Synopsis of the Thesis Entitled

Water Quality Index of Water Bodies of Vadodara

To be submitted to

The Maharaja Sayajirao University of Baroda

For the Degree of

DOCTOR OF PHILOSOPHY

In

Environmental Science

By

Himakshi Bhavesh Parmar

Guided by: Prof. Prakash Samnani

Department of Environmental Studies

Faculty of Science

The Maharaja Sayajirao University of Baroda,

Vadodara 390 002

INDIA

Introduction

When we consider that water makes up more than two-thirds of the surface of the world, the amount of water on the planet is enormous. Due to the close connection between water and life, including both living things and plants and animals, water is woven into the fabric of all civilizations and religious movements in different ways. The Earth is facing enormous environmental challenges, with rapidly declining natural resources endangering the very viability of most ecosystems. Scientists, planners, sociologists, politicians, and economists are all concerned in conserving and preserving the world's natural resources.

Over the years, much focus has been placed on the protection of water sources in order to assure the provision of high-quality water for all human habitats. However, lakes found in many cities are as essential from the standpoint of conservation, even though they may be not a direct source of water supply but have great significance due to scenic, recreational, and habitat value for aquatic life. Ponds all over the world, both established and developing, have seen growing enrichment or eutrophication as a result of man's direct or indirect effect. The lakes offer a wide variety of values and uses, from direct economic benefits to ecological products and services. Direct use values include uses for drinking, irrigation, fishing, ecotourism, and other consumptive and non-consumptive activities. Indirect use values with beneficiary located away from the lake, potential future use & non-use social benefit of availability of a healthy water resource for future generation.

In recent years, anthropogenic pressures on lakes have risen sharply. The land use in these catchments has seen significant changes as natural vegetation has been destroyed and agricultural, urban, and industrial activity have increased. Deforestation, agriculture, urban development, and industrial activities have sped up the ageing process by introducing more sediment, nutrients, and harmful compounds into the lakes through runoffs. Along with the catchment-based activities, there has also been encroachment on lakeshores due to the reclamation of shallow lake margins, sewage disposal, water abstraction, and diversification of in-lake recreational activities. As nearby communities expand exponentially, the majority of lakes built primarily for urban water supply degrade quickly, and the drinking water reservoirs transform into recreational areas and dumps for all manner of urban trash.

Water evaluation in terms of trend assessment and anthropogenic stress has become an important tool for knowing the actual status of a water body. To simplify assessment data, complicated values from the data pool get converted into a simple number known as an index.

Environmental indices largely consist of water quality indices. Regulatory agencies use them as communication tools to examine the effects of regulatory policies on different environmental management practices and to characterise the "quality" or "health" of a particular environmental system (such as air, soil, and sediments). The WQI is one of the most widely used indices, which can also be used to determine if a particular stretch of the river is healthy or not.

- A water quality index can provide a way to summarize overall water quality conditions in a manner that can be communicated to a general audience.
- An index can tell us whether the overall quality of water bodies poses a potential threat to various uses of water.
- Used as a broad tool, an index can indicate success in protection and remediation effort.

Back in history Vadodara has been a city of lakes/pond. Gradually with rapid urbanization lakes/pond started to deplete. Degradation of these Lakes is mainly due to over population, illegally constructed slum quarters and development of the city as an industrial hub along with anthropogenic activities. These are many times used as dumping sites for reclamation.With increasing water demads and keeping in mind the population residing nearby and depending on these water bodies for daily chores, it is necessary to maintain the quality of these water bodies and conserve them.

Keeping in view the aforementioned issues the thesis was entitled "**Water Quality Index of Water bodies of Vadodara**" which consists of **five** chapters.

Chapter 1

First chapter gives a detailed introduction about the lakes, human interaction with lake/pond bodies, sources of pollution, different types of water quality indices, the methods used in development of water quality indices, gaps in the WQI used worldwide and how in future modification are required are specific used of water bodies, followed by the objectives.

The objectives of research:

- To characterize the lake/pond water based on two types of water quality parameters (viz., physical and chemical). Data for three years were collected to observe trend in change in water quality and the data also compared with reported data for the same lakes.

- To construct a Water Quality Index (WQI) based on the studied water quality parameters and compare the WQI with the existing water quality standards.

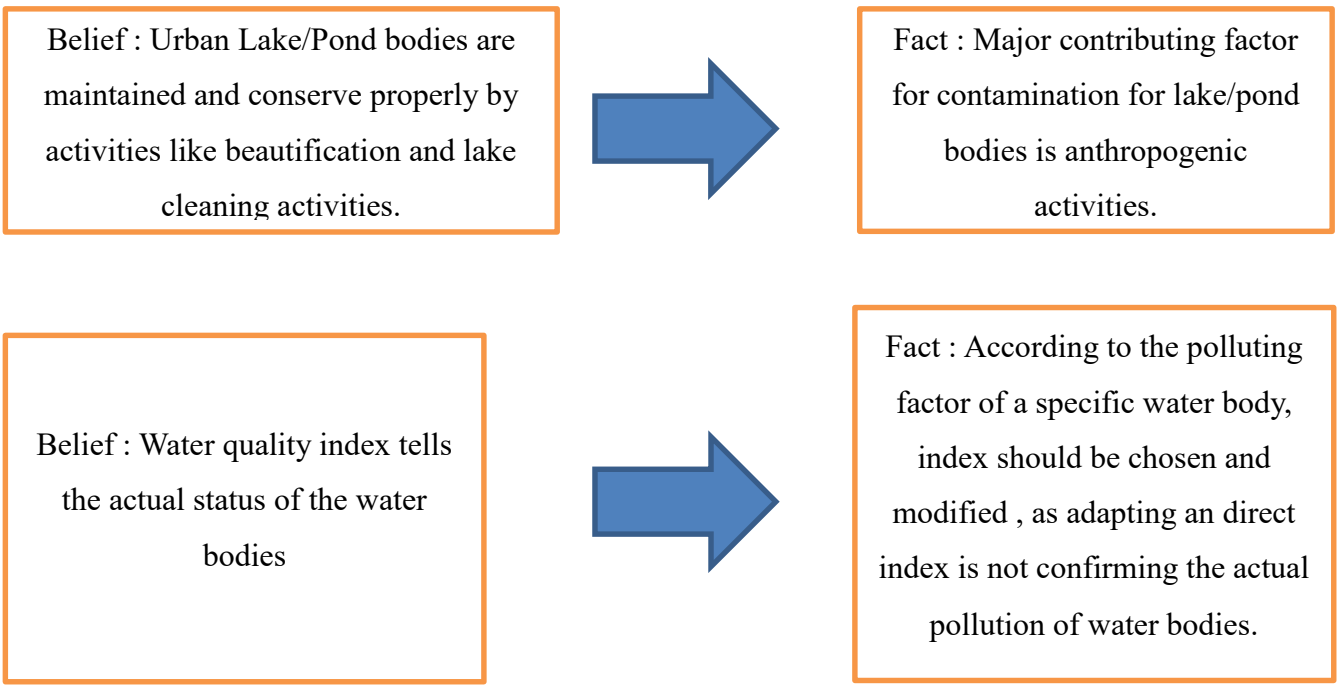
- To identify a critical parameter causing WQI to be high, and to suggest remedial measures based on chemical / physical treatment method focused on that parameter alone. This was followed by determination of WQI again to see whether this treatment was effective.

- To propose suitable modifications in the WQI calculations to suit local needs, which shall give better understanding of the pollution of the lake and to propose solutions to support the Master Plan of the local/state government regarding water resources management issues in changing climate and Proposed New or Modified Water Quality Index.

Chapter 2

Chapter 2 includes Literature review on trend assessment carried on various lake/pond water bodies, different tools and methods adapted for trend assessment as one part of the study. Second part includes Literature review of various indices applied to water bodies specific to lakes/pond water bodies, evaluating methods and parameters used, and weightage factor assigned in each index.

Gap Analysis



Rationale for the present study

With the surge in increasing water demand with increasing population, surface water are the ones which need immediate attention. Contamination and vitiation of the water bodies make up the partial situation of the "tragedies of the commons calling for immediate action for grave necessity to instigate the awareness on restoration and sustenance. Monitoring of such water bodies, recording the major contaminating factor and making people and local authorities aware of the water quality by use of Indices is need of the hour.

Chapter 3

Chapter 3 is divided into 2 parts. Part 3(a) covers details of the study area and the ponds / lakes selected for study.

Water bodies chosen for study purpose are within the Vadodara Municipal limits which include Harni Lake, Dhobi Lake, Gotri Lake, Sama Lake, Bapod Lake, Danteshwar Lake, Gorwa Lake, Motnath Lake and Kamala Lake. The use of term "Lake" for these relatively small water bodies has been taken from the Vadodara Mahanagar Seva Sadan City Plans.

Part 3(b) describes methodology adopted for assessment of the selected lake bodies and description of the 16 indices used in this study.

The analysis of physico-chemical characteristics of samples collected from each target water body at predetermined sampling locations, four times in a year by grab and composite sampling method, were followed to study the trend variation in quality of water bodies. APHA 23rd Edition 2017 methods were followed for analysis of physico- chemical characteristics of water body.

- NSF Index
- NEERI Index
- Overall Water Pollution Index
- DOE index
- Dinnius Index
- Prati Index
- Universal Index
- Integrated Index
- New water quality index
- Dhamija and Jain
- Weighted Arithmetic Mean method
- Numerrow Pollution Index
- NSF 9 Parameters
- Bascaron index
- Objective Bascaron Index
- Eco- Heart Index

Chapter 4

Chapter 4 is divided into 3 sections where section 4(a) includes results of trend assessment monitoring data for 14 month over a period of 4 years i.e., 2018-2021 for 9 ponds and analyzing their trend over a period of time. One typical data set is shown in Table 1.

Parameters	Sep-18	Dec-18	Mar-19	Jun-19	Sep-19	Dec-19	Mar-20	Jun-20	Sep-20	Dec-20	Mar-21	Jun-21	Sep-21	Dec-21
pH	7.48	7.51	8.2	7.72	7.66	7.98	8.47	7.5	7.31	7.4	7.9	7.84	8.25	7.98
TDS (mg/L)	550	300	700	616	754	400	714	687	564	484	580	432	650	567.
TSS (mg/L)	81	41	74	95	147	89	18	12	24	32	32	150	218	174
Conductivity (µS/cm)	741	451	1314	1220	1014	632	1147	1256	1098	1174	1226	874	1108	984
Temperature (^{O} C)	26.7	21.7	20.4	28.8	26.73	23.8	23.13	26.3	25.4	22.4	25.1	26.1	23.7	21.4
Turbidity (NTU)	20	11	30	15	25	20	35	7	1	3	0.6	15	10	23
Colour (Pt-Co)	5.6	3	9.7	7.4	12.72	9.64	11.99	5	6	5	2	9	13.3	8
Flouride (mg/L)	0.23	0.12	0.23	0.74	0.10	0.41	0.57	0.73	0.33	0.00	0.59	0.34	0.67	0.89
Acidity (mg/L)	9	13	25	30	19.33	16.67	33.67	0	0	0	1.12	5	8	10
Alkalinity (mg/L)	242	246	325	345	293.33	357	110.33	104	140	416	140	123	184	151
Hardness (mg/L)	147	161	214	258	133	100.33	130	128	80	172	136	185	220	203
Ca- Hardness (mg/L)	123.9	103.95	130.2	145.5	95.25	82.6	113.05	22.4	24	152	40	114	164	124
Mg-Hardness (mg/L)	23.1	57.05	83.80	112.5	37.75	17.73	16.95	105.6	56	20	96	71	56	79
COD (mg/L)	20	25	17	32	28	47	50	68	7.56	8	120	17	12	18
DO (mg/L)	2.38	3.77	4.57	2.9	4.62	7.22	6.06	5.3	4.8	2.9	1.8	4.2	5.9	3.4
BOD (mg/L)	0.79	1.59	2.58	2.87	2.43	4.9	4.24	18	1.5	0	6	0	2	6
Chloride (mg/L)	145.91	149.88	207.53	256.45	159.21	80.07	93.64	146	106	104	120	165	143.9	134
Ammonical Nitrogen (mg/L)	2.41	2.1	1.78	1.32	1.98	2.10	0.41	0	1.34	2.13	1.45	0.98	0.67	0.99
Total Kjeldahl Nitrogen (mg/L)	0.78	0.56	0.90	0.75	0.43	0.47	0.52	0	0.23	0.65	0.35	0.44	0.1	0.17
Nitrate (mg/L)	1.57	0.39	0.51	1.12	0.52	1.01	1.62	1.01	0	0	0.24	1.14	1.77	1.54
Phosphate (mg/L)	0.92	0.21	0.35	0.75	0.15	0.12	0.14	0.88	0.2	0.32	0.78	0.66	0.99	0.47
Sulphate (mg/L)					350	214	201	160.39	93.26	91.08	465	214	81.2	100.4
Total Coliform (MPN)					35	40	27	27	34	7	4	20	9	29
Faecal Coliforms (MPN)					18	20	11	15	22	11	7	14	3	17

Table 1 : Descriptive Analysis Data set for Harni lake for 2018-2021

Trend assessment of variation of some parameters with time of one lake over 4 year time period i.e., Sept -2018 to Dec- 2022 is shown in the form of graphs from Figures (1) to (8).

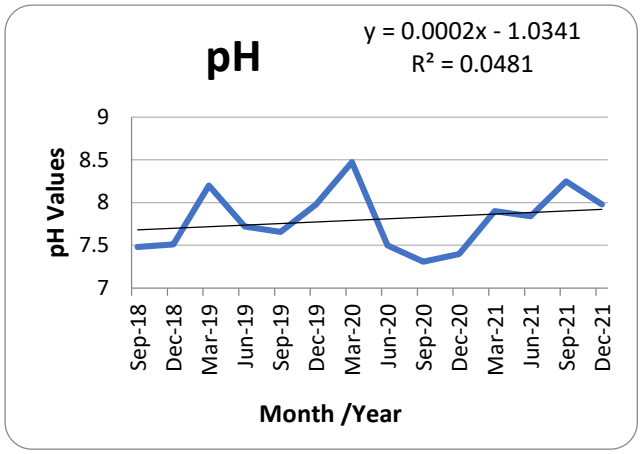


Figure 1 : Trend assessment for pH

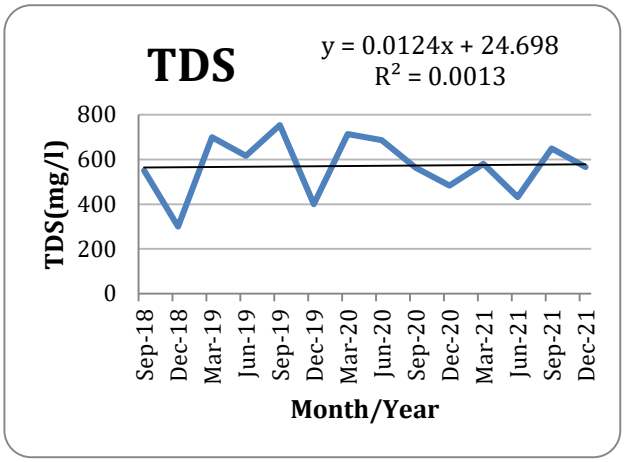


Figure 2 : Trend assessment for TDS

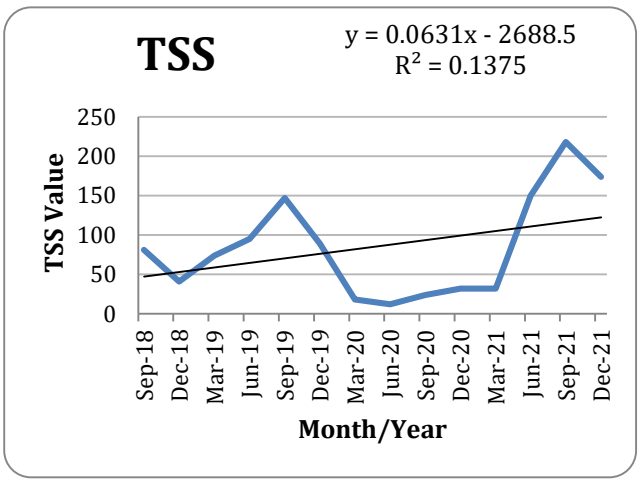


Figure 3 : Trend assessment for TSS

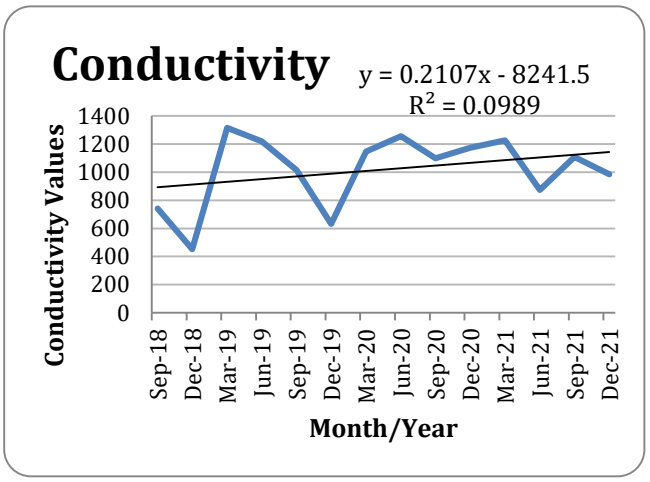


Figure 4 : Trend assessment for Conductivity

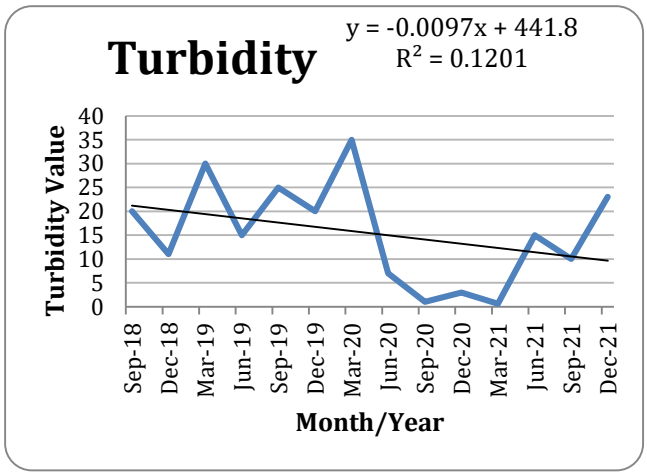


Figure 5 : Trend assessment for Turbidity

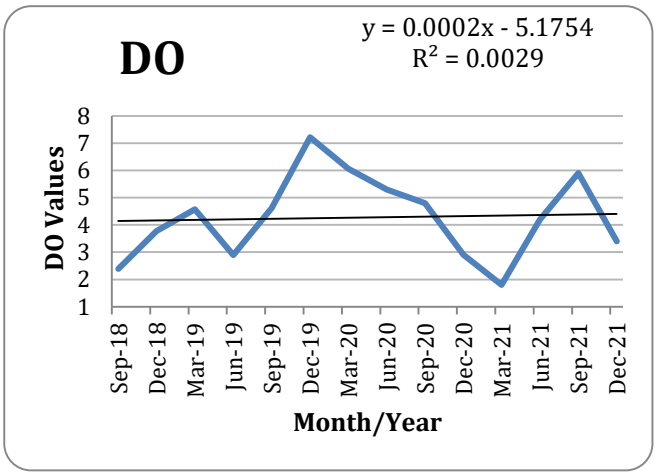


Figure 6 : Trend assessment for Dissolved Oxygen

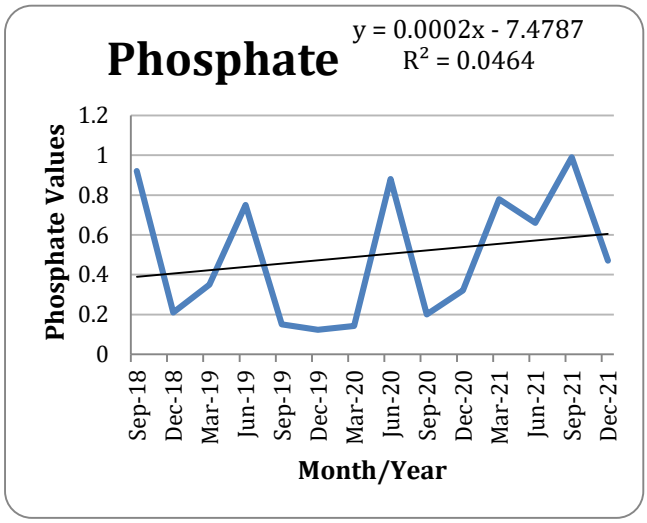


Figure 7 : Trend assessment for Phosphate

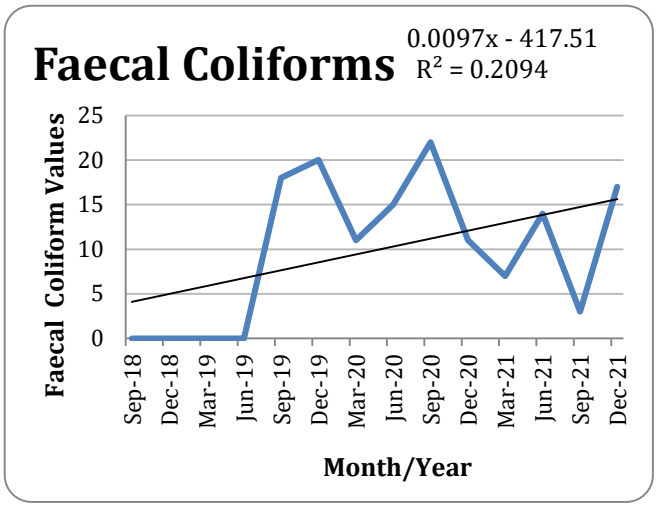


Figure 8 : Trend assessment for Feacal Coliform

4(b) includes result data of 15 WQIs values for all 9 ponds. One resultant Indices set is shown in below tables.

NSF INDEX	
Value	**Classification**
45.48	Bad
53.53	Medium to Good
52.11	Medium to Good
45.56	Bad
74.05	Good to Excellent
75.99	Good to Excellent
75.89	Good to Excellent
67.49	Good to Excellent
77.90	Good to Excellent
70.94	Good to Excellent
54.88	Medium to Good
74.53	Good to Excellent
83.64	Good to Excellent
60.54	Medium to Good

Neeri INDEX	
Value	**Classification**
1.62	Acceptable
0.87	Excellent
1.36	Acceptable
2.05	Slightly Polluted
1.24	Acceptable
1.59	Acceptable
1.54	Acceptable
1.93	Acceptable
0.83	Excellent
1.47	Acceptable
2.22	Slightly Polluted
1.09	Acceptable
1.32	Acceptable
1.25	Acceptable

Overall Water Pollution INDEX	
Value	**Classification**
69.87	Fair
79.35	Good
72.80	Fair
78.79	Good
67.56	Fair
78.30	Good
71.29	Fair
72.46	Fair
78.72	Good
76.82	Good
61.10	Fair
73.55	Fair
71.25	Fair
78.66	Good

DOE INDEX	
Value	**Classification**
61.19	CLASS III
70.22	CLASS III
72.00	CLASS III
62.10	CLASS III
65.26	CLASS III
69.09	CLASS III
78.71	CLASS II
73.61	CLASS III
81.56	CLASS II
70.96	CLASS III
50.05	CLASS IV
69.56	CLASS III
73.69	CLASS III
60.04	CLASS III

Prati INDEX	
Value	**Classification**
2.66	Slightly Polluted
2.29	Slightly Polluted
2.45	Slightly Polluted
2.86	Slightly Polluted
2.67	Slightly Polluted
2.76	Slightly Polluted
1.98	Acceptable
2.91	Slightly Polluted
1.49	Acceptable
1.93	Acceptable
3.94	Slightly Polluted
2.18	Slightly Polluted
2.19	Slightly Polluted
2.88	Slightly Polluted

Dinius INDEX	
Value	**Classification**
66.24	Medium
61.82	Medium
56.31	Medium
71.45	Good
74.23	Good
75.64	Good
65.31	Medium
77.88	Good
75.97	Good
60.72	Medium
55.79	Medium
68.88	Medium
67.46	Medium
54.98	Medium

Universal INDEX	
Value	**Classification**
68.42	Fair
76.70	Good
77.86	Good
68.42	Fair
80.21	Good
87.02	Good
81.94	Good
66.21	Fair
80.03	Good
72.14	Fair
60.79	Fair
73.26	Fair
78.63	Good
65.37	Fair

Integrated WATER INDEX	
Value	**Classification**
1.16	Good
1.26	Good
0.47	Excellent
0.45	Excellent
0.92	Excellent
1.95	Good
1.67	Good
1.92	Good
1.99	Good
1.38	Good
1.65	Good
0.86	Excellent
0.71	Excellent
0.79	Excellent

New Quality Water INDEX	
Value	**Classification**
-0.40	Needs Management Practices
0.18	Needs Management Practices
0.10	Needs Management Practices
-0.26	Needs Management Practices
0.19	Needs Management Practices
0.56	Needs Management Practices
0.34	Needs Management Practices
0.12	Needs Management Practices
0.25	Needs Management Practices
-0.13	Needs Management Practices
-0.49	Needs Management Practices
0.04	Needs Management Practices
0.16	Needs Management Practices
-0.07	Needs Management Practices

Weighted Arithmatic Mean INDEX	
Value	**Classification**
349.95	Unsuitable
93.58	Very Poor
161.94	Unsuitable
298.51	Unsuitable
85.45	Very Poor
83.35	Very Poor
99.81	Very Poor
391.90	Unsuitable
84.89	Very Poor
121.96	Unsuitable
311.04	Unsuitable
253.89	Unsuitable
379.23	Unsuitable
216.23	Unsuitable

Bascaron INDEX	
Value	**Classification**
33.55	Regular
38.95	Regular
34.44	Regular
33.47	Regular
35.69	Regular
37.77	Regular
33.68	Regular
37.61	Regular
39.44	Regular
37.91	Regular
33.33	Regular
35.97	Regular
37.91	Regular
31.11	Regular

Objectiver Bascaron INDEX	
Value	**Classification**
58.66	Regular
74.66	Acceptable
66	Acceptable
60	Regular
63.32	Acceptable
68.66	Acceptable
62	Acceptable
62	Acceptable
83.32	Acceptable
78	Acceptable
64.66	Acceptable
72	Acceptable
76	Acceptable
54	Regular

Numerrow Index	
Value	**Classification**
5.88	Moderately polluted
4.93	Slighty Polluted
6.40	Moderately polluted
5.27	Moderately polluted
6.20	Moderately polluted
5.92	Moderately polluted
6.68	Moderately polluted
4.83	Slighty Polluted
4.73	Slighty Polluted
4.76	Slighty Polluted
3.94	Slighty Polluted
5.32	Moderately polluted
4.99	Slighty Polluted
6.14	Moderately polluted

Dhamija and Jain INDEX	
Value	**Classification**
66.4	Medium
75.2	Good
74.4	Good
53.2	Medium
72	Good
84	Good
90.4	Good
84.8	Good
84	Good
65.2	Medium
63.2	Medium
67.2	Medium
71.6	Medium
67.2	Medium

NSF 9 INDEX	
Value	**Classification**
61.72	Medium
75.98	Good
70.76	Good
61.61	Medium
66.75	Medium
69.48	Medium
67.80	Medium
59.87	Medium
73.60	Good
67.43	Medium
55.74	Medium
65.34	Medium
69.82	Medium
55.88	Medium

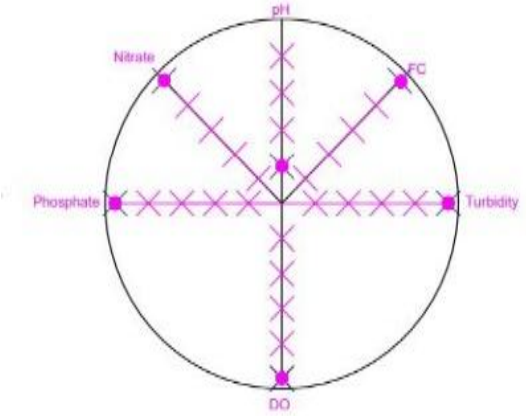
Section 4(c) includes identifying dominating parameters from all indices and suggest modification in selected Indices which can give more better interpretation on quality status of water bodies.

Index	**Dominating Parameters**
NSF INDEX	BOD, DO, pH
Neeri Index	BOD, Hardness, pH
Overall Water Pollution Index	Total Colifrom, ,Nitrate, DO, TDS
DOE Index	DO, BOD, pH
Dinnus Index	DO, pH, Temperature
Prati Index	Ammonical Nitrogen, TSS, COD
Universal Index	Total colifrom, nitrate, Fluoride
Integrated WQI	Mg-Hardness, Chloride and Hardness
New Water Quality Index	Conductivity and Turbidity
Dhamija & Jain	pH, Ca-Hardness and Mg-Hardness
Weighted Arithmatic Mean Method	Phosphate, BOD and turbidity
Numerrow Pollution Index	TS, turbidity and DO
NSF Index 9 Paramaeters	DO, coliform and Nitrate
Bascaron Index	Conductivity, Total colifrom, Turbidity and BOD Main parameters : Aspect Value
Objective Bascaron Index	DO, BOD and turbidity

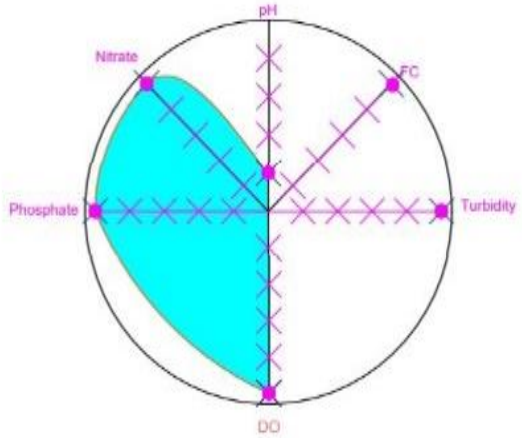
Modification of some indices is suggested below with taking into consideration 2 indices i.e., National Sanitation Foundation Index – Modification and Overall Water Quality Index – modification by modifying their weightage for particular parameters.

Parameters	*NSF INDEX - O*	*NSF INDEX - M*	*OWQ INDEX - O*	*OWQ INDEX –M*
pH	0.11	0.08	1	1
TDS			3	3
Color			2	2
Temperature	0.1	0.17		
DO	0.17	0.2	4	4
Total Solids	0.07	0.07		
5 day BOD	0.11	0.06	2	4
Sulfates			2	3
Total hardness			1	1
Chloride			1	1
Total Coliform			4	3
Fecal Coliform	0.16	0.08		
Turbidity	0.08	0.08	1	4
Flouride			3	1
Nitrate	0.1	0.07	3	1
Phosphate	0.1	0.19	2	4

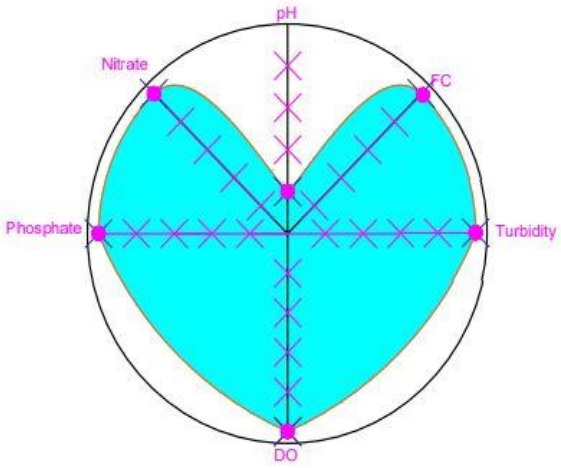
4(c) Concept of Eco-Heart was also used and modified as a new index under sustainable tool which can increased public participation in conserving water bodies through development of index in shape of a Heart. EHI can be considered a community-based water quality indicator with multiple functions



1. Mark



2. Connect

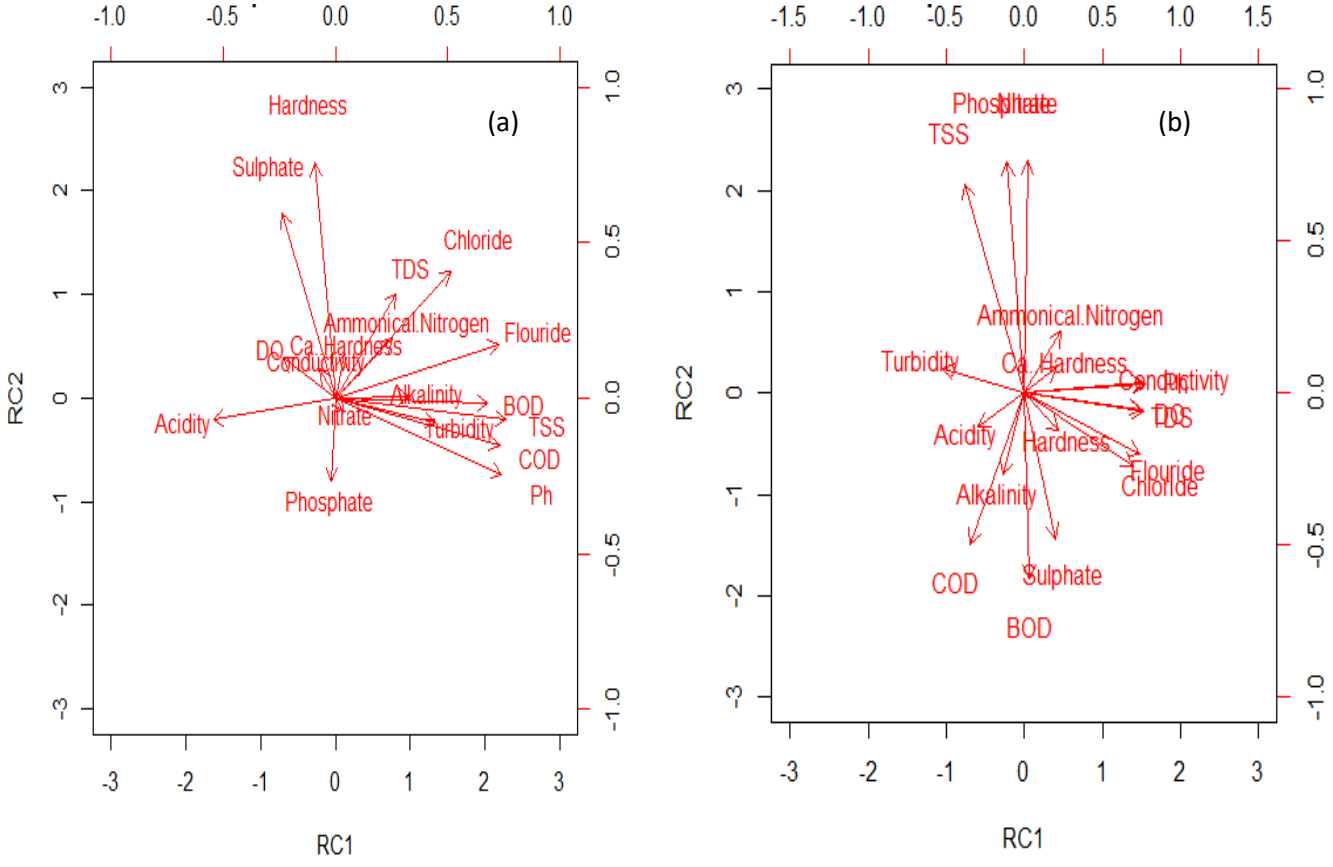


3. EVALUATE

4(e) Application of Statistical Tools like PCA, cluster Analysis on Trend Assessment Data

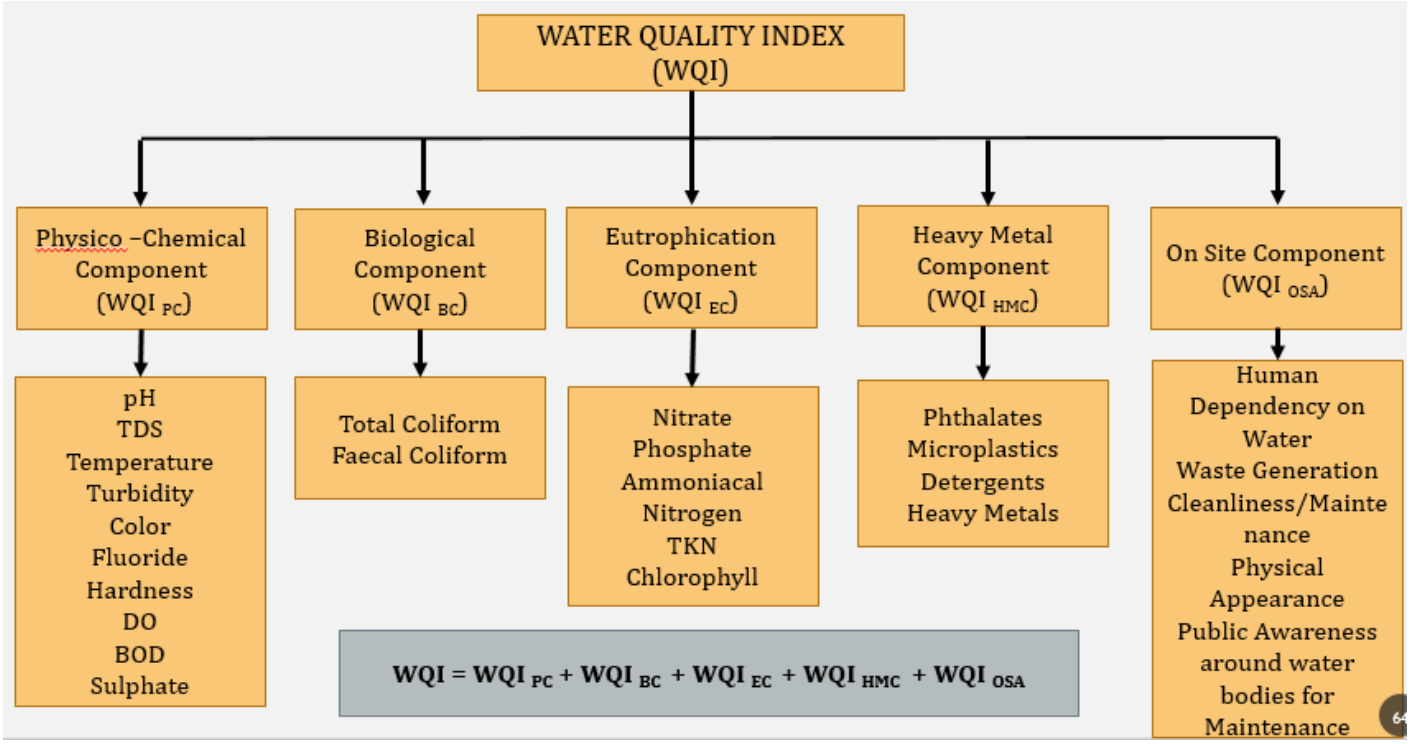
Eigen Values and explained variance of individual component

	Gotri pond		Harni Pond	
Components	Eigen Values	Variance	Eigen Values	Variance
PC1	7.76	43%	7.57	42%
PC2	4.17	23%	5.02	28%
PC3	2.06	11%	2.32	13%
PC4	1.71	9%	1.31	7%
PC5	1.26	7%	1.05	6%
PC6	1.04	6%	0.73	4%
PC7	2.3E-31	0%	8.22E-31	0%



Biplot of Gotri Pond for first two Components and (b)) Biplot of Harni Pond for first two Components

4(f) Development of New Index



Chapter 5

The fifth chapter summarizes the important conclusions of our study with future scope of the study.

From the obtained results it is observed that there is no specific trend pattern for both the water bodies. The main reason for such uneven pattern is a load of anthropogenic stress received by water bodies, mainly during festive seasons value goes high but here no such uniform pattern is observed as values are found high in June, December, and march also. Anthropogenic activities such as the dumping of biodegradable or non-biodegradable wastes such as plastics bags, plastic bottles, food waste from the nearby eateries, flowers, and photo frames are commonly observed in both the water bodies. Other activities like washing utensils, clothes, fishing, and sewage discharge are also observed on regular basis adding to the pollution load in the water body. Direct and indirect anthropogenic sources are directly contributing to the contamination of the body leading to no specific trend pattern and solely depends on the human load received by water bodies.

The study shows that there is no mechanism for achieving 100% impartiality or correctness in producing a WQI, specifically for parameter selection, generation of sub-index values, generation of parameter weights, and selection of index aggregation method. As a result, issues like rigidity, eclipse, and ambiguity will always be a barrier in constructing a WQI. A single universal index should not be used in all situations. An existing index requires updating with new parameters based on factors such as geography, historical and current data, and other factors. When the parameter's value rises, the weighting of a parameter needs to be changed; the index value maybe affected if the weighting is too low. Climate parameters should be chosen concerning the pollution load to calculate the index.

Continuous usage of the indices produces long-term data helpful in managing and making decisions about water quality. People should be involved in programmes for a certain amount of time to make them value water bodies and understand their importance. They also need to know what kinds of human activities can pollute water bodies and how to prevent pollution in the field.

Publications

1. Parmar, H., Samnani, P. Assessment of lakes of Vadodara city in terms of water quality indices and their comparison. Int J Energ Water Res (2022). https://doi.org/10.1007/s42108-022-00231-y
2. Parmar, H., Samnani, P. Towards Sustainable Development—Increasing Public Participation by Simplifying Water Quality Data Presentation in the Form of Eco-Heart Index. Water Conserv Sci Eng 8, 27 (2023). https://doi.org/10.1007/s41101-023-00202-2

Book Chapter

- Parmar, H., Samnani, P. (2023). Water Quality Index: An Important Tool to Assess Water Quality of Lake Waters for Sustainable Development. In: Pathak, B., Dubey, R.S. (eds) Climate Change and Urban Environment Sustainability. Disaster Resilience and Green Growth. Springer, Singapore. https://doi.org/10.1007/978-981-19-7618-6_8
- Human nutritional condition and dental fluorosis in populations with varying concentrations of fluoride in their water sources- Advanced Treatment Technologies for Fluoride Removal in Water – Springer Nature – Accepted Under Publication.

Oral Presentation

- Evaluation of Water Quality Index for Assessment of Surface Water Body of Vadodara at International conference on Ecohealth and Environmental Sustainability –23rd -26th February 2020 Navarachna University Centre for Environment ,Research and Innovation in Collaboration with University of Calgary ,Alberta,Canada .
- Anthropogenic stress evaluation in terms of trend assessment of water bodies of Vadodara, Gujarat at Doctoral Colloquium of Navrachana University - NUV Shodhan, scheduled on 6 August, 2021.

References

1. Narain S N (2007): A report of the working group on rivers, lakes and aquifers by environment and forest for the 11th five year plan"' *Planning Commission, Environment and Forest Unit,* 1-211.
2. Parikh A N, Mankodi P C (2011): Water quality assessment of Harni pond of Vadodara Gujarat, *Electronic Journal of Environmental Sciences,* **4**, 55-59.
3. Liou S M, Wang S H (2004): A generalized water quality index for Taiwan, *Environmental Monitoring and Assessment,* **96**, 35–32.
4. Paun L C, Valeria L C, Laura F C (2016) : Water quality indices - Methods for evaluating the quality of drinking water ,*International Symposium – "The Environment and the Industry"* , 395-402.
5. Bhadrecha M H, Mankodi P C (2018) : Water quality index of Thol Wetland, Mehsana , Gujarat, India, *International Research Journal of Environmental Sciences,* **7(6)**, 19-24.
6. Tirkey P, Bhattacharya T S, Chakraborty S (2015): Water quality indices- important tools for water quality assessment, *International Journal of Advances in Chemistry (IJAC),* **1**, No.1.
7. APHA: American Public Health Association, Washington, D.C. (2017): Standards methods for the Examination of water and waste water.
8. Cude C G (2001). Oregon Water Quality Index: A tool for evaluating water quality management effectiveness. *Journal of the American Water Research Association,* **37,** 125–137.
9. Index of stream condition (2007): The second benchmark of Victorian river. Victorian government department of sustainability and environment, Melbourne, www.Vicwaterdata.Net.

10. Khan F , Husain T, Lumb A (2003) : Water quality evaluation and trend analysis in selected watersheds of the Atlantic region of Canada. *Environmental Monitoring and Assessment*, **88**, 221– 242.
11. Lumb A L, Halliwell D H, Sharma T A (2006) : Application of the CCME water quality index to monitor water quality: A case study of the Mackenzie River Basin, Canada. *Environmental Monitoring and Assessment*, **113**, 411–429.
12. Ayas Z, Ekmekes G , Yerli S V (2007) : Heavy metal accumulation in water, sediments and fished of Nallihan bird paradise, Turkey : *Journal of Environmental Biology* **28(3),** 545-549.
13. Pesce S F, Wunderlin D A (2000). Use of water quality indices to verify the impact of Cordoba city (Argentina) on Suquia river. *Water Research*, **34**, 2915–2926.
14. KRISHNA K S , GIRISH K G (2014) : Phthalate esters in water and sediments of the Kaveri river, India: environmental levels and ecotoxicological evaluations, *Environmental Geochemistry and Health*, **37**, 87-96.
15. Vadodara Municipal Corporation report on India smart city mission (2016): Smart city proposal, Ministry of Urban Development.
16. Raychaudhuri M, Raychaudhuri S, Jena S K (2014): WQI to monitor quality for irrigation and potable use. Directorate of Water Management, Bhubaneshwar, India.
17. Martin, James L. 2013. Restoration and Management of Lakes and Reservoirs. Hydro-Environmental Analysis. https://doi.org/10.1201/b16108-20.
18. Menberu, Zemed, Beshah Mogesse, and Daniel Reddythota. 2021. 'Evaluation of Water Quality and Eutrophication Status of Hawassa Lake Based on Different Water Quality Indices'. Applied Water Science 11 (3). https://doi.org/10.1007/s13201-021-01385-6
19. Abbasi, Tasneem, and S.A. Abbasi. 2012. Why Water-Quality Indices. Water Quality Indices. https://doi.org/10.1016/b978-0-444-54304-2.00001-4.
20. Abidin, Ismail Zainal, Hafizan Juahir, Azman Azid, Ahmad Dasuki Mustafa, and Fazureen Azaman. 2015. 'Penggunaan Excel-VBA Untuk Pengiraan Indeks Kualiti Air Dan Indeks Pencemaran Udara'. Malaysian Journal of Analytical Sciences 19 (5): 1056–64

Himakshi Parmar
(Research Scholar)

Prof. Prakash Samnani
(Research Guide)