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Water Quality Models and their Use in Monitoring the Quality of Surface Water Bodies

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Abstract: Water quality has been considered as one of the major challenges in water resource management. The main reason of degradation of water quality over the years is anthropogenic activities. Also, the monitoring of surface water bodies is a tedious as well as expensive process. For the depiction of water quality in simple and easy to understand terminology Water Quality Index (WQI) is found to be one of the widely used tool. It provides a transparent picture of the status of the pollution of a water body that is why it has been widely accepted by policy makers as well as other concerned authorities. Many WQI models have been developed throughout the world, using various water quality parameters, different techniques to generate subindices and also involving various mathematical techniques for aggregation of subindices. This paper deals with the comparison of various water quality models-based om number of parameters used, methods to generate subindices, aggregation techniques as well as their application and uses.
Keywords: Pollution, water quality index, aggregation techniques, anthropogenic activities

I. INTRODUCTION

Water quality has been considered as one of the major challenges in water resource management. Water quality can be divided in following groups i.e., physical, chemical and biological. Each group involves a numerous number of parameters (Swamee & Tyagi, 2007). Many researchers face difficulty in demarcating water quality as well as also in presenting it in an easy and compact way. One of the main reasons for this is complexity of parameters affecting water quality (Chapman, 1992). Thereby because of the existence of a wide variety of parameters affecting the water body evaluation of water quality becomes difficult. It led to various comprehensive attempts to explain the water quality status in simple terms without neglecting its scientific information. To examine this issue different approaches were introduced like multivariate statistical analysis (Magyar et al., 2013), grey relation analysis (Zhu & Hao, 2009)and water quality indices. Among all of these WQI becomes very popular. A water quality index is a single dimensionless number representing water quality by involving the effect of selected parameters. To determine the status of water quality of river the first WQI was developed by Horton in 1965 (Cude, 2001). Due to flexibility of their use and scientific basis WQI turn out to be an essential and common tool for worldwide monitoring of rivers.

Till now various water quality models have been developed using different number of parameters, aggregation techniques etc. some of them which will be discussed are: Weighted Arithmetic WQI, National Sanitation Foundation WQI (NSF-WQI) and Canadian Council of Ministers of the Environment WQI (CCME-WQI).

II. VARIOUS WQI MODELS

A. Weighted Arithmetic Water Quality Index

Various steps involved in the calculation are as follows (Shah & Joshi, 2015):

1) Determination of unit weight

$$W_i = K / \Sigma K \tag{1}$$

W_i represents the weighting for the ith determinant and this value varies from (0 to 1) and sum $W_i = 1$

K is a proportionality constant

2) Determination of rating scale

$$qi = (O_i - O_d) / (S_i - O_d) * 100 \tag{2}$$

O_i is the observed value of the ith determinant

O_d is the ideal value of the ith determinant in pure water

S_i is the standard value of the ith determinant

3) Determination of WQI

$$WQI = \sum_{i=1}^{n} W_i \, q_i \tag{3}$$

n represents number of determinants

It is very easy to calculate as well also very helpful in conveying the water quality in simple and easy to understand terminology. Different parameters can be used irrespective of their numbers as it is simply based on their observed and permissible value only. The limitation of this method is that it doesn't provide the real time status of the water quality of the surface water body.

B. National Sanitation Foundation WQI (NSF-WQI)

Various steps involved in the calculation are as follows:

1) Experts were selected and were provided the questionnaire with respect to following questions: first questionnaire was with regard to which variables should be included in the calculation to obtain WQI depending upon their impact on water quality, in second questionnaire reviewers were asked to review and change their opinions with regard to parameter if they want, in the third questionnaire they were asked to rate the water quality parameters from 0 to 100

2) Final step was calculation of WQI with the help of aggregation technique:

$$NSF - WQI = \sum_{i=1}^{n} W_i \, q_i \quad (4)$$

It was developed by US National Sanitation Foundation Index inn 1970. A total of one hundred forty-two experts were selected. For the selection of parameters Delphi technique was involved.

S.no	Descriptive words	NSF-WQI
1.	Excellent	90–100
2.	Good	70–89
3.	Medium	50–69
4.	Bad	25–49
5.	Very Bad	0–24

Table 1 Classification Criteria of NSF-WQI

C. Canadian Council of Ministers of the Environment WQI (CCME-WQI)

It was the reformed version of British Council Water Quality Index. For the selection of parameters Delphi technique was used and it consist of four parameters. In this WQI sub indexing as well as weight assignment to parameters was not required.

Steps involved in the process are (Uddin et al., 2021):

1) F_1= (No. of failed water quality variables /Total no. of variables) * 100 (4)

2) F_2= (No. of failed tests/total no. of tests) * 100 (5)

3) Excursion: There are two cases to calculate in this step

a) When the test value must not exceed an objective (limitation),
Excursion= (failed test value/objective) – 1 (6)

b) Excursion When an objective must exceed the test value,
(Objective value/failed test value) –1 (7)

4) normalized state of excursions (nse) = sum (excursion)/total tests (8)

5) F_3 = nse / (0.01 * nse + 0.01) (9)

6) WQI= 100 [- $(F_1^2 + F_2^2 + F_3^2)^{1/2}$ /1.732] (10)

S. No	Class	Water Quality	WQI Value
1.	I.	Excellent	95-100
2.	II.	Good	80-94
3.	III.	Fair	65-79
4.	IV.	Poor	45-64
5.	V.	Very Poor	0-44

Table 2 Classification according to CCME-WQI

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D. Bascaron Index

In this method twenty-six parameters were suggested. Transformation of parameters to common scale was performed with the help of linear functions. All of the sub indices' values were ranged from 0 to 100. For assignment of weight to the indices unequal and fixed method was used. total sum of weights was equal to 54 and each value ranges from 1 to 4. For aggregation of subindices two additive mathematical functions were considered in the study.

S. No	Class	Water Quality	WQI Value
1.	I.	Excellent	90-100
2.	II.	Good	70-90
3.	III.	Medium	50-70
4.	IV.	Bad	25-50
5.	V.	Very Bad	0-25

Table 3 Classification according to Bascaron -WQI

E. Oregon Index

It was the improved form of NSF index. For the study eight parameters were considered with the help of Delphi technique. Sub-index was estimated using averaging mathematical functions. For the assignment of weights sub index values were used directly. the weight arithmetic mean function was recommended by the Oregon department of environment.

S. No	Class	Water Quality	WQI Value
1.	I.	Excellent	90-100
2.	II.	Good	85-89
3.	III.	Fair	80-84
4.	IV.	Poor	60-79
5.	V.	Very Poor	<60

Table 4 Classification according to Oregon -WQI

F. British Colombia Index

In the following study common monitoring parameters were considered. Ten parameters were considered with the help of open system. Expert opinion was taken into consideration for the development of subindices and for the assignment of weights also expert opinion was used. for the aggregation of subindices simple mathematical formulas were considered based of addition.

S. No	Class	Water Quality	WQI Value
1.	I.	Excellent	0-3
2.	II.	Good	4-17
3.	III.	Fair	18-43
4.	IV.	Borderline	44-59
5.	V.	Very Poor	60-100

Table 5 Classification according to British Colombia -WQI

G. West Java Index

For the study thirteen parameters were considered. Parameters were selected based on monitoring data availability and comparison of standards. For generation of subindices simple mathematical formulas were used. for the assignment of weights Multi decision making tools like as Analytic Hierarchy Process (AHP) were considered in the study. For the aggregation process non, equal geometric technique was used.

S. No	Class	Water Quality	WQI Value
1.	I.	Excellent	90-100
2.	II.	Good	75-90
3.	III.	Fair	50-75
4.	IV.	Marginal	25-50
5.	V.	Very Poor	5-25

Table 6 Classification according to West Java -WQI

III. CONCLUSIONS

After the whole study it became clear that the main purpose of WQI is to explain the water quality water bodies in simple and easy to understand terminologies. A single value including impact of all harmful water quality parameters in a single value. It is one of the easiest methods with regard to the representation of status of pollution of water bodies with respect to various water quality parameters. Various water quality parameters are available still none of them has been gained global recognition due to presence of various water quality standards all around the world. WQI helps policy makers as well as other concerned authorities for development of sustainable strategy with respect to fresh water. WQI helps pollution control in monitoring of water quality and development of ways to reform them.

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