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REVISIÓN

Water quality indices (WQI) and contamination indices (WPI) a bibliographic review

Índices de calidad y contaminación del agua: una revisión bibliográfica

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Abstract

Context: surface water sources are the fundamental resource in any activity or development process as an axis of interest for their use. However, anthropogenic activities have deteriorated bodies of water, considerably altering their properties, physicochemical and microbiological characteristics, which are the fundamental indicators of contamination levels in the dynamics of water bodies. At an individual level, they only represent an idea of their concentration in the analyzed samples. Therefore, to assess the quality of the bed, these variables must be integrated through Quality Indicators and Contamination Indicators (WQI and WPI) in lotic, lentic, and underground systems.
Methodoly: a bibliographic review was carried out in the Sciencedirect database and digital platform, using the phrase "water quality index and pollution index" as search criteria. This search pattern was applied to the keywords of the articles consulted. The most relevant documents of the last 10 years were selected, with which the review was performed.
Results: the most common way to characterize water involves determining its physicochemical parameters and analyzing them against national or international maximum permissible values. This process transforms Water Quality Indices and Pollution Indices into useful methods with a simple and practical applications, helping to identify problems related to the concentration levels that vary in lotic, lentic, and underground bodies. This research presents the most frequently used WQIand WPI based on the bibliographic review, revealing that the countries where more research has been conducted are China, India, Brazil, Nigeria, and Indonesia.
Conclusions: the water quality indices and contamination index have been repeatedly implemented in recent years in various countries around the world with the aim of evaluating the quality of both surface (rivers, lakes, seas) and

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groundwater (water streams). Similarly, new indices have been developed from some existing WQI.

Keywords: surface water, groundwater, Pollution Index (WPI), Water Quality Index (WQI), physicochemical parameters.

Resumen

Contexto: las fuentes de agua superficiales son el recurso fundamental en toda actividad o proceso de desarrollo, pues su eje representa un interés de interés. No obstante, las actividades antropogénicas han generado un deterioro de los cuerpos de agua, alterando considerablemente sus propiedades, las características fisicoquímicas y microbiológica, las cuales son los indicadores fundamentales de los niveles de contaminación en la dinámica de los cuerpos hídricos. A nivel individual, estos cuerpos hídricos solo presentan una idea de su concentración en las muestras analizadas, por lo que para tener una evaluación de la calidad del lecho se debe integrar estas variables a través de Indicadores de Calidad e Indicadores de contaminación (ICA e ICO) en sistemas loticos, lenticos y subterráneos.
Metodología: se realizó una revisión bibliográfica en la base de datos y plataforma digital Sciencedirect, utilizando como criterio de búsqueda la frase "water quality index and pollution index". Este patrón de búsqueda se aplicó a las palabras claves de los artículos consultados. Se seleccionaron los documentos más relevantes de los últimos 10 años, con los cuales se procedió a realizar la revisión.
Resultados: la forma más común de caracterizar el agua es a través de determinar sus parámetros fisicoquímicos y analizarlos con valores los máximos que son permitidos nacional e internacionalmente. Así pues, los Índices de Calidad del Agua y los Índices de Contaminación se convierten en métodos útiles, pues tienen un uso simple y práctico que ayuda a identificar problema relacionado con los niveles de concentración que varían en los cuerpos loticos, lenticos y subterráneos. En esta investigación, se presentan los ICA e ICO más usados en la revisión bibliográfica y se establece que los países donde más investigación se realizaron es China, India, Brasil, Nigeria e Indonesia.
Conclusiones: los índices de calidad del agua y el índice de contaminación se han implementado de manera reiterativa en los últimos años en varios países del mundo con el objetivo de evaluar la calidad de cuerpos de agua tanto superficial (ríos, lagos, mares) como subterráneas. De igual manera, se han desarrollado nuevos índices a partir de algunos ICA existentes.

Palabras clave: agua superficial, agua subterránea, Índice de contaminación (ICO), Índice de Calidad del Agua (ICA), parámetros fisicoquímicos

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INTRODUCTION

The sources of water can be mainly take the form of rivers, lakes, rainwater, groundwater, among others. The quality of these fluids is of vital importance for the sustainable development of communities, serving several fundamental purposes such as drinking, bathing, and domestic tasks (Das *et al.*, 2021; Sunitha *et al.*, 2022; Hasan *et al.*, 2019). In addition, water plays a vital role in different sectors of the economy such as livestock, industrial activities, forestry, agriculture, hydroelectric generation, fishing, and other recreational activities. However, these anthropogenic activities release pollutants that have generated an impact on the quality of surface and groundwater bodies that affect their potential uses, causing problems for the environment and human health (Zhao, Kuo, & Chen, 2021; Dimri, Daverey, Kumar, & Sharma, 2021; Oñate & Cortéz, 2020; Effendi, 2016).

Human life has evolved around water. It is an essential resource for the populations, as they rely on this fluid to sustain different socioeconomic activities both in urban and rural centers (Barbulescu *et al.*, 2021; Dash & Kalamdhad, 2021; Torres *et al.*, 2009). Yet, these human activities have a detrimental impact on water quality due to population growth resulting from the urbanization and industrialization associated with them. This decline in quality is, in turn, exacerbated by the excessive use of chemical products in daily activities such as discharging domestic wastewater and solid waste. As a result, the quality of aquatic ecosystems and their ecosystem services is impacted. Their condition is decisive and variable in time and space and can be associated with the concentration of different pollutants in the route and dynamics of the source. Because of this, the global community strives to keep apprised of the current state of these ecosystems, recommending a monitoring system that facilitates the observation of their conditions as an early warning to protect the quality of the rivers (Moyano *et al.*, 2021; Ben Brahim *et al.*, 2021; Granitto *et al.*, 2021; Diaz *et al.*, 2020; Ustaoğlu *et al.*, 2020; Sahoo *et al.*, 2015)

Water quality is of vital importance for people and the aquatic biota upon which they rely for sustenance. The most effective method to assess water quality and ecological status of a body of water is by quantifying its physicochemical parameters (Ustaoğlu *et al.*, 2020). In this context, the WQI is presented as a method that allows to easily evaluate the changes presented in a body of water that alter its quality. The index is based on a mathematical equation that incorporates information from various physical, chemical, and microbiological parameters. This enables the analysis of complex variables and facilitates the generation of an assessment that accurately reflects the current state of the quality of the body of water, allowing in turn to understand the environmental problems associated with the various alterations of the fluid. Consequently, this index becomes a highly valuable tool for environmental authorities to manage and plan the usage of surface water resources. This is evidenced by its global application since the 1960s. The criteria for calculating the WQI can be divided into four steps: (a) selection of important parameters, (b) estimation of sub-index values (generally with the use of binding requirements), (c) calculation of weights for selected parameters, (d) final determination of the ACI by adding weighted sub-index values (Pandit *et al.*, 2022; Uddin *et al.*, 2021; Nayak *et al.*, 2021; Wątor & Zdechlik, 2021).

On the other hand, when assessing water for human consumption, color and odor are fundamental aspects. However, they are not always reliable indicators, as these qualities do not guarantee water's suitability for consumption. Invisible chemical contaminants and pathogenic organisms may be present despite favorable color and odor (Egbueri *et al.*, 2020). Likewise, the Pollution Indices (WPIWPI) are introduced as tools for assessing water quality, applicable to various types of water bodies. They contribute to the control and supervision of water pollution (Sharma *et al.*, 2021; Effendi *et al.*, 2015).

In this context, this bibliographical review serves the purpose of a documentary analysis on water quality indices and contamination indices from the last 10 years. It involves searching, synthesizing, classifying, and comparing previous publications available on the virtual scientific platform Sciencedirect.

Materials and methods

To gather information for this article, the Sciencedirect database was consulted. This platform is one of the largest digital repositories for medical, scientific, and technical research, encompassing twenty-four important scientific disciplines. It stands as the main peer-reviewed literature reviewed platform by Elsevier. This database provides access to approximately 18 million articles and chapters, 2,650 peer-reviewed journals, 42,000 e-books, 362,000 cross-subject pages, 500 journals, and 1.4 million open access articles (Sciencedirect, 2021). The bibliographical review used as search criteria keywords with the following combinations: 'water quality index' and 'pollution index', establishing 'and' as a logical connector. In this way, 55,849 articles related to the search theme were identified from 2008 to 2021. This bibliographical search was based on the foundations recommended by Vera (2016), using mainly (a) secondary sources, (b) a database search strategy with key descriptors, (c) a selection criteria where the title, the authors, the year of publication, and the abstract presented in the Mendeley bibliographic manager were taken into account. In the process of writing of this article, a synthesis, analysis, and comparison of the pertinent articles from the review were conducted, taking into account available evidence, relevant aspects or themes, as well as convergent and divergent critical discussions from various research investigations (Guirao *et al.*, 2008).

Historical analysis of references associated with WQI and WPI

Figure **1** shows a compilation of the selected articles obtained from the Sciendirect platform, illustrating the utilization of WQI and WPI indices over a specified timeframe as indicators to evaluate both underground and surface water bodies. Notably, of the fifty selected articles, more than thirty were published between 2020 and 2021.

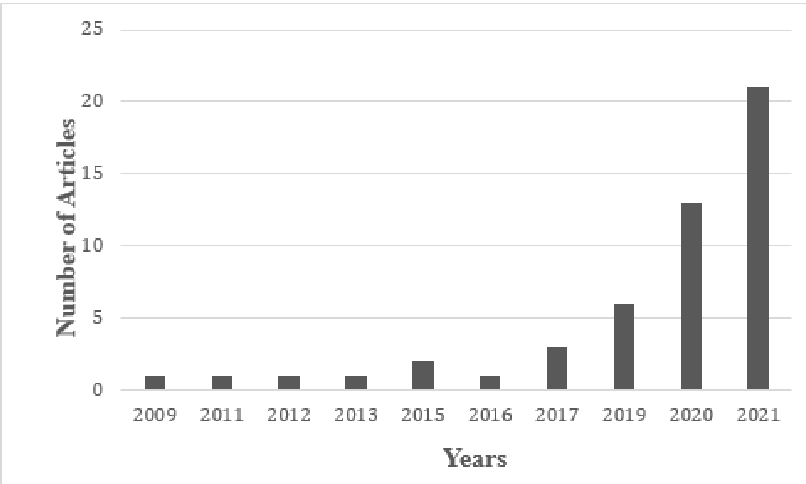

Figure 1. Articles published in the period between 2009 and 2021

Indicators of contamination in water bodies involve analyzing global and/or local maximum permissible values to evaluate the quality of the fluid. The results of these analysis can establish correlations or relationships between water quality and the polluting sources that are determinant for consumptive and non-consumptive uses related to the concentrations of the physicochemical characteristics found in the water samples (Ustaoğlu & Tepe, 2019). In this sense, by employing these indices to assess water quality, it can be predicted possible transformations that the lotic ecosystem may undergo if the multiple measurements of the variables or environmental parameters condensed in the calculation of a dimensionless variable (WQI).

Likewise, these measurements serve as foundational data for environmental authorities and the general public, enabling informed decisions that promote the sustainability of the natural resource (Hasan *et al.*, 2020; Pesce & Wunderlin, 2000; Unda et al., 2020).

In 1965, Horton developed the first water quality index. Subsequently, the National Sanitation Foundation (NSF) introduced a similar ICA based on the opinion of 142 experts. This index is also known as WQINSF by its English abbreviation. Although numerous WQI have been formulated and implemented around the world, today there is no a generally accepted methodology to create an index (Dutra *et al.*, 2019; Noori *et al.*, 2019; Unda *et al.*, 2020).

WQI are used in numerous countries worldwide, with a notable concentration of research related to them in China, India, Brazil, Nigeria, and Indonesia. As a result, WQI are presented in the bibliographic review.

National Sanitation Foundation (NSF) water quality index

The WQI-NFS, known by its English acronym, was developed in 1965 by Brown. It stems from the modified version of Horton's model and was created using the Delphi method. This index holds global prominence and is extensively utilized, particularly within the Indian subcontinent, for assessing surface water quality. Its creation involved a rigorous procedure of the selected parameters, scale definitions, and weight assignments. It is calculated through the application of different parameter quality qualification curves. The WQI-NFS is considered an integral index and universally applicable for categorizing surface water bodies in relation to their quality. This index incorporates nine parameters to evaluate water quality: Temperature, Total Solids, Turbidity, pH, Dissolved Oxygen, Fecal Coliforms, Biological Oxygen Demand (BOD), Total Nitrates, and Phosphates. Each of these parameters has a weight corresponding to its importance and impact on its development as shown in Table 1; The rating of this WQI varies from 0 to 100, presenting a rating scale of five categories: excellent (90-100), good (70-89), medium (50-69), bad (25-49), very bad (0-24) (Uddin, *et al.*, 2021; Nayak *et al.*, 2021; Razaie *et al.*, 2020; Noori *et al.*, 2019; Gupta & Gupta, 2021). The WQI-NFS is defined as follows according to (Brown *et al.*, 1970).

$$\mathrm{WQI} = \sum_{i=1}^{n} w_i q_i \tag{1}$$

Where:

WQI : The water quality index, a number between 0 and 100

q_i : quality of the i-th parameter (Table 1)

w_i : Unit weight of the i-th parameter

Table 1. Weights corresponding to each parameter of the NSFWQI

Parameters	Weight
Temperature	0,10
Dissolved Oxygen (DO)	0,17
Biological Oxygen Demand (BOD)	0,10
Turbidity	0,08
Total Solids	0,08
Match	0,10
Nitrates	0,10
Fecal Coliforms	0,15
pH	0,12
Total = $\sum$ =	1

The WQI-NSF is extensively used worldwide. Despite this, the absence of vitally important parameters such as cyanobacteria, algae, total organic carbon, presents it as an inadequate index to evaluate surface water treatment (Dutra *et al.*, 2019).

Canadian water quality index

The WQI-CCME is an index formulated by the Canadian Council of Ministers of the Environment. It is originated from the WQI of the Ministry of Environment, Lands, and Parks of British Columbia in 1997, with the objective of being used by several agencies in many countries. This WQI offers a flexible index model adaptive to specific site and treatment conditions associated with drinking water assessment. It offers the flexibility to assign values to different combinations of specific parameters. In this regard, the score for the evaluation fluctuates between 0 and 100 with five quality categories: bad (0-44), marginal (45-64), regular (65-79), good (80-94) and excellent (95-100) (Dao *et al.*, 2020; Yu *et al.*, 2020; Abdel-Satar *et al.*, 2017; Hurley *et al.*, 2012). Its greatest strength lies in its capability to incorporate toxic contaminants such as hydrocarbons, pesticides, or heavy metals, aligning with environmental quality guidelines and with current management as an objective (Gikas, *et al.*, 2020).

The calculation for the index in the WQI-CCME method is obtained as shown below:

$$\text{WQI-CCME} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \tag{2}$$

Where: $F_1 =$ (Scope) is the number of parameters that do not comply with the water quality variables:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) \cdot 100 \tag{3}$$

F_2 = **(Frequency) is the number of times the objectives are not met:**

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \tag{4}$$

F_3 = (Amplitude) is the difference between the non-conforming measurements and the corresponding guidelines, this is calculated in three steps.

$$F_3 = \frac{nse}{0.01\ nse + 0.01} \tag{5}$$

$$nse = \frac{\sum \text{excursión}}{\text{Total number of tests}} \tag{6}$$

$$\text{excursión} = \frac{\text{Failed test}}{\text{Standard value}} - 1 \tag{7}$$

From this index, new WQI have been developed such as the modified water quality index, which was developed by Shankar and Raman (2020). This index emerged due to the deficiencies that its creators recognized in the existing indices. The modification of the index was applied to the groundwater in the drinking water sources of the Bommanahalli Area in Bangalore. The main modification it presented was assigning suitable weighting factors for the critical input parameters. Likewise, Ma *et al.*, (2020) incorporated it to evaluate the water quality of the aquaculture area of the southern coast of Dalian, China, covering four main farming areas in forty sampling points. This WQI was used to identify the water quality classes and thus be able to assess spatial and temporal alterations in the sampling area.

Cetesb water quality index

The CETESB index, adapted from the WQI of the NFS by the Environmental Company of the State of São Paulo, was developed with the objective of evaluating the quality of raw water for its use as public supply. To this end, it was taken into account nine parameters with their respective weights (Table 2) that represent the most frequent pollution indicators generated by domestic residual discharges. It should be noted that one of the disadvantages it presents are the limitations related to the limited analysis of parameters such as toxic substances, among these are heavy metals, pesticides, organic compounds are found. Likewise, substances that limit the organoleptic properties of water are excluded (National Water Agency [ANA], 2017; Medeiros *et al.*, 2017).

The calculation of the WQI-CETESB is carried out according to the following formula using the weighted product of the nine parameters (ANA, 2017):

$$\text{ICA-CETESB} = \prod_{i=1}^{n} q_i^{w_i} \tag{8}$$

Where: ICA-CETESB = Water quality index. A number on the scale of 0 to 100

q_i = quality of the ith parameter. A number on the scale 0 to 100, obtained from the respective quality curves, based on its concentration or measure.

w_i = weight assigned to each water quality parameter established by the specialist's judgment, that is, a number on the 0 to 1 scale, such that:

$$\sum_{i=1}^{n} w_i = 1 \tag{9}$$

Table 2. Parameters and weights of the WQI-CETESB

Parameters & Weight
Dissolved oxygen & 0,17
Total Coliforms (Thermotolerant) & 0,15
Hydrogen Potential (pH) & 0,12
Biochemical Oxygen Demand (BOD) & 0,10
Temperature & 0,10
Total Nitrogen & 0,10
Total Phosphorus & 0,10
Turbidity & 0,08
Total Waste & 0,08

Source: National Water Agency [ANA], 2017

Water quality index for public supply in the vale do rio pardo region (WQI-VRP)

The index was developed with the objective of providing a tool to assess water quality for public supply in the Vale do Rio Pardo region, Brazil. This development involved using the databases from the Regional Health Coordinations located in the municipality of Santa Cruz do Sul. For its calculation, the WQI-NFS was taken as a reference, forming a weighted product representing the water quality associated with each parameter under evaluation. Within the weighted product, the weights of importance of the variables are generated (Table 3), assigning a dimensionless value from 0 to 1, which is then multiplied. In order to accomplish this, the arithmetic weight approach is used to assign weighted values (Gad et al., 2021; Torres *et al.*, 2009)

The calculation of the WQI-VRP is carried out according to the following formula:

$$\text{WQI-VRP} = \prod_{i=1}^{n} q_i^{w_i} \tag{10}$$

Where:
q_i : relative quality of the i^{th} parameter
w_i : relative weight of the i^{th} parameter
i : order number of the parameter (1-7).
For the calculation, a step is required where each parameter is transformed to a scale from 0 to 100, with 100 being the highest quality.

Table 3. Parameters and weights of the WQI-VRP

Variables	WQI-VRP weights
Total Coliforms	0.19
E. coli	0.17
Free Residual Chlorine	0.08
Color	0.15
turbidity	0.14
Fluoride	0.12
pH	0.15
Total	1

Source: Klamt *et al.*, 2021

POLLUTION INDICES (WPI)

The WPI serves as a simple and easy method for managing water quality, playing a crucial role in evaluating fluid contamination. In this sense, they have the potential to establish solid arguments and indicators for environmental authorities to promote and implement policies and programs in relation to this renewable natural resource (Effendi *et al.*, 2015; Suriadikusumah *et al.*, 2021).

Hossain & Patra (2020) introduce a contamination index that employs an integrated approach, treating all input parameters as a single value for classifying water quality. This interdependence among these parameters plays a pivotal role in determining water quality. Even minor alterations to the input variables lead to changes in the indicator, with measurement variations directly related to the allowable limits for the groundwater parameters regulated in India's regulations for drinking water and quality guidelines outlined by the World Health Organization (WHO).

19 parameters were used: pH, electrical conductivity, total dissolved solids, Na+, K+, Mg2+, Ca 2+, F -, HCO3 -, Cl -, NO3 -, SO4 2-, and trace elements, namely Zn 2+, Cd 2+, Pb 2+, Cu 2+, Ni 2+, Co 2+, and total Fe (Fe 2+ + Fe 3+). The applications of the indicator have been

numerous due to the wide range of data it processes in its calculations. As a result, the index yields a general representation of the state of the quality of the water body.

However, the WPI can add more variables given the flexibility of n number of parameters within four types of qualifications: (a) excellent quality water (0-0.5), (b) good quality water (0.5-0.75), (c) moderately polluted water (0.75-1), (d) highly polluted water (>1). To calculate this ICO, the following equation is used:

$$\text{WPI} = \frac{1}{n}\sum_{i=1}^{n} PL_i \tag{11}$$

Where:

$$PL_i = 1 + \left(\frac{Ci - Si}{Si}\right) \tag{12}$$

C_i = Observed concentration of the ith parameter.

S_i = Standard limit or maximum allowable limit for the respective parameter.

PL_i = Standardized value of a particular parameter.

If the pH is < 7, the following equation is recommended, with 6.5 being the minimum acceptable value:

$$PL_i = \left(\frac{Ci - 7}{Si_a - 7}\right) \tag{13}$$

If the pH is >7, the following equation is recommended, with 8.5 being the maximum acceptable value:

$$PL_i = \left(\frac{Ci - 7}{Si_b - 7}\right) \tag{14}$$

Organic pollution index

The organic pollution index is a comprehensive tool that includes many components of water quality. It explains the multivariate effects of parameters such as COD, Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphorus, and Dissolved Oxygen, resulting in a dimensionless index that allows for an evaluation of aquatic environments through comparison with standard values and the combination of various contaminants with the same property. It is used in coastal and estuarine waters due to its significant advantage in evaluating the level of organic contamination (Liu *et al.*, 2011).

To determine this index, the following equation is presented:

$$\text{WPI} = \frac{\text{DQO}}{\text{DQO}_S} + \frac{\text{NID}}{\text{NID}_S} + \frac{\text{PID}}{\text{PID}_S} + \frac{\text{OD}}{\text{OD}_S} \tag{15}$$

Where:
BOD = Chemical Oxygen Demand.

NID = Dissolved Inorganic Nitrogen.
PID = Dissolved Inorganic Phosphorus.
DO = Dissolved Oxygen.
CODs, NIDs, PIDs, ODs = are the standard concentrations defined in the regulations.

This index presents 5 types of classification: excellent quality water (if WPI < 0), good quality water (0-1), water starting to become contaminated (1-2), slightly contaminated water (2-3), moderately polluted water (3-4), and highly polluted water (WPI $>$4).

Liu *et al.* (2011) used this index comprehensively to assess the water quality of the Bohai Sea. From their experiences, they affirm that this WPI can be used to reasonably quantify the level of temporal and spatial pollution in coastal waters.

Heavy metal contamination index (HPI)

Heavy metals cause significant pollution in aquatic environments, raising global concerns. This is due to the toxicity and lethal impact these metals impose on aquatic organisms. In response to this issue, the Heavy Metal Pollution Index (HPI) has been developed. It aims to evaluate the compound influence of individual heavy metals that contaminate and deteriorate water quality. The index takes into consideration the aggregation of trace elements, including highly toxic metals and metalloids like nickel, mercury, iron, arsenic, among others (Karaouzas *et al.*, 2021; Wątor & Zdechlik, 2021; Khadija *et al.*, 2021).

This index is based on the weighted arithmetic quality mean method and is calculated as follows:

$$\text{HPI} = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i-1}^{n} W_i} \tag{16}$$

Where:
W_i = unitary weight of the i-th heavy metal.
Q_i= subscript for the i-th heavy metal, it is calculated like this:

$$Q_i = \sum_{i=1}^{N} \frac{|M_i - I_i|}{S_I - I_i} \tag{17}$$

M_i = Examined value of the ith heavy metal.
I_i and S_i = standard and ideal values for drinking water for heavy metals.
n = number of heavy metals.

Values less than 100 mean low heavy metal contamination, values of 100 suggest probable contamination with harmful consequences for health, and values greater than 100 indicate that the water is not suitable for consumption.

Convergent and divergent criteria of background references and associated with the study of WQI and WPI

The WPI and WQIhave found diverse uses since their inception, serving as tools that facilitates the effective management of one or several underground and/or surface water sources, In general terms, the results of their calculation can specify the suitability of the natural element's use (Rana & Ganduly, 2020; Pandit *et al.*, 2022). In fact, they allow researchers and environmental agencies to present an accurate report of quality of a given water body. The combined effects of several quality parameters facilitates the identification of weighted variables with the greatest impact on the alteration. In other words, it could measure how suitable is the studied water for use (Rahman *et al.*, 2021; Gayer *et al.*, 2021).

Countries across Asia, Europe, and America have reported a recent surge in the study of water quality using the aforementioned indices. The emergence of new methodologies suggests that their utilization is likely to exhibit an upward trend in the timeline (Dash & Kalamdhad, 2021), such as Klam, *et al.*, (2021) who developed an ICA-VRP for supply in the Vale do Rio Pardo region (Brazil), using the database of the 13 regional health coordination offices of the municipality of Santa Cruz do Sul. This index is calculated in a similar way to the WQI-NFS, taking as reference 7 parameters: free residual chlorine, turbidity, apparent color, pH, fluoride, total coliforms and Escherichia coli. The aforementioned corroborates what was reported by Barbulescu *et al.* (2021) and Hasan *et al.* (2020). This tool could help in guidelines associated with the development of policies and actions established by the competent authorities, in favor of mitigating the impact on the fluid. Likewise, (Kumar *et al.*, 2019) developed an index to measure the toxicity of heavy metals in water based on median lethality dose (MLD) values, demonstrating their maximum toxicity.

However, one of the main problems reported by Uddin *et al.* (2021) creates uncertainty in the use of WQI. This stems from the way results are described upon concluding the use of such models, since they hide the real nature of water quality. This discrepancy is attributed to potentially inappropriate sub-indexing or incorrect weighting, which fail to accurately represent the dynamics of these parameters in this type of complex systems.

Moreover, other authors such as Nayak *et al.* (2020) explored the dynamism of lotic systems in India and reported high levels of content of BOD5 and Total Solids (TS). The significant presence of these specific parameters suggest that the use of the WQI-NFS may yield inconclusive outcomes. This is because its values of the parameter based on the observed value do not agree with the pollutant loads (BOD5 and ST) of the studied rivers.

On the other hand, issues arising from the use of WPI are related to the concentrations of heavy metals. By only taking into account the traces of metals at the individual level, forgetting the synergistic impacts of different parameters and variables associated with metals, the real state of the contamination is not always detected. In addition to this, a divergence in the results can occur when using these indices in the same place due to the diversification of the results, thus leading to a degree of variability in the conclusions of the study. Despite the fact that there are different contamination indices, a model has not yet been put forward that allows the evaluation of the environmental-chemical state of a body of water at an international level (Liu *et al.*, 2011).

Other aspects that differ in these methods were presented by Kumar, *et al.*, (2019) when they analyzed the groundwater quality and potential sources of trace metal contamination of the Saharanpur district (India), using the contamination index (Cd) and the HPI. In the results, they demonstrate that the analysis and mathematical models are not sufficient to represent the categories of water contamination, reporting more accurate results when the index method was used for the evaluation of water quality. The contamination index is thus shown to be a tool that can provide a better mechanism to show the health of a body of water. When the contamination indices reported by Karaouzas, *et al.*, (2021) were compared, they stated that there is a conceptual convergence in the Contamination Index (CI) and HEI methods. This is due to the integration of the maximum admissible and upper admissible concentration of heavy metals. Conversely, when using the HPI method, an arbitrary classification between 0 and 1 is considered the maximum admissible concentration of metals.

Conclusions

Frequently used trends were identified for the WQI-NFS and WQI-CCME quality indices and for the HPI contamination index. The water quality indices have been used repeatedly in recent years in several countries around the world with the objective of evaluating the quality of bodies of water, both surface (rivers, lakes, seas) and underground. In the same way, new indices have been developed from some existing WQI in an effort to improve deficiencies that appear in the indices, allowing us to evaluate water bodies in a better way. This, in turn, will help to support environmental authorities so that they may best manage water resources.

The discussion of the references allows us to conclude that there are convergences and divergences in the use of contamination and quality indices in the different studies, limiting their use in relation to the dynamics of the fluid to be studied and the limiting weights of each of them. methods.

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