Water Quality Assessment of Water Bodies in Yangon Region Using Water Quality Index

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Abstract

Water quality is one of the most important health indicators in a freshwater ecosystem. The present study concerns the variation of the seasonal water quality index of water bodies in Yangon. The purpose of the present study is to evaluate the quality of surface water in five locations in Yangon (Twente Canal, Hlaing River, Yangon River, Pazundaung Creek, and Bago River) using water quality index (WQI). To assess the water quality of five water bodies, the physico-chemical characteristics and microbiological parameters of selected water samples were determined. The obtained analytical data were compared with surface water quality guidelines published by the EPA (2017). Moreover, the measured results of all water samples are also compared seasonally. The Weight Arithmetic Water Quality Index method was used to compute the values of WQI for five study locations. Using data on physical, chemical and microbiological parameters, the water quality index of the water sample was calculated. The calculated values of WQI were found to be from 33.93 to 44.95 in the rainy season, from 33.53 to 41.50 in the cold season, and from 45.54 to 72.95 in the hot season for five water sources. Based on the WQI values and water quality gradings, the water quality of water bodies in Yangon is good (or grading B) in the rainy and cold seasons. In the hot season, it is still good for locations 1 and 2, but it is poor (or grading C) for locations 3, 4, and 5.

Keywords: surface water quality, water bodies, water quality index, water quality guidelines

1. Introduction

Fresh surface water i.e, rivers, creeks, and canals are precious sources of fresh water for human life and aquatic species. The quality of surface water varies with time. In many places of Myanmar**,** industrial effluent, agricultural run-off and domestic wastewater are discharged into the nearby natural water bodies without proper treatment, resulting in degradation of water quality of natural flowing water bodies. Rapid growth of industrial sector and urbanization poses a significant threat to the surface water quality (ECD, 2019). Especially in Yangon, the population density is very much greater and more facilities and requirements for living standards are needed. Consequently, the industrial and domestic wastewater increases and the surface water gets contaminated. Water quality of Twente canal is contaminated due to run-off from agricultural farmland and wastewater from small factories. Water quality of the Hlaing River and the Yangon River has deteriorated due to the high discharge of the wastewater from Hlaing Tharya, and Shwe Lin Pan industrial zones and also Shwepyithar industrial zone (Cho Cho Thin Kyi et al., 2017). The water quality of Pazundaung Creek has deteriorated due to the rapid urbanization and industrialization along this creek (Hein Htet Aung et al., 2013). The water quality of the Bago River has deteriorated due to the wastewater from industries and sewage

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from settlement area, especially high level of phosphorus (Andreas Ballot et al., 2023). Therefore, the assessment of water quality of water bodies is vital to know whether it is good or poor for different purposes of water usage. In this study, five water bodies in Yangon were selected to assess the quality of surface water covering the periods from June 2022 to May 2023 seasonally, using water quality index method.

Aim

The aim of this study is to evaluate the quality of surface water in five study areas of Yangon (Twente Canal, Hlaing River, Yangon River, Pazundaung Creek, and Bago River) in terms of water quality index (WQI).

Objectives

The objectives of this study are:

1. to determine the physical, chemical, and microbiological parameters of water for five places in Yangon seasonally;
2. to calculate the WQIs of all water samples for each season;
3. to assess the quality of water in five places in terms of WQI; and
4. to compare the status of water in each place seasonally.

2. Study Area

For the assessment of surface water quality, five sampling sites of natural flowing water bodies situated in Yangon Region were selected.

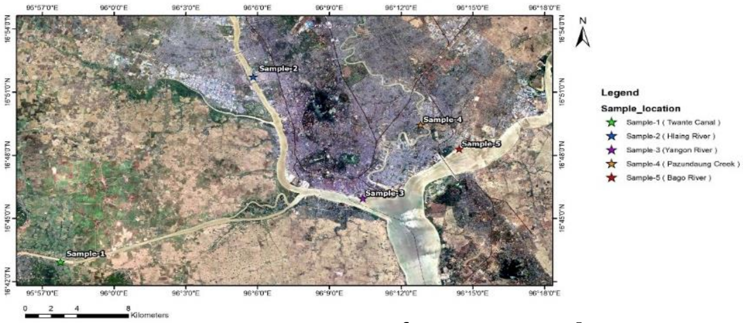

Figure 1. Map of Water Sampling Sites

Water samples were collected from the downstream of Twente Canal, the Hlaing River, the Yangon River, Pazundaung Creek, and the Bago River at Yangon. The location of five sampling sites in this study are shown in Figure 1, and the descriptions of these study sites were listed in Table 1.

3. Materials and Methods

Water Sampling

Before collecting the water sample, sample bottles were prepared according to the following standard sampling methods, as shown in Figure 2(a) and 2(b). Water samples were collected in the rainy season, the cold season and the summer from June 2022 to May 2023 to assess the surface water quality of five water bodies in Yangon. The surrounding conditions of five sampling sites and the geological coordinates of the selected study sites are described in

Table 1. A place with uniform and unidirectional flow (no turbulent flow) in a natural water body was chosen to collect water samples for every sampling site. Sample bottles were triple-rinsed with flowing water before filling. The uncapped bottle was held upside down and submerged nearly two feet below the water's surface. The bottle was tipped upright and allowed water to fill it. The bottle was removed from the water and screwed onto the cap. Surface water samples were collected in triplicate at a depth of two feet from all sites (Thomas J. Danielson, 2014). A professional camera application, including the Global Positioning System (GPS), was used to identify the locations of the selected sampling sites. From GPS data, the geological coordinates of sampling points are obtained. They are provided in Table 1.

Table 1. Descriptions of Study Sites

Sampling sites	Townships	Conditions of sampling sites	Locations
Location-1 (Sample-1)	Tarwa village, Twente Township Twente Canal	Surrounded by most agricultural area pottery activities, and villages.	16°42’ 56” N 95°57’ 46” E
Location-2 (Sample-2)	Hlaing Township Hlaing River	Villages and industrial zones on one side of the river, and housing, some jetties, and sand mining are on the other side of sampling place.	16° 51’ 44”N 96°5’ 49” E
Location-3 (Sample-3)	Botahtaung Township Yangon River	Some harbors, jetties, restaurants, and housings on one side of river and Dala Township on the other side.	16°45’ 57” N 96°10’ 24” E
Location-4 (Sample-4)	Thingangyun Township Pazundaung Creek	Nearby South Dagon industrial zone, and Tharkayta industrial zone.	16°49’ 27” N 96°12’ 49” E
Location-5 (Sample-5)	Tharkayta Township Bago River	Many factories in Dagon Seikkan industrial zone and small-scale fisheries and sand mining along the river.	16°48’ 18” N 96°14’ 26” E

Figure 2(a) Flow Diagram for Preparation of Sampling Bottles for the Analysis of Physical and Chemical Characteristics

Figure 2(b) Flow Diagram for Preparation of Sampling Bottles for the Analysis of Microbiological Characteristics

Physico-chemical Analysis of Water Samples

The study of physico-chemical characteristics is essential to getting better information about the quality of surface water, and the measured results of various physico-chemical parameters were compared with the water quality standard values (EPA, 2017). So, physical parameters: turbidity, TDS and conductivity; and chemical parameters: pH, total alkalinity, total hardness, dissolved oxygen, salinity, ammonia nitrogen, nitrite nitrogen, chlorine, BOD_5, COD, mercury, arsenics, lead, iron, sulphate, and phosphate were analyzed at the ISO TECH laboratory in Insein Township, Yangon. Moreover, other chemical parameters such as cadmium, copper, chromium, zinc, potassium, sodium, magnesium, manganese, and calcium were analyzed at the Universities' Research Centre (URC), University of Yangon. Analytical methods for physical and chemical parameters used in the laboratories are provided in Table 2 and 3.

Table 2. Analytical Methods for Physical Parameters Analysis

Sr No	Physical Parameters	Analytical Methods/Description
1	Turbidity	APHA 2130B (Nephelometric Method)
2	TDS	Instrumental Analysis
3	Conductivity	APHA 2510B (USA Standard Method 22^{nd} Edition)

Table 3. Analytical Methods for Chemical Parameters Analysis

Sr No	Chemical Parameters	Analytical Methods/Description
1	pH	APHA 4500-H+B (USA Standard Method 22nd Edition)
2	Alkalinity	APHA 2320B (Titration Method)
3	Hardness	APHA 2340C (EDTA Titrimetric Method)
4	Dissolved Oxygen	APHA 4500- O C (Azide Modification Method)
5	Salinity	APHA 2520B (Electrical Conductivity Method)
6	Ammonia- nitrogen	Cadmium Reduction Method
7	Nitrate - nitrogen	8153 Spectrophotometer HR, Powder Pillows
8	Chloride, BOD_5, COD	UAS Standard Method 22nd Edition
9	Mercury	In house method based on AOAC Official 974.14
10	Sulphate	Turbidimetric Method
11	Phosphate	USEPA Phos Ver 3 with Acid Persulfate Digestion Method
12	Arsenics, Cadmium, Lead, Copper, Chromium, Iron, Zinc, Potassium, Sodium, Magnesium, Manganese, Calcium	Atomic Absorption spectroscopy method

Microbiological Analysis of Water Sample

Microbiological parameters – E. coli and total coliform were analyzed at the ISO TECH laboratory in Insein Township, Yangon. Analytical methods for microbiological parameters are given in Table 4.

Table 4. Analytical Methods for Microbiological Parameters Analysis

Sr No	Microbiological Parameters	Methods/Description
1	E. coli	Membrane Filtration Method
2	Total Coliform	Membrane Filtration Method

Calculation of Water Quality Index

The water quality index (WQI) model is a popular technique for evaluating surface water quality. Generally, the WQI model has been applied to evaluate water quality based on standard values. WQI model involves four successive steps: (1) selection of the water parameters, (2) generation of sub-indices (3) calculation of the weighting values, and (4) aggregation of sub-indices to calculate the overall water quality index. Several researchers have utilized the WQI model to evaluate the water quality of rivers, canals, lakes, reservoirs. Brown developed a rigorous version of Hortons' model (Chormey et al, 2018). Modified version of weighted arithmetic Water Quality Index (WQI) was applied in this study (M M Mahbubul Syeed et al, 2023). Fourteen parameters – turbidity, TDS, DO, BOD_5, COD, nitrite nitrogen, chloride, phosphate, total coliform, cadmium, arsenic, conductivity, alkalinity and pH – were selected based on water clarity, oxygen demand, nutrients, bacterial, and additional parameters for the study of water quality index.

To compute relative weight of the i^{th} parameter,

$$W_i = \frac{K}{Si}$$

For pH and DO, $q_i = 100 \left[\frac{V_i - V_o}{S_i - V_o}\right]$

For the rest, $q_i = 100 \left[\frac{V_i}{S_i}\right]$

Finally, the weight values and sub-index of parameters were aggregating into the following formula;

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

where,

n = number of water parameters

q_i= water quality rating of the i^{th} parameter

V_i = measured value of the i^{th} parameter.

V_o = ideal value of n^{th} parameter in pure water.

S_i = standard permissible value of i^{th} parameter.

W_i = relative weight or unit weight for i^{th} parameter

k = relative constant

The WQI range, water quality grading and water quality status are shown in Table 5. The WQI values are distinguished into five categories according to water quality status (Tyagi, Shweta, et al., 2013).

Table 5. Water Quality Status and Water Quality Grading for the Calculated Values of WQI

WQI	Water Quality Status	Water Quality Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
>100	Unsuitable for use	E

4. Results and Discussions

The physical characteristics of water samples are shown in Table 6. It was found that the turbidity touches the limit at location 1 and is higher than the standard for the rest of the locations in the hot season. Low water levels, bank erosion, silt and mud, wastewater from construction, and high domestic effluent cause high turbidity. The TDS and conductivity are well below the guidelines for all locations across the three seasons.

Table 6. Physical Characteristics of Water Samples

Sr No	Parameters	Rainy season					Cold season					Hot season					Water Quality Guidelines (EPA, 2017)
		L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	
1	Turbidity (NTU)	15	19	17	14	17	20	24	23	22	20	25	28	35	39	35	25
2	TDS (mg/L)	96	120	119	148	86	130	150	145	150	160	190	250	650	140	350	1000
3	Conductivity (µS/cm)	38	34	41	56	32	80	70	90	80	90	100	90	110	100	120	250

Note: NTU ... Nephelometric Turbidity Unit

Similarly, Table-7 provides the chemical characteristics of water samples. From the results, it was found that dissolved oxygen was close to the standard value at locations 2 and 3 in the rainy season. Dissolved oxygen was high because of waste water from the excessive use of fertilizers, pesticides, and preservatives in the factories of industrial zones.

Ammonia nitrogen, nitrite nitrogen, chloride, and COD have small variations, and they were under the permissible limits for all study locations seasonally. For locations 1, 2, 3, BOD_5

touches the limit in the hot season, and it was very close to the margin at locations 4 and 5. There was also an increase from the rainy season (2022) to the hot season (2023). Effluent from textile, garment and rubber industries can cause high BOD_5. COD values had a little variation across the three seasons. The maximum value of COD was higher than the guideline value at location 5 in the cold season. The rest of the observed values were valid within the guideline value.

From the results, it was found that the concentration of mercury in five study sites were well below the standard during three seasons. Dissolved amount of arsenic at location 1 was a little greater than the permissible value in the rainy and cold seasons. For the rest of the locations, arsenic (As) did not meet the standard value for all seasons. In the rainy season, cadmium values were satisfactory for all locations but they increased across the three seasons. The increasing amount of cadmium was unsatisfactory, and it was close to water quality guidelines values (EPA, 2017) in the hot season. The other values, such as lead (Pb), copper (Cu), chromium (Cr), and zinc (Zn), were well below the permissible limits.

The E. coli for all locations in the rainy season and the cold season were not detected. The E. coli was not detected at locations 1, 2, and 3, but detected at locations 4 and 5 in the hot season. The total coliform obtained from laboratory analysis for all seasons was well below the permissible limit.

Except for turbidity, COD, arsenic, phosphate, and E. coli, most water parameters were well below the permissible limits for surface water quality at the study sites in all seasons. Moreover, the amount of cadmium in all water samples was gradually increasing, and it was close to the standard for five water samples in the summer. In the study area, surface water experiences an increase in mineral content, dyes, pathogens, organic waste, and the acid due to industrial waste and agricultural waste during the hot season.

The calculated values of WQI in all study areas across the three seasons are indicated in Table 9. By noting these results, the values of WQI for all locations in the hot season were greater than those in the rainy season and the cold season, indicating that the surface water quality in Yangon Region is good in the rainy and the cold seasons and poor in the hot season.

5. Conclusion

According to the results of surface water in Yangon Region, most characteristics were well below the permissible limits across the three seasons. Five water parameters: turbidity, COD, arsenic, phosphate, and E. coli – are higher than the permissible limits due to agricultural runoff, wastewater from industrial zones, distillery spent wash, and chemical outflow that were released into the flowing water bodies without treatment. Especially in the hot season, natural water bodies in this study area have low water levels. The flow or current of water bodies becomes slow, and thus soil particles and dissolved minerals settle down at the bottom. This can increase the concentration of some water parameters in the hot season. Based on the values of WQI, the calculated values range from 33.92 to 44.95 for all sampling sites in the rainy season and from 33.53 to 41.50 in the cold season. These ranges indicate that the quality of water bodies in Yangon is in a good water quality status in the two seasons. The values of WQI were from 45.54 to 72.95 in the hot season across five sampling places. Therefore, WQIs in the hot season were greater than those in the rainy and cold seasons. By comparing WQI gradings, it was found that locations 1 and 2 have grade B (good water quality) year-round. But locations 3, 4, and 5 have grade B (good water quality) in the raining and cold seasons and grade C (poor water quality) in the hot season. To conclude, WQI values clearly describe that the water quality for all locations in the rainy season and the cold season are good. Moreover, water quality for locations 1 and 2 are still good in the summer. But there is poor water quality for location 3,4, and 5 in the hot season.

Table 7. Chemical Characteristics of Water Samples

Sr No	Parameters	Rainy season					Cold season					Hot season					Water Quality Guidelines (EPA, 2017)
		L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	
1	pH	7.5	7.3	7.7	7.5	7.6	7.1	7.1	7.2	7.1	7.3	7.3	7.3	7.5	7.1	7.5	6.5 - 8.5
2	Total Alkalinity (mg/L)	80	78	66	86	68	154	140	120	170	156	60	80	80	100	60	500
3	Total Hardness (mg/L)	76	79	106	70	78	100	200	300	200	200	100	200	350	400	380	500
4	Dissolved Oxygen (mg/L)	2.75	4	4	2	3	3	2	1.5	2	3.5	2.5	3	3	2	3	5
5	Salinity (mg/L)	0	0	0	0	0	0	0	2	0	0	0	0	10	0	5	500
6	Ammonia Nitrogen (mg/L)	0.05	0.04	0.04	0.03	0.04	0.13	0.1	0.09	0.09	0.07	0.01	0.01	0.02	0.02	0.02	10
7	Nitrite Nitrogen (mg/L)	0.09	0.1	0.11	0.11	0.15	0.08	0.03	0.05	0.05	0.04	0.11	0.12	0.21	0.07	0.09	1
8	Chloride (mg/L)	20	15	20	20	15	15	60	385	135	215	16.2	65.7	393	148	225	600
9	BOD_5 (mg/L)	1.53	1.04	1.08	1.5	1	2	1.5	1.5	2	2	5	5	5	4	4	5
10	COD (mg/L)	5.15	3.31	3.68	7.36	8.1	3.68	0.74	1.78	2.21	18.4	3.68	1.1	3.68	2.58	1.84	15
11	Mercury (mg/L)	0.00050	0.00009	0.00010	0.00008	0.00007	0.00030	0.00008	0.00020	0.00004	0.00070	0.00040	0.00006	0.00020	0.00003	0.00050	0.006
12	Arsenic (mg/L)	0.012	0.0046	0.0034	0.0032	0.0045	0.011	0.0036	0.0025	0.0021	0.0024	0.0096	0.0037	0.0041	0.0029	0.0052	0.01
13	Cadmium (mg/L)	0.0001	0.0004	0.0002	0.0003	0.0007	0.00009	0.0003	0.00018	0.0002	0.0005	0.0013	0.0015	0.0022	0.0025	0.0023	0.003
14	Lead (mg/L)	ND	0.0004	ND	ND	0.0043	0.0001	0.0002	0.00004	0.00001	0.0009	ND	0.0002	ND	0.0004	0.0019	0.01
15	Copper (mg/L)	0.005	ND	ND	ND	ND	0.013	0.013	0.021	0.022	0.017	0.06	0.059	0.081	0.06	0.073	2
16	Chromium (mg/L)	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05
17	Zinc (mg/L)	0.004	0.002	ND	ND	ND	0.021	0.026	0.033	0.032	0.023	0.025	0.024	0.048	0.023	0.044	3

Table 8. Microbiological Characteristics of Water Samples

Sr No	Parameters	Rainy season					Cold season					Hot season					Water Quality Guidelines (EPA, 2017)
		L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	L-1	L-2	L-3	L-4	L-5	
1	E. coli (cfu/100mL)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	19	17	ND
2	Total Coliform (cfu/100mL)	90	100	140	100	85	82	90	120	83	80	180	142	210	240	195	400

Notes: cfu … colony-forming unit
ND … non-detected

Table 9. WQI for All Water Samples with Water Quality Status across Three Seasons

Sampling Sites	Rainy season			Cold season			Hot season		
	WQI	Range	WQS	WQI	Range	WQS	WQI	Range	WQS
Location 1	44.52	26-50	Good	37.89	26-50	Good	45.54	26-50	Good
Location 2	37.97	26-50	Good	36.89	26-50	Good	46.96	26-50	Good
Location 3	37.26	26-50	Good	35.63	26-50	Good	65.79	51-75	Poor
Location 4	33.93	26-50	Good	33.53	26-50	Good	72.95	51-75	Poor
Location 5	44.95	26-50	Good	41.5	26-50	Good	66.25	51-75	Poor

Notes: WQI --- Water Quality Index
WQS --- Water Quality Status

6. Implications

Weight Arithmetic Water Quality Index (WQI) method give out the effective and efficient information on the level of water purity and pollution of water by not knowing many water parameters' standards. Therefore, the water quality index should be applied to educate the public on environmental conditions.

To overcome the water quality degradation problem, the wastewater and effluents have to be treated before disposing into the waterbody applying some techniques involving adsorption method using activated carbon, and nature-based solution method. In addition, industries should minimize the amount of water used (especially wash water) and deduce the strength of contaminants.

Everyone can help to improve the quality of water and save the surface water sources by composing the kitchen scraps, creating less wastewater, using biodegradable and phosphate-free detergents or soap, and never putting household rubbish into local small streams.

Acknowledgments

Our project team is thankful to Dr Tin Mg Tun (Rector, University of Yangon), Dr Khin Chit Chit (Pro-rector), Dr Cho Cho (Pro-rector), and Dr Thidar Aye (Pro-rector) for giving us the opportunity to carry out this project. And also, we thank Asia Research Committee members for the financial support for the project. I would like to express my gratitude to Professor Dr Seinn Lei Aye (Head, Department of Environment and Water Studies, University of Yangon) for giving me guidance and support. Additionally, we thank the lab-assistants, office-staff working at ISO TECH laboratory and Universities' Research Center (URC), University of Yangon for their contributions to the laboratory analyses.

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