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Water Quality Indices Criteria for Quality Assessment of Water Resources

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Abstract: ***Water is natural resources to basic human need and a precious national asset. India accounts for 2.2% of the global land and 4% of the world water resources but must support more than 16% of the world population. Water forms one of the primary resources for the development activities. In recent year there has been a tremendous demand of the fresh water and India is facing an acute shortage of water during the summer in most part of the country. In societies with the developing economies like India, the optimum development and efficient management of their water resources should be dominant strategy for economic growth. Although in the recent years unscientific planning and management and use of this resource for various purposes almost invariably has created undesirable problem in its wake: water logging and salinity in case agricultural use and environmental pollution of as result of industrial and municipal use. Water quality index is useful and unique rating that depicts the composite influence of different water quality parameter and communicates water quality information to the public and legislative decision makers. It is necessary to predict the overall water quality status in a single term that is helpful for the selection of appropriate treatment techniques to meet the concern issues. It describes the water quality on the basis of the selection of water parameter involve in the usability of the water for particular purposes. Although, there is no globally accepted, composite index of water, quality some countries and regions have used/are using, aggregated water quality data in the development of water quality indices. The present paper reviews the water quality index criteria for the suitably of the drinking water sources and provide the mechanisms in use for presenting a cumulatively derived, numerical expression defining a certain level of water quality.***

Keywords: Water Quality Index, Assessment, Water Quality Perimeters

1. Introduction

Drinking water quality has become a critical issue in many countries especially due to concern that fresh water will be a scare of resources in the future, so a water quality-monitoring program is necessary for the protection of freshwater resources (Pesce and Wunderlin 2000). The importance of water supply with sufficient quantity and acceptable quality has been emphasized in the millennium development goals articulated by the General Assembly of the United Nation. The water quality index (WQI) has been considered as one criteria for drinking water classification based on the use of standard parameter of water characterization. Water quality index (WQI) is one of the most effective ways to describe the suitability of water sources for human consumption. It utilizes the water quality data and helps in modifying the policies formulated by various environmental monitoring agencies. The uses of individual water quality variables in order to describe the water quality for common public are not easily understandable. Hence, WQI has the ability to reduce the bulk of the information into a single value to convey the data in simplified and understandable form. It takes information from a number of sources and combine then to develop and overall status of the water system. They increase the understanding ability of water quality issues highlighted by policy makers and general public as users of the water resources (Nasirian 2007).

A large number of water quality indices viz. Weight Arithmetic Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the environment water quality index (CCMEWQI), Oregon Water Quality Index (OWQI), Bhargava Water Quality Index (B WQI) etc, British Columbia Water quality Index (BC WQI) have been formulated by numerous national and international organizations and applied for evaluation of water quality in a particular area (Lumb et al 2002). There are based on the varying number of water quality characteristics as compare with respective standard of the regions. Water quality indices are accredited to demonstrate annual cycle, spatial and temporal variation in water quality and trend in water quality even at low concentration in an efficient and timely manner. WQI was first developed by Horton (1965) in United States by selecting 10 most commonly used water quality variables(including DO, pH, qualifiers, specific conductance, alkalinity and chloridesetc.) and has been widely applied and accepted in European, African, American as well as Asian countries. The assigned weight reflected a significance of a perimeter for a particular use and has a considerable impact on the index. A new WQI similar to Horton's index has also been developed by the group of Brown (1970), which was based on weights to individual parameters. Lately, many modifications have been considered for WQI concept through various Scientist and experts (Bhargava et al 1998; Dwivedi et al 1997).

Since 1965, when Horton (1965) proposed the first water quality index (WQI), a great deal of consideration has been given to the development of 'water quality index' methods with the intent of providing a tool for simplifying the reporting of water quality data (Liou et al., 2004). WQI improves understanding of water quality issues by integrating complex data and generating a score that describes water quality status and evaluates water quality trends. These indices assess the appropriateness of the quality of the water for a variety of uses (Cude, 2001). They are considered more appropriate for disseminating information to general audiences.

The WQI concept is based on the comparison of the water quality parameter with respective regulatory standards

(Khan et al., 2003). The development process of a water quality index can be generalized in four steps:

Selecting the set of water quality variables of concern - **parameter selection**

Transformation of the different units and dimensions of water quality variables to a common scale -**developing sub-indices**

Weighting of the water quality variables based on their relative importance to overall water quality -**assignment of weights**
Formulation of overall water quality index -**aggregation of sub-indices to produce an overall index**.

2. Methods

Different indexes formulated by the deferent agencies time to time are as under.

2.1. Universal Water Quality Index (UWQI)

In this study a new index called the Universal Water Quality Index (UWQI) was developed to provide a simpler method for describing the quality of the surface water used for drinking water supply. UWQI has advantages over pre-existing indices by reflecting appropriateness of water for specific use - drinking water supply rather than general supply and has been developed by studying the supranational standard (Boyacioglu 2007). Previous indices were mostly developed in order to assess stream-water quality for general recreational uses. In addition they were based on the national standards of any particular country and this limited their application to within the country of origin.

The UWQI was developed on the basis of the following water quality standards:

'The quality required of surface water intended for the abstraction of drinking water in the Member States 75/440/EEC' set by the Council of the European Communities (EC, 1991)

'The classification of inland waters according to quality - Turkish water pollution control regulation - WPCR' (*Official Gazette*, 1988)

According to EC legislation (75/440/EEC), water quality of surface waters intended for the abstraction of drinking water is classified into three groups. For each class the treatment level required to transform surface water into drinking water is different and can be summarized as:

Class I: Simple physical treatment and disinfection, e.g. rapid filtration and disinfection

Class II: Normal physical treatment, chemical treatment and disinfection, e.g. pre-chlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination)

Class III: Intensive physical and chemical treatment, extended treatment and disinfection, e.g. chlorination to break-point, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination) (EC, 1991).

This classification is based on the assessment of about 45 water quality parameters including physical, chemical and microbiological variables such as temperature, pH, colour, sodium, biochemical oxygen demand, mercury, lead, iron and total coliform, etc. Each class is characterized by numerical values for these parameters. Turkish WPCR also has quite a similar categorization scheme, the main difference being that a Category IV is added to the Turkish standard water quality parameters, in which the values exceed those set for Category III. In this study a 4th class was excluded when considering appropriateness of water for potable purposes. UWQI parameters (water quality determinants) were selected among these 45 parameters. The concentration ranges of the determined variables for three categories were defined by referring to the 75/440/EEC and Turkish WPCR. In general among both standards the more restricted value for each class was accepted as the reference value. After water quality variables of the index had been determined, mathematical equations which transformed the actual concentration values into individual quality indices were formulated for all the parameters. Assignment of weights to variables was followed by aggregation of sub-indices using the weighted sum method to obtain an overall index value.

The aggregation function is represented as
UWQ I=$\sum_{i=1}^{n} Wi\, li$

Where
Wi= weight of ith parameter
li= Sub index for ith parameter

Considering treatment required to transform surface water into drinking water and based on expert opinions the proposed UWQI categorization is given Table 1

Table 1: UWQI Index categorization scheme

Rank	WQI value
Excellent	95-100
Good	75-94
Fair	50-74
Marginal	25-49
Poor	0-24

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

CCME WQI provides consistent method formulated by Canadian jurisdictions to convey the water quality information to both management and the public. A committee established under the Canadian Council of Ministers of the Environment (CCME) has developed WQI, which can be applied by many water agencies in different countries with little modification (CCME, 2001; Khan et al. 2003; Lumb et al. 2006). It is developed to evaluate surface water for protection of aquatic life in accordance to specific guidelines. The parameters related with various measurements may vary from one station to the other and sampling protocol requires atleast four parameters, sampled at least four times (Khan et al. 2003). For calculation of index scope.

$$WQI=100-\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}$$

Where,
Scope
(F_1) = Number of variables, whose objectives are not met.
F_1= [No. of failed variables /Total no. of variables]* 100

Frequency
(F_2) = Number of times by which the objectives are notmet.
F_2= [No. of failed tests/Total no. of tests]* 100

Amplitude
(F_3) = Amount by which the objectives are not met.
(a) Excursion I = [Failed test value i /Objective j]-1
(b) Normalized sum of excursions (nse) $=\sum_{i=1}^{1}\frac{excursion}{No.of\ tests}$
(c) F3= [nse /0.01 nse+0.01]

Table 2: Water Quality Rating as per Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

WQI	Value water quality rating
95-100	Excellent
80-94	Good
56-79	Fair
45-59	Marginal
0-44	Poor

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

A commonly used water quality index was developed by the National Sanitation Foundation to provide a standardized method for comparing the water quality of various sources based upon the nine parameter i.e., temperature, pH, turbidity, fecal coliform, dissolved oxygen, biochemical oxygen demand, total phosphates. Nitrates and total solids. This effort was supported by the National Sanitation Foundation (NSF) and also referred as NSFWQI in order to calculate WQI of various water bodies critically polluted. The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by

$$WQI=\sum_{i=1}^{n} Qi\,Wi$$

Where, Qi: sub-index for ith water quality parameter; Wi: weight associated with ith water quality parameter; n: number of water quality parameters.

Table 3: Water Quality Rating as per National Sanitation Foundation Water Quality Index (NSFWQI).

WQI	Value water quality rating
91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
0-25	Very bad

2.4. Weighted Arithmetic Water Quality Index Method (WAW WQI)

This method categorizes the water quality according to its degree of purity by suing the most commonly measured water quality variables. This method has been widely used by the various researchers and the calculation was made (Brown et al. 1972)

By using the following equation
WQI= Σ QIWi/ Σ Wi the quality rating scale (Qi) for each parameter is calculated by suing the expression
Qi= 100[(Vi-Vo/Si-Vo)]
Where,
Vi estimated concentration of the ith parameter in the analyzed water
Vo is the ideal value of this parameter in pure water
Vo=0(except PH=7.0 and DO=14.6 mg/l)
Si is the standard recommended value of the ith parameter

The unit weight (Wi) for each water quality parameters calculated by using the following formula
W i=K/Si
where K is proportionality constant.

The rating of water quality according to WQI, is given in Table 4.

Table 4: Water quality rating as per weight arithmetic water quality index method

WQI	Water quality rating	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purpose	E

2.5. Oregon Water Quality Index

OWQI produces a score to evaluate the general water quality of Oregen stream and its application to other geographic regions, which combines eight water quality variables into a single number. These parameters are temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, ammonia and nitrate nitrogen, total phosphorus, total solids and fecal coliform (Dinius 1987; Dunnette 1979).The original OWQI was designed after the NSFWQI where the Delphi method was used for variable selection. It expresses water quality status and trends for the legislatively mandated water quality status assessment. The index is free from the arbitration in weighting the parameters and employs the concept of harmonic averaging. The mathematical expression of WQI is
Given by
$WQI=\sqrt{n}/\sum_{i=0}^{n}\frac{1}{SI}=^2$
Where, n = number of subindices
SI= subindex of ith parameter
The rating scale of OWQI has been categorized in various classes, which are presented
In Table 5

Table 5: Water Quality Rating as per Oregon Water Quality Index (OWQI)

WQI Value	Water Quality Rating
90-100	Excellent water quality
85-89	Good water quality
80-84	Medium water quality
60-79	Bad water quality
0-59	Very bad water quality

3. Conclusions

Water quality assessment by means of an index is easier than comparing experimentally determined parameter values with existing guidelines. This new index is believed to assist decision makers in reporting the state of the water quality, and investigation of spatial and temporal changes. In addition it is useful to determine the level of acceptability for the individual parameter by referring to the concentration ranges defined in the proposed classification scheme. Based on the above comparative description of different water quality indices, it may be inferred that the aim of WQI is in giving a single value to water quality of a source along with reducing higher number of parameters into a relatively a simple expression resulting into easy interpretation of water quality monitoring data. This paper is an effort to review the important indices used in water quality vulnerability assessment and also provides details about indices composition and mathematical forms. These indices utilizes various physico- chemical and biological parameters and have been resulted as an outcome of efforts and research and development carried out by government agencies and experts in this area worldwide.

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