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Study of Various water quality Indices : A Review

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Abstract : One of the most daunting prospects facing water quality scientist is how to turn often very complex water quality data into information which is understandable and usable by non-scientists e.g., managers, planners, and general public. In an attempt to convey the information content of data more simply, resets have been made to produce just one or perhaps a few numbers, which have been designed to integrate the data pool in some way. Such numbers are called indices. All indexing systems require measurements to be made for a selection of water quality determinants. From these measurements, a sub-index rating value is obtained for each determinant. These values are then aggregated to produce the final index score.

Water quality variables frequently exhibit variability in time. This variability may be cyclical with the seasons, steadily (a trend), abruptly (a step-change) or some other established variation over time. It may affect the mean, median, variance, autocorrelation or almost any other aspect of the data. Detection of temporal trends is one of the most important objectives of environmental monitoring. Trend analysis indicates whether pollution concentrations are increasing or decreasing over time. This chapter is focused on presenting commonly used, basic methods for detecting water quality indices and various methods for detecting monotonic increasing or decreasing trends in water quality variables, which may be useful for routine analysis of trends in environmental monitoring.

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Structure of Various Water Quality Indices:

1. Arithmetic mean water quality index:

This water quality index is an index originally proposed by Horton (1965), also called as the arithmetic water quality index. Many researchers (Brown et al., 1970; Prati et al., 1971; Dinius, 1972) have used this index in their research work.

Several steps of weighted arithmetic index method are given (brown *et al.*, 1972) in the following steps:

- **Calculation of Sub Index of Quality Rating (q_n)**

Let there be n water quality parameters where the quality rating or sub index (q_n) corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of qn is calculated using the following expression.

$$q_n = 100[(V_n - V_{io}) / (S_n - V_{io})] \text{ (1)} \quad (1.1)$$

Where,

q_n = quality rating for the nth water quality parameter.
V_n = estimated value of the nth parameter at a given sampling station.
S_n = standard permissible value of nth parameter
V_{io} = ideal value of nth parameter in pure water.

All the ideal values (*Vio)* are taken as zero for drinking water except for pH = 7.0 and dissolved Oxygen=14.6mg/L. (Tripaty and Sahu, 2005).

- **Calculation of Quality Rating for pH**

For pH the ideal value is 7.0 (for natural water) and a permissible value is 8.5 (for polluted water).
Therefore, the quality rating for pH is calculated from the following relation:

$$q_{pH} = 100 [(V_{pH} -7.0)/(8.5 -7.0)] \text{ (2)} \quad (1.2)$$

Where,

V_{pH} = observed value of pH during the study period.

- **Calculation of Quality Rating for Dissolved Oxygen**

The ideal value (*VDO*) for dissolved oxygen is 14.6 mg/L and standard permitted value for drinking water is 5 mg/L. Therefore, quality rating is calculated from following relation:

$$q_{DO} = 100 [(V_{DO} - 14.6)/(5 – 14.6)] \text{ (3)} \quad (1.3)$$

Where,

V_{DO} = measured value of dissolved oxygen

- **Calculation of Unit Weight (W_n)**

Calculation of unit weight (W_n) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$W_n = K/S_n \ (4) \qquad (1.4)$$

Where,

W_n = unit weight for nth parameters

S_n = standard value for nth parameters
K = constant for proportionality

- **Calculation of WQI**

WQI is calculated from the following equation:

$$WQI = \sum_{n=1}^{n} q_n W_n \Big/ \sum_{n-1}^{n} W_n \qquad (1.5)$$

The WQI values are then converted into rankings by using the index categorization schema as presented in Table 3.1.

Table 3.1 Status of water quality based on Arithmetic WQI method (SOURCE: Brown *et al.*, 1972)

Water quality index	Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
Above 100	Unsuitable for drinking and propagation of fish culture

2. Multiplicative water quality index:

This water quality index is a multiplicative form of index proposed by Brown et al., 1972. Later researchers (Landwehr et al., 1974; Walski and Parker, 1974; Bhargava, 1985, Dinius, 1987) have also employed a weighted geometric mean for aggregation. The multiplicative water quality index (WQI_M) is defined as follows:

$$WQI_M = \prod_{i=1}^{n} q_i^{w_i} \qquad (1.6)$$

The construction of the above two indices suggests that each parameter may be of different weight based on the importance of water quality situation. The possibility that such weights may be unnecessary in distinguishing between situations having different qualities was explored by the formulation of two additional indexes (Landwehr, 1976).

3. Un-weighted Multiplicative Water Quality Index (WQI_{UM}):

Un-weighted multiplicative water quality index (WQI_{UM}) is defined as:

$$WQI_{UM} = \left(\prod_{i=1}^{n} q_i \right)^{1/n} \qquad (1.7)$$

4. Un-weighted Arithmetic Water Quality Index (WQI_{UA})

The un-weighted arithmetic water quality index (WQI_{UA}) is defined as given in the following equation.

$$WQI_{UA} = (1/n) \sum_{i=1}^{n} q_i \qquad (1.8)$$

5. Harkins' Water Quality Index (WQI_H)

This index was proposed by Harkins, 1974 which is based on nonparametric multivariate ranking procedure. Harkins' water quality index values (WQI_H) are calculated as follows:

$$WQI_H = \sum_{i=1}^{n} \frac{(R_{in} - R_{ic})^2}{\text{var}_i} \tag{1.9}$$

Where 'n' is the number of parameters being used, R_{in} is the rank of the nth water sample according to value of the ith parameter when compared to the values of that parameter among all the p water samples, R_{ic} is the control value of the ith parameter and var_i is the rank variance for the ith parameter, which is given by:

$$\text{var}_i = \frac{1}{12p} \times \left[(p^3 - p) - \sum_{j=1}^{k_i} (t_{ij}^3 - t_{ij}) \right] \tag{1.10}$$

Where p is the total number of water samples in the particular data set under consideration, observations plus the number of control points, t_{ij} is the number of elements involved in the jth tie encountered in ordering the measured values of the ith parameter and k_i is the total number of ties encountered in ranking the measured values of the ith parameter.

6. Delphi Approach for Water Quality Index Calculation

Delphi method is based on human evaluation approach. This method is to survey the water quality experts and ask them to give the score for each pollution parameter. The scoring functions can be formed by regression analysis for all the pollution parameters. The mathematical function, such as: arithmetic weighted, arithmetic unweighted, geometric unweighted, geometric weighted, minimum scoring etc are selected upon the purpose of the water use (House and Ellis, 1980). If the mathematical function needs the weight, the experts are asked to provide the relative weighting factors for all the pollution parameters. The WQI is calculated afterward.

7. The British Columbia Index

This water quality index was developed by the Environment Protection Department of British Columbia (Rocchini and Swain, 1995). The British Columbia approach to calculate a water quality index included a factor not considered in any of the other indices:

$$WQI = (F_1 + F_2 + F_3)^{1/2} \quad (1.11)$$

Where:

F_1 is the percentage of water quality guidelines exceeded.

F_2 is the percentage of measurements in which one or more of the guidelines Were exceeded.

F_3 is the maximum (normalized to 100) by which any of the guidelines were Exceeded.

The British Columbia index had the longest and most extensive application. As with the other jurisdictions; British Columbia used its index based on a variety of objectives. Each water body is assessed with respect to designated uses. British Columbia has different objectives for drinking, recreation, irrigation, livestock watering, wildlife, and aquatic life. Separate rankings were published based on each use relevant to the water body.

8. The Canadian water quality index

The Water Quality Index Technical Subcommittee of Canada adopted the conceptual model from the British Columbia index to develop the Canadian Water Quality Index (CWQI) that is used in the whole country. The task group of the Canadian Council of Ministers of the Environment (CCME) developed a computer model for the calculation of CWQI. There are three factors in the index, each of which has been scaled to range between 0 and 100. Figure 3.1 shows the conceptual model for the index. The values of the three measures of variance from selected objectives for water quality are combined to create a vector in an imaginary 'objective exceedence' space. The length of the vector is then scaled to range between zero and 100, and subtracted from 100 to produce an index which is 0 or close to 0 for very poor water quality, and close to 100 for excellent water quality. Since the index is designed to measure water quality, it was felt that the index should produce higher numbers for better water quality.

The CWQI 1.0 model consists of three measures of variance from selected water quality objectives: Scope (F_1), the number of variables not meeting water quality objectives; Frequency (F_2), the number of times these objectives are not met; and Amplitude (F_3), the amount by which the objectives are not met. The index produces a number between zero (worst water quality) and 100 (best water quality). These numbers are divided into five descriptive categories to simplify presentation. The model calculates the WQI as follows:

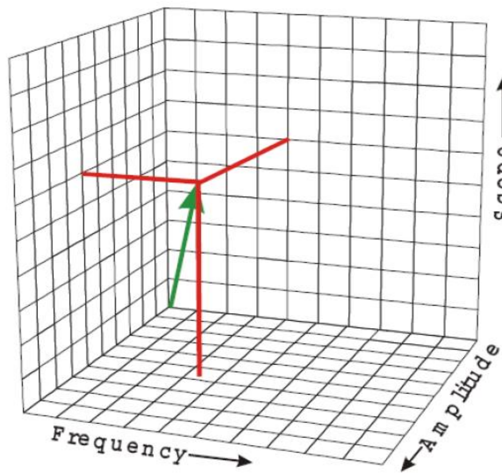

Fig 3.1 CCME water quality index formulation. **(Source:** Muhammad Tousef Bhatti (2005), University of engineering and Technology, Lahore, Pakistan.**)**

Conclusion : The CWQI values are then converted into rankings by using the index categorization schema as presented in Table 3.1. The model provides a mathematical framework for assessing ambient water quality conditions relative to water quality objectives. It is flexible with respect to the type and number of water quality variables to be tested, the period of application, and the type of water body (stream, river reach, lake, etc.) tested. These decisions are left to the user. Therefore, before the index is calculated, the water body, time period, variables, and appropriate objectives need to be defined (CCME, 2001).

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