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A Case Study on Water Quality Assessment of Harvested Rainwater: A Water Quality Index (WQI) Approach

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ABSTRACT: The primary and widely used technique to determining the surface water quality condition is a conventional way of calculating the water quality index. Equally, the quality of harvested rainwater must be maintained for human health. Detailed evaluations and continuous monitoring of water quality are essential to ensure its safety for a range of applications. Major objective of this current study was to create a novel index approach that would be useful for any water quality metrics, irrespective of location or water consumption, and would simplify and ease computation. This study concentrates on defining and establishing the water quality level concerning Water Quality Index to assess the quality of harvested rainwater at Swami Vivekananda Institute of Science & Technology College.

KEYWORDS: Water Quality Index, Rainwater, Monitoring, Quality Metrics.

I. INTRODUCTION

The most widely used method for evaluation of water body's quality level is the Water Quality Index (WQI). WQI is a single dimensionless integer that clustered of quality parameters to identify the quality state of water bodies [1,2]. WQI is a method for providing the public with an abbreviated version of a water body's status that is consistent. WQI comes in several forms that are employed for various objectives. The WQI project is important because it can offer a thorough evaluation of water quality. By quantifying various parameters, such as physical, chemical, and biological indicators, the WQI can indicate the overall health of a water body [3,4]. Various national and international organizations have established a variety of water quality indices depending on location, area, goals, and quality factors. Some globally acceptable methods of determining WQI are described herein.

1.1 Weighted Arithmetic Water Quality Index Method

Weighted arithmetic mean method classified the water quality according to the scale of purity by using the most commonly measured water quality parameters [5, 6,7].

$$WQI = \frac{\sum W_x Q_x}{\sum W_x} \quad (1)$$

Where, Q_x = Quality rating for xth parameter. W_x = weightage factor for xth parameter.

$$Q_x = 100 \frac{V_x - V_o}{S_x - V_o} \quad (2)$$

V_x represents estimated value of each xth parameter. V_o = Ideal values of xth parameter. (0 for each parameter, except pH =7 and for DO =14.6 mg.l⁻¹). S_x = Recommended permissible value of xth parameter. [8].

$$W_x = \frac{K}{S_x} \tag{3}$$

K = Constant of proportionality as expressed in equation no 4

$$K = \frac{1}{\sum \frac{1}{S_x}} \tag{4}$$

Considering the result of the Weighted Arithmetic WQI technique a scale of water quality rating is given in Table 1.

WQI Value Range	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
Above 100	Unsuitable for drinking

Table1. Rating of water quality by weighted arithmetic water quality index method

1.2 National Sanitation Foundation Water Quality Index Method (NSF-WQI)

This is a standard water quality index technique was developed carefully by choosing parameters, creating a shared scale, and allocating weights [9,10,11]. This method is also called as NSF-WQI as it was accepted by National Sanitation Foundation (NSF). [12]

$$WQI = \sum_{i=1}^n Q_x W_x \tag{5}$$

Where,

Q_x = sub-index of xth water quality parameter.

W_x is weight factor associated with xth water quality parameter.

n= no. of water quality parameter.

NSF-WQI facilitates the assessment of WQI between the region and variations in water quality. This approach provides the overall quality state of water so; WQI for individual water usage is not achievable. Based on the value derived from the NFSWQI method, the status of water quality has been expressed at Table 2.

WQI Value Range	Water Quality Status
90-100	Excellent
70-90	Good
50-70	Poor
25-50	Very Poor
0-25	Unsuitable for drinking

Table2. Status of water quality by NSF-WQI

1.3 Oregon Water Quality Index (OWQI)

In this approach eight water quality parameters are combined in a single figure by WQI to assess the overall water quality of Oregon's stream and to apply the procedure for another geographic locations [13,14].OWQI used the Delphi approach to choose the water quality parameter. This method does not require the calculation of each parameter's weight. In OWQI method, 8 water quality parameters are often taken into account including pH, temperature, dissolved

oxygen (DO), biological oxygen demand (BOD), ammonia, nitrate nitrogen, total suspended solids (TSS) and electrical conductivity. The following is the OWQI mathematical expression (equation 6).

$$WQI = \sqrt{\frac{n}{\sum_{x=1}^n SI_x^2}} \quad (6)$$

n = no. of sub-indices, SI_x= sub-index data of xth parameter.

This index is significant for the changing water condition as the formulation is very sensitive. Additionally, this OWQI rating scale has been divided into a number of groups, which are listed beneath at table 3 [15].

WQI Value Range	Water Quality Status
90-100	Excellent
85-89	Good
80-84	Fair
60-79	Poor
0-59	Very Poor

Table 3. Status of water quality rating by Oregon Water Quality Index (OWQI)

1.4 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

This WQI provides a sustainable approach to evaluate surface water for the protection of aquatic existence. Minimum four criteria are needed to develop the CCME WQI, and these might change depending on the location. Moreover, screening needs to be done at least four times [16, 17]. Therefore corresponding values of water quality rating summarized in Table 4 [18, 19]. According to Siraj et al. (2023), mathematical expression of CCME index is mentioned herein [20]

$$WQI = 100 - \frac{\sqrt{F_1^2} + \sqrt{F_2^2} + \sqrt{F_3^2}}{1.7320} \quad (7)$$

Where,

F₁ is scope that is no. of variables whose objective are not encountered

F₁ = [Number of failed variables/Number of total variable] * 100

F₂ is frequency that is number of times by which the objectives are not met

F₂ = [Number of failed test/Number of total test] * 100

F₃ is amplitude that is quantity, by which the objectives are not met where,

$$F_3 = \frac{nse}{0.01nse + 0.01} \quad (8)$$

Excursion_i = [Failed tests value_j/Objective_j] - 1

$$\text{Normalized Sum Excursion} \quad nse = \frac{\sum_{i=1}^n excursion}{No_of_Tests} \quad (9)$$

WQI Value Range	Water Quality Status
95-100	Excellent
80-94	Good
60-79	Fair
45-59	Marginal
0-44	Poor

Table 4. Status of WQI by CCME Method

II. STUDY AREA

The study area consists of 20x30 m² catchment area located in Dakshin Gobindapur near Eastern Metropolitan Bypass (22°23'08.25"N&88°24'45.59"E), Kolkata, West Bengals mentioned in Fig. 1a & Fig. 1b.

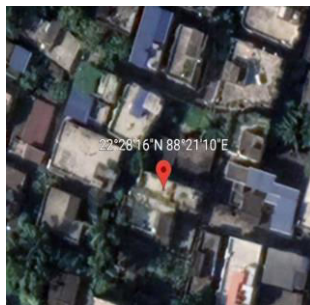


Fig. 1a



Fig. 1b

III. METHODOLOGY

Rainwater samples were collected from the roof of Civil Engineering Department, situated at the campus near Eastern Metropolitan Bypass, Kolkata, West Bengal. West Bengal generally receives ample amount of rainfall throughout the year and the study area received a well distributed annual rainfall with the average rain of 1813 mm (IMD, 2021). Harvested rainwater were collected at a time interval of 30 days to 45 days and further analysed for 7 physiochemical parameters. Five samples of rainwater were obtained from rainfall events that occurred between May and August of 2023. As per previous research findings, the first three millimeters of rainwater were discarded as the first flush [21]. Seven parameters were analyzed for the samples: dissolved oxygen (DO), pH, total suspended solids (TSS), ammonia-nitrogen (NH³-N), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), and electrical conductivity. In this study Weighted Arithmetic Mean Water quality index had been introduced for calculation of index value. Weighted Arithmetic Mean index value was therefore validated by CCME Water quality index.

IV. RESULT AND DISCUSSION

Sample No	pH	DO (mg.l ⁻¹)	BOD ₅ (mg.l ⁻¹)	COD (mg.l ⁻¹)	TSS (mg.l ⁻¹)	EC (µS/cm)	NH ₃ -N (mg.l ⁻¹)
1	5.97	5.47	1.51	0	0	214.24	0.15
2	5.92	5.65	1.54	0	1	226.31	0.23
3	5.93	5.57	1.65	0	1	203.45	0.13
4	5.99	4.78	1.79	0	2	234.69	0.27
5	5.91	5.27	1.82	0	1	255.10	0.20

Table 5. Physiochemical Parameters of collected rainwater

Weighted Arithmetic Mean WQI

Parameters	pH	DO (mg.l ⁻¹)	BOD ₅ (mg.l ⁻¹)	COD (mg.l ⁻¹)	TSS (mg.l ⁻¹)	EC (μS/cm)	NH3-N (mg.l ⁻¹)	$W_{QI} = \frac{\sum W_x Q_x}{\sum W_x}$
Sample 1	5.97	5.47	1.51	0	0	214.24	0.15	32.28
Sample 2	5.92	5.65	1.54	0	1	226.31	0.23	44.27
Sample 3	5.93	5.57	1.65	0	1	203.45	0.13	29.86
Sample 4	5.99	4.78	1.79	0	2	234.69	0.27	49.36
Sample 5	5.91	5.27	1.82	0	1	255.1	0.2	39.98

Table 6. Calculation by Weighted Arithmetic WQI Method

Mean WQI= 39

The research area is located roughly thirty kilometers from the nearest industrial zones and has low traffic intensity. Therefore, it stands to reason that the collected rainwater would be of good quality. Now based on the result obtained from the Weighted Arithmetic mean method the scaling index as mentioned in Table 1 clearly indicates that harvested rainwater quality is Good.

CCME WQI

Parameter	pH	DO (mg.l ⁻¹)	BOD ₅ (mg.l ⁻¹)	COD (mg.l ⁻¹)	TSS (mg.l ⁻¹)	EC (μS/cm)	NH3-N (mg.l ⁻¹)
BIS Standard	8.5	6	5	4	30	300	0.5
Sample 1	5.97	5.47	1.51	0	0	214.24	0.15
Sample 1	5.92	5.65	1.54	0	1	226.31	0.23
Sample 1	5.93	5.57	1.65	0	1	203.45	0.13
Sample 1	5.99	4.78	1.79	0	2	234.69	0.27
Sample 1	5.91	5.27	1.82	0	1	255.1	0.2

Table 7. Calculation of Water Quality Index by CCME

	CODE	CCME DATA	F ₁	F ₂	F ₃
No of Failed Variable(Parameters)	X	1	14.28	14.28	1.76
Total No of Variable (Parameter Studied)	Y	7			
Total No of Test	Z	35			
Total No of Fails Test	E	5			

Table 8. Calculation of Water Quality Index by CCME

From equation no7

CCME WQI=88

The result of CCME WQI clearly indicates that harvested rainwater quality is good in nature according to Table 4. It may be used right away for non-potable tasks like gardening or toilet flushing.

V. CONCLUSION

This study investigates the reliability of the harvested rainwater at Swami Vivekananda Institute of Science & Technology campus as water resource. Total Five samples of rainwater were collected from rooftop on different months were analysed for physical and chemical water parameters (pH, DO, BOD₅, COD, TSS, EC, NH₃-N). Every sample indicates the drinking water requirements established by Indian government were met in terms of pH, DO, TSS, EC and NH₃-N. The pH and oxygen content of the collected rainwater remain almost same and not changed drastically during the research days. Finally the research finding reveals that harvested rainwater may be used for non-potable usage with a little bit of treatment and disinfection is needed for drinkable purposes.

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