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Drinking water quality indices: a systematic review

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ABSTRACT

This analysis applied systematic review as a methodology for identifying, analyzing and interpreting data on the use of water quality indices for human consumption. Scientific articles were searched in the “PubMed”, “Scielo”, “ScienceDirect” and “Web of Science" databases, using the keywords “drinking water” and “water quality index”, with a custom interval between 2000 and 2020. The results indicated 82,573 published articles, with 16 of them being selected after a filtering process. The occurrence of 11 water quality indices was verified, including 47 water quality parameters used to assess the quality of drinking water, highlighting that the parameters pH, Nitrate, Turbidity, Chloride and Sulfate were the most used, cited in 10 of the 16 articles selected (62,5%). We suggest that future studies seek to propose regionalized water quality indicators for consumption, in order to consider local aspects in the evaluation process and to determine intervention priorities by health surveillance agencies.

Keywords: drinking water, systematic review, water quality indices.

Índice de qualidade de água para consumo humano: uma revisão sistemática

RESUMO

Esta análise aplica a revisão sistemática como metodologia para identificar, analisar e interpretar dados sobre o uso de índices de qualidade da água para consumo humano. Os artigos científicos foram pesquisados nas bases de dados “PubMed”, “Scielo”, “Science Direct” e “Web of Science”, usando as palavras-chave “água potável” e “índice de qualidade da água”, com um intervalo personalizado entre 2000 e 2020. Os resultados indicaram 82573 artigos publicados, sendo 16 deles selecionados após um processo de filtragem. Verificou-se a ocorrência de 11 índices de qualidade da água, incluindo 47 parâmetros de qualidade da água utilizados para avaliar a qualidade da água potável, destacando que os parâmetros pH, nitrato, turbidez, cloreto e sulfato foram os mais utilizados, citados em 10 dos 16 artigos selecionados (62,5%). Sugerimos que pesquisas futuras procurem propor indicadores regionalizados de qualidade da água para consumo, a fim de considerar aspectos locais no processo de avaliação e determinar prioridades de intervenção por órgãos de vigilância em saúde.

Palavras-chave: água potável, índices de qualidade da água, revisão sistemática.

1. INTRODUCTION

Sustainable access to drinking water is essential for human life, health and well-being. However, surface water bodies that are the most important water sources for human activities are, unfortunately, under severe environmental stress, being threatened because of anthropogenic activities (Yogendra and Puttaiah, 2008). Thus, poor water quality in rural communities causes health inequality, especially in developing countries. The quality of drinking water can be controlled through a combination of water source protection, treatment process control and water management. The guidelines must be appropriate for regional and local circumstances, which requires adaptation to environmental issues, social, economic and cultural circumstances, and setting priorities (WHO, 2006).

Several physical, chemical and biological parameters are used to characterize water quality, which can be integrated in a Water Quality Index (WQI) to describe, for instance, the degree to which a waterbody is suitable for consumption purposes (Tyagi *et al.*, 2013). A WQI provides a single number that expresses overall water quality based on importance weights assigned to each water quality parameter. WQI’s are widely used as a practical method for representing pollution problems in water bodies. They do not require a huge number of different water quality parameters for development and validation, only the concentration of a limited number of parameters (Akkoyunlu and Akiner, 2012). Water resource specialists generally determine the water quality state and its trends, based on the assessment of individual water quality parameters. While professionals readily understand this technical language, non-technical people have difficulty in understanding these water quality results (Cude, 2001).

One of the most widespread indices in the world is the National Sanitation Foundation Water Quality Index (NSF WQI) developed by Brown *et al.* (1970) for the United States. The NSF WQI was established by selecting nine variables: dissolved oxygen, fecal coliforms, pH, biochemical oxygen demand (BOD), temperature, total phosphate and nitrate concentrations, turbidity, and total solid content. Five classes for water quality were defined: red (very poor), orange (poor), yellow (average), green (good) and blue (excellent) (Kachroud *et al.*, 2019). The NSF WQI was developed to compare the quality of water bodies and monitor temporal or spatial changes in water quality, mainly applied to pollution from domestic sewage and eutrophication processes (Finotti *et al.*, 2015; Klamt *et al.*, 2019). The WQI can also indicate the contribution of industrial effluents, as long as they are of a biodegradable organic nature (CETESB, 2019). The NSF WQI was calibrated for subtropical and temperate Brazilian lotic systems by Moretto *et al.* (2012), based on Resolution 357/2015 from the Brazilian National Environment Council (CONAMA, 2005). The calculations were made using the IQAData software (Posselt *et al.*, 2015).

The potability standards in Brazil are established in Consolidation Ordinance No. 5/2017 (Brasil, 2017), which provides the procedures for the control and surveillance of water quality and potability standards for human consumption, as well as establishing the competences and responsibilities assigned to public health authorities. The Annex XX of this Consolidation Ordinance shows the physical-chemical and bacteriological parameters for consumption, highlighting the Free Residual Chlorine, pH, Apparent Color, Fluoride, Turbidity, Total Coliforms, Escherichia coli and Heterotrophic Bacteria as standards of potability. Changes in their physical-chemical and microbiological properties can compromise their quality, enabling the creation of environments favorable to the development of vectors, which can alter and/or suppress ecosystems and biomes, in addition to causing the emergence and aggravation of population's health problems.

According to Chapter II, Art. 5º, Section II of this Consolidation Ordinance, drinking water is defined as the water that meets the potability standard established in Annex XX, not offering health risks (BRASIL, 2017). On the other hand, according to the National Health Foundation

(FUNASA), water for human consumption must not contain pathogenic microorganisms and be free of bacteria from coliform group, which are indicators of fecal contamination, being represented mainly by Escherichia coli (FUNASA, 2009).

Currently, there is a lack of WQI's for drinking purposes, especially those focused on simpler parameters, at low cost, generating qualitative information accessible to the population. In this context, this study uses the systematic review methodology developed by Petersen *et al.* (2008), aimed at identifying, analyzing and interpreting data on the use of WQI's for human consumption, trying to find the most relevant publications, the possible research gaps, and their challenges, but mainly to identify the main parameters used and the composition of WQI's.

2. METHODOLOGY

This study is characterized as a systematic review, defined by the use of data from the literature, seeking to integrate information from a set of studies carried out separately on a given topic, which may present conflicting or coincident results (Sampaio, 2007). A scientific article that applies the systematic review as a methodology aims to identify, analyze and interpret all available evidence related to a specific research question (Kitchenham and Charters, 2007), in this case addressed to the use of WQI's for human consumption. This type of methodology discusses not only the conclusion, but also all activities related to the main theme. Thus, a systematic study collects data on the places where the activity occurs and the media in which it was published. The methodology consists of elaborating the research questions, designing the research process and defining the criteria for filtering the results (Cooper, 2016).

2.1. Research questions

The review covers articles published from January 2000 until March 2020, over a period of 20 years. The first general question (GQ1) is to identify which WQI's were applied to classify water quality (Table 1). From this, a specific question (FQ1) and a statistical question (SQ1) were defined.

Table 1. Research questions.

Reference	**Questions**
General question (GQ1)	Which indices were applied to classify the quality of drinking water?
Specific question (FQ1)	Which variables were found in the research?
Statistic question (SQ1)	Where were the surveys published?

2.2. Research process

According to Petersen *et al.* (2008), three stages are defined during the research process: (1) Specify the research keywords, (2) Choose the databases to apply the research keywords, and (3) Get the results. The first step begins by identifying the main terms and their most relevant synonyms. Thus, scientific articles were searched using the keywords "drinking water" and "water quality index", in the PubMed, Scielo, ScienceDirect and Web of Science databases, with a custom interval between 2000 and 2020.

2.3. Applying filters

In order to filter the most relevant scientific information, the following criteria (C) were included:

C1. The study must be published in a scientific magazine or newspaper.

C2. The study must be directly related to WQI's for consumption.

C3. The study must be a complete work.

C4. Keywords must be included in the title.

The selected articles were stored in EndNote X7© software (Thomson Reuters), where the texts were organized in specific folders for each research database. The next filter was based on the three-step approach introduced by Srinivasan Keshav (2007). The first step was a quick scan and consists of reading the title, summary and introduction. In the second step, only the section and subsection headings are read. Finally, in the third step, the mathematical content (if any) is examined to determine the underlying theoretical foundations.

3. RESULTS AND DISCUSSION

Table 2 shows the filtering process, with criteria C1 to C4 applied in each stage. Based on the results obtained, the articles were organized by title, year of publication, authors, databases, technologies and work objectives.

Table 2. Filtering process.

Database	Initial search	Keywords in the title	C1	C2	C3/C4
PubMed	126	32	24	24	3 (2,38%)
Scielo	38	1	1	1	0 (0%)
Science Direct	42815	356	356	344	10 (0,02%)
Web of science	39594	26	15	15	3 (0,01%)
Total	82573	415	396	381	16 (0,02%)

3.1. GQ1 – Which indices were applied to classify water quality?

A WQI is a tool to present a numerical expression derived cumulatively to define a certain level of water quality. In other words, a WQI summarizes large amounts of water quality data in simple terms (for example, excellent, good and bad) to report to management authorities and non-technical people consistently. The WQI concept is based on the comparison of water quality parameters with their respective regulatory standards, and gives a unique value to water quality, which translates the list of constituents and their concentrations present in a sample. The formulation and use of indices have been strongly advocated by agencies responsible for water supply and water pollution control. Table 3 shows the WQIs for consumption that have been used.

In some studies, more than one WQI was used, being modified for consumption purposes, and several citations followed the standards of the World Health Organization, which deals with drinking water guidelines. The Indian Standard Bureau (ISB) is an institution that regulates and provides details on the permitted and desirable standard specifications and limits of various parameters in drinking water. The CCME Water Quality Index, based on a formula developed by the British Columbia Ministry of Environment, is a quality index that summarizes complex data on water quality to facilitate its communication to the public. The NSF index was developed to provide a standardized method for comparing the water quality of various bodies.

Table 3. Water quality indices used and respective references.

Water Quality Indices	**Articles**
Bhargava Water Quality Index.	Avvannavar and Shrihari (2008).
GWQI - Groundwater Quality Index.	Masocha *et al.* (2019).
National Sanitation Foundation Index (NSF).	Gharibi *et al.* (2012); Barakat *et al.* (2018); Cooray *et al.* (2019).
WQI CCME.	Gharibi *et al.* (2012); Hurley *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015).
Water Quality Index (WQI).	Batabyal and Chakraborty (2015).
Drinking Water Quality Index (DWQI).	Scheili *et al.* (2015); Jasmin and Mallikarjuna (2014); Ramesh *et al.* (2010); Ponsadailakshmi *et al.* (2018).
Fuzzy-based Water Quality Index.	Gharibi *et al.* (2012).
Additive Water Quality Index (AWQI).	Paca *et al.* (2019).
Multiplicative Water Quality Index (MWQI).	Paca *et al.* (2019).
Scottish Water Quality Index (SDD).	Bordalo and Savva-Bordalo (2007).
Integrated Water Quality Index (IWQI).	Mukate *et al.* (2019).

3.2. FQ1 – Which variables were found in the research?

The researchers explored each index as a performance measure that aggregates information, reflecting the influence of physical, chemical and biological variables of water quality conditions. These are based on quality parameters with their respective regulatory standards, presenting a single value for water quality. Table 4 shows the parameters used and their respective references.

Table 4. Parameters used to assess the quality of drinking water and respective references.

Parameters (Nº of citations)	**Articles**
pH (16)	Paca *et al.* (2019); Batabyal and Chakraborty (2015); Scheili *et al.* (2015); Jasmin and Mallikarjuna (2014); Cooray *et al.* (2019); Avvannavar and Shrihari (2008); Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Hurley *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Nitrate (13)	Paca *et al.* (2019); Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Hurley *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Turbidity (11)	Paca *et al.* (2019); Batabyal and Chakraborty (2015); Scheili *et al.* (2015); Avvannavar and Shrihari (2008); Bordalo and Savva-Bordalo (2007); Gharibi *et al.* (2012); Hurley *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Masocha *et al.* (2019).
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Chlorides (10)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Cooray *et al.* (2019); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Mukate *et al.* (2019).
Sulfate (10)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Cooray *et al.* (2019); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Total hardness (9)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Cooray *et al.* (2019); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019).
Iron (9)	Batabyal and Chakraborty (2015); Cooray *et al.* (2019); Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Hurley *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019).
Calcium (9)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Magnesium (8)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Sodium (8)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019); Mukate *et al.* (2019).
Fluorides (8)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Cooray *et al.* (2019); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018).
Electric conductivity (8)	Paca *et al.* (2019); Batabyal and Chakraborty (2015); Cooray *et al.* (2019); Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018); Masocha *et al.* (2019).
Total coliforms (7)	Avvannavar and Shrihari (2008); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Hurley *et al.* (2012); Barakat *et al.* (2018); Masocha *et al.* (2019); Bordalo and Savva-Bordalo (2007).
Total dissolved solids (6)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Mukate *et al.* (2019).
Chrome (6)	Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018).
Nitrite (6)	Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018).
Total alkalinity (5)	Batabyal and Chakraborty (2015); Cooray *et al.* (2019); Ramesh *et al.* (2010); Barakat *et al.* (2018); Ponsadailakshmi *et al.* (2018).
Manganese (5)	Batabya and Chakraborty (2015); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018).
Zinc (5)	Batabyal and Chakraborty (2015); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018).
Copper (5)	Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Ponsadailakshmi *et al.* (2018).
Ammonia (5)	Paca *et al.* (2019); Bordalo and Savva-Bordalo (2007); Mohebbi *et al.* (2013); Abtahi *et al.* (2015); Barakat *et al.* (2018).
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Potassium (4)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014); Masocha *et al.* (2019); Mukate *et al.* (2019).
Lead (4)	Ramesh *et al.* (2010); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Ponsadailakshmi *et al.* (2018).
Dissolved oxygen (4)	Paca *et al.* (2019); Bordalo and Savva-Bordalo (2007); Gharibi *et al.* (2012); Barakat *et al.* (2018).
Arsenic (4)	Bordalo and Savva-Bordalo (2007); Gharibi *et al.* (2012); Mohebbi *et al.* (2013); Abtahi *et al.* (2015).
Temperature (4)	Scheili *et al.* (2015); Bordalo and Savva-Bordalo (2007); Gharibi *et al.* (2012); Barakat *et al.* (2018).
Escherichia coli (3)	Hurley *et al.* (2012); Abtahi *et al.* (2015); Barakat *et al.* (2018).
Fecal coliforms (3)	Paca *et al.* (2019); Bordalo and Savva-Bordalo (2007); Mohebbi *et al.* (2013).
Biochemical oxygen demand (3)	Paca *et al.* (2019); Avvannavar and Shrihari (2008); Gharibi *et al.* (2012).
Total organic carbon (3)	Scheili *et al.* (2015); Hurley *et al.* (2012); Cooray *et al.* (2019).
Cadmium (3)	Ramesh *et al.* (2010); Mohebbi *et al.* (2013); Gharibi *et al.* (2012).
Aluminium (2)	Mohebbi *et al.* (2013); Abtahi *et al.* (2015).
Phosphate (2)	Paca *et al.* (2019); Gharibi *et al.* (2012).
Mercury (2)	Gharibi *et al.* (2012); Mohebbi *et al.* (2013).
Fecal enterococci (2)	Bordalo and Savva-Bordalo (2007); Barakat *et al.* (2018).
Bicarbonate (2)	Batabyal and Chakraborty (2015); Jasmin and Mallikarjuna (2014).
Nickel (1)	Ramesh *et al.* (2010).
Free chlorine (1)	Scheili *et al.* (2015).
Barium (1)	Gharibi *et al.* (2012).
Cyanide (1)	Bordalo and Savva-Bordalo (2007).
Ryznar Index (1)	Abtahi *et al.* (2015).
Colour (1)	Bordalo and Savva-Bordalo (2007).
Salmonella (1)	Ramesh *et al.* (2010).
Trihalomethanes (1)	Scheili *et al.* (2015).
Haloacetic acid (1)	Scheili *et al.* (2015).
Ultraviolet absorption (1)	Scheili *et al.* (2015).
Heterotrophic coliforms (1)	Scheili *et al.* (2015).

The parameters most used to assess water quality were pH, nitrate, turbidity, chloride and sulfate, cited in 10 of the 16 articles selected in this study (62,5% of the total). The inorganic contaminant of greatest concern in groundwater is the nitrate ion, NO_3^-, which normally occurs in aquifers in rural and suburban areas. Nitrate in groundwater comes mainly from four sources: application of nitrogen fertilizers, animal manure in plantations; soil cultivation; human sewage deposited in septic systems; and atmospheric deposition (Baird and Cann, 2011).

A recent concern deals with the increase in nitrate ion levels in drinking water, particularly in well water in rural localities, the main source of this nitrate being leaching from cultivated land into rivers and water flows. Excess nitrate ion in drinking water is worrying because it causes blue baby syndrome in newborns; in adults, it may be responsible for causing stomach cancer and increase the likelihood of breast cancer in women (Baird and Cann, 2011).

Chloride in drinking water comes from natural sources, sewers, industries, effluents, urban runoff containing defrost salt, and saline intrusion. High concentrations of chloride increase the metal corrosion rates in the distribution system, depending on the alkalinity of the water, and give a salty taste to water. The taste limits for the chloride anion depend on the associated cation and are in the range of 200-300 mg L^{-1} for sodium, potassium and calcium chloride. Excess concentrations of 250 mg L^{-1} are more likely to be detected by taste, but some consumers may get used to low levels of chloride-induced flavor. No health-based guideline proposes a concentration value for chloride in drinking water (WHO, 2017).

The presence of sulfate in drinking water can cause a noticeable taste, and very high levels can cause a laxative effect in unaccustomed consumers. Sulfates occur naturally in various minerals and are used commercially, mainly in the chemical industry. They are discharged into water in industrial waste and by atmospheric deposition; however, the highest levels generally occur in groundwater and are from natural sources. In general, the average daily intake of drinking water, air and food sulfate is approximately 500 mg, with food being the main source. However, in areas with drinking water supplies containing high levels of sulfate, drinking water can be the main intake source. No health-based guidelines are proposed for sulfate. However, due to gastrointestinal effects resulting from drinking water containing a high sulfate content, it is recommended that health authorities are notified of drinking water sources containing sulfate concentrations above 500 mg L^{-1} (WHO, 2017).

pH is a measure of the concentration of H^+ ions in water. The balance of hydrogen and hydroxide ions (OH^-) determines how acidic or basic water is. In chemically pure water, the H^+ ions are in equilibrium with the OH^- ions and their pH is neutral, that is, equal to 7. The main factors that determine the pH of water are dissolved carbon dioxide (CO_2) and alkalinity. pH has a direct relationship with the quality of water for human consumption. Water with a high carbon dioxide content, reduced total alkalinity and low pH is considered aggressive. Aggressive waters are those that tend to dissolve calcium carbonate. Water with a low pH promotes corrosion of metal pipes and fittings, namely copper, lead and zinc, which can cause problems such as a metallic or sour taste (ERSAR, 2008; WHO, 2011).

A pH greater than 8.5 may indicate that the water is hard. It does not pose a health risk, but it can cause esthetic problems, such as incrustations in pipes and equipment, causing a decrease in the inside diameter; alkaline flavor; difficulty in obtaining foam; and formation of insoluble precipitates on clothes. Turbidity has a potential health effect: it is often associated with the presence of microorganisms originating in surface runoff from soil (WHO, 2017).

The presence of microbiological agents (*Escherichia coli*, coliforms), can generate acute and generalized effects on the health of consumers without changing the flavor, odor or color of water. The greatest public health risk of microbes in water is associated with drinking water that is contaminated with human and animal excrement, although other sources and routes of exposure may also be significant. Outbreaks transmitted by water have been associated with inadequate water treatment and unsatisfactory management of drinking water distribution.

There are few chemical substances in the water causing health problems, except for massive water contamination, such as in environmental accidents, and it is commonly impossible to consume the water due to its taste, odor or general appearance. Therefore, variations in the concentration of chemical elements in the water, even if for short periods they present values above those allowed does not necessarily mean that it is not fit for consumption.

The proportion by which the permitted values can be exceeded and the period for which this situation can be prolonged without prejudice to health will depend on each substance or element considered.

The problems related to the elements or chemical substances present in water for human consumption are mainly due to the negative effects to health after prolonged periods of exposure to organic contaminants and toxic heavy metals. The radioactive aspects depend on naturally occurring radioactive isotopes that start from the uranium decay series, such as lead 210 mg L^{-1} and uranium 238 mg L^{-1} and 234 mg L^{-1}. The presence of radionuclides, even in normal circumstances, must be considered.

As for the acceptability aspects of drinking water, the population bases them on properties such as taste, color, odor, appearance, turbidity and other parameters perceptible to its taste. Esthetically unacceptable water will decrease consumer confidence, leading to complaints and, more importantly, to the use of water from less secure sources. Consumers have no means of judging the quality of their drinking water, but their attitude towards drinking water supplies and suppliers will be largely affected by the aspects of quality that they are able to perceive with their own senses. Consumers consider unacceptable water that is not colorless or which has an unpleasant taste or smell, even though these characteristics may not have direct health impacts.

It is important to consider whether existing water treatment and distribution practices can affect the acceptability of drinking water, as well as managing changes and operations to minimize the risk of acceptability problems. For example, chloramination that is not properly managed can lead to the formation of trichloramines, which can cause unacceptable taste and odor. Other problems can be indirect, such as internal deposits in pipes when the flow in distribution systems is disturbed or altered.

The water quality parameters used to assess the quality of drinking water were classified into microbiological, chemical, radioactive and acceptance aspects, as described in the *Guidelines for Drinking-water Quality* (WHO, 2017). The parameters not included in these categories were classified in “others” (Table 5).

In Brazil, according to the Consolidation Ordinance nº 5/2017 of the Ministry of Health (Brasil, 2017), some physical, chemical and bacteriological parameters must be followed to ensure their potability, considering their respective regulatory standards listed in Annex XX (Table 6), which deals with the control and surveillance of water quality for human consumption. All water intended for human consumption from an individual alternative water supply solution, regardless of how the population accesses it, is subject to water quality monitoring.

3.3. SQ1 – Where the surveys were published?

The articles were categorized in the four databases used in this systematic review. Table 7 shows the number of articles published by the database, highlighting ScienceDirect with 10 articles. No articles were published in the Scielo database. In a general way, little is found in the literature about comparative analysis related to the development, comparison and application of different WQI’s; currently, there is great concern about controlling the quality of the water we consume. A series of indices are being developed and adapted for consumption.

The database that stood out most for the publication of studies on WQI within the selection criteria was ScienceDirect. It was observed that the impact of human activity was severe in most parameters. The maximum permitted values have exceeded the tolerable limits in some situations. Yet the main cause of deterioration in water quality is the lack of adequate sanitation, unprotected river areas and high anthropogenic activity. Water is essential to sustain life; there must be a satisfactory supply (adequate, safe and accessible) and it must be available to everyone. Improving access to contaminant-free drinking water can result in tangible health benefits. Every effort should be made to obtain drinking water that is as safe as possible.

Table 5. Water quality parameter classification (WHO, 2017).

Microbiological	Chemicals	Radioactive	Acceptability	Others
Total coliforms	Fluoride	Lead	pH	Temperature
Escherichia coli	Total hardness		Chloride	Calcium
Fecal coliforms	Nitrate		Sulfate	Magnesium
Fecal enterococci	Aluminum		Chlorine	Phosphate
Salmonella	Potassium		Sodium	Total organic carbon
Heterotrophic coliforms	Chromium		Total dissolved solids	Electric conductivity
	Zinc		Iron	Total alkalinity
	Copper		Manganese	Biochemical oxygen demand
	Nitrite		Turbidity	
	Cyanide		Total hardness	
	Ammonia		Zinc	
	Cadmium		Dissolved oxygen	
	Arsenic		Aluminium	
	Barium		Ammonia	
	Nickel		Colour	
	Mercury		Copper	
	Chloride			
	Manganese			
	pH			
	Sodium			
	Sulfate			
	Iron			
	Lead			
	Bicarbonate			
	Total dissolved solids			

Table 6. Water quality parameters in Brazil, following the Consolidation Ordinance nº 5/2017 of the Ministry of Health (Brasil, 2017).

Potability parameter	Maximum value allowed
Free Residual Chlorine	0,2 - 2,0 mg L^{-1}
pH	6,0 - 9,5
Apparent Color	15 CU
Fluoride	1,5 mg L^{-1}
Turbidity	5 NTU
Total Coliforms	Absence in 100 mL
Escherichia coli	Absence in 100 mL
Heterotrophic Bacteria	500 UFC mL^{-1}

Table 7. Classification of results.

Database	Articles
PubMed	Paca *et al.* (2019); Batabyal and Chakraborty (2015); Cooray *et al.* (2019).
Web of Science	Avvannavar and Shrihari (2008); Jasmin and Mallikarjuna (2014); Scheili *et al.* (2015).
Science Direct	Masocha *et al.* (2019); Mukate *et al.* (2019); Ponsadailakshmi *et al.* (2018); Barakat *et al.* (2018); Mohebbi *et al.* (2013); Hurley *et al.* (2012); Gharibi *et al.* (2012); Abtahi *et al.* (2015); Bordalo and Savva-Bordalo (2007); Ramesh *et al.* (2010).

Safe drinking water, as defined by authorities that determine its parameters, does not represent a significant health risk during the entire consumption life, including in those with sensitivities that can occur at different stages of life. Those most at risk for waterborne diseases are children and elderly people, especially when living in unsanitary conditions. Those who are generally at risk for waterborne illnesses may need to take additional measures to protect themselves from exposure to waterborne pathogens, such as boiling drinking water. Safe drinking water is required for all usual household purposes, including drinking, food preparation and personal hygiene. Therefore, the development of indices to assess the quality of drinking water is essential for each human being to have access to the quality of the water they are consuming.

4. CONCLUSION

This systematic review presented the search for WQI’s for human consumption. In addition, it presented different models of variables associated with the quality of drinking water, in order to obtain a better result for water quality. However, none of the reviewed articles documented how a historical database could effectively improve this goal with the support of new technologies. The bibliographic references selected in this systematic review allow us to observe that, although the frequency of studies related to WQI’s for drinking has increased in recent years, the number of studies is still insufficient to obtain effective scientific evidence. One of the gaps found during this research corresponds to evaluation of the parameters analyzed and their separation between microbiological, radioactive, chemical, acceptability and others, highlighting that the basic and essential requirements to guarantee the safety of drinking water are based on the health established by competent health system authorities and adequate surveillance systems.

We suggest that future research seek to propose regionalized WQI’s for consumption, in order to consider local aspects in the evaluation process and to determine intervention priorities for health surveillance agencies. In addition, the development of computerized platforms for centralizing information on these WQI's, accessible to the public in real time, is essential for the effective implementation of programs for monitoring the quality of drinking water.

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