IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
November 2022 Vol.:23, Issue:1

Qualitative and Quantitative Study of Water Springs of Cities in The Cariri Cearense in Brazil

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Fabrynne Mendes de Oliveira*[1], Germário Marcos Araújo[2], Otacilio Correia Lima Neto[3], Yannice Tatiane da Costa Santos[2], Rafael Bezerra Tavares Vasques Landim[3], Daniel Pereira de Morais[1], Alex Souza Moraes[1]

1 Master's student at Universidade Federal Rural do Pernambuco (UFRPE), Brasil.

2 Teacher at Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE) , Brasil.

3 Water Resources Analyst at Companhia de Gestão dos Recursos Hídricos (COGERH) , Brasil.

Submitted: 20 October 2022
Accepted: 27 October 2022
Published: 30 November 2022

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Water Resources; Springs; Sources; Water

ABSTRACT

The predominance of springs in the Araripe Sedimentary Basin has an important social, environmental and economic bias, representing the main means of obtaining water for rural properties and communities. Quantitative and qualitative parameters were analyzed historically and compared to legislation and literature, in search of a general understanding of the current situation of 25 strategic sources selected in the brazilian municipalities of Cariri Cearense: Barbalha, Crato, Jardim, Missão Velha and Porteiras, being compared in the periods 2018/2019 and 2021/2022, totaling 09 campaigns. In the quantitative aspect, the source with the highest flow is Batateira, also the one with the highest standard deviation among the analyzed campaigns, due to the association of different measurement methods. Some sources obtained values with greater oscillations between campaigns due to field conditions, such as the Farias Source which is evaluated through the junction of two levadas approximately 100 meters apart. In most of the sources, the maximum flows recorded were not higher than 50% of the average value. As for the qualitative aspect, the majority did not obtain a variation of more than 50% in each parameter (between the minimum and maximum value recorded), highlighting that pH and temperature obtained the most constant results in all campaigns. Despite the difficulty due to some inconsistencies in data and lack of parameters that could help in determining the environmental quality of these water bodies, it was possible to conclude that this is an abundant natural resource with excellent conditions for multiple uses, resembling the general characteristics of groundwater.

1. INTRODUCTION

The water is a natural, vital, essential resource and, despite its abundance, it has an uneven distribution and portions that are not fit for use. This is associated with environmental, social and economic terms, already notoriously known its findable nature and the need for strategic, decentralized, egalitarian management and with concern for preservation purposes, especially in its origin, the springs (MACHADO, 2018).

The water springs, also called fountains, water eyes, mines, headwaters or water wires, are composed as a fundamental part of the functioning of the hydrological cycle of watersheds, since they are outcrops of water from underground flow and the water table. They have peculiar importance in the maintenance of the deposit and sustainability of the water resource, being, therefore, subject to monitoring, maintenance, protection and conservation processes (FRANÇA, 2019).

The fountains consists in the origin of water flows that form the drainage network, ideally necessary for the supply of good quality water in an abundant and continuous manner, adequately distributed over time and with minimal variation in flow throughout the year (CALHEIROS, 2009). In these places, water emerges naturally, from a rock or soil, to the ground surface or to a surface water body (UNESCO, 2011).

Approximately 60% of Brazil's water supply comes from wells (public or private) or springs (IBGE, 2000). More specifically, according to Rural Environmental Cadastre (CAR, 2017), 1.5 million springs and water eyes are regularly counted (FRANCE, 2019). Knowing the intense exploitation and dependence on water for various human activities, the high demand may be indicative of a future scarcity, considering the springs as strategic points of preservation to serve future generations (CAPELLARI, 2018).

According to França (2019), the protection of springs has an important contribution, from for environmental gains to the improvement in the quality of human life, since it represents benefits for ecosystems, riparian forest, biodiversity, flora, fauna and soil, besides preserving water with adequate quality for consumption, which directly impacts the well-being of all species, since they depend on this resource for their survival.

The springs of underground water reservoirs in the Cariri, region in the brazilian state Ceará, have notable occurrences in the Araripe Sedimentary Basin, which supply populations through exuterations (springs) and deep tube wells, providing all the benefits of quality water resource and with adequate availability for distribution and, consequently, socioeconomic development (GOMES *et al.*, 2018).

Over the area of the Araripe Sedimentary Basin is the plateau of the same name, known as '*Chapada do Araripe*'. Its drainage is intermittent, i.e., some times of the year it does not present surface flow, and this basin is rich in underground water resources (CEARÁ, 2009).

According to Silva (2021), the geological conformation of the soil of Cariri allowed the formation of a sedimentary basin with three aquifer systems and, specifically in the upper aquifer, there is a predominance of sprouting fountains from 680 to 750 meters above sea level. The Chapada do Araripe is in the territories of two other brazilian states: Pernambuco and Piauí, but it is in Ceará that the largest quantity of springs is concentrated.

According to the former National Department of Mineral Production (DNPM), now the National Mining Agency (ANM), in a pioneering study carried out in 1996, 344 natural outflows were inventoried in the field, distributed in Ceará (293 = 85.17%), Pernambuco (43 = 12.50%) and Piauí (8 = 2.33%). Of these points located in the state of Ceará, 112 occur between the municipalities of Crato and Barbalha, with emergences of water from fractures and geological faults in the free aquifer domain of the Exu Formation with a recharge area at the top of the Chapada do Araripe.

The predominance in the state of Ceará of springs on the slopes, as is the case in the Chapada do Araripe, has an important social bias, since it represents the main means of obtaining water for properties and rural communities, which suffer from the impossibility of supplying piped water and building dams (weirs) to meet the demands of these populations, due to the difficult access and the rugged and high topography (FRANÇA, 2019).

The quality of these water is dependent on the environmental conditions, reinforcing the importance of maintaining the ecosystems, with the preservation of the soil and vegetation cover. To evaluate this quality, physical, chemical, and microbiological analyses are carried out, which can translate aspects of the balance between the environmental components and the characterization of the water. Any changes that may indicate deterioration or pollution are sought, according to the attributes and parameters defined in legislation, such as Ordinance 2,914/11 of the Ministry of Health (CARVALHO, 2015), now Consolidation Ordinance No. 5, Annex 20, amended by Ordinance 888/21. In this case, Resolution No. 396/2008 of the National Council of the Environment (CONAMA) establishes parameters for the framing of groundwater (aquifers) according to classes, conditioned to the predominant uses and the requirement of a minimum quality based on organic and inorganic parameters, with the goal of glimpsing the perpetuation of their natural quality conditions.

The possible influences that can condition changes in the water quality of the springs are due to the percolation of contaminants in the soil, the lithology of the site and, mainly, the impact of anthropic action, since the content of dissolved substances increases in its path through the soil profile characterizing the chemical evolution of the water resource (SANTOS *et al.*, 2021).

Aiming to prevent the occurrence of possible adverse impacts from human activities, the locations of water sources can be converted into conservation units of the Permanent Preservation Area (APP) type, legally supported by the Brazilian Forest Code (Law No. 12.651/2012). In Ceará, Law No. 12,522/1995 defines as "specially protected areas the springs and waterways and the natural vegetation around them". The characterization of these areas can occur as to the origin of the water, as to the geomorphology of the area of occurrence, as to the form of water availability, as to the position of the spillway, as to the regularity of the water flow, and as to the flow of the water volume (FRANÇA, 2019).

According to Sá and Campos (2000), the use of spring waters in Cariri cearense must be based on the principles, objectives, guidelines and instruments contained in the National Water Resources Policy (Federal Law No. 9.433/1997) and the State Water Resources Policy (State Law No. 18.844/2010). In several Brazilian states, programs have already been created and implemented to ensure the preservation of this important water resource, with a greater focus on the reforestation of spring areas. In Ceará, in 2016 the Secretary of the Environment of the State of Ceará (SEMA-CE) made available a primer entitled "Environmental Education for the Conservation of Springs" with the goal of being used to assist in raising awareness for the development of an ecologically balanced environment that makes possible human well-being and a healthy quality of life (FRANÇA, 2019).

In addition, Ceará is a pioneer in the management of hydric resources and in the implementation of its management instruments and guidelines, such as the full compliance with state decree No. 31.076/2012, which regulates the law of grants. The competent state agencies must effectively implement the instrument of granting the right to use water resources, in order to control the distribution of flow and ecologically conserve the quality of this important resource, a process in which the government must act in partnership with users in the management of these springs (SABIÁ and FRISCHKORN, 2004).

Knowing that the distribution of water is intrinsically dependent on the conditions of environmental quality and availability of flow to meet various demands, there are proposed activities to monitor variables that may be indicative of influences of natural factors and human actions on the environment, changing the quality of water (ALVES, 2006).

Some of these activities are field campaigns for the monitoring of organic, inorganic, and microbiological parameters of water quality, such as total dissolved solids, hydrogen potential (pH), electrical conductivity, temperature, salinity, alkalinity, suspended solids, Escherichia coli; and the availability of water, with the measurement of flow that allows its quantification. The determination of the quantity and quality helps in the adequate application of the control instruments of the hydric resources, such as the granting and the inspection, as recommended by the legislation.

The water resources in the springs of watersheds are susceptible to significant changes due to the intensification of anthropic actions, such as deforestation, burning, agricultural and livestock activities, and the occurrence of pasture areas around springs (PEREIRA, 2012). The parameters can be compared historically and compared to the CONAMA Resolution No. 396/2008, in search of a general understanding about the current situation of the water body in question, crucial for decision making for the management of this resource.

Based on this, this work aims to evaluate and discuss the quantitative (flow) and qualitative data (Total Dissolved Solids, pH, Electrical Conductivity, and Temperature) according to the variables monitored in some of the springs in the municipalities of Cariri cearense, in two periods: 2018/2019 and 2021/2022, through the information from projects and studies made available by the Ceará Water Resources Management Company (Cogerh).

2. MATERIAL AND METHODS

2.1 Definition of the study period

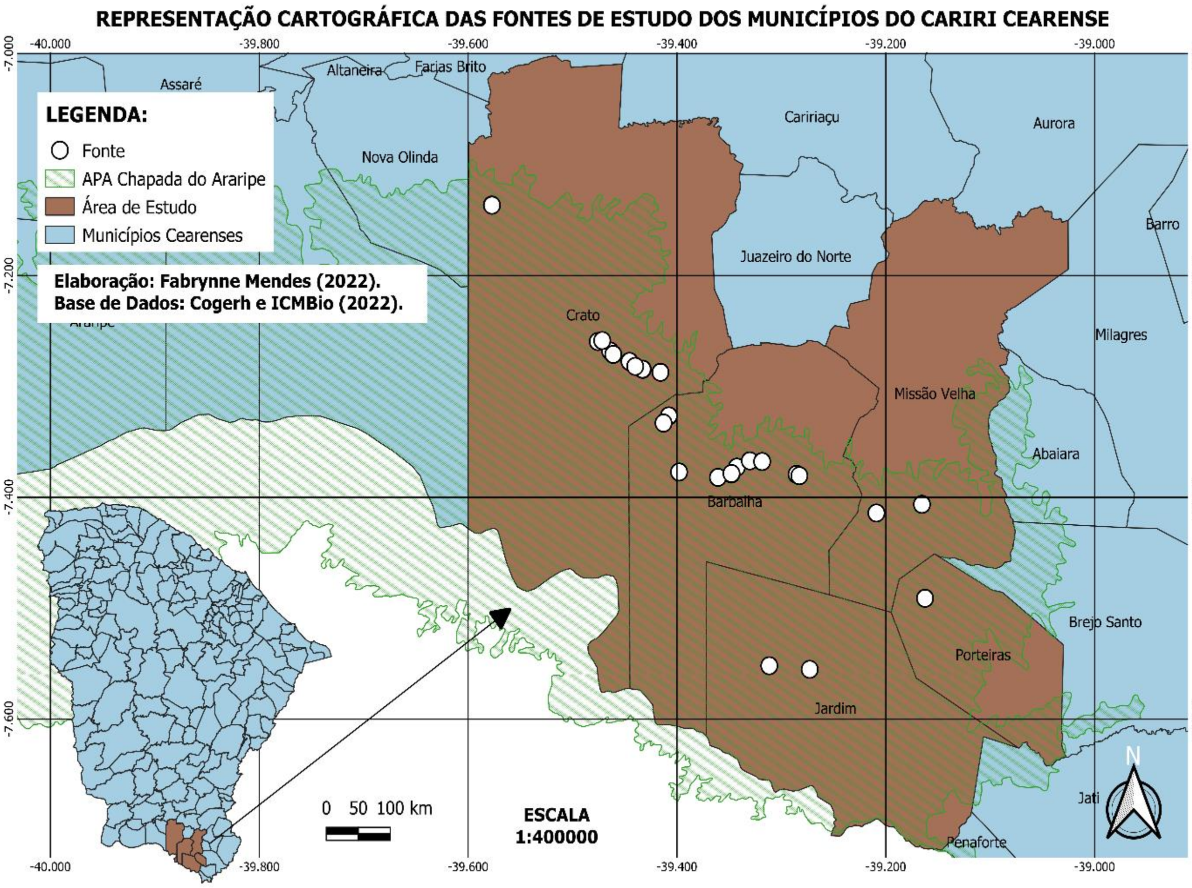
Two study periods were established, according to the projects that referenced this work. The first period included the 06 campaigns carried out between 2018 and 2019, data from products 16 and 17 of the "Registration of users and measurements of natural water sources flow in the Cariri region", published in March 2020 by the Secretary of Water Resources (SRH) of Ceará, through a contract between Cogerh and 'GEOPLAN – *Consultoria e Licenciamento Ambiental* LTDA'. The second study period contemplated 03 campaigns carried out between 2021 and 2022, based on data made available directly by Cogerh. This new monitoring is based on the last project and arose from the need for continuity in the monitoring of the conditions of the sources granted.

2.2 Definition of the study área

In the south of the State of Ceará, in the emerging Metropolitan Region of Cariri and adjacent municipalities, there are several occurrences of groundwater sources. The territory covered by the presence of springs permeates the municipalities of Barbalha, Brejo Santo, Crato, Jardim, Missão Velha, Nova Olinda, Porteiras and Santana do Cariri, which are monitored by the regional management of the Upper Jaguaribe basin and the Salgado basin.

The main locality where the abundance of underground water originates is in the environment of the springs of the Chapada do Araripe, more precisely in the Area of Environmental Protection (APA) contained in the Araripe National Forest, contemplating the cities that are in the vicinity of the slopes of the plateau and depend hydrically on the Araripe Basin (Figure 1).

All sources of this study are located within the territory of the Conservation Unit (UC) of the Environmental Protection Area (APA) type, called Chapada do Araripe, established by Decree 5.587 of August 4, 1997, which has an area of 972,605.18 hectares, passing through more than 30 municipalities in the States of Ceará, Pernambuco and Piauí. For study purposes, the municipalities of Barbalha, Crato, Jardim, Missão Velha and Porteiras were defined, since they have consolidated data for the two study periods, which could be made compatible and compared.



Source: Prepared by the authors using QGIS v. 3.10.14 (2022) software.

Figure 1 – Map of location of Cariri's sources

2.3 Data Selection

The data were selected from a database of 3,645 water points registered in the Araripe Sedimentary Basin, of which 252 are natural springs (CEARÁ, 2009). According to the studies and projects used, of this total of springs, only a few have data and conditions to be analyzed historically. In the first monitoring (2018/2019), 80 sources were evaluated, while in the second (2021/2022), Cogerh selected 26 strategic springs for monitoring. Therefore, of the 26 monitored, 25 sources were chosen, distributed in the municipalities of Barbalha (10), Crato (10), Jardim (2), Missão Velha (2), and Porteiras (1). The João Coelho spring (FCR009) was excluded from this study because it had a very low flow rate, which made its measurement impossible.

After the previous studies and projects were carried out, and due to the need for continuous monitoring, the Crato regional management started frequent campaigns (every 3 months) in 2021, to monitor the quality and quantity of the sources granted. The sources were analyzed with the following identifications:

Table 1 – Monitored sources selected for the study

N°	Spring/Source of Water	ID	UTM Coordinates	City
1	Bom Jesus	FCR001	9184347 m S 461613 m E	Barbalha
2	Camelo	FCR002	9185025 m S 462179 m E	Barbalha
3	Céu	FCR003	9190138 m S 454993 m E	Barbalha
4	Cocos	FCR004	9184323 m S 468497 m E	Barbalha
5	Criolo	FCR005	9184179 m S 468791 m E	Barbalha
6	Embiribeira	FCR006	9184539 m S 456081 m E	Barbalha
7	Farias	FCR007	9189421 m S 454432 m E	Barbalha
8	Guaribas	FCR008	9184014 m S 460188 m E	Barbalha
9	Riacho do Meio	FCR010	9195664 m S 463557 m E	Barbalha
10	Santa Rita II	FCR011	9185593 m S 464857 m E	Barbalha
11	Água Fria	FCR012	9196597 m S 448782 m E	Crato

12	Água Grande	FCR013	9194482 m S 454101 m E	Crato
13	Batateira	FCR014	9197541 m S 447475 m E	Crato
14	Caianas	FCR015	9195559 m S 450827 m E	Crato
15	Coqueiro I	FCR016a	9194772 m S 452233 m E	Crato
	Coqueiro II	FCR016b	9194791 m S 452199 m E	Crato
16	Engenho da Serra	FCR017	9211136 m S 436258 m E	Crato
17	Granjeiro	FCR018	9195067 m S 451432 m E	Crato
18	Preguiça	FCR019	9197641 m S 447942 m E	Crato
19	Serrano	FCR020	9196261 m S 449111 m E	Crato
20	Vale Verde	FCR021	9211114 m S 436271 m E	Crato
21	Boca da Mata	FCR022	9164877 m S 469900 m E	Jardim
22	Gravatá	FCR023	9165239 m S 465628 m E	Jardim
23	Pendência	FCR024	9180467 m S 476936 m E	Missão Velha
24	São Valentim de Cima	FCR025	9181333 m S 481750 m E	Missão Velha
25	Saco	FCR026	9171971 m S 482078 m E	Porteiras

Source: Cogerh, adapted by the authors (2022)

The coordinates of the monitored sources were obtained from the use of a portable Global Positioning System (GPS) navigation device, which provides UTM geographic location coordinates with high accuracy.

2.4 Methods of measuring quantitative parameters

The flow measurements are made by field technicians, at the sources, using the volumetric method or with the aid of the Flowtracker device, depending on local conditions, the desired precision and the flow rate.

The volumetric method (figure 2) consists in using a container, which has a known volume (in liters) and a stopwatch counts the amount of time (in seconds) that the water takes to fill the entire container. From this, the flow rate is calculated using equation 1:

$$Q = \frac{V\ (L)}{t\ (s)}$$

In this equation, Q is the flow rate (in L/s), V is the volume in liters of the container that will be filled and t is the average time measured in seconds needed for total filling. Generally this form is used to empirically quantify water bodies with small flows, as is the case of most of the springs in Cariri cearense. Fundamentally, more than one volumetric flow measurement is performed, aiming to ensure more stability and reliability in the data that is recorded.

Figure 2 – Flow measurement performed by the volumetric method at FCR005

Source: Cogerh (2022)

The second method for measuring flow in the field is with the use of the Flowtracker device, which has ADV® (Acoustic Doppler Velocimeter) technology and automatically calculates the flow through an acoustic flow meter. However, this method is only used in one of the springs (FCR007), which has a Parshall flume along its flow.

2.5 Methods of measuring the qualitative parameters

To monitor the water quality parameters, the responsible agency uses a multiparameter probe (HACH® MP-6) to read the parameters in the field (figure 3), by collecting a small sample that is placed in a cuvette, exposed to sensors that detect and transmit on the screen the values of Total Dissolved Solids (TDS in ppm), Hydrogen Potential (pH), Electrical Conductivity (EC in µS/cm) and Temperature (in °C). After reading the parameters, the sample is discarded.

Figure 3 – Reading of qualitative parameters in the field at FCR003

Source: Cogerh (2022)

2.6 Data Treatment

In view of the reports of the latest monitoring of the springs under study, the methods of statistical treatment were defined in order to give more technical support to the proposed discussions. From the identification data of the points, with the geographic coordinates, the map (figure 1) was built with the use of the free software QGIS version 3.10.14.

All numerical data (qualitative and quantitative aspects) were tabulated using Microsoft Excel® version 2016, where the maximum, minimum, average, median, quartile and standard deviation values were calculated, aiming at the construction of graphs and discussion of the results obtained.

The quantitative data (flow rates) were transformed into bar graphs, in order to observe the variation in the 09 analysis campaigns, identifying any sudden changes or patterns of changes. The standard deviation results were also discussed, aiming to understand the degree of dispersion or uniformity of the data set.

Qualitative data (pH, electrical conductivity, total dissolved solids, and temperature) were represented by means of boxplots, a comparative graphical arrangement that also allows visual identification of the distribution of values and the presence or absence of considerable variability. CONAMA Resolution N° 396/08 and scientific literature were used to discuss the products.

Possible justifications for the most significant changes were also identified, with the inclusion of the graph of rainfall index in the municipalities where the largest quantities of springs are located, through the organization of data from the Meteorology and Water Resources Foundation of Ceará (Funceme) stations.

3. RESULTS AND DISCUSSION

By being included in the APA, the region of the springs of Cariri cearense already has a preservation character and its exploration is carried out in a moderate way, since the Chico Mendes Institute for Biodiversity Conservation (ICMBio), the agency that manages the UC, has the federal backing to apply legal measures to prevent or avoid the exercise of activities that cause degradation of environmental quality.

According to DNPM (1996), there are 293 water points in the State of Ceará, which is a significant number of water sources, but not all of them are monitored or contain consistent data so that it is possible to make a historical series. This is old data and considered outdated, demonstrating the need for constant updating for an effective management process. However, those that are monitored, specifically the 25 in this study, may represent an overview of the conditions of most of them, since their geographic locations are close, as it was possible to observe in figure 1.

Although the physical distribution has a certain pattern, mainly due to the similar natural, hydrogeological and geomorphologic conditions, because they are in the same region, each source has particularities, such as altitude that can influence the flow, and their water availability is different when compared among themselves and when compared in different periods of the year. The analysis of these comparisons is carried out with the standardization of monitoring methods.

Some springs have more than one source and their flow measurement is performed by the sum of all readings taken, as well as the average of the repetitions required for reliability of the method. Other sources, such as Coqueiro (FCR016), require different and separate measurements, but are equivalent to the same source. Another case of source with peculiarity and that requires different treatment is Farias (FCR007), which has the '*Levada Farias'* and the '*Levada Santo Antônio'*, both of which can be measured by two different methods: with the help of the Flowtracker or with the Parshall flume reading. For monitoring purposes, FCR016 is subdivided into Coqueiro I and II, while FCR007 is analyzed by joining the flows of the two levadas with the same type of flow measurement methodology that has been used since the first campaign period, the Parshall flume. These specifics for each measurement can affect the precision and accuracy of the monitoring data, and should be taken into consideration when examining the results obtained.

In figure 4 it is possible to observe that most of the sources did not undergo abrupt changes in their flow rates during the two campaign periods, however, there were variations in all of them, which may be due to natural differences in water availability by natural factors such as precipitation and evaporation or, mainly, by the infiltration process.

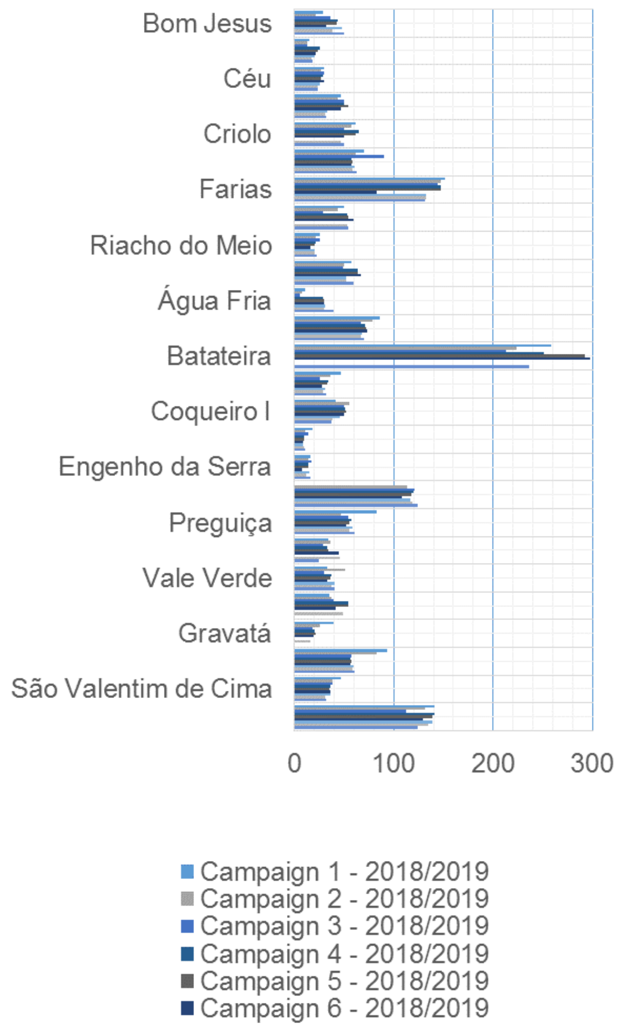


Figure 4 – Flow variation (m³/h) of the sources in the 09 study campaigns

Source: Prepared by the authors (2022)

The spring that had the highest standard deviation of flow was the Batateira (FCR014), with a value of 29.93, representing 11.82% in relation to its average value of all campaigns, as represented below in table 2. A possible cause for this greater variation is because this is the source with the highest recorded flow rate (297.20 m³/h), which reflects in a greater difficulty for measurement, since it requires different methods. The Batateira spring is old and has built structures that make volumetric measurement difficult, since there is a runoff through tiles before the measurement site. There is also a pipe where an ultrasonic meter is used for forced conduits, where there may be errors when air is present in the pipe. Each methodology used is associated with an acceptable margin of error, however, the use of more than one method exposes the analysis to a greater propensity to error.

Table 2 – Statistical calculations of the flows (m^3/h) measured in all 9 campaigns

SPRING/SOURCE OF WATER	MINIMAL FLOW	AVERAGE FLOW	MAXIMUM FLOW	PATTERN DEVIATION	
Bom Jesus	21,6	37,71	49,5	8,56	22,70%
Camelo	12,92	18,42	25,25	4,15	22,55%
Céu	23,01	27,10	30,2	2,46	9,08%
Cocos	30,98	43,21	54,4	8,27	19,14%
Criolo	46,44	55,25	64,8	6,33	11,45%
Embiribeira	56,92	64,02	90,14	10,00	15,62%
Farias	82,8	135,98	151,2	22,53	16,57%
Guaribas	28,8	49,63	59,19	8,94	18,01%
Riacho do Meio	16,27	21,32	25,2	2,60	12,19%
Santa Rita II	49,18	57,23	67,35	6,32	11,05%
Água Fria	5,47	23,48	39,51	11,59	49,37%
Água Grande	66,87	72,59	86,11	5,86	8,07%
Batateira	213,48	253,18	297,2	29,93	11,82%
Caianas	25,2	32,78	46,8	5,85	17,85%
Coqueiro I	37,11	46,70	55,51	6,18	13,23%
Coqueiro II	8,55	11,09	18	2,95	26,56%
Engenho da Serra	8,09	14,03	17,5	2,60	18,51%
Granjeiro	108,46	117,44	124,09	4,56	3,88%
Preguiça	46,8	58,02	82,8	9,54	16,44%
Serrano	25	35,18	45,34	6,60	18,76%
Vale Verde	29,81	37,74	51,41	5,80	15,36%
Boca da Mata	34,78	44,40	54,29	7,36	16,58%
Gravatá	15,93	22,78	39,6	7,38	32,42%
Pendência	55,85	64,62	93,6	12,94	20,02%
São Valentim de Cima	30,4	36,55	46,62	4,32	11,81%
Sítio Saco	112,18	132,31	141,05	8,99	6,79%

Source: Prepared by the authors (2022)

The remaining sources showed standard deviation in the range of 4.00 to 32.00% from their mean value. Most were concentrated in the range below 20.00% variation, while two other sources (Coqueiro II and Gravatá springs) were close to 30.00%. The second highest standard deviation is from Farias spring, which in the sixth campaign presented a value far below (82.80 m^3/h) its average value (135.98 m^3/h). As mentioned above, the Farias spring has the peculiarity of being subdivided into two fountains, which are located almost 100 meters apart.

Some errors and variability can be justified due to the different methods used, since the consolidation of the methodology is still being carried out from this new monitoring applied by Cogerh, thus the comparative basis is not always the same. An example is that in the project of the 1st period (2018/2019) of campaigns, some campaigns were carried out by the windlass method, while in this 2nd period (2021/2022) this is no longer a methodology used, that is, the comparison may suffer with greater divergences than faithfully to the reality.

In the new monitoring some data are missing or lacking, as this consistency has been made and some measurements have been excluded. The measurements that remain are being standardized. In relation to the project and the monitoring, there is more standardization nowadays, since data consistency is made and the large variations in the campaigns of the first period are due to the fact that at the time the method was not yet fixed.

For comparative purposes, the rainfall indices of the cities of Crato (post pluviometric Lameiro) and Barbalha (post pluviometric Barbalha) contained in figure 5 were analyzed, since they cover the largest quantity of the sources selected in this study. It was verified that there are yearly similarities in the behavior of the rainy season, with higher levels in the first 5 months of each year. The values not marked on the graph are equal to zero, due to lack of rain or some problem in the pluviometric stations.

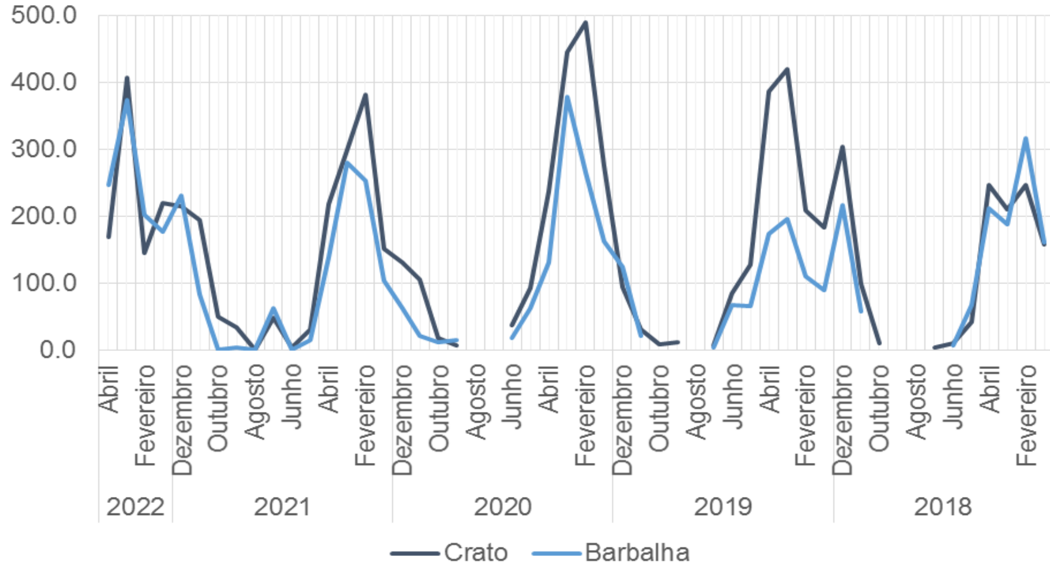


Figure 5 – Precipitation (mm) in Crato and Barbalha – CE

Source: Prepared by the authors (2022)

According to Cambraia Neto and Rodrigues (2021), there is a great difficulty in quantifying the recharge of the sources, given the complex interaction between the factors involved, climate, soil and vegetation conditions, besides the exploration of groundwater not being done in the same proportion as its exploitation (economic exploitation). It is possible that this precipitation is already influencing higher flows in campaigns carried out a few months after the rainy season, since the cycle of hydraulic infiltration into the aquifers and groundwater occurs gradually, unlike what occurs in surface reservoirs, such as dams, which is practically instantaneous. To respect the natural recharge cycle of the aquifers by means of underground infiltration, it is appropriate to emphasize the importance of the proper management of these waters.

In addition to the State Water Resources Policy (PERH) of Ceará, state decrees have been issued that regulate water management in detail. Decree No. 31.077/12, in its article 2, includes the springs as a subterranean water resource, subject to management from the instruments, such as the law of grants, the previous decree (31.076/12) and others, aiming to assist with normatization for the control of management and, consequently, for the mitigation of qualitative and quantitative changes that may harm the natural conditions of the aquifer, preserving the exhaustion and degradation of its quality and its use being charged in the form of law.

An important instrument for maintaining the available and distributed flow is the granting of the right to use water resources. Formally, the user receives the authorization to use the spring according to the registered purpose and according to the released flow, which is authorized by means of detailed technical studies, allowing, in terms and conditions expressed for a determined period of time, the fulfillment of the right of use in a fair and balanced way.

Another widespread instrument, legally supported and of fundamental importance for water management in Ceará is the inspection. This activity, according to Article 14 of Law No. 14.844/10, focuses on guidance to users, in order to ensure compliance with water resources and environmental legislation. In the springs, the inspection plays a significant contribution in regularizing the distribution of water. However, this control is not limited only to the attendance and verification of the source's flow (quantification), but also includes detailed technical studies for fixing and following up on water quality aspects.

As for the qualitative aspects, only the parameters that can be read in loco with the multiparameter probe available were analyzed.

The first parameter discussed is the hydrogen potential, better known as pH; its values obtained from the probe readings at the springs during the study periods (figure 6) range from 4.42 to 8.43. Most of the springs can be characterized as more acidic waters (those whose values are below 7.0), usually associated with the presence of organic matter, causing more acidic conditions to the aquatic environment or by the type of soil that the water travels through until it reaches the surface where it is born. Citing the study by Salati et al. (2002), even in a preserved hydrographic basin, in natural balance, the quality of the water can suffer variations influenced by the climate and the physical and biological characteristics of the ecosystems, because of the permanent and irreversible interaction between the lithosphere, biosphere and atmosphere.

According to Von Sperling (2005), the pH is a parameter that must be analyzed for water quality, since it may be related to natural factors, such as rock dissolution, absorption of atmospheric gases, oxidation of organic matter, and photosynthesis, or anthropogenic factors, such as domestic sewage dumping (oxidation of organic matter) and industrial sewage dumping (acid washing of tanks).

In the case of groundwater, from where the springs mine, contamination by effluents is an almost discarded hypothesis due to the difficult accessibility conditions to the water body, which is not so vulnerable to the reception of sanitary effluents. However, according to Peixoto (2020), infiltration can act as a process of conduction of contaminants from domestic effluents to groundwater.

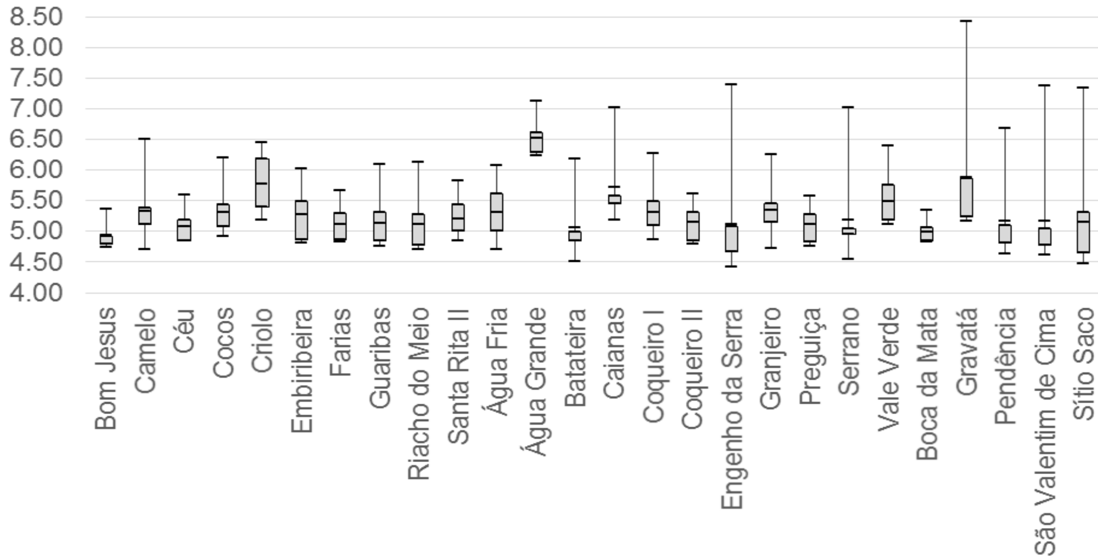


Figure 6 – pH variation of the sources

Source: Prepared by the authors (2022)

According to Boesch (2002) and Esteves (2011), the electrical conductivity can be indicative of changes in the composition of water bodies, but does not specify quantities and components. In Brazil, as a tropical region, this parameter is often related in the literature to the geochemical characteristics of the region and climatic conditions (precipitation periodicity). Tundisi and Matsumura-Tundisi (2008) point out that there is a statistical correlation between water conductivity and the concentration of various elements and ions. In the case of the Araripe Sedimentary Basin springs, it is observed that they come from hydrogeological conformations amidst several minerals and rocks, which can translate into higher conductivity in this water.

For the electric conductivity parameter, during the campaigns, as shown in figure 7, variations from 9.28 (Água Grande spring) to 59.33 µS/cm (Preguiça spring) were registered. There is no range in the legislation to guide the discussion of values for this parameter, however, Von

Sperling (2007) estimates in his studies that natural waters have conductivity contents in the range of 10 to 100 µS/cm. Thus, with due consistency and approximations, all sources of the study are within these limits shown ideal for natural waters.

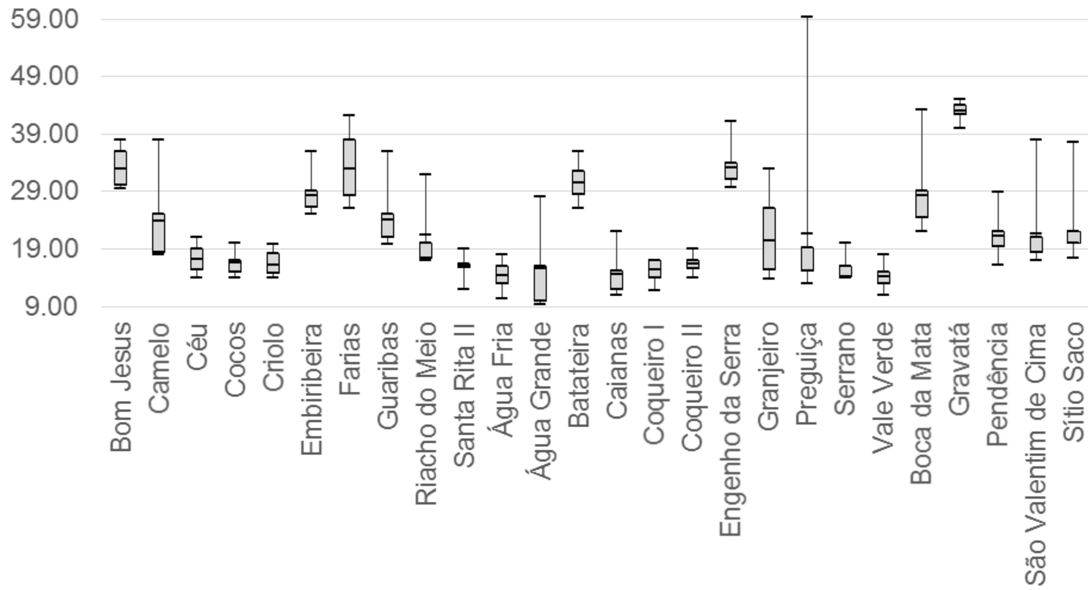


Figure 7 – Electrical Conductivity variation (µS/cm) of the sources

Source: Prepared by the authors (2022)

The resolution CONAMA No. 396/08 provides about the classification and environmental guidelines for the framing of groundwater and its Annex I can be used as a basis for legislation to classify the springs according to their predominant use. Despite this, in this study it was only possible to use the Maximum Allowable Value (VMP) and the Practicable Quantification Limit (LQP) of the Total Dissolved Solids (TDS) parameter, due to the absence of data on the other parameters contained, which were not analyzed by the monitoring that are the target of this work.

The TDS values of the fountains of Cariri ranged from 5.00 (Água Grande, Caianas and Vale Verde springs) to 37.18 mg/L (Preguiça spring), shown in figure 8. These results are within the range contained in the above resolution, which has a VMP equal to 1000 mg/L for the predominant use of human consumption, the noblest use and demanding the best water quality. This parameter is also considered as an organoleptic effect, because it has properties that can be easily perceived by the senses of humans.

The TDS parameter is directly related to the electrical conductivity and, according to Van Niekerk et al. (2014), this parameter is analyzed laboratorially aiming to represent the salinity of the water or the effects caused by some anthropic activity affecting a water body.

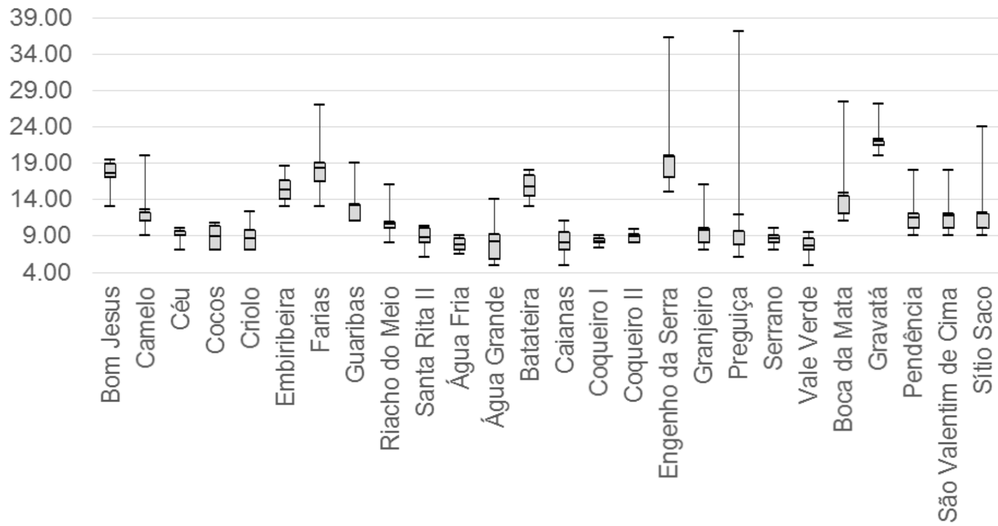


Figure 8 – Total Dissolved Solids variation (mg/L) of the sources

Source: Prepared by the authors (2022)

Tundisi and Matsumura Tundisi (2008) mention that continental waters have variations of TDS related to the regional hydrogeochemistry and drainage of igneous or sedimentary rocks, and include all the salts and ionic and non-ionic components coming mostly from the processes of weathering. In the case of springs, geomorphological conformity could justify some higher TDS values; however, these characteristics, such as the presence of mainly mineral salts, are also related to the benefit of considering a natural treatment for the water resource.

The temperature values measured in the source monitoring campaigns, reflect the measurement of heat intensity, degree of water heating and solar radiation. According to Matic *et al.* (2013), this parameter is influenced by variables such as climate, geological composition and electrical conductivity of the rocks.

For the resulting comparison in Figure 9, rainy, intermediate and dry seasons were not differentiated. Despite this, no significant variations were registered in the temperatures of the spring waters since they only oscillated between 22.30 and 28.60°C. This low variability may be due to the very nature of the aquifers where the springs are located, or also to the microclimate of the Araripe National Forest, which has its own natural maintenance, and little incidence of anthropic activities that could result in an increase in temperature, such as the inadequate disposal of domestic or industrial effluents.

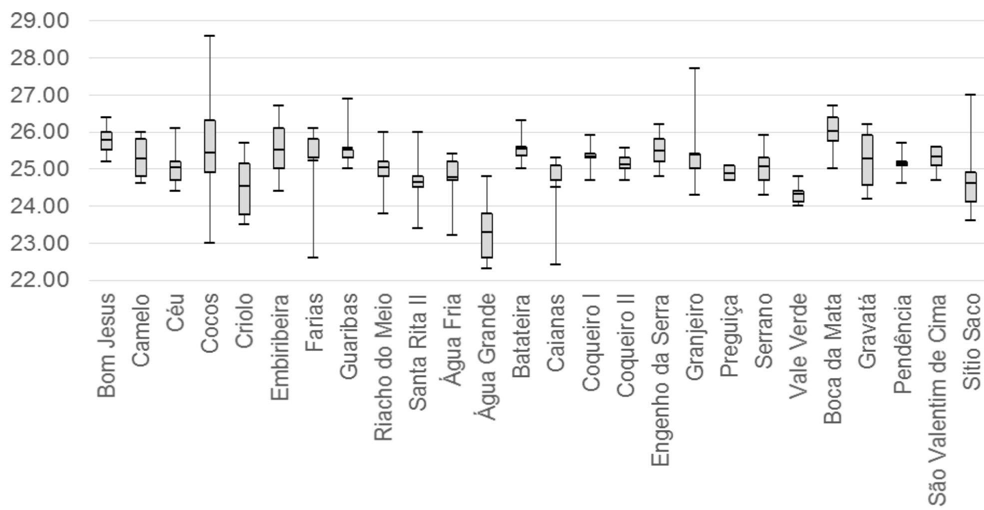


Figure 9 – Temperature variation (°C) of the sources

Source: Prepared by the authors (2022)

In the resolution CONAMA 396/08, it is defined that an aquifer is a hydrogeological body with the ability to accumulate and transmit water through its pores, fissures or spaces resulting from the dissolution and carriage of rocky materials, thus justifying the use of this resolution to frame the springs. Among the classes contained in article 3, the springs in Cariri can be identified as class 1 or 2, differentiating themselves only due to the criterion of requiring or not treating the water.

As class 2, the use of water treatment is at the discretion of the particular use, i.e., it is the responsibility of the user, depending on the purpose of its use. However, for uses that do not prioritize such a high quality, such as for irrigation and animal feeding, it is not necessary to include treatment steps. However, when the water is used for human consumption, which is the most noble use, as in other sanitary legislations, some type of treatment is required prior to supply.

The main uses of the water from the sources are: human consumption, irrigation, recreation, and animal feeding, all of which are subject to the granting of water resource use rights. The charge for the use of water resources is updated annually by complementary decrees, but is only charged if there is a monthly consumption of more than 5 m^3/hour. Since the flows granted in the sources are generally very low, the charging instrument is not applicable.

4. CONCLUSION

The monitoring and comparison of data from springs is of fundamental importance in the context of the management of this water resource, since the updating of the flows and the water quality parameters allow us to understand the seasonality of the water that is being made available, checking whether it is possible to meet the ever-increasing demands.

Despite the effective water management existing in Ceará, it is known that this is not a reality in all Brazilian states. Added to this, there is no or insufficient specific legislation at the federal and state level that allows the classification and qualitative monitoring of groundwater springs. A divergence is observed regarding works that seek to classify these water bodies, since many use different legislations (such as Consolidation Ordinance No. 5/2017 of the Ministry of Health or CONAMA Resolution No. 357/05) or even seek to estimate and propose acceptable ranges for the discussion of these aspects.

The comparison proposed in the work was hampered due to the existence of some inconsistencies in data, as well as the lack of parameters that could help in the qualitative determination of water bodies. Furthermore, it is still perceived that more detailed studies should be explored, with periodic laboratory analyses, since the parameters currently monitored are only those made available in the field by the multiparameter probe. Other complementary studies suggested are: the comparison of rainfall variations with the flow measured at the springs, seeking to find direct relations between the two in the process of recharge by infiltration of rainwater into the underground aquifers; and the important monitoring of the occupation of the proximities of the springs and the level of impact of private properties in the preservation areas.

For the monitoring to be more effective, it is essential that the methods of analysis of the qualitative parameters be reviewed, seeking to include more indicators that can better portray presumable contamination of sources, such as the identification of Escherichia coli, which can translate the presence of this bacterium originating from the intestines of homeothermic animals, i.e., when there is environmental contamination in the water resource by excreta containing microorganisms that are pathogenic to living beings.

It is indispensable to emphasize the awareness of the considerable ecological function of the springs, a vital role in the hydrological cycle and in the perpetuation of water availability for this and future generations that will certainly have even greater demands.

For many years Ceará has adequately applied the instruments of water resources management, mainly the granting and inspection. These instruments have great importance and impact on the control of the available flows from the sources, besides implementing the need for details that can provide an excellent database for the monitoring of the sources, since they have a fundamental role in the development of the areas where they are located.

5. REFERENCES

1) ALVES, E. C. Monitoramento da Qualidade da Água da Bacia do Rio Pirapó. 2006. 105f. Dissertação (Mestrado em Engenharia Química). **Programa de Pós-Graduação em Engenharia Química**, Universidade Estadual de Maringá, 2006.

2) BOESCH, D. F. Challenges and opportunities for science in reducing nutrient over-enrichment of coastal ecosystems. **Estuaries**, v. 25, n. 4b, p. 886– 900, 2002. http://dx.doi.org/10.1007/BF02804914

3) BRASIL. **Decreto Federal n° 5.597, de 4 de agosto de 1997**. Dispõe sobre a criação da área de proteção ambiental da Chapada do Araripe, nos estados do Ceara, Pernambuco e Piaui, e da outras providências. Brasília, 1997.

4) BRASIL. **Lei Federal n° 9.433, de 8 de janeiro de 1997**. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal e altera o art. 1° da Lei 8.001, de 13 de março de 1990, que modificou a Lei 7.990, de 28 de dezembro de 1989. Brasília, 1997.

5) BRASIL. **Lei Federal nº 12.651, de 25 de maio de 2012**. Institui o novo código florestal brasileiro. Brasília, 2012.

6) CALHEIROS, R. O. **Caderno da Mata Ciliar**. Secretaria de Estado do Meio Ambiente, Departamento de Proteção da Biodiversidade. São Paulo, 2009.

7) CAMBRAIA NETO, Arnaldo José; RODRIGUES, Lineu Neiva. Impact of land use and occupation on potential groundwater recharge in a Brazilian savannah watershed. **Water International**, v. 46, n. 3, p. 348-364, 26 mar. 2021. Informa UK Limited. http://dx.doi.org/10.1080/02508060.2021.1898862.

8) CAPELLARI, Adalberto; CAPELLARI, Marta Botti. A água como bem jurídico, econômico e social: a necessidade de proteção das nascentes. **Cidades. Comunidades e Territórios**, São Paulo, n. 36, set. 2018. Disponível em: http://journals.openedition.org/cidades/657.

9) CARVALHO, Brenda Mayra Fernandes de. **Qualidade hídrica e perfil de resistência de bactérias heterotróficas em águas de nascentes sobre diferentes usos do solo, na microbacia do ribeirão José Pereira (Itajubá – MG)**. 2015. 92 f. Dissertação (Mestrado) - Curso de Mestrado em Ciências em Meio Ambiente e Recursos Hídricos, Programa de Pós-graduação em Meio Ambiente e Recursos Hídricos, Universidade Federal de Itajubá, Itajubá (Mg), 2015. Disponível em:

https://repositorio.unifei.edu.br/xmlui/bitstream/handle/123456789/426/dissertacao_carvalho2_2015.pdf?sequence=1&isAllowed=y.

10) CEARÁ. 2009. **Caderno regional da sub-bacia do Salgado**. Assembleia Legislativa, Fortaleza, 131p. Disponível em: <https://portal.cogerh.com.br/wp-content/uploads/2018/09/Bacia-do-Salgado.pdf>.

11) CEARÁ. Cadastramento de Usuários e Medições de Vazões de Fontes de Água Naturais da Região do Cariri, Ceará. Fortaleza – CE, 2020.

12) CEARÁ. **Decreto Nº 31.076, de 12 de dezembro de 2012**. Regulamenta os artigos 6º a 13 da Lei Nº 14.844, de 28 de dezembro de 2010, referentes à outorga de direito de uso dos recursos hídricos.

13) CEARÁ. **Decreto Nº 31.077, de 12 de dezembro de 2012**. Regulamenta a Lei N° 14.844, de 28 de dezembro de 2010, que dispõe sobre a política estadual de recursos hídricos, no que diz respeito à conservação e à proteção das águas subterrâneas no Estado do Ceará, e dá outras providências.

14) CEARÁ. **Lei n.º 12.522, de 15 de dezembro de 1995**. Define como áreas especialmente protegidas as nascentes e olhos dágua, e a vegetação natural no seu entorno e dá outras providências.

15) CEARÁ. **Lei n.º 14.844, de 30 de dezembro de 2010**. Dispõe sobre a Política Estadual de Recursos Hídricos, institui o Sistema Integrado de Gestão de Recursos Hídricos - SIGERH, e dá outras providências.

16) CONSELHO NACIONAL DO MEIO AMBIENTE. Resolução N° 396, de 03 de Abril de 2008. Dispõe sobre a classificação e diretrizes ambientais para o enquadramento das águas subterrâneas e dá outras providências. CONAMA. **Diário Oficial [da] União**, n. 66, 07 abril 2008, Brasilia, 2008.

17) DNPM. 1996. Projeto avaliação hidrogeológica da Bacia Sedimentar do Araripe. **Programa nacional de estudos dos distritos mineiros**. Recife, Departamento Nacional de Produção Mineral (DNPM), distritos regionais Pernambuco e Ceará, 101 p.

18) ESTEVES, F. **Fundamentos de limnologia**. 3. ed. Rio de Janeiro: Interciência, 2011. 826 p.

19) FRANÇA, Francisco Mavignier Cavalcante. **Nascentes hídricas do Ceará: importância, proteção e uso sustentável** / Francisco Mavignier Cavalcante França. -- Fortaleza, SECITECE/Instituto CENTEC, 2019

20) GOMES, Cristiano Cardoso; DIAS, Franciel Rodrigues; GONÇALVES, José Yarley de Brito; SOUZA, André Ramos de. Avaliação do nível de degradação de uma fonte na Chapada do Araripe e sua influência na disponibilidade hídrica. **48º Congresso Nacional de Saneamento da ASSEMAE - Associação Nacional dos Serviços Municipais de Saneamento**, Fortaleza, p. 1833-1838, maio 2018. Disponível em: https://www.researchgate.net/publication/332739723.

21) IBGE – Instituto Brasileiro de Geografia e Estatística. Censo Demográfico 2000. Disponível em: http://www.ibge.gov.br.

22) MACHADO, Carolina Barroso**. Identificação e preservação das nascentes no Estado do Ceará**. 2018. 39 f. Monografia (Especialização) – Curso de Especialização em Gestão de Recursos Hídricos, Ambientais e Energéticos, Instituto de Engenharias e Desenvolvimento Sustentável - IEDS, Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Redenção, 2018. Disponível em: repositorio.unilab.edu.br/jspui/handle/123456789/1727.

23) MATIC, N.; MIKLAVCIC, I.; MALDINI, K.; DAMIR, T.; CUCULIC, V.; CARDELLINI, C. ET AL. Geochemical and isotopic characteristics of karstic springs in coastal mountains (Southern Croatia). **Journal of Geochemical Exploration**, n. 132, p. 90–110, 2013. http://dx.doi.org/10.1016/j.gexplo.2013.06.007

24) PEIXOTO, Filipe da Silva. GROUNDWATER CONTAMINATION RISK IN URBAN WATERSHED. **Mercator**, v. 19, n. 6, p. 1-17, 15 jun. 2020. Mercator - Revista de Geografia da UFC. http://dx.doi.org/10.4215/rm2020.e19013.

25) PEREIRA, Leidiane Cândido. **Uso e conservação de nascentes em assentamentos rurais**. 2012. 181 f. Dissertação (Mestrado em Engenharia Civil) – Universidade Federal de Pernambuco, Programa de Pós-Graduação em Engenharia Civil. Recife, 2012. Disponível em: https://repositorio.ufpe.br/handle/123456789/10645.

26) SÁ, José Adonis Callou de Araújo, CAMPOS, Luciana Ribeiro. A água e o direito. In: **A gestão de água: princípios e pratica**. Organizado por Nilson Bezerra Campos e Ticiana Marinho de Carvalho Studart. Fortaleza, 2000.

27) SABIÁ, Rodolfo José. FRISCHKORN, Horst. Gestão das fontes da chapada do araripe: descaso ou incompetência. **Congresso brasileiro de Ciência e Tecnologia em Resíduos e Desenvolvimento sustentável**. p.

1306-1313. Costão do Santinho – Florianópolis – Santa Catarina, ICTR 2004.
28) SALATI, E.; LEMOS, H.M.; SALATI, E. Água e desenvolvimento sustentável. In: REBOUÇAS, A.C; BRAGA, B.; TUNDISI, J.G. **Águas doces no Brasil: capital ecológico, uso e conservação**. 2.ed. São Paulo: Escrituras, 2002. p.39-63
29) SANTOS, Roberto Jefferson da Silva; MENDONÇA, Luiz Alberto Ribeiro; SILVA, Fernando José Araújo da. Geoquímica das Águas Subterrâneas da Bacia Sedimentar do Cariri Cearense, Nordeste Do Brasil. **Revista Geociências UNESP**, São Paulo, v. 40, n. 4, p. 925-938, 2021. Disponível em: https://www.periodicos.rc.biblioteca.unesp.br/index.php/geociencias/issue/view/1144.
30) SILVA, Daniele Costa da. Dilemas na gestão das águas de nascentes no Cariri, Ceará, Brasil (2014 - 2016). **Agua y Territorio / Water And Landscape**, n. 18, p. 73-88, 17 jun. 2021. Universidad de Jaen. http://dx.doi.org/10.17561/at.18.4713.
31) TUNDISI, J. G.; MATSUMURA TUNDISI, T. **Limnologia**. São Paulo: Oficina de Textos, 2008. 632 p.
32) UNESCO. Glossário Internacional de Hidrogeologia. 2011. Disponível em: http://webworld.unesco.org/water/ihp/db/ glossary/glu/PT/GF1166PT.HTM.
33) VAN NIEKERK, H.; SILBERBAUER, M. J.; MALULEKE, M. Geographical differences in the relationship between total dissolved solids and electrical conductivity in South African rivers. **Water SA**, v. 40, n. 1, p. 133–137, 2014.
34) VON SPERLING, M. **Estudos de modelagem da qualidade da água de rios**. Belo Horizonte: UFMG, 2007. Vol. 7. 452 p.
35) VON SPERLING, M. Introdução à qualidade das águas e ao tratamento de esgotos. 3.ed. Belo Horizonte: UFMG/**Departamento de Engenharia Sanitária**, 2005. v.1, 452p.