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A Review of Different Methods Used to Compute the Drinking Water Quality Index

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ABSTRACT

These days, the globe is very concerned about diminishing water quality (WQ) due to factors including increased industrial and agricultural activities, fast population expansion, global warming, and climate change that affect hydrological cycles. For biological purposes, freshwater availability must be sufficient, and it is also a crucial component of integrated sustainable environmental development. Among the most used instruments for characterizing WQ is the Water Quality Index (WQI). It is calculated as a single number between 0 and 100 by combining physical, chemical, and biological components. Additionally, WQI was projected as a single number that condensed the enormous number of WQ characteristics and succinctly summarized the data. Decision-making for scientists, environmental engineers, and water resource managers was facilitated by the long-term data produced by the ongoing use of WQI technology.

The primary objective of this article is to outline the top five widely used approaches for determining the drinking WQI, along with the benefits and drawbacks of each. The methods include the Weighted Arithmetic WQI (WAWQI), the National Sanitation Foundation WQI (NSF WQI), the Canadian Council of Ministers of the Environment WQI (CCME WQI), the Oregon WQI (OWQI), and the Bhargava WQI (BWQI). The study's goal and the water's characteristics should be considered when selecting one of the five approaches.

Key Worlds: Drinking Water, BWQI. OWQI, WQI, WAWQI, NSF WQI, CCME WQI.

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1. INTRODUCTION

The main component of an ecosystem is water, a valuable national resource and top natural resource. The survival of humans would be at jeopardy without water [1]. The welfare of humans depends on the availability of fresh water. Among all the resources that people want in cities and rural areas, water is one of the most in demand because of human activity. The most popular sources of surface water have historically been rivers, streams, and lakes because of their accessibility and availability [2]. Most human advancement has occurred quickly along riverbanks as a result of this situation [3,4]. Beyond the need for drinking water (DW), water resources are critical for many other economic sectors, such as forestry, agriculture, fishery, manufacturing, hydropower generation, and cattle rearing. Numerous important causes, including as urbanization, industry, and population increase, have contributed to the deterioration in surface and groundwater availability and quality. By 2025, it is expected that about two-thirds of all nations would experience water stress, with over 1.1 billion people now without access to clean DW [5]. Due to human influences, climate change, and hydrology, there is a possibility that the vast social and economic growth may cause contaminants to accumulate in surface water, which could eventually alter the quality of the water supply [6]. As was already noted, having an adequate supply of water in both an ideal quantity and quality is vital for survival; However, the water resources management sector has challenges in maintaining an adequate level of WQ [7].

It is imperative to conduct routine water quality monitoring of the available water resources in order to evaluate the water quality for industrial, agricultural, residential, and ecological health and hygiene purposes [8]. Any location or source's WQ can be assessed using physical, chemical, and biological variables. When these factors' values above specific thresholds, there is a potential risk to human health [9,10].

One of the most effective ways to describe the quality of water is to use the WQI, which reduces a lot of data to a single value between 0 and 100. In light of this, WQI has been used to characterize the acceptability of various water sources for human consumption. [11]. Therefore, the study's goal is to evaluate the WQI idea by enumerating some of the significant WQI that are used globally for WQ evaluation, outlining the benefits and drawbacks of the indices that were chosen.

2. WATER QUALITY INDEX

To assess the ecological state of a water body, a numerical expression known as the WQI is used [12-14]. Originally created in the United States by Horton in 1965 [15], WQI was extensively recognized and used in Asian, African, and European countries. It was created using 10 of the most commonly used WQ variables, such as dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity, and chloride. In 1970, Brown and colleagues developed the NFS-WQI index. This is a better Horton's index version [16,17]. Various worldwide and national organizations representing various states have created a variety of WQI in response to their requirement to assess the quality of the water in a particular area of interest. As of yet, experts have not proposed a reliable technique for evaluating the quality of water that could be applied globally. Furthermore, no technique for assessing the quality of water provides 100% objectivity and accuracy [18].

A variety of WQI have been developed globally, some examples of which are the Oregon WQI (OWQI), the Bhargava WQI (BWQI), the US National Sanitation Foundation WQI (NSF WQI), and the Canadian Council of Ministers of the Environment WQI (CCME WQI) [19 -22]. The Weighted Arithmetic WQI Method (WAWQI), which incorporates several quality parameters into a single basic mathematical equation, is a more suitable approach than other approaches for calculating the WQI [23]. These indices compare various parameters in accordance with standards to provide a single number for water quality.

This paper's primary objective is to outline the five most common techniques for determining the drinking water quality index (WQI) and to assess how beneficial these techniques are for research assessing water quality.

2.1. Weighted Arithmetic Water Quality Index (WAWQI)

The weighted arithmetic index is used to calculate the treated WQI; to put it another way, this method uses the most frequently measured WQ variables (pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), Total Hardness (TH), chloride (Cl), turbidity, alkalinity, and sulfate (SO_4) to classify the water quality based on the level of purity [24,25]. Scientists have utilized this process extensively [26-30] and using the subsequent equation, the WQI was calculated [31]:

$$\boldsymbol{WAWQI = \sum W_n\, Q_n / \sum W_n} \quad \textbf{(1)}$$

Where: *WAWQI*, which evaluates the water quality, has a value between 0 and 100; *n* is the number of parameters considered; For every parameter, the quality rating scale (Q_n) is computed using the following expression [32,33]:

$$\boldsymbol{Q_n = [(v_n - v_0)/(s_n - v_0)] * 100} \quad \textbf{(2)}$$

Where,

v_n is the water's analyzed ith parameter's estimated concentration.

v_0 is this parameter's optimal value in pure water (v_0 = 0 except pH =7.0 and DO = 14.6 mg/l).

s_n is the standard acceptable value for the nth parameter.

W_n is a factor that indicates how important a parameter is in determining the WQI (relative weight); W_n is calculated by using the following formula [32,33]:

$$\boldsymbol{W_n = k/s_n} \quad \textbf{(3)}$$

Where, *k* is the proportionality constant, which is also computed with the use of the subsequent formula [25,34]:

$$\boldsymbol{k = 1/\sum(1/s_n)} \quad \textbf{(4)}$$

The water ecological status can be ascertained using the value derived from the Weighted Arithmetic WQI approach, as shown in Table 1.

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Table 1: Rating of Water Quality Using Water Quality Index Techniques

Class	WAWQI [2,11,25,33]	NSF WQI [18,44,45]	CCME WQI [2,21,31,53]	OWQI [11,56,60,61]	BWQI [51,56,57]	Water Quality
I	0 - 25	91 - 100	95 - 100	90 - 100	95 - 100	Excellent water
II	26 - 50	71 - 90	80 - 94	85 - 89	75 - 94	Good water
III	51 - 75	51 - 70	60 - 79	80 - 84	50 - 74	Fair water
IV	76 - 100	26 - 50	45 - 59	60 - 79	25 - 49	Poor water
V	> 100	0 - 25	0 - 44	0 - 59	0 - 24	Very poor water

Of benefits of this method, according to earlier research, is that it incorporates the data from various physico-chemical water quality criteria into a mathematical formula that illustrates the water's ecological condition; it also reflects the significance of each parameter in the evaluation and management of WQ and requires fewer parameters overall for a given use [2,11]. useful for informing concerned individuals and decision-makers on the general state of the water quality and outlining which surface and groundwater sources are suitable for human use.

Among this method's drawbacks, this indicator might not offer sufficient details regarding the actual state of the WQ [2,11]. Many consumers of water quality data have needs that an index cannot meet. one figure cannot adequately convey the tale of the state of the water due to the exaggeration or overstretching of a single wrong parameter value, numerous additional WQ factors are not included in the index [34,35].

2.2. National Sanitation Foundation Water Quality Index (NSF WQI)

Brown first presented the NSF WQI model in 1965 [36,37]. The National Sanitation Foundation (NSF) of the United States created the NSFWQI in 1970 [38,39]. It is a modified version of Horton's WQI. This WQI has undergone substantial field testing and is used to calculate and evaluate the WQI of various water bodies [36,38]. Currently, several researchers are using this approach to assess the quality of water that is fit for human consumption [36,40,41].

Based on the study of nine variables or parameters, including temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates, and total solids [42,43], Asia, Africa and Europe have all adopted and widely utilized the NSF WQI [30]. The following is the mathematical expression for NSF WQI:

$$\boldsymbol{NSF\ WQI = \sum_{n=1}^{i} W_n Q_n} \qquad \textbf{(5)}$$

where Q_n is the sub-index of the quality parameter n, derived from the conversion curve (which converts parameters based on values in the interval 0-100); W_n is the weighting factor for each parameter (DO = 0.17, coliforms = 0.16, pH = 0.11, BOD = 0.11, Temperature = 0.1, Nitrates = 0.1, Total phosphate = 0.1, Turbidity = 0.08, TDS = 0.07) [18,44,45], i = number of water quality parameters.

Using Table 1, the WQ ratings for this NSFWQI approach have been determined. Among the advantages of this approach, prior studies have found that it summarizes the data pertaining to the parameters under analysis inside a single number quickly, objectively, and reproducibly; The assessment of water quality varies across different regions; the water use potential is indicated by the index value [46,47]. The lack of use of a sophisticated scale of water quality metrics is one of this method's shortcomings [2,11].

2.3. The Canadian Council of Ministers of the Environment Index (CCME WQI)

CCME has established a WQI to alleviate the complexity and technicality of WQ data [48,49]. Complex and technical facts are made simpler using the CCME WQI approach [50]. The CCME model was used by most researchers to assess the quality of surface water. Because of its simplicity of use and flexibility in choosing WQ, the CCME model was nevertheless embraced by several studies for the assessment of drink water quality [51,52]. When choosing WQ parameters to determine the acceptability of drinking water, the model mostly took expert opinion on account. The review noted that 13 physicochemical items were employed by the model to set DWQ [52]. The final result is shown as a single unit-less number between 0 and 100, indicating whether the variables were equal or below the chosen benchmarks and formula 6 is typically used to calculate them [11,21,53].

$$\boldsymbol{CCME\ WQI = 100 - \left(\sqrt{F_1^2 + F_2^2 + F_3^2}/1.732\right)} \qquad \textbf{(6)}$$

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Where,

F_1 (scope) is the % of variables (failed variables) that, in relation to the total number of variables, failed to satisfy the aim (above or below the permissible range of the selected parameter) at least once and they are usually calculated by:

$$F_1 = (No.\,of\ failed\ variables/Total\ No.\,of\ variables) * 100 \qquad (7)$$

F_2 (frequency) is represented the percentage of individual tests that completely fail to achieve the objectives, or failed tests. F_2 can be expressed as:

$$F_2 = (No.\,of\ failed\ test/Total\ No.\,of\ tests) * 100 \qquad (8)$$

F_3 (amplitude) is the shows how much the values of failed tests fell short of the desired results (beyond or inside the permitted range of the chosen parameter). It takes three steps to compute.

a. The excursion is defined as the number of an individual parameter that is greater than or less than the objective when the aim is a minimum, as determined by two equations (9,10) that apply to two different scenarios. If the test value is required to stay below the goal:

$$excursion_i = (failed\ test\ value/objective) - 1 \qquad (9)$$

For the situations when the test value cannot be less than the goal:

$$excursion_i = (objective/failed\ test\ value) - 1 \qquad (10)$$

The computation of the normalized sum of excursions (*nse*) involves adding up the deviations of each test from its objectives and dividing the result by the entire number of tests (including those that do not satisfy the objectives):

$$nse = \sum_{i=1}^{n} excursion/No.\,of\ tests \qquad (11)$$

b. Next, a function called F_3 is computed, which scales the normalized sum of the deviations from targets (*nse*).

$$F_3 = (nse/0.01\,nse + 0.01) \qquad (12)$$

When the collected values are normalized to lie between 0 and 100, where 0 represents the lowest water quality and 100 represents the highest, using 1.732 as a scaling factor. Table 1 shows the ranking of WQ after the CCME WQI value has been determined.

The benefit of using the CCME WQI is that it can integrate several measures combining multiple measurements into one metric, in addition to conveying measurements of several variables as a single number. adaptability in the objectives and choice of input parameters. flexibility to accommodate various water applications and legal constraints. The CCME WQI's objective is to support water managers in communicating the overall quality of their water in a more consistent and continuous way, rather than to take the role of detailed variable analysis [54,55]. The method's drawbacks include that all factors are given equal weight when determining the index, and F1 performs incorrectly when a few numbers of variables are taken into account [2,11].

2.4. Oregon Water Quality Index (OWQI)

The OWQI, which was developed by the Oregon Department of Environmental Quality (ODEQ) in the late 1970s and has subsequently undergone numerous updates, is another extensively utilized WQI that is in the public domain. [30,38,56]. But since it took so much time and money to calculate and report the results, the original OWQI was abandoned in 1983. Following its demise in 1983, the OWQI was modified once more in 1995 with improved data visualization techniques that demonstrated a solid grasp of WQ [56]. The NSFWQI was the model for the original OWQI, using the Delphi method for variable selection [57]. The recreational WQI was developed using the Delphi technique. This method can be used to organize information based on a group of experts in order to solve a complex problem and obtain good consensus based on the best knowledge currently accessible [58]. In terms of the aggregate formulation and sub-indices computation, it was an improved version of the earlier one. Initially, eight WQPs (temperature, DO, BOD, pH, TDS, ammonia, nitrate nitrogen, total phosphorous and bacteria) were combined to determine the WQ of streams located in Oregon using OWQI [59]. However, with certain modifications and warnings, it was also applied to other geographical areas. The OWQI was combined to create Eq. (13) [11,60].

$$OWQI = \sqrt{n/\sum_{i=1}^{n} 1/SIi^2} \qquad (13)$$

Where, *n* is the numbers of parameters (*n*=8), and *SI* is the subindex ith parameter [11,50,60]. Additionally, The OWQI scores, as indicated in Table 1, range from 10 for the worst-case situation to 100 for the ideal WQ [56,61].

One of the advantages of this approach is that it recognizes that various metrics of WQ will have differing effects on the overall quality of the water at different times and places. The most impacted parameter might have the biggest impact on the WQI according to the unweighted harmonic square mean formula that is used to integrate sub-indices. The formula has a strong influence on WQ and is sensitive to changes in the environment. [56,62].

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The limitations of this method include its inability to assess all potential health risks (toxics, bacteria, metals, etc.) [2,11] and its incapacity to establish the WQ for specific purposes or to offer definitive data regarding the WQ without taking into account all relevant physical, chemical, and biological data [56,62].

2.5. Bhargava Water Quality Index (BWQI)

One of the earliest Asian-based water quality indices, created specifically to categorize water fit for human consumption [16,55]. Bhargava (1985) developed sensitivity functions that included the effects of different parameter concentrations as well as their weighting in relation to their level of importance in the overall index calculation process. This is in contrast to most indices, which consider sub-indices and weighting factors separately. Bhargava therefore proposed a logical and straightforward model for determining the water quality index value, which is represented by Equation (14). This model is based on an approach where the relevance of each water quality parameter is contained inside the sensitivity function [16,55].

$$\boldsymbol{BWQI} = \left[\prod_{i=1}^{n} \boldsymbol{f_i}(\boldsymbol{P_i})\right]^{1/n} \quad \textbf{(14)}$$

Where, *Fi (Pi)* is the sensitivity function that takes into account the weights of the ith variable and the number of factors deemed more relevant is *n*.

Bhargava distinguished four parameter categories. There were sets of the same kind of parameters in each category. The first group of organisms comprised coliforms, which are representative of the bacterial quality of drinking water. The second category includes toxicants and heavy metals. The third group contained turbidity, color, and odor—parameters that have a physical impact. The fourth group had both organic and inorganic materials, such as sulfate and chloride, among others. Based on the BWQI score, Bhargava categorized WQ into five groups, as seen in Table 1.

3. CONCLUSION

Many techniques for calculating the WQI have been proposed in order to determine the overall quality of the water. WQI are used to evaluate various water bodies, sources, and DWQ. Every index is applied in accordance with the evaluation's goal. In order to describe water quality in a clear and accessible manner, WQI is a simple technique that gives a single value to WQ while taking into consideration a specific number of variables, or physical, chemical, and biological characteristics.

The study looked at the most important drinking water quality indices and their mathematical formulations, components, advantages, and disadvantages. These indexes are produced by experts and foreign government agencies, and they are based on parameters. This helps to explain why WQIs have been applied so successfully in recent years: they employ a straightforward, dimensionless score to help represent the state of water quality to the public and decision-makers while also assisting in the deduction of a large quantity of scientific data. The distribution of the water quality evaluation scores among the "poor," "fair," "medium," "good," and "excellent" groups makes them understandable even to non-technical stakeholders. Nothing has become a widely acknowledged index, even with all the efforts and discussed indexes being used globally. As a result, efforts are ongoing to find a more useful and universal WQI that can be adopted and used with minimal modifications by water agencies, users, and managers worldwide.

REFERENCES

[1] Zhang L. (2017). Different methods for the evaluation of surface water quality: the case of the Liao River, Liaoning Province, China. *International Review for Spatial Planning and Sustainable Development*, 5:4–18. https://doi.org/10.14246/irspsd.5.4_4.

[2] Paun I., Cruceru L., Chiriac F.L., Niculescu M, Vasile G.G. and Marin N.M. (2016). Water quality indices—methods for evaluating the quality of drinking water. In: Proceedings of the 19th INCD ECOIND International Symposium—SIMI 2016, “The Environment and the Industry”, Bucharest, Romania: 395–402. https://doi.org/10.21698/simi.2016.0055.

[3] Loucks D.P. and Van Beek E. (2017). Water quality modeling and prediction. In: Water Resource Systems Planning and Management: An Introduction to Methods, Models, and Applications. *Springer International Publishing*, Cham, pp. 417–467. https://doi.org/10.1007/978-3-319-44234-1_10.

[4] Higler L.W.G. (2012). Fresh Surface Water: Biology and Biodiversity of River Systems. *Encyclopedia of Life Support Systems (EOLSS)*, ALTERRA, Wageningen, The Netherlands.

DOI: 10.31695/IJASRE.2024.7.9

[5] Kumar P. (2018). Simulation of Gomti River (Lucknow City, India) future water quality under different mitigation strategies. *Heliyon*. Vol. 4, no. 12. https://doi.org/10.1016/j.heliyon.2018.e01074

[6] Shan W. (2011). Discussion on parameter choice for managing water quality of the drinking water source. *Procedia Environ Sci*, 11:1465–1468.

[7] Mukate S., Wagh V., Panaskar D., Jacobs J.A. and Sawant A. (2019). Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water. *Ecol Indic* 101:348–354.

[8] Bharti N. and Katyal D. (2011). Water quality indices used for surface water vulnerability assessment, *Int. J. Environ. Sci.*, 2(1): pp154-173.

[9] WHO, World Health Organization. World Health Assembly. WHO library Geneva, Switzerland: World Health Organization, 1986.

[10] WHO, World Health Organization. *Guidelines for Drinking Water Quality.* WHO library Geneva, Switzerland: World Health Organization, 2011.

[11] Tyagi S., Sharma B., Singh P. and Dobhal R. (2013). Water quality assessment in terms of water quality index. *American Journal of Water Resources*, 1:34–38.

[12] Ismail A. and Robescu L.D. (2017). Chemical water quality assessment of the Danube River in the lower course using water quality indices, *UPB Scientific Bulletin, Series B*, 79: 51-61.

[13] Effendi H. and Romanto Wardiatno Y. (2015). Water Quality Status of Ciambulawung River, Banten Province, Based on Pollution Index and NSF-WQI, *Procedia Environ Sci.*, 24: 228-237.

[14] Gazzaz N.M., Yusoff M.K., Aris A.Z., Juahir H. and Ramli M.F. (2012). Artificial neural network modeling of the water quality index for Kinta River (Malaysia) using water quality variables as predictors. *Marine Pollution Bulletin*, 64: 2409-2420.

[15] Banda T.D. and Kumarasamy M.A. (2020). Review of the existing water quality indices (WQIs). *Pollution Research*, 39(2):1–19.

[16] Lumb A., Sharma T.C. and Bibeault J.F. (2011). Review of Genesis and Evolution of Water Quality Index (WQI) and Some Future Directions. *Water Qual. Expo. Health*, 3:11-24.

[17] Ichwana I., Syahrul S. and Wirda N. (2016). Water Quality Index by Using National Sanitation Foundation-Water Quality Index (NSF WQI) Method at Krueng Tamiang Aceh. *International Conference on Technology, Innovation and Society (ICTIS)*,110-117.

[18] Uddin M.G., Moniruzzaman M. and Khan M. (2017). Evaluation of Groundwater Quality Using CCME Water Quality Index in the Rooppur Nuclear Power Plant Area, Ishwardi, Pabna, Bangladesh. *American Journal of Environmental Protection*, 5(2): 33-43.

[19] Abbasi S.A. (2002). Water quality indices, state of the art report. *National Institute of Hydrology, scientific contribution* no. INCOH/SAR-25/2002, Roorkee: INCOH, 73.

[20] Kannel P.R., Lee S., Lee Y.S., Kanel S.R. and 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: pp 93–110.

[21] Lumb A., Halliwell D. and Sharma T. (2006). Application of CCME Water Quality Index to monitor water quality: A case of the Mackenzie River Basin, Canada. *Environ. Monit. Assess*,113: pp411– 429.

[22] Hui T., Xiujuan L., Qifa S., Qiang L., Zhuang K. and Yan G. (2021). Evaluation of drinking water quality using the water quality index (WQI), the synthetic pollution index (SPI) and geospatial tools in Lianhuashan District, China. *Polish Journal of Environmental Studies*, 30(1):141–153. https://doi.org/10.15244/pjoes/120765.

[23] Chandra D.S., Asadi S.S. and Raju M.V.S. (2017). Estimation of Water Quality Index by Weighted Arithmetic Water Quality Index Method: A Model Study. *International Journal of Civil Engineering and Technology (IJCIET)*, 8(4): 1215-1222.

[24] Iticescu C., Georgescu L.P. and Ţopa C.M. (2013). Assessing the Danube water quality index in the city of Galati, Romania, Carpath. *J. Earth Environ. Sci.*, 8: 155-164.

[25] Oni O. and Fasakin O. (2016). The Use of Water Quality Index Method to Determine the Potability of Surface Water and Groundwater in the Vicinity of a Municipal Solid Waste Dumpsite in Nigeria. *American journal of Engineering Research*, 5: 96-101.

[26] Chauhan A. and Singh S. (2010). Evaluation of Ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand, India. *Report Opinion*, 2(9): 53-61.

DOI: 10.31695/IJASRE.2024.7.9

[27] Chowdhury R.M., Muntasir S.Y. and Hossain M.M. (2012). Water quality index of water bodies along Faridpur-Barisal Road in Bangladesh. *Glob. Eng. Tech. Rev.*, 2(3): 1-8.

[28] Rao C.S., Rao B.S., Hariharan A.H. and Bharathi N.M. (2010). Determination of water quality index of some areas in Guntur district Andhra Pradesh. *Int. J. Appl. Bio. Pharm. Tech.*, 1(1): 79-86.

[29] Balan I.N., Shivakumar M. and Kumar P.M. (2012). An assessment of ground water quality using water quality index in Chennai, Tamil Nadu, India. *Chronicles Young Scient.*, 3(2):146-150.

[30] Singh P.K., Tiwari A.K., Panigary B.P. and Mahato K. (2013). Water quality indices used for water resources vulnerability assessment using GIS technique: a review. *Int J Earth Sci Eng.*, 6:1594–1600.

[31] Kizar F.M. (2018). A comparison between weighted arithmetic and Canadian methods for a drinking water quality index at selected locations in shatt al-kufa. *IOP Conf Ser: Mater Sci Eng*, 433:012026. https://doi.org/10.1088/1757-899X/433/1/012026.

[32] Jena V., Dixit S. and Gupta S. (2013). Assessment of water quality index of industrial area surface water samples. *Int J Chem. Tech. Res.*, 5:278–283.

[33] Al Chalabi A.S., Naeem S.M. and Alkhafaji R.J. (2023). Water Quality Index (WQI) for Main Water Treatment Plants in Basra City, Iraq. *International Journal of Design & Nature and Ecodynamics*, 18(6): 1407-1416.

[34] Akoteyon I.S., Omotayo A.O., Soladoye, O. and Olaoye H.O. (2011). Determination of Water Quality Index and Suitability of Urban River for Municipal Water Supply in Lagos-Nigeria. *Eur. J. Sci Res,* 54: 263-271.

[35] Yogendra K. and Puttaiah E.T. (2008). Determination of water quality index and suitability of an urban waterbody in Shimoga Town, Karnataka. *Proceedings of Taal2007: The 12th World Lake Conference*, pp. 342-346.

[36] Uddin M.G., Nash S. and Olbert A.I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators*,122. https://doi.org/10.1016/j.ecolind.2020.107218.

[37] Kachroud M., Trolard F., Kefi M., Jebari S. and Bourrié G. (2019). Water quality indices: challenges and application limits in the literature. *Water*,11(2):361. https://doi.org/10.3390/w11020361.

[38] Hamlat A., Guidoum A. and Koulala I. (2017). Status and trends of water quality in the Tafna catchment: a comparative study using water quality indices. *J. Water Reuse Desal,* 7:228–245. https://doi.org/10.2166/wrd.2016.155.

[39] Samadi M.T., Sadeghi S., Rahmani A. and Saghi M.H. (2015). Survey of water quality in Moradbeik river basis on WQI index by GIS. *Environ. Eng. Manag. J.*, 2:7–11.

[40] Al-Hamdany N., Al-Shaker Y. and Al-Saffawi A. (2020). Water quality assessment using the NSFWQI model for drinking and domestic purposes: a case study of groundwater on the left side of Mosul city, Iraq. *Plant Archives*, 20(1):3079–3085.

[41] Gupta S. and Gupta S.K. (2021). A critical review on water quality index tool: genesis, evolution and future directions. *Eco. Inform.*, 63:101–299.

[42] RadFard M., Seif M, GhazizadehHashemi A.H., Zarei A., Saghi M.H., Shalyari N., Morovati R., Heidarinejad Z. and Samaei M.R. (2019). Protocol for the estimation of drinking water quality index (DWQI) in water resources: artificial neural network (ANFIS)and Arc-Gis. *MethodsX*, 6:1021–1029.

[43] Gorai A.K., Hasni S.A. and Iqbal J. (2016). Prediction of ground water quality index to assess suitability for drinking purposes using fuzzy rule-based approach. *Appl Water Sci*, 6(4):393–405. https://doi.org/10.1007/s13201-014-0241-3.

[44] Ewaid S.H. (2017). Water quality evaluation of Al-Gharraf river by two water quality indices. *Applied Water Science*, 7: 3759–3765.

[45] Behmanesh A. (2015). Assessment the water quality of Babolrood river based on the NSF Water Quality Index, International Journal of Biology, Pharmacy, *Allied Sciences (IJBPAS)*, 4 (5): 342-352.

[46] Mnisi L.N. (2010). Assessment of the state of the water quality of the Lusushwana River, Swaziland, using selected water quality indices. M.Sc. Thesis, University of Zimbabwe, Harare.

[47] Fathi E., Zamani-Ahmad mahmoodi R. and Zare-Bidaki R. (2018). Water quality evaluation using water quality index and multivariate methods, Beheshtabad River, Iran. *Appl Water Sci.*, 8(7):1–6. https://doi.org/10.1007/s13201-018-0859-7.

DOI: 10.31695/IJASRE.2024.7.9

[48] Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Index 1.0 Technical report and user's manual, (2001). Canadian Environmental Quality Guidelines Water Quality Index Technical Subcommittee, Gatineau, QC, Canada.

[49] Khan A.A., Paterson R. and Khan H. (2003). Modification and Application of the CCME WQI for the Communication of Drinking Water Quality Data in Newfoundland and Labrador. Proceedings of the 38th Central Symposium on Water Quality Research, Canadian Association on Water Quality, Burlington, Canada.

[50] Tirkey P., Bhattacharya T. and Chakraborty S. (2015). Water quality indices-important tools for water quality assessment: a review. *Int J Adv Chem*, 1:15–28.

[51] Saw S., Mahato J.K. and Singh P.K. (2021). Suitability Evaluation of CCME-WQI and GWQI for the modeling of groundwater and human health risk assessment of heavy metals - Eastern India. *Res Square*, 1–24. https://doi.org/10.21203/rs.3.rs-1000020/v1.

[52] Wagh V.M., Panaskar D.B., Muley A.A. and Mukate S.V. (2017). Groundwater suitability evaluation by CCME WQI model for Kadava River Basin, Nashik, Maharashtra, India. *Model Earth Syst Environ*, 3(2):557–565. https://doi.org/10.1007/s40808-017-0316-x.

[53] Mahagamagea M.G.Y.L. and Managea P.M. (2014). Water Quality Index (CCME-WQI) Based Assessment Study of Water Quality in Kelani River Basin, Sri Lanka. *Environ. Nat. Resource. J.*, 12: 199-204.

[54] Terrado M., Barcelo D., Tauler R., Borrell E. and Campos S.D. (2010). Surface-water-quality indices for the analysis of data generated by automated sampling networks. *Trends Anal. Chem.*, 29(1): 40-52.

[55] Abbasi T. and Abbasi S.A. (2012). Water quality indices. *Elsevier*, Amsterdam, The Netherlands. https://doi.org/10.1016/C2010-0-69472-7.

[56] Cude C., (2001). A tool for evaluating water quality management effectiveness. *J. American Water Resource. Assess.*, 37: pp125–137.

[57] Perrin J.L., Salles C., Bancon-Montigny C., Raïs N., Chahinian N., Dowse L., Rodier C. and Tournoud M.G. (2018). Comparison of index systems for rating water quality in intermittent rivers. *Environ. Monit. Assess.*, 190 (2): 70. https://doi.org/10.1007/s10661-017-6396-2.

[58] Tunc Dede O., Telci I.T. and Aral M.M. (2013). The use of water quality index models for the evaluation of surface water quality: a case study for Kirmir Basin, Ankara, Turkey. *Water Qual. Expo. Heal.*, 5: 41–56. https://doi.org/10.1007/s12403-013-0085-3.

[59] Kareem S.L., Jaber W.S., Al-Maliki L.A., Al-husseiny R.A., Al-Mamoori S.K. and Alansari N. (2021). Water quality assessment and phosphorus effect using water quality indices: Euphrates river- Iraq as a case study. *Groundwater Sustainable Development*, 14:100630. https://doi.org/10.1016/j.gsd.2021.100630.

[60] Darvishi G., Kootenaei F.G., Ramezani M., Lotfi E. and Asgharnia H. (2016). Comparative investigation of river water quality by OWQI, NSFWQI and Wilcox indexes (Case study: The Talar River – IRAN). *Archives of Environmental Protection*, 42(1):41–48. https://doi.org/10.1515/aep-2016-0005.

[61] Brown D. (2019). Oregon Water Quality Index: background, analysis and usage. State of Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Program.

[62] Hubler S., Miller S., Merrick L., Leferink R. and Borisenko A. (2009). High level indicators of Oregon's forested streams. *Lab. Environ. Assess. Div.*, Hillsboro, Oregon.

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