Management of water resources in semi-arid: assessment of the drinking water supply in rural communities of Chapada do Apodi-RN

Gestão dos recursos hídricos no semiárido: avaliação do abastecimento de água para consumo humano nas comunidades rurais da Chapada do Apodi-RN

Jorge Luís de Oliveira Pinto Filho[a]
Alana Ticiane Alves do Rêgo[b]
Anderson Rodrigues da Silva Lunes[c]

[a]Universidade Federal Rural do Semi-Árido – Ufersa, Campus Pau dos Ferros, Pau dos Ferros, RN, Brasil.

E-mail: jorge.filho@ufersa.edu.br
[b]Universidade Federal Rural do Semi-Árido – Ufersa, Campus Pau dos Ferros, Pau dos Ferros, RN, Brasil.

E-mail: alana_ticiane10@hotmail.com
[c]Universidade Federal Rural do Semi-Árido – Ufersa, Campus Pau dos Ferros, Pau dos Ferros, RN, Brasil.
E-mail: anderson_lunes@hotmail.com

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ABSTRACT

Water is a natural resource, present in metabolic processes of living beings, which has been used for various purposes, especially human consumption. This study aimed to evaluate the system of supply and the quality of water for human consumption in rural communities of Chapada do Apodi, RN. The methodology consisted of identifying and evaluating the supply system as well as the quality of the water from the environmental perception and physical-chemical and biological analyses in water. Electrical conductivity, turbidity, dissolved oxygen, and Total Residue showed standards required for human consumption according to values presented by current legislation. On the other hand, the results for pH parameters, total coliforms, and coliforms Escherichia coli type termotolerantes showed disagreement in accordance with the laws concerning the limits established for water bodies of water intended for human consumption. The infrastructural conditions of water supply systems, as well as the physical and chemical parameters of untreated water, were considered unsatisfactory.

Keywords: Traditional rural communities. Water supply. Domestic consumption of water. Waterborne diseases.

RESUMO

A água é recurso natural, presente em processos metabólicos dos seres vivos, que vem sendo utilizada para diversos fins, em especial o consumo humano. O estudo objetivou avaliar o sistema de abastecimento e a qualidade da água para consumo humano das comunidades rurais da Chapada do Apodi, Rio Grande do Norte. A metodologia constou de identificação e avaliação do sistema de abastecimento a partir da percepção ambiental e de análises físico-químicas e biológicas na água. Os dados de condutividade elétrica, turbidez, resíduo total e oxigênio dissolvido apresentaram padrões aceitáveis para o consumo humano de acordo com valores apresentados pela legislação vigente. Em contrapartida, os resultados encontrados para os parâmetros de pH, coliformes totais e coliformes Termotolerantes do tipo Escherichia coli apresentaram discordância com a legislação para corpos hídricos de águas doces destinados ao consumo humano. Podem-se considerar como insatisfatórias as condições de infraestrutura dos sistemas de abastecimento de água e os parâmetros físico-químicos da água sem prévio tratamento.

Palavras-chave: Comunidades rurais tradicionais. Abastecimento de Água. Consumo Doméstico de Água. Doenças de Veiculação Hídrica.

1 INTRODUCTION

Water is an important natural resource and it is present in most metabolic processes of living beings, constituting an element of vital importance for their survival. Depending on its quality, it can be used for various purposes, such as human consumption, agricultural and livestock activities, electricity generation, waterway transportation, industrial use, fishing and aquaculture, tourism and leisure (DERÍSIO, 2012). These multiple uses can result in changes in the physicochemical and biological characteristics of water through processes of pollution and/or contamination, causing social, economic, political, environmental, ecological and health-related consequences.

This natural resource is used worldwide, but it becomes particularly relevant in semi-arid regions, due to its climate specificities. In the case of the brazilian Northeast, strategies concerning water resources management is notorious, since such resources are ultimate for territorial planning. From the perspective of multiple uses of water resources, Chapada do Apodi has been adopting an economic model based on the implementation of irrigated perimeters, which facilitate access to water resources.

Chapada do Apodi spreads across the states of Ceará and Rio Grande do Norte, surrounding the cities of Apodi, Baraúna, Felipe Guerra, and Governor Dix-Sept Rosado, in the state of Rio Grande do Norte, and Alto Santo, Jaguaruana, Limoeiro do Norte, Quixeré and Tabuleiro do Norte, in the state of Ceará (PINTO et al., 2016).

The agricultural production model based on irrigated perimeters in Chapada do Apodi is a prevalent practice in agribusiness, which according to Rigotto and Teixeira (2009), has consequences related to work, environment and health: land concentration and population displacement; violence; food safety risks; social changes; imposition of new habits; formation of rural slums; intensive use of mechanization; use of fertilizers and pesticides; precarious working relations and conditions; non-compliance with labor legislation; intensification of work; health-risk exposure; reduction of biodiversity and environmental services; soil degradation; high water consumption; air contamination; water pollution; exposure of workers and surrounding communities to pesticides.

Because of the aforementioned scenario of agricultural production, Chapada do Apodi has been the object of scientific studies with several approaches: workers' conditions (SAMPAIO; LIMA; FREITAS, 2011); public health, land concentration, environmental, social and political-related issues (RIGOTTO, 2011), and pesticides (CARNEIRO; RIGOTTO; PIGNATI, 2012). However, these studies are particularly focused on the limits of Chapada do Apodi in the state of Ceará, therefore further investigation in Rio Grande do Norte is needed.

The relevance of the present study accounts for the lack of scientific studies in Chapada do Apodi/RN. It is, therefore, urgent to address environmental problems in the region, which are related to the early stages of the implementation of Santa Cruz do Apodi Irrigated Perimeter and the establishment of agricultural companies. Such issues impact on environmental quality, especially water resources, as they are an indispensable natural element for this economic sector and also necessary for regional human development.

In Brazil, several studies on water supply have been developed, especially: Amaral et al. (2003), Araújo et al. (2011), Bortoli et al. (2018), Brum et al. (2016), Cavalcante (2014), Giatti (2007), Lemos (2003), Medeiros, Lima e Guimarães (2016), Morais et al. (2017), Pessôa (2013), Pinto Filho et al. (2018), Quesado Júnior et al. (2008), Soares et al. (2018) e Souza et al. (2016). However, similar studies have not yet been conducted in Chapada do Apodi/RN, being important for providing data on local environmental sanitation, which will allow to inhibit, or prevent the occurrence of diseases.

Taking that into account, it is relevant to investigate the water supply system for human consumption in the communities of Chapada do Apodi/RN, since it is a scenario in the Brazilian semi-arid region with deficiencies in environmental sanitation conditions, climate specificities and agroindustrial influence. An investigation of this context can be carried out through environmental perception, which is a kind of approach that considers the representations a population has about their environment (DEL RIO; OLIVEIRA, 1996) and, through the monitoring of water, looking at changes in its quality characteristics which might result from anthropic activities and natural phenomena (TUCCI, 2006). Following such investigative approach, it is possible to identify the relations between environmental conditions and population.

This study aims to identify the environmental perception of the local population, for it is considered as an instrument that sheds light on the understanding about the interrelationships between society and the environment (MELAZO, 2005). In addition to that, water monitoring will be administered, with the objective to verify whether legal standards of water quality are being obeyed, as well as to identify what is being changed, and to understand the reasons that justify such changes (TUCCI, 2006).

In this perspective, in addition to the environmental perception data, water monitoring is likewise necessary to reduce the pressure of anthropogenic degradation on aquatic ecosystems, as it allows to know the conditions of adaptability of the environment and the loads of polluting agents, enabling the aid of planning when it comes to decision making (MAROTTA; SANTOS; ENRICH-PRAST, 2008). However, the unavailability of water quality data is one of the central problems of developing countries (BHATTI; LATIF, 2011), which increases the relevance of this research.

Taking this discussion into account, this study presents a systematic approach to the problem investigated: it is environmentally-based, for taking into account the quality of water for human consumption; it is socially-based for identifying the role of water in local development; it is also economically-based for analyzing the effects of water scarcity in the region; scientifically-based for contributing to water quality studies in semi-arid areas; technically-based for providing data to official environmental agencies; and ultimately, this study is politically-based for investigating how water has been used and for whom it should be prioritized.

Bearing that in mind, the objective of this work is to evaluate the water supply system for human consumption in the rural communities of Chapada do Apodi/RN. For this, the following specific objectives were listed: a) to identify the forms of water supply for the population in the study area; b) to evaluate the supply system from the environmental perception of the population and c) to analyze the physicochemical and biological quality in water for human consumption.

2 MATERIAL AND METHODS

2.1 RESEARCH CLASSIFICATION

The present study can be classified according to its approach, type, objectives, sources, and techniques (GIL, 2008). This research follows a qualitative approach, as it presents an evaluation of the human supply system in communities surrounding Chapada do Apodi/RN based on environmental perception. Furthermore, such investigation is also quantitative, once it analyzes aspects regarding water quality. This kind of research has its roots in a logical positivist thinking, which tends to emphasize deductive reasoning, logic rules, and the measurable attributes of human experience (FONSECA, 2002).

This kind of research can be categorized as a case study, because it evaluates the specificity of water supply and its relationship with Santa Cruz do Apodi Irrigated Perimeter. Gil (2008) points out that a case study is a detailed analysis of one or a few objects so that its in-depth knowledge can be obtained through the investigation of a phenomenon within its real context.

This study has an explanatory objective, since it seeks to identify the supply system from the local population’s environmental perception. According to Gil (2008), exploratory research aims to identify the factors that determine or contribute to the occurrence of phenomena.

In order to implement this research, different means of data collection strategies were adopted, such as bibliographic research, document analysis and field observation (documentation research, interviewing, observation and chemical analysis) (GIL, 2008).

2.2 STUDY AREA DELIMITATION AND CHARACTERIZATION

Apodi is a municipality located in the microregion of Chapada do Apodi and in the western potiguar mesoregion of Rio Grande do Norte (Figure 1). It is 340 km away from Natal, and its territorial area reaches 1,602,477 km² (IBGE, 2018).

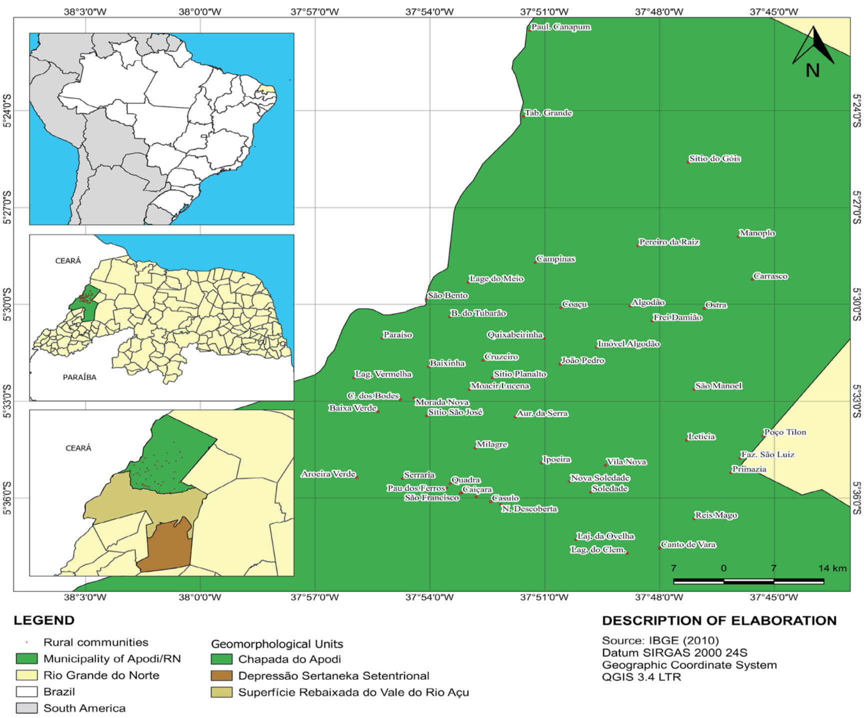


Figure 1: Location map of Apodi municipality, Rio Grande do Norte (RN), and rural communities of Chapada do Apodi / RN.
Source: Authors (2019).

The municipality of Apodi/RN has a population of 35,814 inhabitants, most of whom are located in rural areas (almost 52%) (IBGE, 2018). The rural area of Apodi is characterized according to its geological formations and it is divided in the following rural zones: Açu Formation (Apodi Sand Region); Crystal Basement and Northern Country Depression (Apodi Stone Region); Alluvial Deposits (Apodi Valley); and Jandaíra (Chapada do Apodi) (Figure 1).

The region of Chapada do Apodi/RN had its territorial planning process over the years with agricultural activities. Some decades ago it was occupied by large farms, however, in the late 1970s and early 1980s, with the emergence of rural community associations created by actions carried out by churches through the Basic Ecclesial Communities – CEBs, a process of popular organization of rural workers came to exist in Apodi. (PONTES, 2012).

The articulate work of Apodi farmers culminated in the 1990s, with the creation of the Apodi Workers and Rural Workers Syndicate (Sindicato dos trabalhadores Rurais de Apodi – STTR), an important articulator of family farming in the region. From 1990, Apodi began to manifest changes in the rural context caused by the cotton crisis, which was characterized by biological pests, the increasing use of pesticides, scarcity of economic resources, high interest rates for financing production, lack of scale economy, and restriction in agricultural mechanization. This scenario resulted in the weakening of great landowners, which somehow encouraged local workers to fight for agricultural reformation (PONTES, 2012).

Consequently, small-holder farmers obtained their land through expropriations carried out by the National Institute of Agrarian Reform - Incra, and rural communities from the Land Credit, an important public policy instrument for access to land throughout the Country. In Chapada do Apodi/RN, where large states were once predominant, is nowadays characterized by several settlements and traditional rural communities which work with agroecological family farming (PONTES, 2012).

As a result, in this area, successful experiences of agroecological and family farming in the Northeast have been consolidated in recent years, covering 55 rural communities (Figure 1 and Table 1) (PONTES et al., 2013). Table 1 shows the geographical coordinates of the rural communities of Chapada do Apodi / RN of this study.

Table 1 | Geographic coordinates of rural communities of Chapada do Apodi-RN.

Type	*Communities*	*Coordinates*	*Type*			*Type*		
RURAL COMMUNITIES	Algodão	05º 30 ‘ 03 ‘’ S	INCRA SITTING PROJECT	Frei Damião	05º 30 ‘ 30.97 ‘’ S	FUNDY CREDIT DESIGN	A. Palmares	05º 35’ 57.57 ‘’ S
		37º 48’ 46’’ W			37º 48 ‘ 11.63 ‘’ O			37º 52’ 47.76’’ O
	Aroeira Verde	5º 35’ 21.73’’ S		Caiçara	5º 35’ 50.57 ‘’ S		Casulo	05º 36’ 6.81’’ S
		37º 55’55.06’’ S			37º 53 ‘ 10.99 ‘’ O			37º 52’ 24.91’’ O
	B. do Tubarão	05º 30’ 23’’ S		Paul. Canapum	05º 21 ‘ 12.33’’ S		Letícia	05º 34’ 23’’ S
		37º 53’ 29’’ S			37º 51 ‘ 59.59’’ O			37º 47’ 17’’ W
	Baixinha	05º 31’ 56’’ S		São Bento	05º 29’ 48.66 ‘’ S		Imóvel Algodão	05º 31’ 20’’ S
		37º 54’ 02’’ W			37º 54 ‘ 8.09 ‘’ O			37º 49’ 39’’ W
	Campinas	05º 28’ 42’’ S		Tab. Grande	05º 23’ 51.57 ‘’ S		Baixa Verde	5º 33’ 19.61’’ S
		37º 51’ 15’’ W			37º 52 ‘ 25.76 ‘’ O			37º 55’ 21.62’’ O
	Canto de Vara	05º 37’ 33’’ S		Sítio do Góis	05º 25 ‘ 35.86 ‘’ S		Cruzeiro	05º 31’ 44’’ S
		37º 48’ 00’’ W			37º 47 ‘ 15.25 ‘’ O			37º 52’ 37’’ W
	Carrasco	05º 29’ 14’’ S		Vila Nova	05º 34 ‘ 59’’ S			
		37º 45’ 35’’ W			37º 49 ‘ 25’’ W			
	C. dos Bodes	5º 32’ 56.95’’ S		Aur. Da Serra	05º 33 ‘ 29 ‘’ S			
		37º 54’ 46.54’’ O			37º 51’ 46’’ W			
	Coaçu	05º 30’ 06’’ S		Moacir Lucena	05º 32’ 38’’ S			
		37º 50’ 36’’ W			37º 52’ 58’’ S			
	Nova Soledade	5º 35’ 28,48’’ S		Milagre	05º 34 ‘ 27 ‘’ S			
		37º 50’ 21.06’’ O			37º 52’ 49’’ W			
	Faz. São Luiz	05º 34’ 46’’ S		Paraíso	05º 31’ 03’’ S			
		37º 45’ 54’’ W			37º 55’ 15’’ W			
	Ipoeira	5º 34’ 54.53’’ S		Lage do Meio	05º 29’ 19’’ S			
		37º 51’ 4.90’’ O			37º 53’ 00’’ W			
	João Pedro	05º 31’ 51’’ S		São Manoel	05º 32’ 38’’ S			
		37º 50’ 36’’ W			37º 47’ 06’’ W			
	Lage do Meio	05º 29’ 19’’ S		N. Descoberta	5º 36’ 12.02’’ S			
		37º 53’ 00’’ W			37º 52’ 9.21’’ O			
	Lag. Do Clem.	05º 37’ 42.67’’ S						
		37º 48’ 50.63’’ O						
	Lag. Vermelha	05º 32’ 16’’ S						
		37º 55’ 59’’ W						
	Laj. Da Ovelha	5º 37’ 17.53’’ S						
		37º 50’ 11.07’’ O						
	Manoplo	05º 27’ 54’’ S						
		37º 45’ 56’’ W						
	Morada Nova	05º 32’ 54’’ S						
		37º 54’ 25’’ W						
RURAL COMMUNITIES	Mulungu	5º 27’ 29.30’’ S						
		37º 40’ 26.35’’ O						
	Ostra	05º 30’ 08’’ S						
		37º 46’ 50’’ W						
	Pau dos Ferros	5º 35’ 41.29’’ S						
		37º 53’ 34.19’’ O						
	Pereiro da Raiz	05º 28’ 11’’ S						
		05º 28’ 11’’ S						
	Poço Tilon	05º 34’ 04’’ S						
		37º 45’ 18’’ W						
	Primazia	05º 35’ 13’’ S						
		37º 46’ 08’’ W						
	Quadra	5º 35’ 32.83’’ S						
		37º 53’ 28.34’’ O						
	Quixabeirinha	05º 31’ 03’’ S						
		37º 51’ 01’’ W						
	Reis Mago	05º 36’ 38’’ S						
		37º 47’ 06’’ W						
	São Francisco	05º 35’ 51’’ S						
		37º 53’ 12’’ W						
	Serraria	5º 35’ 23.73’’ S						
		37º 54’ 43.08’’ O						
	Sítio Cruzeiro	05º 31’ 44’’ S						
		37º 52’ 37’’ W						
	Sítio do Gois	5º 25’ 35.86’’ S						
		37º 47’ 15.25’’ O						
	Sítio Planalto	05º 32’ 16’’ S						
		37º 52’ 22’’ W						
	Sítio São José	05º 33’ 27’’ S						
		37º 54’ 05’’ W						
	Soledade	05º 35’ 49’’ S						
		37º 49’ 48’’ W						

Source: Authors (2019).

2.3 THEORETICAL AND METHODOLOGICAL PROCEDURES OF ENVIRONMENTAL PERCEPTION

To investigate the problem of the study area, an environmental perception approach was used. This research strategy is considered a sustainability tool through which society and nature are put into communion, therefore allowing us to understand the conditions of the water supply system for human consumption in rural communities, as well as to identify the reflection of these conditions on the community's quality of life. Regarding this methodology, the following procedures were set: a) definition of the instrument for collecting environmental perception; b) sampling process; c) field research and; d) data processing. It is also relevant to emphasize that the perception of the local community is considered an indicator of management effectiveness. Rodrigues et al. (2012) state that this instrument allows the monitoring of services in the lives of residents.

A) ENVIRONMENTAL PERCEPTION COLLECTION INSTRUMENT

A semi-structured questionnaire addressing the socioeconomic profile of the local population was adopted as a tool for collecting environmental perception; characteristics of water uses for human consumption; evaluation of supply water quality and quantity; and the most common diseases in the investigated region to possibly correlate with water disease vectors.

B) SAMPLING PROCESS

The study sampling process was carried out by drawing at least 10% of the households. We used as data source the Basic Health Unit (*Unidade Básica de Saúde*) - UBS (2018) of rural communities belonging to the investigated region which accounted for 1,649 households.

Based on that, water samples were collected from 186 households. This value has been set by Bolfarine and Bussab (2005) who consider that a sample equal to or greater than 25 will always be considered normal, i.e. significant. Therefore, a non-probabilistic sample was established, in which this number represents more than 10% of the total local population (Table 1).

The defined sample consisted of 186 questionnaires which represent 11.28% of the total of households, being distributed proportionally among the rural communities investigated and matching the statistical requirements (Table 2).

Table 2 | Population Distribution of rural communities of Chapada do Apodi-RN.

TYPE	COMMUNITIES	HOUSEHOLDS SAMPLE	TYPE	COMMUNITIES	HOUSEHOLDS SAMPLE	TYPE	COMMUNITIES	HOUSEHOLD SAMPLE
RURAL COMMUNITIES	Algodão	07 – 01	INCRA SITTING PROJECT	Frei Damião	50 – 05	FUNDY CREDIT DESIGN	Agrovila Palmares	30 – 03
	Aroeira Verde	03 – 01		Caiçara	60 – 06		Casulo	12 – 02
	B. do Tubarão	10 – 01		Paul. Canapum	60 – 06		Letícia	15 – 02
	Baixinha	03 – 01		São Bento	45 – 04		Imóvel Algodão	17 – 02
	Campinas	15 – 02		Tab. Grande	60 – 06		Baixa Verde	51 – 06
	Canto de Vara	10 – 01		Sítio do Góis	60 – 06		Cruzeiro	07 – 01
	Carrasco	04 – 01		Vila Nova	10 – 01			
	C. dos Bodes	01 – 01		Aur. da Serra	70 – 07			
	Coaçu	01 – 01		Moacir Lucena	25 – 03			
	Nova Soledade	01 – 01		Milagre	32 – 04			
	Faz. São Luiz	10 – 01		Paraíso	36 – 04			
	Ipoeira	07 – 01		Lage do Meio	28 – 03			
	João Pedro	18 – 02		São Manoel	26 – 03			
	Lage do Meio	100 – 10		N. Descoberta	42 – 05			

TYPE	COMMUNITIES	HOUSEHOLDS SAMPLE	TYPE	COMMUNITIES	HOUSEHOLDS SAMPLE	TYPE	COMMUNITIES	HOUSEHOLD SAMPLE
RURAL COMMUNITIES	Lag. do Clem.	05 – 01	INCRA SITTING PROJECT			FUNDY CREDIT DESIGN		
	Lag. Vermelha	06 – 01						
	Laj. da Ovelha	10 – 01						
	Manoplo	20 – 02						
	Morada Nova	02 – 01						
	Mulungu	40 – 04						
	Ostra	01 – 01						
	Pau dos Ferros	15 – 02						
	Pereiro da Raiz	02 – 01						
	Poço Tilon	03 – 01						
	Primazia	20 – 02						
	Quadra	01 – 01						
	Quixabeirinha	65 – 06						
	Reis Mago	01 – 01						
	São Francisco	05 – 01						
	Serraria	02 – 01						
	Sítio Cruzeiro	60 – 06						
	Sítio do Gois	04 – 01						
	Sítio Planalto	06 – 01						
	Sítio São José	05 – 01						
	Soledade	450 – 46						
	TOTAL A	**913 - 106**		**TOTAL B**	**604 – 63**		**TOTAL C**	**132 – 16**
GRAND TOTAL (A + B + C) =								**1.649 – 186**

Source: Authors (2019).

C) FIELD RESEARCH

In January, February and March, 2018, the questionnaires were applied to the rural communities investigated. The Informed Consent Form (ICF) was made available to the participants, including the research explanations and general information about the researchers. The inclusion and exclusion criteria of participants and the research risks were likewise mentioned. The choice of the survey method was due to its descriptive, explanatory and exploratory statements about a population, i.e. to discover the distribution of attributes of the investigated population (BABBIE, 2001).

The monitoring of water quality for human consumption took place through analysis of physicochemical parameters in the reservoirs of households (cisterns, wells, water tanks, and taps). This monitoring was based on the American Public Health Association - APHA (1995), using multiparameter probe, model HORIBA U-50, which allows real-time quantification of hydrogen potential (pH), turbidity (NTU), temperature (ºC), dissolved oxygen (mg/L), electrical conductivity (mS/cm), solids Total Dissolved (g/L), Salinity (ppt), Oxidation Reduction Potential (mV) and Percent Dissolved Oxygen (%). Total coliforms (UFC/100mL), thermotolerant coliforms (UFC/100mL) and Escherichia coli (UFC/100mL) were performed in a commercial laboratory.

D) DATA PROCESSING

The results were submitted to nonparametric statistical analysis by Spearman correlation, the same procedure used by Ribeiro et al. (2016) and Bertossi et al. (2013). Data was processed through Microsoft Office Excel, version 2013, and through graphing of boxplot type of each variable. The correlation matrix composed of the 10 variables was processed using a free statistical software, R studio, which shows the relationship between the selected variables in each component. The results were compared with studies of water supply in rural communities, according to Resolution values of National Environment Council - Conama N° 357/2005 and the Ordinance of the Ministry of Health N° 2,914 / 2011.

3 RESULTS AND DISCUSSION

3.1 WATER SUPPLY SYSTEM IN RURAL COMMUNITIES OF CHAPADA DO APODI/RN VIA ENVIRONMENTAL PERCEPTION OF LOCAL POPULATION

The distribution of water supply system from communities of Chapada do Apodi occurs in an heterogeneous way, in time and space, with quantitative limitation, and presenting source variation: wells (85,07%), Sanitation Company of the State of Rio Grande do Norte (Companhia de Águas e Esgotos do Rio Grande do Norte - Caern) (3,73%) Tank truck (3,36%), wells and Tank trucks (4,10%), wells and Cern (0,37%), and others (3,36%). Similar results about supply infrastructure have been found by Amaral et al. (2003), Giatti (2007) and Pinto Filho et al. (2018) when the difficulties of rural communities in accessing potable water were analyzed by their research. Thus, it can be induced that there is an unequal and difficult relation concerning the access to potable water by rural population of Chapada do Apodi/RN.

Through the local population perception, the existence of deficiencies in the water supply was noticed, especially regarding the absence of water distribution system. To solve this kind of problem, Souza et al. (2016) point to the adoption of alternative collective solutions in supplying the consumption necessities. Inserting the possibilities of a viable alternative, Morais et al. (2017) emphasize social technologies of water collection and storage in addition to actions of environmental education (which is a sensibilization and transformation vehicle) for stimulation of the strengthening and use of sanitation barriers that preserve the quality of this natural resource.

Still in this conception, Amaral et al. (2003) assert that water, when taken from natural sources without any treatment, results in a deficiency in the water supply system, consequently presenting possible coliform contamination and risk of water-borne infections. It can be seen from the present research that 72% of the population consumes water without any previous treatment, 18.66% use ceramic filters in their homes, 5.60% use chlorine for disinfection to inactivate organisms. Referring to pathogens, only 0.75% carry out a boil pretreatment as a preventive measure, and 2.99% answered that they treat water by using other procedures. Similar situations were found by other researchers, such like Lemos (2003), who made his study in rural area of Maquiné/RS, where 87% of population does not previously treat the collected water, and like Bortoli et al. (2018) who observed that from water samples intended for human consumption in rural properties located in Rio Grande do Sul, only 58% received chlorine treatment, and the remaining percentage do not use any treatment. Therefore, it is clear that the water supply for human consumption in rural areas still is a recurring problem, consequently making the local population vulnerable to water-borne diseases.

It is well known that Inadequate sanitation conditions in rural areas, correlated with the lack of information of the population, enable the development of water-borne diseases (ARAÚJO et al., 2011; CAVALCANTE, 2014). In the investigated rural communities, problems in the water supply system were enough to influence human health, since the occurrence of some symptoms and diseases, such as diarrhea (11.9%), typhoid fever (7.0%), and dengue (1.9%), which are amongst the most mentioned by the population of the study (Figure 2). In the study carried out by Pinto Filho et al. (2018), residents from rural communities of CPCA/RN mentioned health problems associated with water quality, including diarrhea (10.5%), and dengue (3.4%). Taking these figures into account, it can be assumed the evident connection between water quality and the emergence of water-borne diseases (BRUM et al., 2016; SOARES et al., 2018).

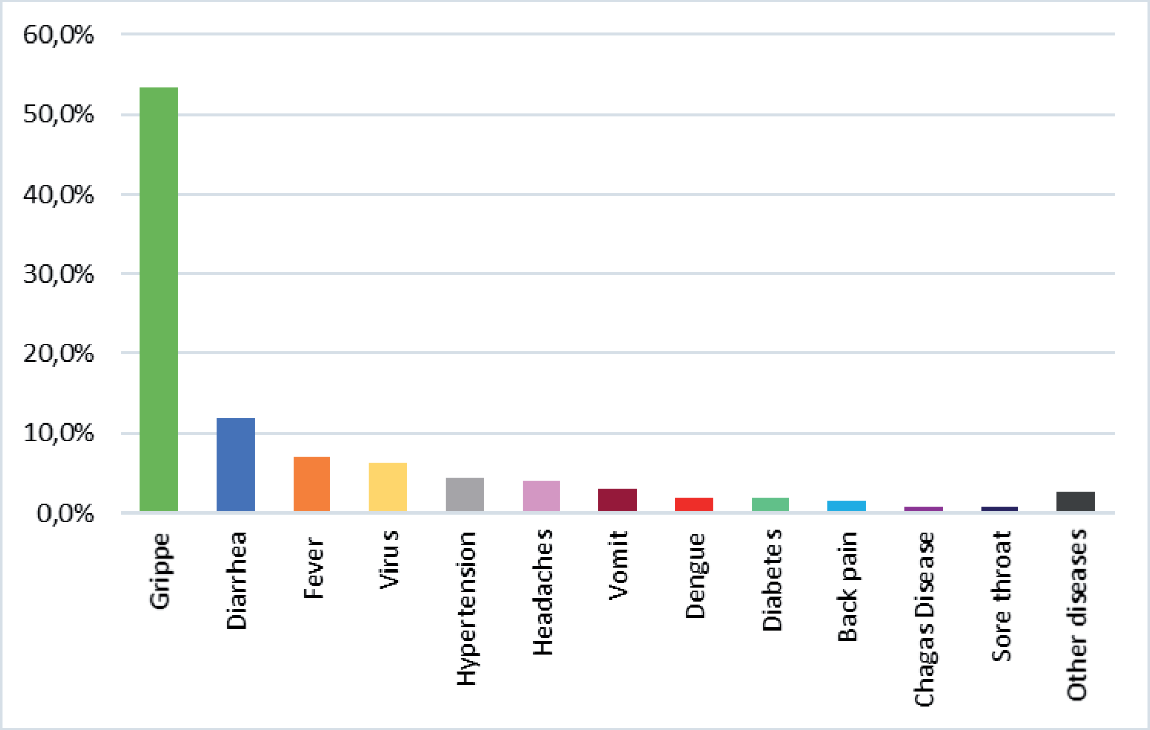


Figure 2: Symptoms and diseases cited by inhabitants of Chapada do Apodi communities.

Source: Authors (2019).

Thus, to associate health and environmental quality, it is necessary to analyze the water condition for human consumption in the rural communities studied. Since the lack of monitoring of these sources and the lack of information of the population about the causes and problems associated with contamination contribute to a greater incidence of waterborne diseases. (CAVALCANTE, 2014).

3.2 WATER QUALITY OF THE HUMAN CONSUMPTION SUPPLY SYSTEM IN THE RURAL COMMUNITIES STUDIED

Table 3 contains the physicochemical (temperature, pH, redox potential, electrical conductivity, turbidity, dissolved oxygen, total residue, and salinity) and biological (thermotolerant coliforms E.coli) variables for drinking water samples in rural communities of Chapada do Apodi / RN.

In bodies of water, temperature can be analyzed along with other parameters, and may also influence the reactions of this vehicle (NOGUEIRA, COSTA e PEREIRA, 2015). The values obtained in the analysis for temperature presented an average of 29.14 °C (Table 3). However, the rural community of A. Palmares showed an excessive temperature of 33,05 °C (row 174 and column 02, Table 3). A similar result was observed in a study by Araújo et al. (2011), which demonstrated excessive values, up to 30.1 °C, in a community from the state of São Paulo. Current brazilian legislation does not establish values for a temperature parameter, so it is not possible to reference as legal non-compliance.

The hydrogenic potential - pH may be the result of natural and anthropogenic factors (LIBANIO, 2005). The pH values of the studied water samples presented an average of 5.92 (Table 3), and in the rural community of Paraíso, analysis 01, it could be observed value of 4.120 (row 132 and Column 03, Table 3). Thus, the minimum and average values are not under the Conama Resolution No. 357/2005 and Ordinance MS No. 2.914 / 2011, which provide for the maximum values between 6.0 to 9.0 and 6.0 to 9.5, respectively.

These results showed similar quality to values obtained by Medeiros, Lima, and Guimarães (2016) from groundwater source waters in municipalities of Pará state, the samples revealed acid values that do not match the recommended values for human consumption; by Brum et al. (2016), which ranged values between 4.46 to 6.96, in shallow wells from an area with lack of basic sanitation in Cuiabá/MT; and by Araújo et al. (2011) who obtained data of 4.25 and 4.46, from a residential water tank and from one of the springs that supply the rural communities in the state of São Paulo. Therefore, it is observed a tendency for waters in rural areas to have acidic quality.

Redox potential - ORP represents changes in the oxidation state of several ions or nutrients and it is related to nutrient availability for aquatic communities (TUNDISI; TUNDISI, 2008). The values of ORP found presented an average of 292,566 mV (Table 3) and values that indicated up to 383.0 mV in relation to the rural communities of: São Bento, analysis 02 (row 127 and Column 04); Aur. da Serra, analysis 03 (Line 145 and Column 04); Lage do Meio, analysis 02 (Line 162 and Column 04); A. Palmares, analysis 01 (Line 172 and Column 04); and Real Estate Cotton, analysis 02 (Line 180) and Column 04). The Conama Resolution does not have redox potential standards for freshwater classes. However, according to Fiorucci and Benedetti Filho (2005), ORP values between 200 mV and 600 mV indicate a strongly oxidizing vehicle, and differences of potential between -100 mV and -200 mV reveal reducing ones. Thus, it is possible to evaluate the quality of water samples from Chapada do Apodi/RN as considerably oxidizing.

The electrical conductivity - EC represents a measure of the anthropic effect, since it depends on the ionic concentrations and temperature, indicating the existence of salts in the water (SÃO PAULO STATE ENVIRONMENTAL COMPANY - CETESB, 2010). EC results indicated an average of 138.565 µS/cm (Table 3), and presented values up to 843 µS/cm, as in the rural community of B. do Tubarão, analysis 01 (row 04 and column 05, Table 3), values considered above than allowed, given that the Ordinance MS No. 2,914/2011 establishes a standard of acceptance for consumption a limit of 1,000 µS/cm (BRAZIL, 2011). When compared to the results of Brum et al. (2016) significant differences were observed, since these authors found values up to 486.7 µS/cm, representing that the investigated samples are inside the limit established by the ordinance. However, controlling these concentrations under the limits of the legislation is an important tool to avoid the degrading effects of the water pollution process (TUNDISI, 2003).

Turbidity - Turb can be of both natural and anthropogenic origin and does not pose direct problems, but it is aesthetically unpleasant; moreover suspended solids can provide refuge for pathogenic microorganisms (PERPÉTUO, 2014). The results obtained from Turb reached an average of 12,998 Nephelometric Turbidity Units (UNT) (Table 3). However, in the rural community of N. Descoberta, analysis 05 (Row 171 and Column 06, Table 3), this parameter showed a surplus value of 420 UNT.

The average data analyzed was lower than the maximum allowable limit (up to 40 UNT) proposed by Conama Resolution No. 357/2005 for Class 1 freshwater supplies for human consumption with disinfection, indicating that they are in accordance with the conditions established by law. When compared to the Ordinance MS No. 2,914 / 2011, it is observed that the average presented results considered not acceptable for human consumption, for its value was above the recommended limit of 5 UNT, which requires previous treatment for consumption. We also emphasize that the results obtained for Turb were also different and superior to those determined by other studies of water evaluation, such as Pinto Filho et al. (2018), which determined values up to 6.61 UNT. It can be inferred that some values found were above the standard established by current legislation, therefore, the organoleptic characteristics of water may be compromised.

Dissolved oxygen - OD is the main parameter for characterizing the effects of water pollution by organic waste (VON SPERLING, 2005). This element influences all chemical and biological processes that occur in water and indicates possible pollution by organic matter (ESTEVES, 2011). In the analyzed samples, the OD values expressed an average of 9.75 mg/L (Table 3) and, in the rural community of São Francisco, analysis 03 (Row 47 and Column 07, Table 3) showed a value corresponding to 4,92 mg/L, favoring a negative value according to Conama Resolution No. 357/2005. The MS Ordinance No. 2.914/2011 does not establish values for this parameter.

When comparing with data from the literature, it is observed that the results obtained were superior, since Pinto Filho et al. (2018) obtained values ranging from 3.89 to 7.60 mg/L in water collected for human consumption in the CPCA / RN, and presented a total of 84.51% of the samples below 6.0 mg/L and; Araújo et al. (2011), found values between 2.7 and 8.3 mg/L in water samples collected in rural communities in the state of São Paulo. So, the obtained values with low dissolved oxygen levels may be related to the waste of organic substances in water bodies and its decomposition by aerobic microorganisms that consume dissolved oxygen present in water (ARAÚJO et al., 2011; PESSÔA, 2013).

Total residue - STD is considered a potential problem: its excess in water causes changes in taste, leads to corrosion problems of pipes and its consumption can cause risks to human health (CASALI, 2008) The values found in this study presented an average of 279 mg/L (Table 03), but in the rural communities of Poço Tilon, analysis 02 (Row 39 and Column 09, Table 3); Quixabeirinha, analysis 02 (Row 43 and Column 09, Table 3); São Francisco, Analysis 04 (Row 48 and Column 09, Table 3); Aur. da Serra, analysis 04 (Row 146 and Column 09, from Table 3); Lage do Meio, analysis 03 (Row 163 and Column 09, from Table 3); and Baixa Verde, analysis 04 (Row 184 and Column 09, from Table 3), values of 1,584 mg/L were obtained. When compared with Conama Resolution 357/2005, to classify the water body in Classes 1, 2 and 3, although, some values are above the standard established by current legislation, it is observed that the average presented resulted as acceptable for human consumption, because it presented value below the recommended limit of 500 mg/L.

Therefore, the behavior of total solids is similar to turbidity, since both variables are related, and may have presented high values due to the higher concentration of organic matter presented during rainy seasons (BUZELLI; CUNHA-SANTINO, 2013). Salinity is the measure of the total concentration of dissolved ions in water, influenced by natural soil conditions, the regional climate and anthropic, being considered one of the main causes of water quality problems for irrigation purposes (PALÁCIO et al., 2011; QUESADO JÚNIOR et al., 2008).

The average Salinity analytical results for the investigated waters was 0.128 ppt (Table 3), but in the rural community Moacir Lucena, analysis 02 (Row 151 and Column 10, Table 3) presented a value of 0.900 ppt. Similar result was obtained by Quesado Júnior et al. (2008) who obtained an average of 0.85 ppt, minimum of 0.01 and maximum of 2.34 ppt. The Conama Resolution 357/2005 and the Ordinance No. 2,914 / 2011 do not assign reference values for salinity in relation to potability, but according to this Resolution, the values presented in the analysis according to the average obtained are classified as freshwater, which are classified by Oliveira et al. (2017) as good for irrigation practices, once they present few restrictions of use, and low risk of developing salinity problems (OLIVEIRA et al., 2017). Thus, regarding salinity, the investigated water samples are related as compatible with the most demanding uses (PESSÔA, 2013).

The values obtained for total coliforms - C. Totals averaged 149.266 CFU/100mL (Table 3), with values of at least 100.0 CFU/100mL, as the rural communities of Soledade, analysis 01 (Row 63 and Column 11, Table 3); Soledade, analysis 02 (Row 64 and Column 11, from Table 3); Soledade, analysis 04 (Row 66 and Column 11, from Table 3); and Soledade, analysis 08 (Row 70 and Column 11, of Table 3). Regarding the values of thermotolerant coliforms of Escherichia coli - E. coli type, it was obtained an average of 65,910 CFU/100mL (Table 3), with values of at least 34.0 CFU/100mL, in the rural community of Soledade, analysis 43 (Row 105 and Column 12 of Table 3. In similar studies by Bortoli et al. (2018), it was also observed determination of total coliforms in 62.5% of the sources used for human consumption in rural properties, and the presence of E. coli in 31.7%, being inappropriate for human consumption.

So, it is possible to indicate the pollution and water contamination, since according to Ordinance MS 2914/2011 should be considered the absence of total coliforms and E. coli thermotolerant coliforms in water intended for human consumption. This representation is recurrent in rural areas and it is worrying, since, according to Bortoli et al. (2018), the amount of coliforms present in the analyzed water samples may be related to the inadequate management of animal waste and the infiltration of pits, which compromise the groundwater, making the structural improvement of water supply important, especially in the regarding sanitation measures, proper storage in homes and measures for disinfection (CAVALCANTE, 2014).

Table 3 | Descriptive statistics of the physicochemical and biological parameters of water samples from rural communities of Chapada do Apodi-RN

Sample	Temp (ºc)	pH	ORP (mV)	EC (µS/cm)	Turbidity (NTU)	OD (mg/L)	OD (%)	Solids Total Dissolved (mg/L)	Salinity (ppt)	Total coliforms (UFC/100 mL)	*E. coli* (UFC/100 mL)
Algodão 01	29,920	4,950	300,000	233,000	0,000	11,790	153,200	151,000	0,100	101,000	71,000
Aroeira Verde 01	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	103,000	73,000
B. do Tubarão 01	29,300	5,360	285,000	843,000	0,000	9,730	128,200	548,000	0,400	107,000	77,000
Campinas 01	28,320	5,660	313,000	138,000	0,000	10,320	133,800	90,000	0,100	109,000	79,000
Canto de Vara 01	27,180	5,910	319,000	278,000	4,400	13,330	170,800	180,000	0,100	110,000	76,000
Canto de Vara 02	25,800	6,190	324,000	141,000	84,400	9,350	118,500	85,000	0,100	102,000	82,000
Carrasco 01	28,320	5,660	313,000	138,000	0,000	10,320	133,800	90,000	0,100	104,000	84,000
C. dos Bodes 01	28,000	5,000	321,000	140,000	0,000	10,610	137,100	90,000	0,100	105,000	70,000
Coaçu 01	27,680	4,340	329,000	142,000	0,000	10,900	140,400	90,000	0,100	107,821	77,000
Nova Soledade 01	29,920	4,950	300,000	233,000	0,000	11,790	153,200	151,000	0,100	110,226	78,000
Faz. São Luiz 01	32,130	5,750	295,000	115,000	0,100	8,720	118,200	910,000	0,200	112,631	80,000
Ipoeira 01	30,460	4,770	288,000	172,000	50,100	8,480	113,500	112,000	0,100	115,036	82,000
João Pedro 01	28,000	6,000	200,000	150,000	40,000	8,000	110,000	200,000	0,100	117,440	87,000
Lage do Meio 01	29,910	4,710	276,000	117,000	0,000	8,970	119,000	76,000	0,100	119,845	67,000
Lage do Meio 02	28,630	4,360	252,000	0,000	19,700	10,300	134,200	0,000	0,000	122,250	68,000
L. do Clem. 01	30,460	4,770	288,000	172,000	50,100	8,480	113,500	112,000	0,100	124,655	69,000
L. do Clem. 02	29,920	4,950	300,000	233,000	0,000	11,790	153,200	151,000	0,100	127,060	70,000
L. do Clem. 03	29,910	4,710	276,000	117,000	0,000	8,970	119,000	76,000	0,100	129,464	71,000
L. do Clem. 04	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	131,869	72,000
L. do Clem. 05	29,272	4,720	270,000	91,500	18,450	8,482	136,817	59,000	0,100	134,274	73,000
L. do Clem. 06	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	136,679	74,000
L. do Clem. 07	29,722	4,660	258,000	136,500	10,550	8,972	142,317	123,000	0,100	139,083	75,000
L. do Clem. 08	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	141,488	76,000
L. do Clem. 09	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	143,893	77,000
L. do Clem. 10	29,897	4,570	240,000	146,000	13,700	9,707	150,567	131,000	0,100	146,298	78,000
Laj. da Ovelha 01	26,980	5,830	315,000	336,000	8,000	7,720	98,200	218,000	0,200	148,702	79,000
Manoplo 01	28,000	6,000	319,000	320,000	9,000	7,000	110,000	200,000	0,100	151,107	80,000
Morada Nova 01	27,000	6,700	300,000	300,000	10,000	7,720	100,000	218,000	0,200	153,512	81,000
Mulungu 01	25,800	6,190	324,000	141,000	84,400	9,350	118,500	85,000	0,100	155,917	62,000
Mulungu 02	25,800	6,190	324,000	141,000	84,400	9,350	118,500	85,000	0,100	158,321	63,000
Ostra 01	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	160,726	64,000
Pau dos Ferros 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	163,131	65,000
Pau dos Ferros 02	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	165,536	66,000
Pau dos Ferros 03	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	167,940	67,000
Pau dos Ferros 04	26,740	6,140	306,000	114,000	10,000	12,890	112,600	109,000	0,100	170,345	68,000
Pereiro da Raiz 01	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	172,750	69,000
Poço Tilon 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	175,155	70,000
Poço Tilon 02	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	177,560	71,000
Primazia 01	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	179,964	72,000
Quadra 01	26,740	6,140	306,000	114,000	110,000	12,890	112,600	109,000	0,100	182,369	73,000
Quixabeirinha 01	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	184,774	74,000
Quixabeirinha 02	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	187,179	75,000
Reis Mago 01	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	189,583	76,000
São Francisco 01	26,860	4,580	313,000	100,000	2,300	17,300	219,500	73,000	0,100	191,988	77,000

Sample	Temp (ºc)	pH	ORP (mV)	EC (µS/cm)	Turbidity (NTU)	OD (mg/L)	OD (%)	Solids Total Dissolved (mg/L)	Salinity (ppt)	Total coliforms (UFC/100 mL)	*E. coli* (UFC/100 mL)
São Francisco 02	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	194,393	45,000
São Francisco 03	31,820	6,659	289,667	142,556	2,100	4,920	203,500	1147,000	0,100	196,798	47,000
São Francisco 04	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	199,202	49,000
São Francisco 05	30,780	7,738	266,333	185,111	1,300	11,460	226,500	1421,000	0,300	201,607	51,000
São Francisco 06	31,260	7,277	254,667	206,389	2,450	8,650	138,000	1258,000	0,400	204,012	53,000
Serraria 01	28,100	7,000	320,567	133,694	0,478	9,338	105,000	156,000	0,200	206,417	55,000
Sítio Baixinha 01	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	208,821	57,000
Sítio Cruzeiro 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	211,226	59,000
Sítio do Góis 01	26,860	4,580	313,000	100,000	2,300	17,300	219,500	73,000	0,100	213,631	61,000
Sítio do Góis 02	28,770	5,140	329,000	270,000	0,000	8,800	114,000	175,000	0,100	216,036	63,000
Sítio do Góis 03	28,320	5,050	260,000	100,000	0,000	8,500	100,000	62,000	0,000	218,440	65,000
Sítio do Góis 04	29,443	5,393	247,667	156,667	1,533	9,733	125,000	92,000	0,100	220,845	67,000
Sítio do Góis 05	30,173	5,628	221,167	156,667	2,683	7,667	134,750	87,000	0,100	223,250	69,000
Sítio do Góis 06	30,903	5,863	194,667	156,667	3,833	8,067	164,500	81,000	0,100	225,655	71,000
L. Vermelha 01	29,410	4,950	360,000	45,000	0,000	6,740	88,800	29,000	0,000	228,060	73,000
Sítio Planalto 01	26,580	4,890	289,000	60,000	0,000	6,610	85,000	39,000	0,000	230,464	75,000
Sítio São José 01	23,750	4,830	218,000	75,000	0,000	6,480	81,200	49,000	0,000	232,869	77,000
Soledade 01	28,320	5,050	260,000	100,000	0,000	8,500	100,000	62,000	0,000	100,000	79,000
Soledade 02	28,820	5,780	270,000	105,000	0,000	8,800	107,000	68,000	0,000	100,000	81,000
Soledade 03	28,320	5,660	313,000	138,000	0,000	10,320	133,800	90,000	0,100	106,000	83,000
Soledade 04	28,000	5,000	321,000	140,000	0,000	10,610	137,100	90,000	0,100	100,000	85,000
Soledade 05	28,330	4,600	325,000	138,000	0,000	11,110	143,400	92,000	0,100	104,000	67,000
Soledade 06	32,130	5,750	295,000	115,000	0,100	8,720	118,200	910,000	0,200	108,000	67,000
Soledade 07	29,350	6,000	299,000	127,000	0,100	10,390	140,000	85,000	0,200	340,000	64,000
Soledade 08	28,990	5,600	290,000	11,700	0,000	10,230	133,000	70,000	0,100	100,000	76,000
Soledade 09	30,210	5,800	270,000	104,000	0,100	8,500	115,000	56,000	0,200	120,000	79,000
Soledade 10	28,000	5,795	297,500	120,861	0,092	9,898	110,000	62,000	0,000	102,000	78,000
Soledade 11	28,050	5,860	298,267	120,944	0,103	9,941	105,000	68,000	0,000	230,000	78,000
Soledade 12	28,930	5,925	299,033	121,028	0,115	9,983	108,000	90,000	0,100	203,000	75,000
Soledade 13	28,760	5,990	299,800	121,111	0,127	10,025	107,000	90,000	0,100	203,000	77,000
Soledade 14	29,000	6,055	300,567	121,194	0,138	10,068	106,000	92,000	0,100	300,000	52,000
Soledade 15	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	340,000	44,000
Soledade 16	29,330	6,184	302,100	121,361	0,162	10,152	109,000	85,000	0,000	400,000	49,000
Soledade 17	29,000	6,249	302,867	121,444	0,173	10,195	110,000	70,000	0,100	135,000	52,000
Soledade 18	28,000	6,314	303,633	121,528	0,185	10,237	111,000	56,000	0,100	234,000	56,333
Soledade 19	27,900	6,379	304,400	121,611	0,197	10,279	123,000	62,000	0,100	345,000	60,333
Soledade 20	28,900	6,444	305,167	121,694	0,208	10,322	111,000	68,000	0,200	146,000	64,333
Soledade 21	28,700	6,508	305,933	121,778	0,220	10,364	123,000	90,000	0,200	145,000	68,333
Soledade 22	27,900	6,573	306,700	121,861	0,232	10,406	120,000	90,000	0,100	167,000	72,333
Soledade 23	29,000	6,638	307,467	121,944	0,243	10,449	119,000	62,000	0,200	157,000	76,333
Soledade 24	28,900	6,703	308,233	122,028	0,255	10,491	111,000	68,000	0,000	157,000	80,333
Soledade 25	28,000	6,768	309,000	122,111	0,267	10,533	112,000	90,000	0,100	169,000	84,333
Soledade 26	29,000	6,833	309,767	122,194	0,278	10,576	121,000	90,000	0,100	178,000	62,000
Soledade 27	27,900	6,897	310,533	122,278	0,290	10,618	124,000	92,000	0,100	189,000	63,000
Soledade 28	29,200	6,962	311,300	122,361	0,302	10,660	124,000	910,000	0,200	190,000	64,000
Soledade 29	29,100	7,027	312,067	122,444	0,313	10,703	125,000	85,000	0,000	157,000	65,000
Soledade 30	29,000	7,092	312,833	122,528	0,325	10,745	134,000	70,000	0,000	146,000	66,000

Sample	Temp (ºc)	pH	ORP (mV)	EC (µS/cm)	Turbidity (NTU)	OD (mg/L)	OD (%)	Solids Total Dissolved (mg/L)	Salinity (ppt)	Total coliforms (UFC/100 mL)	*E. coli* (UFC/100 mL)
Soledade 31	28,500	7,157	313,600	122,611	0,337	10,787	120,000	56,000	0,100	170,000	67,000
Soledade 32	28,400	7,222	314,367	122,694	0,348	10,830	120,000	62,000	0,100	109,000	68,000
Soledade 33	28,400	7,286	315,133	122,778	0,360	10,872	140,000	68,000	0,100	190,000	69,000
Soledade 34	28,400	7,351	315,900	122,861	0,372	10,914	140,000	90,000	0,200	191,000	70,000
Soledade 35	28,500	7,416	316,667	122,944	0,383	10,957	105,000	90,000	0,200	192,000	71,000
Soledade 36	28,000	7,481	317,433	123,028	0,395	10,999	104,000	62,000	0,100	195,000	72,000
Soledade 37	29,100	7,546	318,200	123,111	0,407	11,041	106,000	68,000	0,200	140,000	73,000
Soledade 38	29,000	7,611	318,967	123,194	0,418	11,084	105,000	90,000	0,100	140,000	74,000
Soledade 39	29,200	7,675	319,733	123,278	0,430	11,126	106,000	90,000	0,100	194,000	75,000
Soledade 40	29,300	7,740	320,500	123,361	0,442	11,168	104,000	92,000	0,200	195,000	76,000
Soledade 41	29,200	7,805	321,267	123,444	0,453	11,211	106,000	910,000	0,200	195,000	77,000
Soledade 42	29,400	7,870	322,033	123,528	0,465	11,253	107,000	85,000	0,100	196,000	78,000
Soledade 43	29,500	7,935	322,800	123,611	0,477	11,295	107,000	70,000	0,200	197,000	34,000
Soledade 44	28,100	8,000	323,567	123,694	0,488	11,338	107,000	56,000	0,400	198,000	35,000
Soledade 45	28,700	8,064	324,333	123,778	0,500	11,380	107,000	0,000	0,200	198,000	37,000
Soledade 46	28,700	8,129	325,100	123,861	0,512	11,422	108,000	0,000	0,300	199,000	39,000
Frei Damião 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	110,000	40,500
Frei Damião 02	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	110,000	42,200
Frei Damião 03	28,100	7,000	320,567	133,694	0,478	9,338	105,000	156,000	0,200	102,000	43,900
Frei Damião 04	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	102,000	45,600
Frei Damião 05	26,740	6,140	306,000	114,000	110,000	12,890	112,600	109,000	0,100	103,000	47,300
Caiçara 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	103,333	49,000
Caiçara 02	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	103,833	50,700
Caiçara 03	29,300	7,740	320,500	123,361	0,442	11,168	104,000	92,000	0,200	104,333	52,400
Caiçara 04	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	104,833	54,100
Caiçara 05	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	105,333	55,800
Caiçara 06	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	105,833	57,500
Paul. Canapum 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	106,333	59,200
Paul. Canapum 02	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	106,833	60,900
Paul. Canapum 03	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	107,333	62,600
Paul. Canapum 04	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	107,833	64,300
Paul. Canapum 05	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	108,333	66,000
Paul. Canapum 06	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	108,833	67,700
São Bento 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	109,333	69,400
São Bento 02	32,850	6,710	383,000	109,000	0,000	10,850	149,900	71,000	0,000	109,833	71,100
São Bento 03	29,447	4,630	252,000	109,000	33,600	8,217	145,067	105,000	0,100	110,333	72,800
São Bento 04	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	110,833	74,500
Tab. Grande 01	28,500	5,000	332,000	267,000	0,000	8,300	104,000	170,000	0,100	111,333	76,200
Tab. Grande 02	28,100	7,000	320,567	133,694	0,478	9,338	105,000	156,000	0,200	111,833	77,900
Tab. Grande 03	27,700	8,999	309,133	0,389	0,957	8,375	106,000	142,000	0,300	112,333	41,000
Tab. Grande 04	27,300	7,999	297,700	132,917	0,435	8,413	107,000	128,000	0,400	112,833	42,000
Tab. Grande 05	26,900	7,998	286,267	266,222	0,913	8,451	108,000	114,000	0,500	113,333	43,000
Tab. Grande 06	26,500	7,998	274,833	299,528	0,392	8,488	109,000	100,000	0,600	113,833	44,000
Sítio do Góis 01	28,770	5,140	329,000	270,000	0,000	8,800	114,000	175,000	0,100	114,333	45,000
Sítio do Góis 02	29,260	6,187	339,433	282,361	0,478	8,929	116,333	191,000	0,000	114,833	46,000
Sítio do Góis 03	30,195	6,758	360,800	284,250	0,935	9,104	119,333	221,000	0,200	115,333	47,000
Sítio do Góis 04	30,130	6,329	302,167	286,139	0,392	9,278	122,333	252,000	0,400	115,833	48,000
Sítio do Góis 05	30,065	6,101	63,533	288,028	0,848	9,453	125,333	282,000	0,600	116,333	49,000
Sítio do Góis 06	30,000	6,530	324,900	289,917	2,305	9,628	128,333	313,000	0,800	116,833	50,000

Sample	Temp (ºc)	pH	ORP (mV)	EC (µS/cm)	Turbidity (NTU)	OD (mg/L)	OD (%)	Solids Total Dissolved (mg/L)	Salinity (ppt)	Total coliforms (UFC/100 mL)	*E. coli* (UFC/100 mL)
Sítio do Góis 06	30,000	6,530	324,900	289,917	2,305	9,628	128,333	313,000	0,800	116,833	50,000
Vila Nova 01	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	117,333	51,000
Aur. da Serra 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	117,833	52,000
Aur. da Serra 02	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	118,333	53,000
Aur. da Serra 03	32,850	6,710	383,000	109,000	0,000	10,850	149,900	71,000	0,000	118,833	54,000
Aur. da Serra 04	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	119,333	55,000
Aur. da Serra 05	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	119,833	56,000
Aur. da Serra 06	28,100	7,000	320,567	133,694	0,478	9,338	105,000	156,000	0,200	120,333	57,000
Aur. da Serra 07	29,547	4,750	276,000	119,000	13,400	8,237	134,067	77,000	0,100	120,833	58,000
Moacir Lucena 01	27,620	4,700	340,000	0,000	261,000	10,100	128,400	0,000	0,000	121,333	59,000
Moacir Lucena 02	32,010	7,050	169,000	176,000	0,000	8,060	110,500	1130,000	0,900	121,833	60,000
Moacir Lucena 03	28,880	4,960	300,000	17,600	0,000	9,120	110,000	114,000	0,100	122,333	61,000
Milagre 01	28,630	4,360	252,000	0,000	19,700	10,300	134,200	0,000	0,000	122,833	62,000
Milagre 02	28,130	4,810	313,000	85,000	0,100	19,740	255,300	57,000	0,000	123,333	63,000
Milagre 03	26,340	4,740	310,000	96,000	0,000	7,930	100,000	62,000	0,000	123,833	64,000
Milagre 04	27,410	5,017	349,667	156,333	13,100	10,287	128,967	102,000	0,000	124,333	65,000
Paraíso 01	28,000	4,120	300,000	153,000	0,000	8,000	110,000	116,000	0,100	124,833	66,000
Paraíso 02	31,890	4,690	345,000	172,000	0,000	8,000	108,000	112,000	0,100	125,333	67,000
Paraíso 03	30,380	4,840	336,000	180,000	0,000	9,510	126,200	116,000	0,100	125,833	68,000
Paraíso 04	30,290	4,740	339,000	181,000	0,000	9,700	128,000	117,000	0,100	126,333	69,000
Lage do Meio 01	28,870	4,450	315,000	178,000	0,000	8,540	111,700	116,000	0,100	126,833	70,000
Lage do Meio 02	32,850	6,710	383,000	109,000	0,000	10,850	149,900	71,000	0,000	127,333	71,000
Lage do Meio 03	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	127,833	72,000
São Manoel 01	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	128,333	73,000
São Manoel 02	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	128,833	74,000
São Manoel 03	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	129,333	75,000
N. Descoberta 01	28,380	5,820	360,000	168,000	0,000	16,330	212,000	109,000	0,100	129,833	76,000
N. Descoberta 02	25,560	4,480	333,000	77,000	105,000	17,720	99,700	0,000	0,000	130,333	77,000
N. Descoberta 03	26,740	6,140	306,000	114,000	110,000	12,890	112,600	109,000	0,100	130,833	78,000
N. Descoberta 04	29,920	6,800	279,000	105,000	115,000	19,500	124,900	218,000	0,200	131,333	79,000
N. Descoberta 05	27,100	6,460	252,000	196,000	420,000	18,110	237,200	327,000	0,300	131,833	80,000
A. Palmares 01	32,850	6,710	383,000	109,000	0,000	10,850	149,900	71,000	0,000	132,333	81,000
A. Palmares 02	32,950	4,290	348,000	76,000	56,400	7,120	98,100	52,000	0,000	132,833	82,000
A. Palmares 03	33,050	4,870	313,000	43,000	17,800	8,390	146,300	33,000	0,000	133,333	83,000
Casulo 01	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	133,833	84,000
Casulo 02	26,740	6,140	306,000	114,000	11,000	12,890	112,600	109,000	0,100	134,333	85,000
Letícia 01	28,100	7,000	320,567	13,369	0,478	9,338	105,000	156,000	0,200	134,833	86,000
Letícia 02	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	135,333	87,000
Imóvel Algodão 01	32,000	6,700	240,000	178,000	0,100	9,000	118,200	910,000	0,200	135,833	63,000
Imóvel Algodão 02	32,850	6,710	383,000	109,000	0,000	10,850	149,900	71,000	0,000	136,333	62,000
Baixa Verde 01	29,340	6,119	301,333	121,278	0,150	10,110	108,000	910,000	0,000	136,833	61,000
Baixa Verde 02	26,740	6,140	306,000	114,000	10,000	12,890	112,600	109,000	0,100	137,333	60,000
Baixa Verde 03	29,997	4,690	264,000	64,000	13,500	8,727	139,567	141,000	0,100	137,833	59,000
Baixa Verde 04	30,300	7,198	278,000	163,833	1,900	5,270	115,000	1584,000	0,200	138,333	58,000
Baixa Verde 05	28,100	7,000	320,567	133,694	0,478	9,338	105,000	156,000	0,200	138,833	57,000
Baixa Verde 06	29,172	4,600	246,000	118,500	10,650	8,462	147,817	113,000	0,100	139,333	56,000
Cruzeiro 01	28,000	6,000	200,000	150,000	10,000	8,000	110,000	200,000	0,100	139,833	55,000
Average	29,148	5,924	292,566	138,565	12,998	9,750	126,013	278,866	0,128	149,266	65,910
Median	29,172	6,055	301,333	122,028	0,442	9,350	118,500	109,000	0,100	132,833	68,000
Standard deviation	1,558	1,093	39,972	77,907	41,244	2,242	25,745	388,809	0,127	49,229	12,107
Minimum	23,750	4,120	63,533	0,000	0,000	4,920	81,200	0,000	0,000	100,000	34,000
Maximum	33,050	8,999	383,000	843,000	420,000	19,740	255,300	1584,000	0,900	400,000	87,000

Source: Authors (2019).

According to the table presented, the results of the physicochemical (temperature, pH, redox potential, electrical conductivity, turbidity, dissolved oxygen, total residue and salinity) and biological variables (E. coli Thermotolerant Coliforms) of the drinking water samples in the rural communities of Chapada do Apodi/RN showed varying behavior (minimum and maximum) (Figure 3).

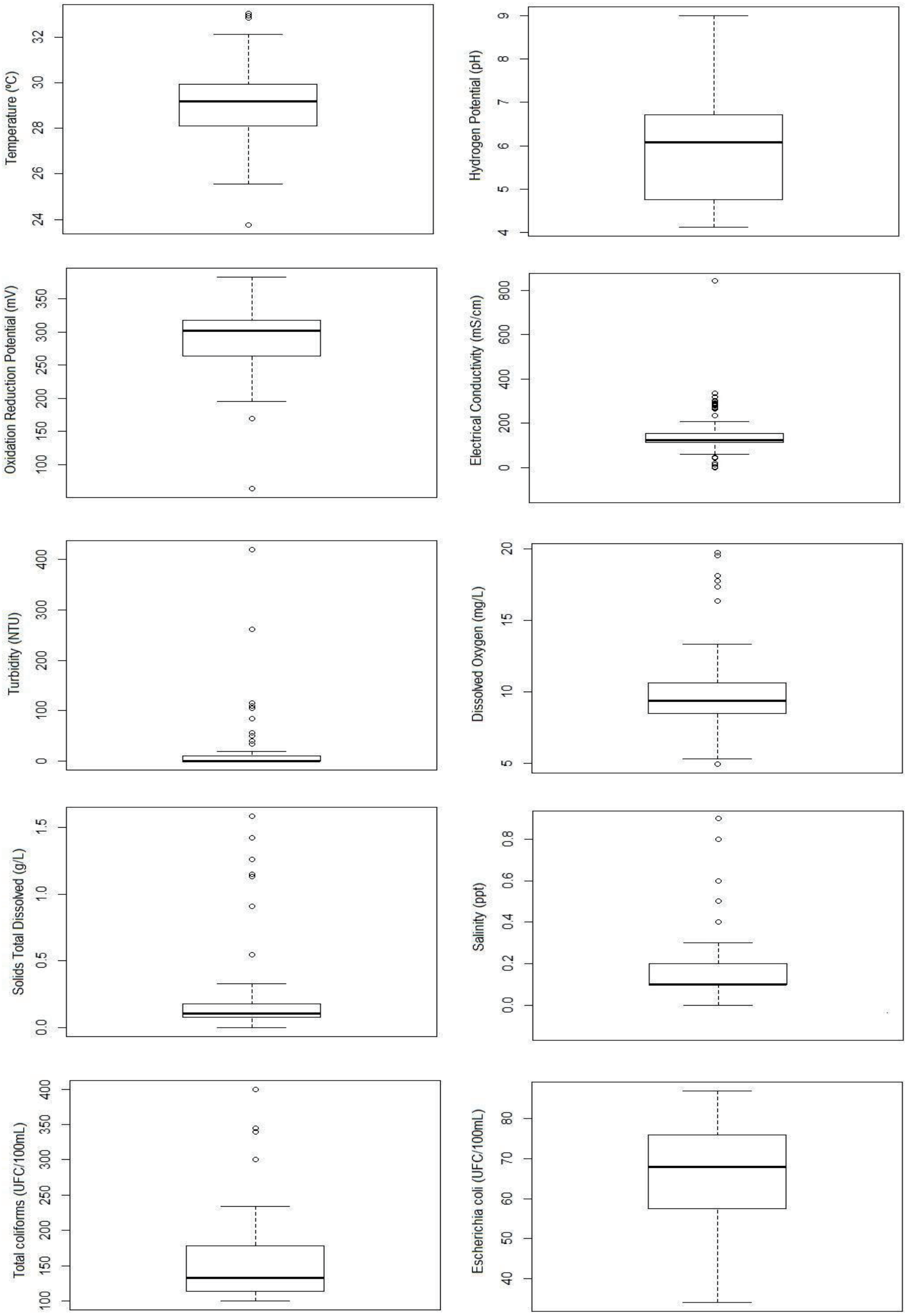


Figure 3 | Boxplot graphs of the physicochemical and biological parameters of the investigated samples.

Source: Authors (2019).

Through these data, it is possible to compare and evaluate the intensity of the relation between the physicochemical parameter values obtained in water samples in the residential reservoirs of the rural communities under this study, using the Spearman correlation matrix, which allows observing the influence between water characteristics (Table 4).

It can be observed that there is a negative correlation between the temperature and total coliforms variables (Table 4, row 10, column 1). It happens as a result of the high temperature influencing the presence of total coliforms in the water samples since it interferes with the life cycle of bacteria and parasites. Thus, the values analyzed for total and thermotolerant coliforms of type E. coli, were above the recommended by legislation, this is explained by contaminating anthropogenic sources near the points that supply the rural communities of Chapada do Apodi/RN.

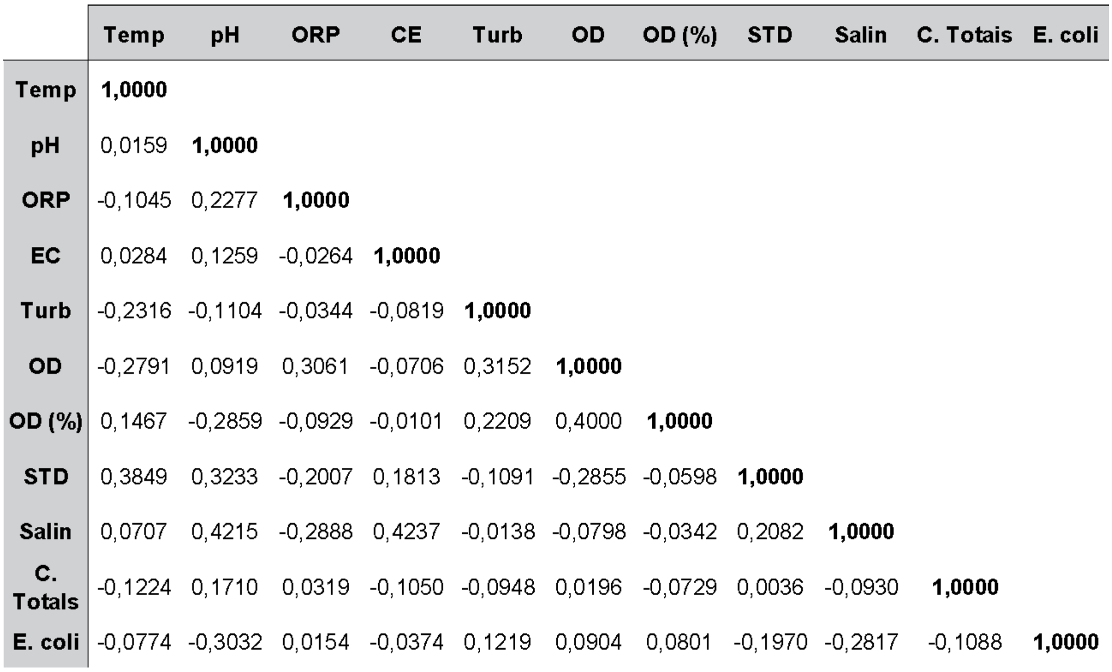
The EC parameter showed positive correlations between pH (Table 4, row 2, column 4) and STD (Table 4, row 08, column 2), this is due to the relation of EC with the presence of dissolved ions in water. The EC parameter does not pose any risk to human health, but for its value, the concentration of STD can be calculated. Which offers risk because, when in excess, it makes the water unpleasant to the taste, corroding pipes and, its consumption may cause the accumulation of salts in the bloodstream (SANTOS; MOHR, 2013).

A positive ORP value was also found when associated with pH (Table 4, row 2, column 3) and OD (Table 4, row 6, column 3), being possible when there is a larger amount of organic solid within the system leading the pH to be more acid, increasing the oxygen consumption (BRAZ et al., 2012).

The results also showed a positive correlation between turbidity and dissolved oxygen (Table 4, row 6, column 5), since the turbidity is the main physical factor which affects water for the excess of segments, and may influence gas consumption like dissolved oxygen (TUNDISI, 2005).

Finally, a relation between STD variables and temperature was found (Table 4, row 1, column 8). Seeing that, the particulate matter when reaches waterbody through runoff, can influence its temperature, once when in high concentration, the solids may absorb a large amount of heat (MALHEIROS et al., 2012).

Table 4 | Spearman correlation matrix between the physicochemical parameters of the rural communities of Chapada do Apodi - RN.



	Temp	**pH**	**ORP**	**CE**	**Turb**	**OD**	**OD (%)**	**STD**	**Salin**	**C. Totais**	**E. coli**
Temp	**1,0000**										
pH	0,0159	**1,0000**									
ORP	-0,1045	0,2277	**1,0000**								
EC	0,0284	0,1259	-0,0264	**1,0000**							
Turb	-0,2316	-0,1104	-0,0344	-0,0819	**1,0000**						
OD	-0,2791	0,0919	0,3061	-0,0706	0,3152	**1,0000**					
OD (%)	0,1467	-0,2859	-0,0929	-0,0101	0,2209	0,4000	**1,0000**				
STD	0,3849	0,3233	-0,2007	0,1813	-0,1091	-0,2855	-0,0598	**1,0000**			
Salin	0,0707	0,4215	-0,2888	0,4237	-0,0138	-0,0798	-0,0342	0,2082	**1,0000**		
C. Totals	-0,1224	0,1710	0,0319	-0,1050	-0,0948	0,0196	-0,0729	0,0036	-0,0930	**1,0000**	
E. coli	-0,0774	-0,3032	0,0154	-0,0374	0,1219	0,0904	0,0801	-0,1970	-0,2817	-0,1088	**1,0000**

Source: Authors (2019).

Observing such context of environmental perception and water quality results, there are deficiencies, irregularities and a lack of an adequate water supply system in the rural communities of Chapada do Apodi/RN, reflecting directly on access, distribution, and quality of water for human consumption.

4 FINAL CONSIDERATIONS

The water supply system in the rural communities of Chapada do Apodi/RN occurs through the use of water tanks and wells, with irregularities in the form of water storage and treatment applied before human consumption. Despite these irregularities, this feature has been used for a variety of purposes, including home use, irrigation, and animal use.

The form of water use in Chapada do Apodi/RN contributes to a panorama of risks to human health, as 72% of the population consumes water without any previous treatment. The risk is evidenced by the occurrence of symptoms and diseases of water transmission cited by the population, such as diarrhea, fever, and dengue.

In the evaluation of water quality, only the parameters of electrical conductivity, turbidity, total residue, and dissolved oxygen showed acceptable standards for human consumption according to the average values presented by Conama Resolution 357/2005 and Ordinance MS No. 2.914 / 2011. In contrast, the results found for the pH parameters, total coliforms, and E. coli thermotolerant coliforms presented disagreement according to current legislation. Salinity values presented were, according to Conama Resolution 357/2005, within the limit established for freshwater bodies intended for human consumption.

The results obtained considered the infrastructure conditions of water supply systems, as well as the physical-chemical and biological parameters of water intended for human consumption without previous treatment as unsatisfactory. Thus, it is necessary to adopt preventive measures with the residents of rural communities, prioritizing the preservation of water quality and its treatment, to minimize the risks of water-borne diseases.

In this context, further studies on the quality of water with physical-chemical, biological, heavy metals and pesticides parameters, present in water intended for human consumption, during rainy and drought periods, and its possible relationship with agro-industrial and agricultural activities are recommended; aiming to correlate the results obtained from these parameters in the different interferences of the quality of life of traditional rural communities.

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