	1.0–2.0	Moderate
Very less	0.0–1.0	Heavy pollution

Table 5: Relations between Shannon Diversity Index and Pollution Level.

maximum dominance between summer and monsoon. Therefore, from the interpretation of result of NSFWQI and SDI, it can be concluded that physicochemical and biological characteristic of Kankaria lake water shows sign of further improvement somewhere between summer and monsoon. Further, in depth study of Naviculla Species in both the season will open a scope for further improvement of lake water quality.

Conclusions

Looking at the importance of the Kankaria Lake for tourism and recreation, the water quality and biodiversity is studied for the assessment of lake water quality. The results indicated that NSFWQI from 70-80 while SDI from 3.4-3.5 for summer, monsoon and winter season is indication of slight pollution (Table 5) of the lake. A comparison with Indian lake water quality standard, it is found that Kankaria Lake is fit for outdoor bathing. Through NSFWQI and SDI, it

can also be concluded that physicochemical and biological characteristic of Kankaria lake water shows sign of further improvement somewhere between summer and monsoon. The Naviculla Species is found to be dominant among the investigated phytoplankton genera and has great impact on the lake water quality. Further, it is suggested to do an extensive study of Naviculla Species in summer and monsoon for further improvement of lake water quality in future.

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