A Review Paper on Water Quality Index Models: Genesis, Evolution and Their Applications

G. Tirumalesh[1], S. Sharada[1*], N. Raveendhar[2]

[*1,1]*Department of Chemical Engineering, JNTUA College of Engineering Ananthapuramu, affiliated to JNTU Anantapur, Ananthapuramu, Andhra Pradesh,515 002, India*

[2]*Environment Protection Training and Research Institute, Gachibowli, Hyderabad, Telangana, India, 500032*

Abstract-The water quality index (WQI) model is a prominent technique for assessing the quality of water. Aggregation methods are used to reduce enormous volumes of water quality data to a single value or index. The WQI model has been used across the world to assess surface and groundwater quality using particular water quality criteria. From its inception in the 1960s, it's been a technique due to its universal shape and ease of use. WQI models typically require four stages: [a] the selection of water quality parameters, [b] the development of sub-indices for each parameter, [c] the computation of parameter weighting values, and [d] the aggregation of sub-indices to calculate the overall water quality index. The WQI tells that environmental factors such as geographic location and sample time had an impact on water quality. Moreover, WQI was shown as a single number that condensed a vast number of water quality variables to simplify the data. The continuous use of the WQI tool provided long-term data that assisted water management administrators, environmental consultants, and scientists make decisions and manage their resources. WQI and its development methodologies are addressed in this study, WQI's advantages as well as disadvantages and applications are discussed.

Keywords: **Water Quality Index (WQI), Water quality parameters, Sub-index Aggregation function, Water quality classification, Weight factor.**

1. INTRODUCTION

The environment cannot exist while absence of water, however the quality of both surface and groundwater is deteriorating for a long time as a result of both natural and human-caused activities. Natural factors which affect water quality Hydrogeochemical, meteorological, atmospheric, topography, and geomorphologic elements all have an impact on water quality (Magesh et al., 2013; Uddinet al., 2017, 2018). Mining, livestock grazing, wastage and land filling (industrial, municipal, and agro - industrial), Heavy metal contamination (S'anchez et al., 2007) and increased sediment run-off from land-use change (Lobato et al., 2015) appear to be a few instances of anthropogenic causes that adversely affect on water quality. As efforts are made to increase water supply and sanitation, water quality must be protected (Carvalho et al., 2011; Debels et al., 2005; Kannel et al., 2007; Ortega et al., 2016). Even developed nations have struggled to preserve or improve the quality of their water in the face of issues like vegetation and soil resource depletion as well as the provision of water and wastewater services to rising populations (Abbasi and Abbasi, 2012; Debels et al., 2005). Large water quality records that may be challenging to grasp and integrate must be gathered and reviewed in order to manage water quality. The Water Quality Index (WQI) model is one method created to analyse data on water quality. The water quality index (WQI) models, which are based on clustering techniques and enable examination of large datasets of water quality that fluctuate both temporally and geographically, generate a single value, that water quality index, which indicates the quality of the water body. Four stages or components commonly make up a WQI. Picked first are the water quality parameters that are the most important. The quantities at each water quality parameter are then converted into a single-value dimensionless sub-index once the water quality data have been read. After determining the weighting factor for each water quality parameter in step three, an aggregation function combines the sub-indices and the weighing factor for all water quality characteristics to generate a final single value water quality index Figure 1.1 illustrate that General structure of WQI model (Debels et al., 2005; Jha et al., 2015; Kannel et al., 2007; Sun et al., 2016).

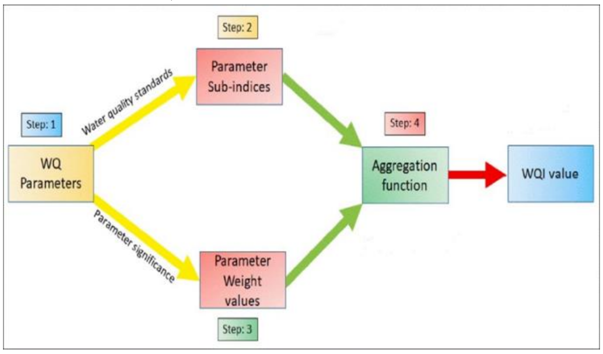

Figure 2.1 General structure of WQI model (Md.G. Uddin et al.2021)

1.1 A Brief History of WQI Models

The development history of the WQI model is roughly shown in Figure 2. Though just developed in the last 50 years, water quality indices (WQI) models have been used to categorize water quality since the mid-1800s (Abbasi and Abassi, 2012). In the 1960s, Horton created the first WQI model based on 10 water quality parameters that he thought were crucial for many waterbodies (Horton, 1965). The NSF helped Brown to create the NSF-WQI, a more rigorous iteration of Horton's WQI concept. On the choice of parameters and weighting for this model, a group of 142 water quality specialists offered their opinions (Abbasi and Abbasi, 2012). Eventually, the NSF-WQI used as the foundation for a number of other WQI models. The 1973 SRDD-WQI, developed by the Scottish Research Development Department (SRDD) to assess the quality of river water, was based on Brown's model. The Dalmatian Index, the Home Index, and the Bascaron Index are additional adaptations of the SRDD-WQI (Stambuk-Giljanovic, 2003).The Environmental Quality Index model was later developed by Steinhart et al. (1982) for the evaluation of water quality in the Great Lakes ecosystems. Another important development was the British Columbia WQI (BCWQI), which was introduced by the British Columbia Ministry for Environment, Lands and Parks in the middle of the 1990s and used to evaluate the state of many waterbodies in the province of British Columbia, Canada (Saffran et al., 2001). The BCWQI was recommended by Said et al. to be the most sensitive to sample design and dependent on the exact execution of water quality objectives (Said et al., 2004). The Canadian Council of Ministry of the Environment's Guidelines for Water Quality Working Group developed the CCME WQI in 2001 after researching and improving the BCWQI model.(Saffran et al., 2001). (Lumb et al., 2011). Since 1990, the CCME has approved the BCWQI model (Dunn, 1995). That evolution of WQI year wise presented in Table1.

Table 1. Historical development of the WQI model Year wise

S. No	WQI Model	Year of establishment	Place of established
1	Horton Index (First WQI Model)	1960	USA
2	NSF Index	1965	USA
3	SRDO Index	1970	Scotland
4	Dinius Index (Modified version of NSF	1972	USA
5	Ross Index)	1977	USA
6	Bascaron Index (Modified version of SRDD)	1979	Spain
7	Oregon Index (Modified version of NSF	1980	Oregon State and North America, USA
8	Environmental Quality Index	1982	The Great Lake, Northern America
9	House Index (Modified version SRDD, UK	1986	SRDD, UK
10	Smith Index)	1990	New Zealand
11	Dojildo Index	1994	The Vistula River, Poland
12	British Colombia WQI	1995	Canada
13	Dalmatian Index (Modified version of SRDD)	1999	Southern Croatia
14	CCME Index (Modified version BCWQI)	2001	Canada
15	Liou Index	2003	Taiwan
16	Said Index	2004	USA
17	Malaysian Index	2007	Malaysia
18	Hanh Index (Modified version of Said Index	2010	Vietnam
19	Almedia Index	2012	Argentina
20	West Java Index (Modified version of NSF)	2017	Indonesia

More than 35 WQI models have been developed to assess surface water quality worldwide (Abbasi and Abbasi, 2012; Dadolahi-Sohrab et al., 2012; Kannel et al., 2007; Stoner, 1978). The majority of the world has adopted the WQI models depicted in Fig. 2.While WQI models have been applied to evaluate the quality of all important types of water bodies, Table 2 shows that 82% of those uses have been to rivers. The data also shows that the CCME and NSF models were used in 50% of the publications that were assessed.

Table 2. Summary of WQI model applications (in total and by study area) found in literature published from 1960 to 2019.

S. No	WQI Model	Number of applications	Type of study area		
			Lake	Marine/coastal/ Sea	River
1	CCME	36	5	3	28
2	NSF	18	1	-	17
3	FIS	12	1	1	10
4	MWQI	8	1	1	6
5	Horton	7	-	1	6
6	SRDD	6	-	-	6
7	Bascaron	4	-	1	3
8	EQI	2	1	-	1
9	Oregon	2	-	-	2
10	Smith	2	--	-	2
11	Almedia	1	-	-	1
12	BCWQI	1	-	-	1
13	Dalmatian	1	-	1	-
14	Dojildo	1	-	-	1
15	Dinius	1	-	–	1
16	Hanh index	1	-	-	1
17	House Index	1	-	-	1
18	Liou Index	1	-	-	1
19	Said	1	-	1	-
20	WJWQI	1	-	1	-

2. MAJOR WQI MODELS

Twenty different WQI models were observed and noted in the study; by Using four models . Combined, they cover 85% of the 107 WQI entries that were examined. So, the design of these four models, including the methods for parameter estimation, the sub-index methods, the factor weighing schemes, and the aggregation functions, are discussed further. Four major methods are discussed in this paper.

2.1 Horton Index:

Many studies in a variety of nations have used the Horton model to analyse fresh surface water that is shown in Fig.2. The four core WQI components—parameter selection, sub-index computation, parameter weighting, and semi-aggregation and WQI evaluation can be found in Table.3 (Alobaidy et al., 2010; Ewaid and Abed, 2017).

(a) Choosing a parameter

The original Horton model included eight physicochemical water quality parameters, such as DO, pH, E -coli, specific conductance (actual TDS measured), carbon chloroforms extract, alkalinity, and chlorides. Shah and Joshi (2015); Abbasi and Abbasi (2012). Also, the percentage of the population covered by upstream treatment was included as a parameter for the model's evaluation of sewage treatment. Environmental factors that are crucial, such as parameter importance and the proportional influence of other parameters, and other considerations guided the selection of the model's parameters and data authenticity and dependability (Abbasi and Abbasi, 2012).

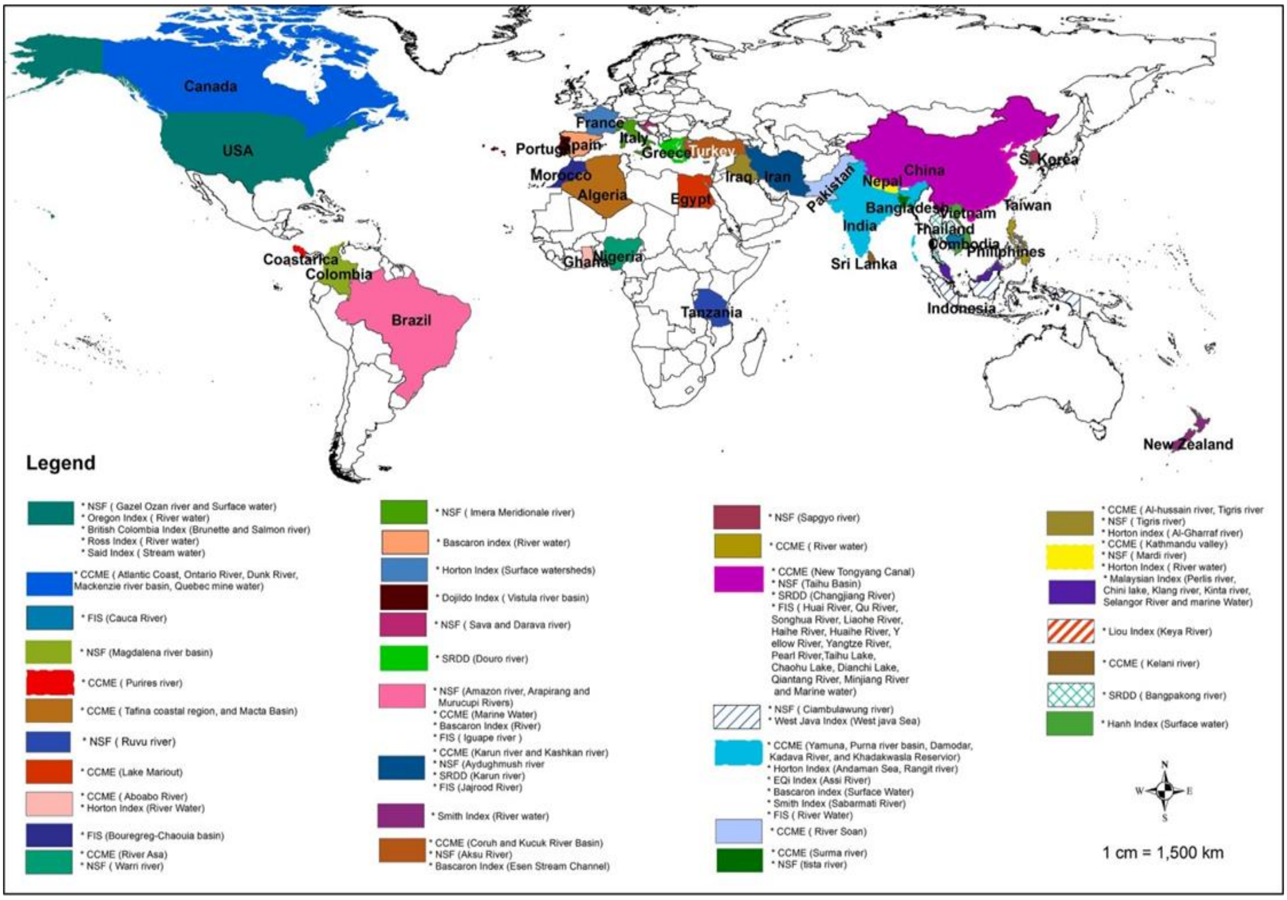

Figure 3. Countries and types of water bodies in which WQIs have been applied globally. (Md. G. Uddin et al., 2021)

(b) Sub-index Development

Horton used a linear scaling function to transform parameter values to sub-index values with sub-index values determined by the quantity or state of the pollutants. Values for the sub-index ranged from 0 to 100, with 0 indicating poor quality conditions and 100 indicating perfection. A value of 100 is awarded to the sewage treatment sub-index when treatment facilities are running and practically the whole upstream inhabitants (95 to 100%) is affected in a direct, measurable way at the location in question. A value of zero is applied if 50% of the inhabitants is given. The population being used is this taken into account while evaluating rating levels between such limits. (Horton, 1965).

(c) Weighting of parameters

The Delphi approach was used to select the parameter weight values. Weight values were assigned based on environmental importance and relative consequences. The expert panel awarded weight values to the different water quality parameters ranging from 1 to 4. Horton provided scores of 1, 2, and 4, respectively. For one parameter (faecal coliforms), Horton provided scores of 2 and 4. (DO, sewerage treatment and pH).

(d) Aggregation

The resulting WQI value is aggregated using the following formula:

$$WQI = \left[\frac{W_1S_1 + W_2S_2 + W_33 + \cdots + W_nS_n}{W + W_2 + W_{3+\cdots}W_n}\right] m_1 m_2 \text{(eq.1)}$$

Where m_1 and m_2 stand for the apparent pollution and temperature coefficients, respectively. m1 = 0.5 is used when the temperature is below 34 °C, while m1 = 1.0 is used when the temperature is above 34 °C Things that irritate the eyes and nose are referred to as the obvious pollution. The development of filth deposits, the existence of oil, waste, foam, mucus, or other liquid elements, and waste discharge are only a few examples of these conditions that causes a color or odour disturbance. When there are visible indicators of emissions, m_2 is set to 0.5; otherwise, it is set to 1.0. In 1970, Brown conducted a critical review of the Horton index. (1970; Brown et al.). According to this study, the two additional criterion temperature and evident pollution utilized in the aggregation function were not graded; therefore the index just shows fluctuations in water quality. Brown further investigated the model parameters, taking into account advice from experts and suggested weight values, and gave the weighted average index formula for stream water as follows:

$$Brown\ WQI = \sum_{i=1}^{n} \mathrm{W_i}\, S_i \qquad \text{(eq.2)}$$

(e) WQI evaluation

Table. 3. The Horton model recommends the following five water quality classes for the value of the final water quality index:

S. No	WQI Value	Water Classification
1	91–100	Very good
2	71 – 90	Good
3	51 – 70)	Poor
4	31 – 50	Bad
5	0 – 30)	Very bad

2.2 National Sanitation Foundation Water Quality Index: *(*Sneha S. Phadatare et al., 2015)

National Sanitation Foundation (NSF) Water Quality Index" (WQI), which was developed by the US National Sanitation Foundation in 1970. The WQI was developed utilizing the Delphi method and a panel of 142 people from around the United States with experience in various elements of water quality management. There are 101 regulatory authorities, five managers of neighborhood public utilities, six consulting engineers, 26 academics, and four more individuals, comprising industrial waste control engineers and officials of trade associations, and that questions which can asked by authorities presented in Table.4 to complete water quality parameters and the water quality index, the organization conducts the following actions:

1. The panelists received three questionnaires in all.
2. Based on its significance to overall water quality, they were asked to mark each water pollutant variable in Table 4 as "include," "undecided," or "do not include" in the first questionnaire.
3. From highest relative importance to lowest relative significance, the scale goes down.
4. In the second questionnaire, respondents have the chance to reflect on their first assessment and, if they so want, amend their opinion. The most significant criteria are dissolved oxygen, faecal coliform, pH, 5-day biological oxygen demand, nitrates, phosphates, temperature fluctuations, turbidity (in NTU), and total solids.
5. The third questionnaire asked participants to develop a rating curve for each variable that was included. For this reason, blank graphs are provided, with the ordinate of each graph stating the degree of water overall quality from 0 to 100.
6. Participants were to build a graph curve to depict the variation in water quality brought on by different concentrations of each pollution variable.
7. After sorting the curves, the research team produced a set of "average curves" as a consequence of their work. A solid line represents the arithmetic mean of all participants, while dotted lines that are bound by a shaded area reflect the 80% confidence range.

The mathematical formula for the NSF Water Quality Index is: for calculating the total WQI.

$$NSF\ WQI = \sum_{i=0}^{n} W_i Q_i \quad \text{(eq.1)}$$

Where,

Qi is a sub-index for ith parameters relating to water quality. Wi is the important weight attached to the i_{th} water quality parameter. The number of variables affecting water quality is n.

Table 4. Different variables considering for NSF WQI questionnaires

Candidates' variables considered for the NSE WQI in questionnaire	
Dissolved Oxygen	Oil and grease
Fecal coliforms	Turbidity
pH	Chlorides
Biological Oxygen demand (5 Days)	Alkalinity
Coliform Organisms	Iron
Herbicides	Color
Phosphates	Manganese
Temperature	Fluorides
Pesticides	Copper
Nitrates	Sulfates
Dissolved Oxygen	Calcium
Radioactivity	Hardness
Phenols	Sodium& Potassium
Chemical Oxygen Demand	Acidity
Carbon chloroform	Bicarbonates
Ammonia	Magnesium
Total Solids	Aluminum

2.2.1 Advantages of NSF-WQI are as follows:

1.The NSFWQI allows for the objective, quick, and repeatable summarization of data into a single index value.

2. By examining many aspects, we can spot changes in water quality.

3. The values of the index relate to a possible consumption of water.

2.2.2 Disadvantages of NSF-WQI are as follows:

1.It indicates generic water quality rather than a specific application of water, and there is data loss during handling.

2.In this failure to address the subjectivity and unpredictability that complex environmental issues contain.

2.3 Weighted Arithmetic Water Quality Index: (Sneha S. Phadatare et al., 2015)

For assessing the most frequent quality variables, this method is used. The parameters or variables were examined in the lab using APHA 1995 standard techniques. The following equation is used to determine the water quality index:

Step1: To calculate quality rating (Qn):

$$\text{Quantity rating (Qn)} = 100 \times \frac{V_n - V_i}{V_s - V_i} \qquad \text{(eq.1)}$$

Where,

Vn represents the actual value of a given parameter in a water sample.

Vi = the parameter's ideal value (0 for all variables except pH, which has a 7 Milligram/ Liter value).

VS stands for the parameter's standard value.

Step2: To find unit weight (Wn):

$$\text{Wn=K/ Vs} \qquad \text{(eq.2)}$$

$$\text{Where } K = \frac{1}{\frac{1}{V_{s1}} + \frac{1}{V_{s2}} + \frac{1}{V_{s3}} \ldots + \frac{1}{V_{sn}}} \qquad \text{(eq.3)}$$

Step3: To calculate water quality index (WQI):

$$WQI = \frac{\sum \mathrm{Q_n W_n}}{\sum \mathrm{W_n}} \qquad \text{(eq.4)}$$

Table. 5. Weighted Arithmetic Quality index and status of water

Water Quality Index	Description Status	Category
0-25	Excellent quality	A
26-50	Good quality	B
51-75	Poor quality	C
76-100	Very poor quality	D
>100	Unsuitable for drinking	E

2.3.1 The advantages of Weight Arithmetic WQI:

1. We may include a variety of quality factors into mathematical equations that assign ratings and grades to water bodies.
2. The usage of water simplifies comparisons because there are fewer parameters to compare.
3. This value is highly valuable for communicating overall water quality information to policymakers and public.
4. In the case of fresh water bodies, assurance concerning the appropriateness of the water for human consumption.
5. Several criteria that may be employed with their composition for water quality evaluation and management.

1.3.2. *The disadvantages of the Weight Arithmetic WQI:*

1. The figure provided by the water quality index may not accurately reflect the current state of water quality.

2. The Water Quality Index's can be completely changed by a single failed or exceeded parameter value.
3. The index does not take into account different other water quality factors.

2.4 Canadian Council of Ministers of the Environment (CCME) WQI

The British Columbia WQI Model (BCWQI) was utilized to create the CCME model in 2001. (Lumb et al., 2011). Several surface water bodies across the world have employed the CCME WQI model (Abbasi and Abbasi, 2012; Uddin et al., 2017). Due to its simplicity of use and versatility. It is quite popular in selecting the water quality criterion to be included in the model. The study revealed that several CCME model applications for assessing the quality of surface water (river or ocean) in various regions of the world and it is presented in Fig. 2, and Table 6. Represents that CWQI evaluation and water quality status

a) Selecting a parameter

At least four water quality metrics are required to be used according to the CCME WQI model. But the user is free to select which ones to utilize (Saffran et al., 2001).The developers advise utilizing the evaluation procedures for expert panels for choosing model parameters.

b) Calculating a sub-index

There is no sub-index calculation component in the CCME model. This is a significant flaw in this paradigm relative to other ones.

c) Weightings of the parameters

To calculate the final WQI, parameter weight values are not necessary.

d) Aggregation

The CCME uses an aggregation function that is very different from that of other models. It is written as:

$$CWQI = 100 - \left[\frac{\sqrt{{F_1}^2+{F_2}^2+{F_3}^2}}{1.732}\right] \quad \text{(eq.1)}$$

(a) F1: Also known as the "scope," this number represents the proportion of all parameters that fall short of the stated goals. It is written as:

$$F_1 = \left[\frac{number\ of\ failed\ parameters}{total\ number\ of\ parameters}\right] \times 100 \quad \text{(eq.2)}$$

(b) F2: also known as the "frequency," this number represents the proportion of individual test results that fall short of the set goals (failed tests). It is written as:

$$F_2 = \left[\frac{number\ of\ failed\ tests}{total\ number\ of\ tests}\right] \times 100 \quad \text{(eq.3)}$$

(c) F3: Also known as the "amplitude," this figure reflects how far test results fall short of the desired results. The asymptotic function that produces a number between 0 and 100 by scalating the normalized sum of excursions (nse) of the test values from the objectives is used to compute the amplitude.

$$F_3 = \left[\frac{nse}{0.01(nse)+0.01}\right] \times 100 \quad \text{(eq.4)}$$

When a test value differs from the objective level, the deviation is calculated as follows:

$$excursion_i = \left[\frac{failed\ test\ value_i}{Objective_j}\right] -1 \quad \text{(eq.5)}$$

Conversely, the excursion value is computed as follows if the test value is greater than the objective value:

$$excursion_i = \left[\frac{Objective_j}{failed\ test\ value_i}\right] - 1 \quad \text{(eq.6)}$$

The aggregate deviation, or nse, between specific test results and their objectives is then calculated by summing all of the variances and dividing them by the total amount of tests. Mathematically, this is written as:

$$nse = \left[\frac{\sum_{i=1}^{n} excursion_j}{number\ of\ test}\right] - 1 \quad \text{(eq.7)}$$

To ensure that the resultant WQI is between 0 and 100, where 0 represents the "worst" water quality and 100 represents the "best," the divisor of 1.732 in equation 1 is used as a normalisation factor (Saffran et al., 2001). Because the highest value of each of the three independent index components (F1, F2, and F3) is 100,the numerator can have a maximum value of 173.2, resulting in the factor of 1.732 (Neary et al., 2001).

Table 6. CCME WQI evaluation

CCME WQI	Description of WQI	Type of water
95-100	Excellent	natural water quality
80-94	Good	water quality is departed from natural or desirable levels
65-79	Fair	water quality condition sometimes departs from natural or desirable levels
45-64	Marginal	water quality is frequently threatened or impaired; conditions often depart from natural or desirable level
0-44	Poor	water quality is not suitable for using purposes at any level.

2.4.1 Advantages of CCME WQI Method:

1. Flexibility when choosing input parameters and goals
2. Flexibility to accommodate various regulatory mandates and water use variations
3. Simplifying complicated multivariate data using statistics
4. A diagnosis that is simple to understand for management and the general public.
5. A useful instrument for assessing the water quality in a particular area
6. Tolerance for incomplete data
7. Simple to compute
8. Appropriate for data analysis using automated sampling
9. Implementation expertise
10. Thinks about amplitude (of difference from the objective)

2.4.2 Disadvantages of CCME WQI Method:

1. Instructions about the variables to be utilised in the calculation of the index are missing
2. Lack of standards about the goals related to each site and individual water usage
3. Simple to control (biased)
4. All factors are given equal weight.
5. No combining of biological data or other indications
6. The water quality is only partially diagnostic.
7. When too few variables are taken into account or when there is an excessive amount of covariance between them, F1 does not function properly. The weight of the element in computing the index is excessive.

3. WQI APPLICATION

The same four strategies that had previously been employed to establish a WQI were investigated by Sutadian et al. in 2016 for 30 WQIs that had been established and implemented in various locations throughout the world. This study simultaneously examined the most popular indices in a separate nation, concentrating on the Iraqi publications throughout the previous four years presented in Table.7. The most widely used indicator for evaluating the water quality in various Iraqi municipalities is the CCME. It has little sensitivity to missing data, is flexible in creating standards or criteria, and may encompass a large number of variables. [Ismail AH, Robescu D and Hameed MA 2018].

Table 7. List of Reviewed WQIs with their Application

WQI name	Location	Numbers of Parameters	Purpose of application	Ref..
Weighted arithmetic mean (Brown index)	India	5	Surface water	[Nihalani S et al., 2020]
	Bengal	9	Drinking and health risk assessment	[Pattnaik P et al., 2020]
	Egypt/ Lake Qarun	Irrigation =12 Aquatic Life = 7	Irrigation and aquatic life	[Afify A et al., 2019]
	Kenya	9	Human use	[Robert G K et al., 2020]
	Nigeria	12	Drinking	[Emeka D et al.,2019]
	Iraq/ Al Hammar marsh	12	Surface water quality	[38]
	Iraq/ Springe water	11	Drinking-water	[Ameen HA 2019]
	Iraq Shatt – Al Kufa in Najaf	11	Irrigation	[Kizar M F 2018]
	Iraq/ Baghdad/ Tigris River	11	Drinking	[Al-Obaidy A et al., 2016]
NSF WQI	Nigeria	9	Drinking	[Kalagbor I A et al., 2019]
	Iran	7	Irrigation	[Misaghi F et al., 2017]
	Indonesia	9	Drinking-water	[Ichwana I et al., 2016]
	Lower Zab River	8	Surface water	[Ahmed SM et al.,2020]

CCME	All states in Canada	28	Versions use	[Khan F et al.,2003]
	Hungarian	8	Groundwater	[Mester T et al.,2020]
	Algeria	7	Irrigation	[Bouhezila F et al.,2020.]
	Romania	13	Drinking	[Ismail AH et al., 2018]
	Egypt Lake	30	Irrigation and aquatic life	[Goher M E et al.,2019
	Turkey	12	Surface water	[Bilgin A 2018]
	Iraq/ Mosul/ Tigris River	13	Drinking	[Ramadhan O et al.,2018]
	Iraq/ Mosul/ Wells	11	Drinking and civilian purposes	[Al-Saffawi A et al.,2019]
	Iraq/ Anbar/ Euphrates River	14	Drinking- water quality	[Saod W et al.,2020]
	Iraq/ Baghdad/Tigris	10	River	[Ahmed Q N and Gubashi R K 2020]
	Iraq/Diyala river	8	Aquatic life	[Hassan F M et al.,2017]
	Iraq/ Diwanyiah River	9	Aquatic life	[Abbas A and Hassan F M 2018]
	Iraq/ Garmat Ali	5	River water quality	[Mohamed A et al.,2017]

CONCLUSIONS

An effective and simple method for reporting data on water quality is the water quality index. It has shown to be a useful technique for assessing temporal and spatial water changes in any area of the world. Large volumes of intricate water quality data may be easily and consistently reduced to a single number using water quality indices. This procedure shows how widely and effectively WQIs have been used during the past 60 years. They assist in drawing conclusions from vast volumes of complex scientific data and in communicating the state of water quality to the general public and governmental decision-makers. The straightforward dimensionless index score will be easy for non-technical stakeholders to grasp. After cover the benefits and drawbacks of the National Sanitation Foundation WQI, CCME, and Weight Arithmetic WQI, Horton all of which are beneficial for monitoring, evaluating, and conducting impact studies for various water bodies in various geographic areas. It is beneficial for various decision-makers to take appropriate action or identify solutions.

ACKNOWLEDGEMENT

The authors thank the Environmental Protection Training and Research Centre (EPTRI), Telangana, India and the Department of Chemical Engineering at Jawaharlal Nehru Technological University Ananthapuramu (JNTUCEA), Andhra Pradesh, India for their assistance throughout the study.

REFERENCE

[1] Abbas A and Hassan F M 2018 Water quality assessment of Euphrates River in Qadisiyah Province(Diwaniyah River), Iraq. Iraqi J Agric Sci. 49 2 251–61.

[2] Abbasi, T., Abbasi, S.A., 2012. Water-Quality Indices. Water Quality Indices. Elsevier, pp. 353–356. https://doi.org/10.1016/B978-0-444-54304-2.00016-6.

[3] Afify A D, Tahoun U M and Abdo M H 2019 Egyptian Journal of Aquatic Biology & Fisheries. Egypt J AquatBiol Fish 23 1 341–57. Available from: http://www.elsevier.com/locate/scp

[4] Ahmed Q N and Gubashi R K 2020 Water Quality index in Tigris River within Baghdad City. J EngSustain Dev. 24 80–90.

[5] Ahmed SM, Taha O M, Najemalden M A, Ahmed R T and Abedulwahab A .2020 Assessment of Lower Zab river water quality using both Canadian Water Quality Index Method and NSF Water Quality Index Method. Sci Rev Eng Environ Sci. 29 2 155–71.

[6] Al-Musawi NO, Al-Obaidi SK and Al-Rubaie FM 2018 Evaluating water quality index of al Hammar Marsh, south of Iraq with the application of GIS technique. J Eng Sci Technol. 13(12):4118–30.

[7] Al-Obaidy A M J, Awad ES and Zahraw Z 2016 Impact of Medical City and Al-Rasheed Power Plant Effluents on the Water Quality Index Value of

Tigris River at Baghdad City. Eng&Tech J. 34 4715–24.

[8] Al-Saffawi A A 2019 Water quality of Nimrud District wells southeast of Mosul city for drinking and civil purpose using the Canadian model of water quality. Pakistan J Anal Environ Chem. 201 75–81.

[9] Bilgin A 2018 Evaluation of surface water quality by using Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) method and discriminant analysis method: a case study Coruh River Basin. Environ Monit Assess.190 544 1–11.

[10] Bouhezila F, Hacene H, Aichouni M 2020 Water quality assessment in Reghaia (North of Algeria)lake basin by using traditional approach and water quality indices. Kuwait J. Sci. 47 4 57-71, Available from http://helios-eie.ekt.gr/EIE/handle/10442/13107

[11] Carvalho, L., Cortes, R., Bordalo, A.A., 2011. Evaluation of the ecological status of an impaired watershed by using a multi-index approach. Environ. Monit. Assess. 174, 493–508.

[12] Dadolahi-Sohrab, A., Arjomand, F., Fadaei-Nasab, M., 2012. Water quality index as a simple indicator of watersheds pollution in southwestern part of Iran. Water Environ. J. 26, 445–454. https://doi.org/10.1111/j.1747-6593.2011.00303.x.

[13] Debels, P., Figueroa, R., Urrutia, R., Barra, R., Niell, X., 2005. Evaluation of water quality in the Chill´an River (Central Chile) using physicochemical parameters and a modified Water Quality Index. Environ. Monit. Assess. https://doi.org/10.1007/ s10661-005-8064-1.

[14] Dunn, G.W., 1995. Trends in water quality variables at the Alberta/ Saskatchewan Boundary. Prepared For The Committee On Water Quality.

[15] Emeka D A and Chinonyerem S E 2109 Application of Water Quality Index in the Drinking Water Quality. Quality Assessment of a Southeastern Nigeria River. J. of Facu. of Food Enginee. eXVIII 4 308 – 314

[16] Ewaid, S.H., Abed, S.A., 2017. Water quality index for Al-Gharraf River, southern Iraq. Egypt. J. Aquat. Res. https://doi.org/10.1016/j.ejar.2017.03.001.

[17] Goher M E, Mahdy E S, Abdo M H, El Dars F M, Korium M A, Elsherif A 2019 Water quality status and pollution indices of Wadi El-Rayan lakes, El-Fayoum, Egypt. Sustain Water ResourManag. 5 2 387–400.

[18] Hassan F M, Al-Jibouri K D and HakmanA .A 2017 Water quality assessment of Diyala river in Diyala province, Iraq. Mesop environ j. 4 41 52–61.

[19] Horton, R.K., 1965. An index-number system for rating water quality. J. Water Pollut. Control Fed. 37, 300–306. https://doi.org/10.2307/25035251.

[20] Ichwana I, Syahrul S and Nelly W 2016 Water Quality Index by Using National Sanitation Foundation-Water Quality Index (NSF-WQI) Method at KruengTamiang Aceh. Int Conf Technolnnov Soc. 3 110–7.

[21] Ismail AH, Robescu D and Hameed MA 2018 Application of CCME WQI in the Assessment of the Water Quality of Danube River, Romania. Engineer. and Techno. 36 2 142–6. Available from: http://dx.doi.org/10.30684/etj.36.2C.8

[22] Jha, D.K., Devi, M.P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N.V., Kirubagaran, R., 2015. Water quality assessment using water quality index and geographical information methods in the coastal waters of Andaman Sea, India. Mar. Pollut. Bull. 100, 555–561. https://doi.org/10.1016/j.marpolbul.2015.08.032.

[23] Kalagbor I A, Johnny V I and Ogbolokot I E 2019 Application of National Sanitation Foundation and Weighted Arithmetic Water Quality Indices for the Assessment of Kaani and Kpean Rivers in Nigeria. Am J Water Resour. 7 1 11–5.

[24] Kannel, P.R., Lee, S., Lee, Y.-S., Kanel, S.R., Khan, S.P., 2007. Application of Water Quality Indices and Dissolved Oxygen as Indicators for River Water Classification and Urban Impact Assessment. Environ. Monit. Assess. 132, 93–110. https://doi. org/10.1007/s10661-006-9505-1.

[25] Khan F, Husain T and Lumb A 2003 Water quality evaluation and trend analysis in selected watersheds of the Atlantic region of Canada. Environ Monit Assess 88 1–3 221–48.

[26] Kizar M F 2018 Using Arithmetic Weighted and Bhargava Methods to Classify Irrigation Water Quality Index for Shatt-Al Kufa in Najaf Province, Iraq. Int J Eng Technol. 7 4.20 431–7.

[27] Lobato, T.C., Hauser-Davis, R.A., Oliveira, T.F., Silveira, A.M., Silva, H.A.N., Tavares, M. R.M., Saraiva, A.C.F., 2015. Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: A case study in the Amazon region. J. Hydrol. 522, 674–683. https://doi.org/10.1016/j.jhydrol.2015.01.021.

[28] Lumb, A., Sharma, T.C., Bibeault, J.-F., 2011. A Review of Genesis and Evolution of Water Quality Index (WQI) and Some Future Directions. Water Qual. Expo. Heal. https://doi.org/10.1007/s12403-011-0040-0.

[29] Magesh, N.S., Krishnakumar, S., Chandrasekar, N., Soundranayagam, J.P., 2013. Groundwater quality assessment using WQI and GIS techniques, Dindiguldistrict,Tamil Nadu, India. Arab. J.

Geosci. 6, 4179–4189. https://doi.org/10.1007/s12517-012-0673-8.

[30] Mester T, Balla D and Szabo G 2020 Assessment of Groundwater Quality Changes in the RuralEnvironment of the Hungarian Great Plain Based on Selected Water Quality Indicators. Water AirSoil Pollut. 231 536 1–14. Available from: http://dx.doi.org/10.1007/s11270-020-04910-6

[31] Misaghi F, Delgosha F, Razzaghmanesh M and Myers B 2017 Introducing a water quality index for assessing water for irrigation purposes: A case study of the Ghezel Ozan River. Sci Total Environ 589 107–16.

[32] Mohamed A-RM, Younis KH and Hameed EK 2017 the Ecological Condition of the Garmat AliRiver, Iraq. Glob J Biol Agric Heal Sci. 6 (3):13–21.

[33] Nihalani S and Meeruty A 2020 A Water quality index evaluation for major rivers in Gujarat. Environ Sci Pollut Res Int. Aug 19. doi: 10.1007/s11356-020-10509-5.

[34] Ortega, D.J.P., Perez, D.A., Americo, J.H.P., De Carvalho, S.L., Segovia, J.A., 2016. Development of index of resilience for surface water in watersheds. J. Urban Environ. Eng. 10, 72–82.

[35] Pattnaik P and Bhowmick PK 2020 Determination of Water Quality Index of Drinking Water Sources and Health Risk Assessment of Arsenic-Contaminated Rural Areas in Basirhat-1 Block of West Bengal. Int J InnovTechnolExplor Eng. 9 3 677–84.

[36] Phadatare, S. S., & Gawande, S. (2016). Review paper on development of water quality index. International Journal of Engineering Research and Technology (IJERT), 5(5), 765-767.

[37] Ramadhan O, Al-Saffawi A, Al-Mashhdany M 2018 Application of water quality index [CCMEWQI] to assess surface water quality: A case study of Khosar and Tigris rivers in Mosul, Iraq.Interna. J. of Enha. Rese. in Scie. Technol. &Enginee. 7 12, 1-8.

[38] Robert G K, Onyari C N and Mbaka J G 2020 Development of a Water Quality Assessment Index\ for Kenya's Chania River. African J Aquat Sci. 45 1–11.

[39] S´anchez, E., Colmenarejo, M.F., Vicente, J., Rubio, A., García, M.G., Travieso, L., Borja, R., 2007. Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecol. Indic. 7, 315–328. https://doi.org/ 10.1016/j.ecolind.2006.02.005.

[40] Saffran, K., Environment, A., Cash, K., Canada, E., 2001. Canadian Water Quality Guidelines for the Protection of Aquatic Life CCME WATER QUALITY INDEX 1 . 0 User ' s Manual. Quality 1–5.

[41] Saod W M, Al-Heety E A and Mohammed M M 2020 Spatial and temporal variation of water quality index of Euphrates River in Anbar Governorate, Iraq. AIP Conf Proc. 2213 1–8.

[42] Shah, K.A., Joshi, G.S., 2015. Evaluation of water quality index for River Sabarmati, Gujarat, India. Appl. Water Sci. https://doi.org/10.1007/s13201-015-0318-7.

[43] Stambuk-Giljanovic, 2003. Comparison of Dalmatian Water Evaluation Indices. Water Environ. Res. 75, 388–405. https://doi.org/10.2175/106143003X141196.

[44] Steinhart, C.E., Schierow, L.-J., Sonzogni, W.C., 1982. An environmental quality index for the great lakes. JAWRA J. Am. Water Resour. Assoc. https://doi.org/10.1111/ j.1752-1688.1982.tb00110.x.

[45] Stoner, J.D., 1978. Water-Quality Indices for Specific Water Uses. Geol. Surv. Circ.

[46] Alobaidy, A.H.M.J., Abid, H.S., Maulood, B.K., 2010. Application of Water Quality Index for Assessment of Dokan Lake Ecosystem, Kurdistan Region, Iraq. J. Water Resour. Prot. Doi: 10.4236/jwarp.2010.29093.

[47] Sutadian AD, Muttil N, Yilmaz A and Perera C 2016 Development of River Water Quality Indices

[48] A Review. Environ Monit Assess. 188 58 1–33.

[49] Sun, W., Xia, C., Xu, M., Guo, J., Sun, G., 2016. Application of modified water quality indices as indicators to assess the spatial and temporal trends of water quality in the Dongjiang River. Ecol. Indic. 66 https://doi.org/10.1016/j.ecolind.2016.01.054.

[50] Uddin, M.G., Moniruzzaman, M., Quader, M.A., Hasan, M.A., 2018. Spatial variability in the distribution of trace metals in groundwater around the Rooppur nuclear power plant in Ishwardi, Bangladesh. Groundw. Sustain. Dev. https://doi.org/10.1016/j. gsd.2018.06.002.