Water Quality Index

Subjects: Water Resources

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A critical water quality index (WQI) method has been used to determine the overall water quality status of surface water and groundwater systems globally since the 1960s. WQI follows four steps: parameter selection, sub-indices, establishing weights, and final index aggregation.

Keywords: water quality assessment ; physicochemical and biological parameters ; water quality index ; multi-criteria decision-making ; analytical hierarchical process ; MACBETH

1. Introduction

Water quality is intrinsically connected to human health, food production, gender equality, reduction of poverty, ecosystem livelihoods, economic development, and social growth in our communities [1]. It is also one of the major problems in water resource planning and management. Furthermore, an increase in urbanization, construction, agricultural activities, industrial applications, and natural processes has adversely impacted the quality of surface water and groundwater, and its effects on human health throughout the world, as shown in Figure 1 [2]. Water quality is usually classified into biological, physical, and chemical parameters, and there are several parameters for each category [3]. The evaluation of these three categories, based on parameters through field monitoring of water sampling, provides essential information for identifying trends, a wider range of knowledge to water resource authorities, and future planning recommendations [4]. Water quality analysis typically relates to the quality of natural water and its possible uses (drinking, domestic, irrigation, and industries). In reality, it is expensive and laborious to monitor the parameters of multiple contamination sources entering into surface water bodies and groundwater systems. Furthermore, numerous researchers and scientists have faced difficulties in describing and addressing water in a consolidated and simple way [5]. These difficulties happen because of the complexity of water quality parameters and the wide variability in parameters utilized for characterizing the status of water quality of water resources. This has contributed to several comprehensive efforts, without losing its scientific basis, to define the water quality status in simple ways [6].

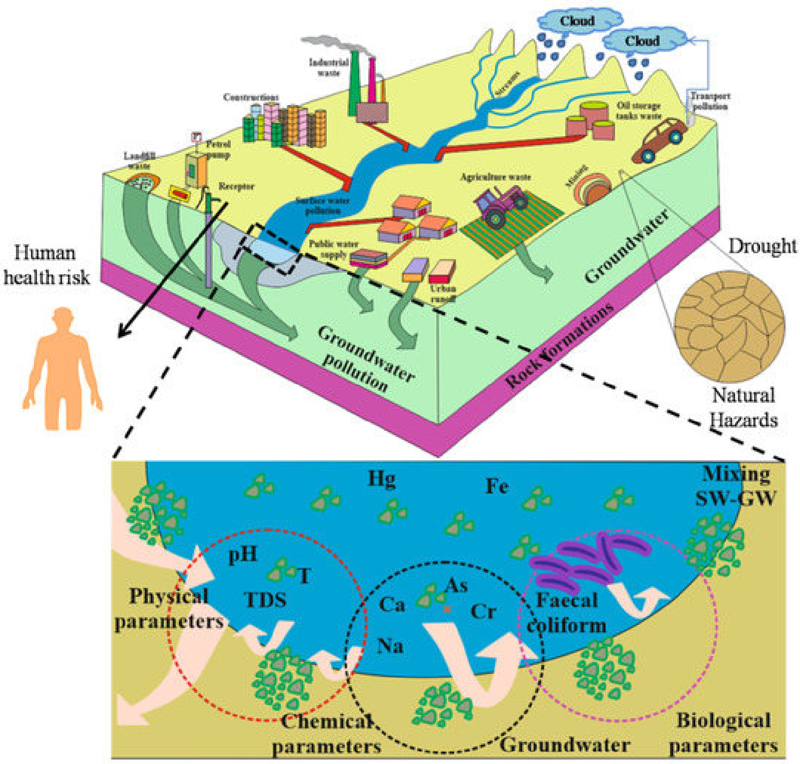

Figure 1. Shows the quality of surface water and groundwater resources degrading by anthropogenic and natural processes from various sources, as well as the effect on human health through these activities.

Regardless of this development, a simple evaluation of the water quality of groundwater and surface water is challenging to determine. The combined impact of many different factors that characterize the water quality and the challenges of classifying the significant parameters used to measure the status of water resources quantitatively are very complex to understand. Therefore, the water quality index (WQI) is considered a mathematical tool that significantly minimizes the complex water quality data sets and provides a single classifying value that describes the water quality status of water bodies or degree of pollution. Furthermore, WQI is a single dimensionless number that describes the overview of the overall water quality status in a simple way by aggregating the measurements of selected parameters such as pH, nitrate, dissolved oxygen (DO), heavy metal. [7]. As early as 1965, this method was introduced through mathematical equations to determine water quality status in the river by Horton [8]. The WQI is determined based on various biological, physical, and chemical parameters that define the various purposes of utilization of water bodies for human consumption, such as recreation, drinking, industries, irrigation, and domestic. After the proposed WQI method by Horton, the numbers of WQI methods have been developed for various purposes by numerous organizations across the globe, such as the National Sanitation Foundation Water Quality Index (NSFWQI) [9], Scottish Research Development Department (SRDD) [10], River Status Index (RSI) [11], Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) [12], British Columbia Water Quality Index (BCWQI) [13], Overall Index of Pollution (OIP) [14], Oregon Water Quality Index (OWQI) [15], Bhargava Method Water Quality Index (BMWQI) [16], Malaysia Water Quality Index (MWQI) [17], Water Contamination Index (WCI) [18], Vaal Water Quality Index (Vaal WQI) [19], etc.

Moreover, four common steps have been used in the WQI method, including the parameters selection, sub-indices establishment, assigning of weights (equally or unequally), and aggregation of sub-indices to obtain the final index [4]. Previous studies have shown that most researchers have applied all steps (because they used unequal weights, such as NSFWQI, SRDD, MWQI, etc.). Some of them used three steps (equal weights, such as OIP, WCI, RSI, etc.), but few of them reported that they directly used the formula for water quality assessment (CCMEWQI) [20]. Furthermore, the WQI method has been applied for different purposes, but mainly for surface water quality (especially for river water) [21][22][23][24][25][26][27][28][29], groundwater quality [1][30][31][32][33][34][35][36], and wetland [37][38][39][40][41][42] across the world. Moreover, the Environmental Protection Agency (EPA) of the Republic of Serbia also utilizes WQI to inform about the overall status of the river water system [43]. In this technique, a large resource of water is easily accessed for water quality assessment because of the consistent scale using the WQI equation. Multiple parameters are used to calculate in a single number and the flexibility of selecting the characteristics of water quality. However, the calculation of WQI is a prolonged process in which numerous national and international standards are taken into consideration, in terms of criteria of water consumption. This makes the process more complicated, despite having simple calculations. Moreover, it is easy to bias the process of selecting parameters and calculating the individual weighting values. Therefore, the covered parameters cannot be definite in number that they would give a simple WQI; it may not be enough to understand, as a whole, the WQI of a large water body because certain parameters can influence the water quality in a wider manner, which can be neglected during the calculation.

The literature reviewed indicates that all of the indices have their limitations and strengths; therefore, many organizations and agencies do not consider this methodology for developing a WQI worldwide [7][44]. However, it is pertinent to mention that the strengths and weaknesses of the processes in establishing WQI for water quality assessment can be simplified by multi-criteria decision-making (MCDM) approaches to evaluate the parameter's weight separately. In previous years, analytical techniques have significantly increased to resolve the problems related to water resources, where MCDM procedures are generally regarded as very effective in addressing water management problems [45]. The effectiveness of such procedures depends on the conceptual framework of assessment processes and on the common language used to identify and address complex water challenges. Moreover, MCDM easily allows—in the process of decision-making—the impact of uncertainties that often define water management problems [46]. In previous decades, several authors have applied the MCDM method to various purposes in water resource management, assessment of water quality [46][47] as well as in other areas, to solve problems surrounding the environment, energy, and sustainability [48], safety and risk management [49], and technology and information management [50]. There are numerous MCDM approaches available for solving problems related to water resources, such as analytical network process (ANP), analytical hierarchical process (AHP), data envelopment analysis (DEA), fuzzy decision-making (FDM), measuring attractiveness by a categorically based evaluation technique (MACBETH), simple additive weighting (SAW), supply chain management (SCM), a technique for order preference by similarity to ideal solution (TOPSIS), compromise programming (CP), etc. [51][52][53][54][55].

2. Importance of WQI

In general, WQI is the comparison of the amount with an arbitrary or scientific standard or with a pre-specified base. Therefore, the WQI monitored and reported environmental status and trends on standards quantitatively. The WQI method provides effective information on the degree of purity and pollution of water, by avoiding an overwhelming quantity of data to demonstrate water quality [56]. The WQI tool also facilitates a perfect quality monitoring system accessible. The monitoring data should formulate easy to comprehend indices to executive management and the overall development of public policies to accomplish this. The National Academy of Sciences (NAS)'s Planning Committee on Environmental Indices [57], found that environmental indicators play an active role in assisting with program design, assigning policy details, and communicating facilitation with affected individuals.

Ott [58] identified the following six basic usages of WQI after examining relevant literature available on the subject: resource assignment, standard enforcement, trend analysis, location ranking, public information, and scientific research. This means that indices are descriptive and objective methods for evaluating water quality trends. Parameters are not concisely graphical against one another, or against time, and do not explicitly indicate the patterns due to overlap in data and volume.

- Scientific research: indices can be used to minimize a large number of data into a process that provide insight into research and perform an analysis of many of these environmental programs.
- Public information: indices can be applied to educate the public on environmental conditions.
- Trend analysis: indices can be utilized for environmental information, at various time periods, to evaluate changes in environmental quality that have taken place over the period.
- Standard enforcement: indices can be applied to particular areas to evaluate the extent to which legislature standards and existing criteria are fulfilled or exceeded.
- Resource assignment: the location ranking, by evaluating the environmental conditions at various places or geographical regions.

Almost every WQI relies on normalization, the data parameter-by-parameter, as per the predicted concentration levels, and the interpretation of "bad" versus "good" levels. After this, index is calculated as a weighted average for all observed values, with weighted parameters according to their perceived significance to overall water quality. The purposes of the WQI method are, particularly, for the evaluation of the overall status of water quality (parameters of physical, biological, and chemical) and the use of water resources for multiple purposes. WQI methods were developed by individuals, organizations, and agencies, and classified into four groups (discussed below):

- Specific indices: the water classification in this category is based on the type of use and requirement (drinking, irrigation, industries, bathing, etc.), which is defined by OWQI, CCME, etc.
- Public indices: the type of water used in the assessment process, such as NSFWQI, (Horton 1965), are ignored in this category.
- Statistical indices: the statistical approaches are used in these indices and personal opinions are not included.
- Planning indices: this step includes an instrument tool that facilitates decision-making and makes a plan for managing water quality projects.

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