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Analysis of the quality of water from artesian wells in a rural area of the semi-arid region in the State of Pernambuco

Análise da qualidade da água de poços artesianos em zona rural do semiárido do Estado de Pernambuco

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Abstract: About 30% of the freshwater available on the planet is groundwater, and this resource is widely used as an alternative source in northeastern Brazil. In the semi-arid region, groundwater plays an essential role in supplying cities and rural communities, often being the main source of water during drought periods. This study aimed to assess the quality of the water from the main artesian wells used for public supply in the rural area of the municipality of Passira-PE. Five wells were selected, two of which were equipped with desalination units. Throughout the research, seven water samples were collected, both before and after the use of the desalination units, to verify their actual impact on water quality. The physicochemical and microbiological analyses performed included tests for total coliforms, *Escherichia coli*, calcium hardness, total hardness, alkalinity, salinity, turbidity, electrical conductivity, pH, and color. The results showed that all five wells failed to meet drinking water standards, particularly in terms of total hardness and the presence of total coliforms and *Escherichia coli*, which poses a significant public health risk. Desalination was crucial not only for reducing water salinity, but also for lowering the levels of pathogens, total hardness, alkalinity, salinity, and electrical conductivity.

Keywords: Groundwater; Water scarcity; Desalination; Water supply.

Resumo: Cerca de 30% da água doce disponível no planeta é subterrânea, e esse recurso é amplamente utilizado como fonte alternativa no nordeste do Brasil. No semiárido, a água subterrânea desempenha um papel essencial no abastecimento de cidades e comunidades rurais, sendo frequentemente a principal fonte durante os períodos de seca. Este estudo teve como objetivo avaliar a qualidade da água dos principais poços artesianos utilizados para abastecimento público na zona rural do município de Passira-PE. Foram selecionados cinco poços, dos quais dois possuíam dessalinizadores. Ao longo da pesquisa, foram coletadas sete amostras de água, antes e depois do uso dos dessalinizadores, para verificar suas reais influências na qualidade da água. As análises físico-químicas e microbiológicas realizadas incluíram testes de coliformes totais, *Escherichia coli*, dureza de cálcio, dureza total, alcalinidade, salinidade, turbidez, condutividade elétrica, pH e cor. Os resultados revelaram que todos os cinco poços estavam fora dos padrões de potabilidade, especialmente quanto à dureza total e à presença de coliformes totais e *Escherichia coli*, o que representa um risco significativo para a saúde pública. A dessalinização foi crucial não apenas para reduzir a salinidade da água quanto para reduzir os níveis de patógenos, dureza total, alcalinidade, salinidade e condutividade elétrica.

Palavras-chave: Água subterrânea; Escassez hídrica; Dessalinização; Abastecimento.

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1. Introduction

Water availability is abundant on planet Earth; nonetheless, around 30% of the available freshwater is groundwater (AGÊNCIA NACIONAL DE ÁGUAS, 2024). In the northeastern region of Brazil, this resource is commonly used, since the supply of surface water is limited. In the semi-arid region, this water source plays a fundamental role in the supply of cities and in rural communities, often being the main water source in the drought periods (CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS, 2012).

It is essential that water arrives in all communities in appropriate quantity and quality, especially in regions that are difficult to access and present low rainfall levels. When water quality is not guaranteed, serious public health problems may arise (GASPARINI, 2020).

The Brazilian Northeast covers 1.5 million km² and comprises nine states of the Brazilian Federation. The predominant climate is semi-arid, covering 60% of the total area. This region has an annual rainfall of 500 mm in some places, below the national average, which varies from 1200 mm/year to 2000 mm/year (MOLION; BERNADO, 2002). The irregular spatial and temporal distribution of rainfall, together with high evapotranspiration, has been causing the phenomenon of droughts, which, historically, has led to numerous socioeconomic disorders to the region (BRITTO; MELO; SILVA, 2006).

The Brazilian semi-arid region is composed of 1262 municipalities, where more than 26 million people live, which corresponds to 12% of the Brazilian population. Of these inhabitants, more than 9.6 million live in the rural area, corresponding to 36.88% of the population in the semi-arid region (INSTITUTO BRASILEIRO DE GEOGRAFIA ESTATÍSTICA, 2010). According to the National Survey on Basic Sanitation (2017), 48% of the total of the cities in the Brazilian semi-arid region are supplied with treated water, whereas 39% do not have water treatment. In the year 2017, 1,099 municipalities (65%) faced water rationing. According to the National Sanitation Information System (SNIS, 2019), regarding the water supply indices in the semi-arid region, 84% of the population supplied is urban, and 30% corresponds to the rural.

On March 16, 2016, the State of Pernambuco declared a state of emergency due to drought in 55 municipalities in Agreste, and the municipality of Passira was included in this list of municipalities (G1, 2016). With the strong dry season, the municipality of Passira suffered from the imposed rationing, especially the urban center, with intermittent water supply by the Pernambuco Sanitation Company (Compesa). The Jucazinho dam, located in the municipality of Surubim/PE, operated to supply the city of Passira and 12 other cities in the Agreste region of Pernambuco. In this period, the dam suffered a collapse because of the scarcity of rain, making supply impossible in these cities (GRIESINGER, 2016).

Given this scenario, the city of Passira searched, on an emergency basis, for other alternative sources to supply the city. One of the proposed technologies was the exploration of groundwater, found in several localities, especially in the rural areas. One of the limiting aspects was the process of soil salinization these areas faced, and that resulted in the loss of groundwater quality. Thus, desalination units were the technology employed aiming at minimizing this aspect of water. Currently, these wells, often coupled to desalination units, are fundamental sources for water supply (SILVA et al., 2020). This research aimed at characterizing water quality and the efficiency of the equipment employed to ensure water potability. Furthermore, the work proposes an action plan for the region, aiming at guiding corrective and preventive actions, in case needs for intervention are identified.

2. Methodology

Figure 1 presents the flowchart with the sequence of the methodological steps adopted in this study, from the delimitation of the research area to the analysis and interpretation of the results obtained. The steps were organized in a way to ensure the systematization of the investigative process, initially involving a survey of information on the active artesian wells in the municipality of Passira-PE, followed by the definition of sample selection criteria, the performance of technical visits, data collection in the field and, finally, physicochemical and microbiological laboratory analyses. The results were then compared with the potability parameters established by the current legislation.

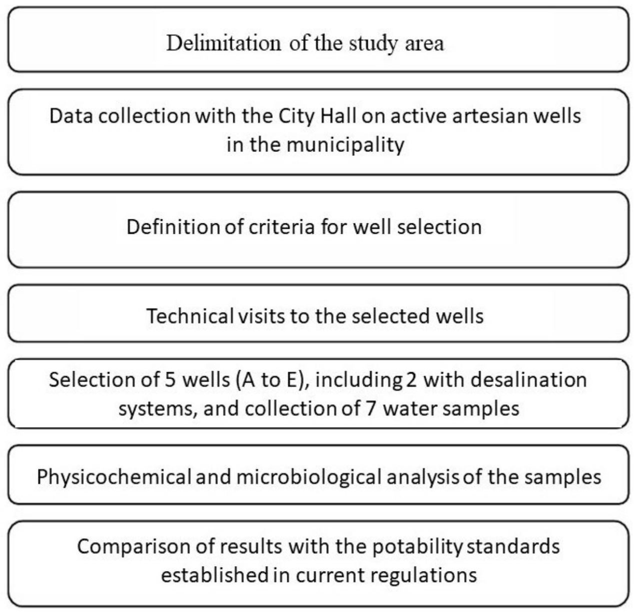

Figure 1 – Flowchart of the methodological steps of the study.
Source: Barbosa et al (2025).

The study was conducted in the municipality of Passira, located in the Agreste of the State of Pernambuco, as presented in Figure 2.

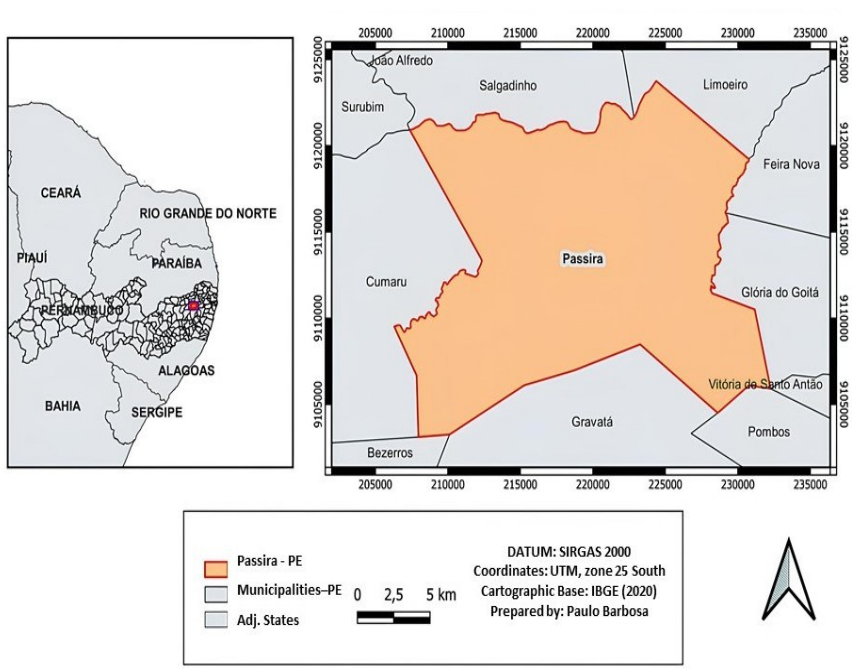

Figure 2 – Map of the municipality of Passira in the context of state and region.
Source: Authors (2025).

According to data provided by the Brazilian Institute of Geography and Statistics (IBGE, 2021), the municipality has 326.757 km² of territorial extension and is 107 km away from the capital, Recife. The estimated population of the city of Passira in the year 2021 was of approximately 28,856 people, with a population density of 87.61 inhabitants/km².

The municipality was created by the State Law nº 4,981 of December 20, 1963. It belonged, previously, to the municipality of Limoeiro, which then had Passira and Bengalas as its main districts. The average monthly salary of formal workers is of 1.5 minimum wages (IBGE, 2020), the main economic activities of the municipality being local commerce, artisanal lace production – which today involves more than 5 thousand lacemakers, livestock farming, agriculture and activities of plant extraction and forestry.

According to the Groundwater Supply Source Registration Project (2005), the relief in the municipality is generally rough with deep and wavy valleys, and the region has a semi-arid climate and vegetation that varies from hypoxeraphylous caatinga to deciduous forest.

According to the Pernambuco Water and Climate Agency (APAC, 2024), the rainiest period is observed between the months of May and July, with a peak in June (approximately 140 mm), indicating the rainiest period of the year, while the months from September to December have the lowest rates, characterizing the dry season.

To define the criterion of choice of the wells to be studied, information on the active artesian wells was surveyed together with the Passira City Hall, including locality, the supplied regions and the number of inhabitants supplied. The inspection was performed by technical visit in the studied regions and, at the time of the visit, information was collected on geographic coordinates, altitudes, photographs of the outside of the wells, as well as information on the main practices of groundwater use by local communities.

Three criteria were considered for the choice of the wells, the first being the distance between wells, in order to obtain a possible equidistance between them for a better understanding of the quality of the groundwater in the region, with distances between villages varying between approximately 4.4 km and 15.4 km away from the city center, which allows a representative cover of the studied area. The second point was the number of inhabitants that use this supply system, choosing the systems that met the largest number of inhabitants, so that the areas with the highest demands for drinking water were prioritized. The most populous village has approximately 500 families served, whereas the village with the smallest number of inhabitants supplied, among the chosen ones, had around 120 families (SECRETARIA DE AGRICULTURA DE PASSIRA, 2022). This value was adopted as a minimum reference to guarantee the feasibility of the analysis, considering there is a significant number of communities with even smaller populations, which would make it unfeasible to include all of them in the scope of the study. The third criterion was easy access to wells for sample collection, since it was not possible to conduct a technical visit to all wells because of factors such as: long distances traveled, difficult access through roads in poor maintenance condition, or the absence of roads.

Five wells of the Passira city hall were selected (Table 1), located in the rural area of the municipality, by a list provided by the secretary of agriculture and with the authorization of the managers of the communities that looked after the installations. Any water disinfection measure required by Ordinance N° 888 of May 4, 2021 of the Ministry of Health was considered sanitary protection.

For the analysis of the data obtained, the Analysis of Variance (ANOVA) was employed to verify the existence of statistically significant differences between the studied wells. The hypothesis that guided the application of ANOVA was that there could be statistically significant differences in the water quality parameters between the studied wells, given the geographic and hydrogeological heterogeneity of the region, that may directly influence the physicochemical characteristics of groundwater in each location. ANOVA was chosen, since it is appropriate to the comparison of means between three or more groups of independent data, assuming normality and homogeneity of variances between samples. After detecting significant differences by ANOVA, the Tukey's multiple comparison test was applied with a significance level of 5% ($p < 0.05$). All tests were performed using the statistical software JASP (Jeffrey's Amazing Statistics Program). Other similar studies have also used the analysis of variance (ANOVA) as a statistical tool to evaluate the quality of water from wells. An example is the research performed in the Marajó Archipelago, in the State of Pará, that analyzed domestic wells in rural communities. ANOVA was used to identify significant differences in the physicochemical and microbiological parameters of the water, emphasizing the presence of total coliforms and *Escherichia coli*, which evidences potential health risks (SIMÕES et al., 2020).

Table 1 – Data on location, well coordinates, altitude, sanitary protection, number of families supplied, flow rate and depth of the pump.

Well	Location	Geographic coordinates (DATUM WGS84)	Altitude (m)	Number of inhabitants	Flow rate (m³/h)	Depth (m)
A	Cutias de Baixo	8° 0' 22.94" S 35° 36' 16.34" W	218	600	5	50
B	Poço do Pau	7° 56' 49.09" S 35° 32' 48.85" W	158	520	12	50
C	Poço do Pau	7° 56' 54.71" S 35° 32' 27.86" W	152	2000	5	50
D	Candiais	7° 59' 20.42" S 35°31' 51.34" W	163	720	5	50
E	Bengalas	8° 0' 47.08" S 35° 29' 0.77" W	131	480	9	50

Source: Barbosa et al (2025).

Figure 3 presents the location of the five wells studied, in the context of the limits of the municipality of Passira. The proximity of wells B and C is noted, both located in the community of Poço do Pau. Despite being close to each other, these wells have distinct purposes: well B is used exclusively to feed the desalination unit, whereas well C is intended for direct supply to homes, through the pipeline network.

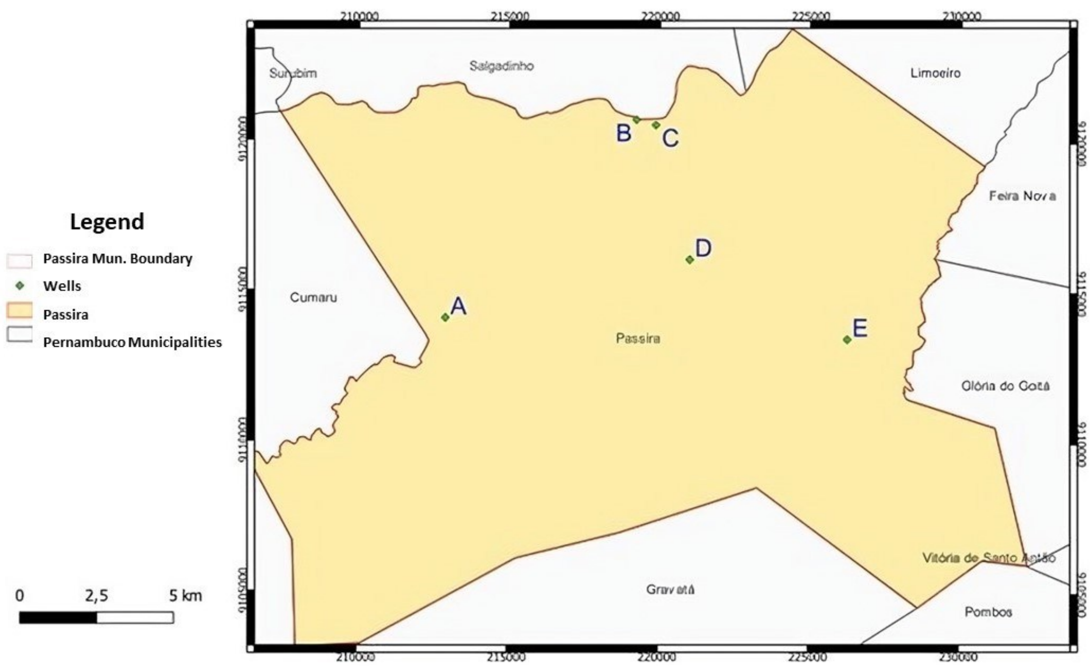

Figure 3 – Map of the location of the wells studied in Passira.
Source: Barbosa et al (2025).

Figure 4 presents the public fountain in the Community of Cutias de Baixo (Well A). This installation has a pump house and two equalization tanks, so that water taken from the water table can be stored.

Figure 4 – Public Fountain of Cutias de Baixo (Well A).
Source: Barbosa et al (2025).

Figure 5 shows the public fountain in the community of Poço do Pau (Well B). This community presents two wells, with salt being removed from the water in this first well. This facility has an equipment house, a desalination unit and two equalization tanks.

Figure 5 – Fountain of Poço do Pau (Well B).
Source: Barbosa et al (2025).

After the process of salt removal, the water is stored in tanks and can be collected by two taps in front of the fountain. Figure 6 shows the desalination unit of well B.

Figure 6 – Desalination unit of Poço do Pau (Well B).
Source: Barbosa et al (2025).

Figure 7 shows well C, also located in the community of Poço do Pau. Differently from well B, in this well the water does not pass through the desalination process. The pump is directly connected to the community's supply network. No protection or water storage structure can be seen in the image.

Figure 7 – Well C in Poço do Pau.
Source: Barbosa et al (2025).

Figure 8 shows well D in the Community of Candiais. Similarly to well C, this well also does not have any extra protection, and the pump is directly connected to the community's supply network.

Figure 8 – Well D in Candiais.
Source: Barbosa et al (2025).

Figure 9 shows the desalination unit of the public fountain in the Community of Bengalas (Well E). This community has only one well; nevertheless, there are two supply systems, the first consisting in the removal of salt from the water using a desalination unit, followed by storage in equalization tanks. The second presents the supply directly connected to the residences, without undergoing any filtering process. This facility has an equipment house, a desalination unit and two equalization tanks.

Figure 9 – Desalination unit of the public fountain of Bengalas (well E).
Source: Barbosa et al (2025).

The schematic drawing of Figure 10 presents a flowchart for a better understanding of the distribution of water to each well, in addition to the situation of the collection points for water quality analysis.

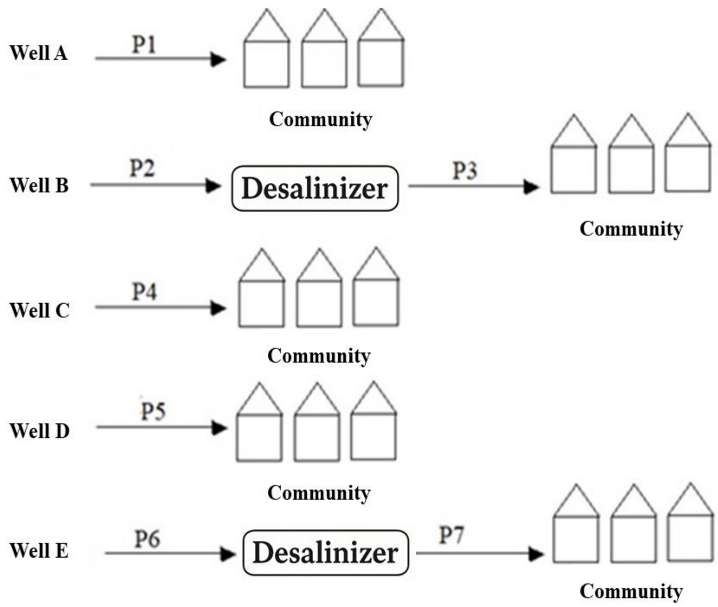

Figure 10 – Schematic drawing representing the installations of the 5 wells studied (Wells from A to E), and the 7 points of collection of the water samples (P1 to P7).
Source: Barbosa et al (2025).

The collection procedure followed the guidelines of the practical water analysis manual of FUNASA (2013). Two containers were used for each collection point: the first consisted in autoclavable Nalgon bottles for the microbiological analyses, and the second, polyethylene plastic bottles for the physicochemical analysis. The collection was performed at the pump outlet, or immediately after the desalination unit, if applicable. When easy access to the pump was not possible, the water was collected at the closest outlet point to the artesian well. When the well had a desalination unit, a sample of the water was collected before passing through the equipment, and another sample after the equipment, to verify the true effects of the desalination unit on this supply.

The membranes of the filters of the desalination units are of the type Lewabrane RO B085 FR 4040, which has a feed spacer thickness of 0.86 mm (LANXESS, 2018). At the moment of each of the collections, the water was allowed to run for five minutes to eliminate any possible contaminants present in the water's path. After this sample collection step, the containers were stored in an insulated box containing ice to maintain a stable temperature during the trip to the Environmental Engineering Laboratory at UFPE – Agreste Campus, where the analyses were conducted. Table 2 presents the evaluated parameters and their respective methodologies, all following the Standard Methods for the Examination of Water and Wastewater of the American Public Health Association (BAIRD, 2012).

Table 2 – Methodology of the physicochemical and biological procedures for each variable analyzed.

Methodologies of the analyses		
Characteristics	**Variable**	**Methodology**
Biological	Total Coliforms	Membrane Filter Method
	Escherichia coli	Membrane Filter Method
Physicochemical	Calcium Hardness	EDTA titrimetry
	Total Hardness	EDTA titrimetry
	Alkalinity	Potentiometric Titration

	Salinity	Electrical conductivity method
	Turbidity	Nephelometric method
	Electrical Conductivity	Conductometric method
	pH	Potentiometric Method
	Color	Spectrophotometric Method

Source: Barbosa et al (2025).

To identify whether the studied waters complied with potability standards, the data were compared with the limits established in Ordinance GM/MS N° 888 of May 04, 2021, by the Ministry of Health. This ordinance provides procedures for controlling and monitoring the quality of water for human consumption and its potability standards. In this study, the CONAMA Resolution N° 357 of March 17, 2005, was also used to classify the water according to salinity.

3. Results and discussion

3.1 Statistical analysis

Table 3 presents the statistical analysis by ANOVA and Tukey between the wells, for each water quality parameter evaluated. For the parameters pH and turbidity, there was no significant difference at the 5% significance level between the collection points. For the parameter color, a similar result was observed, except for point P1 (well A).

For the parameters salinity, electrical conductivity, total hardness, *E. coli* and alkalinity, the points P3 and P7 are similar to each other. This behavior was expected, since these are samples from desalination units, which can efficiently remove salts and coliforms from the water.

Wells B and C, which present the smallest distance from each other (Figure 2), presented a similar water quality before desalination (points P2 and P4) for the parameters pH, color, turbidity, electrical conductivity, total hardness, alkalinity and coliforms, which indicates similar soil use and occupation, as well as soil geology, impacting water quality in a similar way.

Table 3 – Parameter means with ANOVA and Tukey significance grouping

Means of the water quality parameters with significance grouping (ANOVA and Tukey)									
ID	**pH**	**Color**	**Turbidity**	**Conductivity**	**Salinity**	**Hardness**	**Alkalinity**	**Total C.**	***E. coli***
P1	7.03^{a}	5.00^{b}	0.20^{a}	8.52^{d}	4.56^{d}	1911.38^{c}	456.71^{c}	31.75^{abc}	0.37^{a}
P2	7.25^{a}	1.38^{a}	0.21^{a}	3.78^{bc}	2.03^{bc}	916.13^{b}	296.71^{bc}	63.25^{c}	1.75^{a}
P3	7.65^{a}	0.08^{a}	0.10^{a}	0.18^{a}	0.09^{a}	4.63^{a}	15.57^{a}	6.62^{a}	0.62^{a}
P4	7.05^{a}	1.08^{a}	0.07^{a}	4.71^{c}	2.94^{c}	919.88^{b}	368.29^{bc}	62^{bc}	14^{ab}
P5	7.04^{a}	0.84^{a}	0.16^{a}	3.64^{bc}	2.36^{bc}	707.25^{b}	268.29^{bc}	19.88^{abc}	3.12^{a}
P6	6.78^{a}	1.72^{a}	0.12^{a}	3.09^{b}	1.60^{b}	768.38^{b}	195.14^{ab}	63.88^{c}	39^{b}
P7	7.81^{a}	0.74^{a}	0.29^{a}	0.08^{a}	0.05^{a}	8.25^{a}	8.71^{a}	10.88^{ab}	1^{a}

Source: Barbosa et al (2025).

3.2 Coliforms

The results of the determination of the microbiological parameters are presented in Table 4, where the presence or absence of total coliforms and *Escherichia coli* in the seven samples are demonstrated, in eight different collection campaigns. Ordinance N° 888 of the Ministry of Health (BRASIL, 2021) establishes there must be the absence of total coliforms and *E. coli* in 100 mL of water for all water samples, from the seven collection points, intended for human consumption. In this aspect, all wells are in legal non-compliance, since they presented contamination with total coliforms and/or *Escherichia coli* at some point during monitoring. This implies that the water coming from these wells cannot be used for public supply without treatment.

According to Silveira et al. (2023), in an analysis of 18 studies, it was observed that groundwater contamination is directly related to the proximity of septic tanks to water sources. The study suggests septic tanks may allow the infiltration of contaminated liquids into the upper layers of the water table. This factor can be aggravated during rainy periods, when greater water percolation on the soil facilitates the migration of pathogens to the water table, particularly during the refilling of wells.

It is also important to highlight that all studied wells were lacking sanitary protection, and their locations are close to residences and villages. These communities do not present a conventional sewage system, which leads the community to dispose of their waste in septic tanks and sumps, often installed without observing the necessary technical standards. This factor is aggravated when excrement from pigs, goats and/or cattle are present, or when this material is used as organic fertilizer for the characteristic plantations of that region, both parts of the economic source of the municipality studied.

Table 4 – Results of the microbiological analysis for the parameters total coliforms and Escherichia coli, in colony forming units, for the seven collection points in the wells of the rural area in Passira, PE.

Results of the microbiological analyses (CFU/100 mL)																
	Collection 1		**Collection 2**		**Collection 3**		**Collection 4**		**Collection 5**		**Collection 6**		**Collection 7**		**Collection 8**	
ID	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***	**TC**	***EC***
P1	nd	nd	34	nd	14	nd	3	nd	>100	3	3	nd	nd	nd	>100	nd
P2	>100	nd	60	nd	71	nd	48	nd	>100	nd	74	4	1	1	52	9
P3	nd	nd	21	nd	5	nd	nd	nd	11	nd	8	nd	nd	nd	8	5
P4	29	3	>100	3	>100	nd	nd	nd	>100	>100	81	3	1	nd	85	3
P5	11	nd	10	3	>100	2	2	2	27	nd	1	nd	6	2	2	16
P6	>100	39	34	16	49	35	13	11	>100	>100	>100	9	15	2	>100	>100
P7	11	nd	28	5	nd	nd	7	3	11	nd	26	nd	nd	nd	4	nd

ID: Identification of the collection points; CFU: Colony forming units; nd: Not detected; EC: Escherichia coli; TC: Total coliforms.

Source: Barbosa et al (2025).

In P2 (well B), in the water sample upstream of the desalination unit, total coliforms were observed in all samples, and *E.coli*, in the samples from points P6, P7 and P8. On the other hand, at point P3, downstream of the desalination unit, total coliforms were observed; nevertheless, when going through the desalination process, contamination decreases or becomes absent. Between points P6 and P7, the same behavior was observed. Although this equipment has not been designed for the removal of microorganisms, it also contributes to the improvement in water quality from a bacteriological point of view. Similar results observing the reduction in pathogen number in the water can be found in other water filtration systems using desalination units. According to the research performed by Bovatori (2018), when evaluating a pilot-scale brackish water desalination system, it was observed that the system removed the total coliforms and *E. coli*. In a complementary manner, Aoueryagel (2024) verified that, after treatment by reverse osmosis, the treated water did not exhibit detectable levels of pathogenic indicators, indicating effective removal.

3.3 Hardness

The samples collected from the seven points did not present calcium hardness. According to the Groundwater Supply Source Registration Project of the municipality of Passira (2005), the most predominant soils in the municipality are lithic soils, non-calcic brown soils and planosols, which explains these low levels or the absence of calcium hardness in the water samples. Nonetheless, the samples presented total hardness values, as demonstrated in Figure 11. The Ordinance N° 888 of the Ministry of Health (BRASIL, 2021) establishes, as the organoleptic standard limits for potability regarding hardness, a maximum of 300 mg/L of $CaCO_3$.

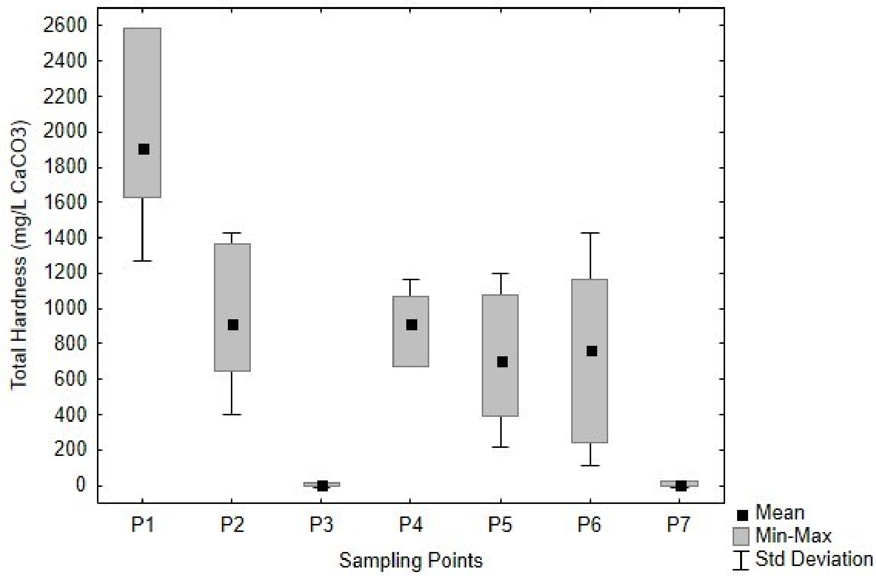

Figure 11 – Total hardness (mg/L of $CaCO_3$) distribution in the water samples from the wells located in the rural area of Passira, PE.
Source: Barbosa et al (2025).

It is noted that, for all wells, crude water presents values above the legal limits. Only the points after the desalination units (points P3 and P7) are suitable for human consumption, since alkaline earth ions are retained by the equipment's filters. These data indicate the importance of installing desalination units for all wells. For groundwaters, higher hardness values are expected compared to surface waters (CRUZ, 2014).

3.4 Alkalinity and pH

Figure 12 shows the alkalinity values of the studied collection points. Points P1, P3, P4, P5 and P6 present mean values of approximately 470 mg/L, 300 mg/L, 380 mg/L, 290 mg/L and 200 mg/L, respectively. It is important to note that, at points P3 and P7, alkalinity tends to zero, which shows this process removes the substances of the water capable of neutralizing the acids almost in their totality. A similar case occurred in the study of Aish (2010), who evaluated the quality of the water from small-scale desalination units in the Gaza Strip – Palestine, observing that the samples analyzed after the desalination process obtained a significantly large drop in alkalinity, reaching less than 50 mg/L.

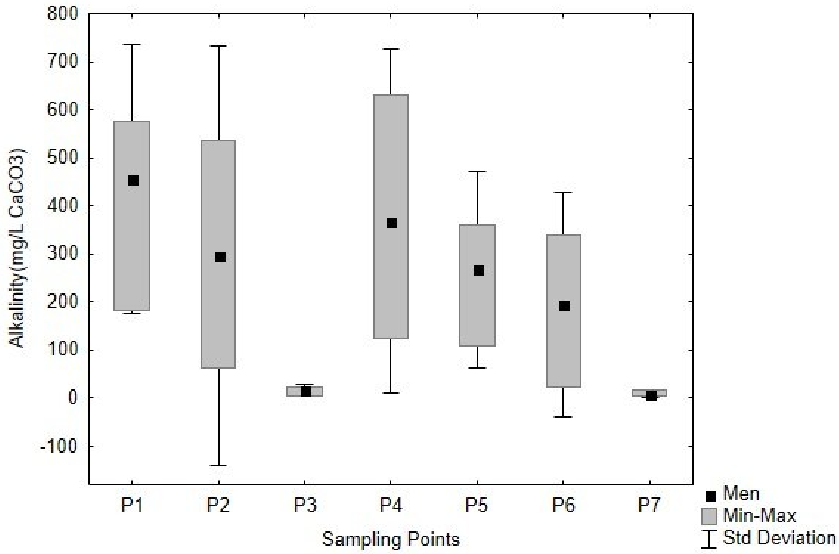

Figure 12 – Alkalinity (mg/L of $CaCO_3$) distribution in the water samples from the wells located in the rural area of Passira, PE.
Source: Barbosa et al (2025).

Drinking water must have a balanced alkalinity (around 40-200 mg/L of $CaCO_3$), avoiding corrosivity and excessive mineral deposits. Although high or reduced alkalinity may affect water taste and safety, it usually does not represent a direct risk to human health at moderate levels (OMS, 2017). For the parameter alkalinity, the relevant ordinance (BRASIL, 2021) does not establish limits for potability; however, its measurement is essential during the water treatment process, for instance. The adequate water alkalinity is essential to maintain its quality and preserve the infrastructure of water distribution.

According to the water potability standards (BRASIL, 2021), it is recommended that the pH of the water in the distribution system be between 6.0 and 9.0. In all samples of the seven collection points analyzed in eight collections, the pH values stayed within the recommended indices, as demonstrated in Figure 13.

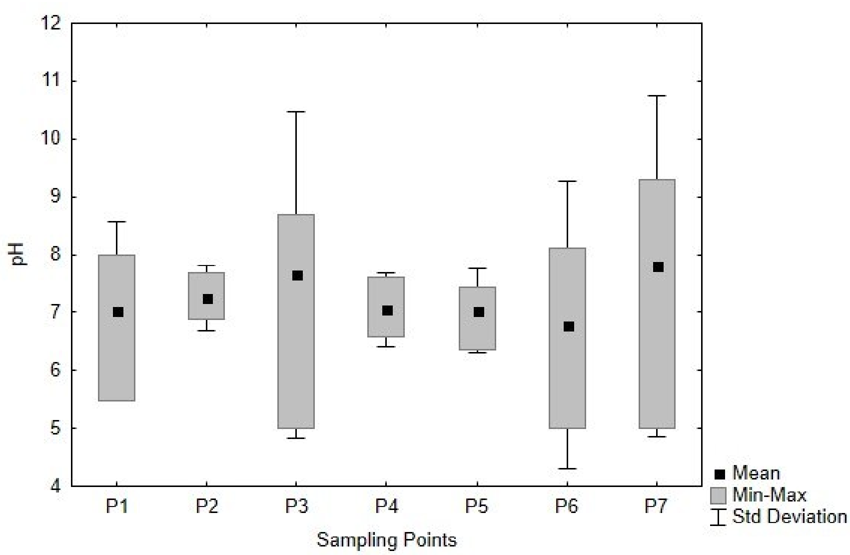

Figure 13 – pH distribution in the water samples from the studied wells.
Source: Barbosa et al (2025).

3.5 Salinity, electrical conductivity and color

Water salinity must be appropriate, since it may generate human health problems. Kaczmarek (2023) highlights several difficulties and negative aspects associated to saline water in a research work on the quality of water in the in the arid basin of the Draa River, in Morocco, such as: health problems, in which a significant proportion of the respondents reported physical illnesses attributed to salinity, including kidney problems and emotional distress, as well as impacts on the environment, representing a threat to agricultural practices, for example.

The Ordinance N° 888 of the Ministry of Health (BRASIL, 2021) does not establish limits for salinity in waters destined for human consumption. The CONAMA Resolution Nº 357 (CONAMA, 2005) adopts the following classification: freshwater: presents salinity equal to or inferior to 500 mg/L (0.5 ppt); brackish water: presents salinity between 500 mg/L and 30,000 mg/L (30 ppt); saline water: presents salinity equal to or above 30,000 mg/L.

Figure 14.a presents the salinity values of the seven collection points. Observing the values of the mean, point P1 presented the highest salinity, around 4.5 ppt, whereas points P2, P4, P5 and P6 present mean values of 2; 2.5; 2.2 and 1.5, respectively, all, according to the CONAMA Resolution (2005), classified as brackish. At points P3 and P7 downstream of the desalination unit, the water is classified as fresh water according to the relevant Resolution.

The efficiency of reverse osmosis desalination units is also seen by Souza (2019), who observed a significant reduction in water salinity in communities. The removal efficiency in the study ranged from 13% to 88%. It is important that, given these results, public authorities reflect on the need to install desalination units in wells A, C and D, with the main purpose of removing salt from the water, so that it offers better quality to the inhabitants.

Figure 14.b presents the values of electrical conductivity for the samples of the seven collection points studied. As expected, the same behavior regarding salinity was observed for conductivity. P1 presented a very high conductivity, whereas collection points P2, P4, P5 and P6 presented high conductivity. For points P3 and P7, which undergo the desalination process, there is a significant reduction in conductivity. The Ordinance N° 888 of the Ministry of Health (BRASIL, 2021) does not establish limits for this parameter. Water can be classified as presenting low conductivity when it has values below 0.30 mS/cm, median conductivity between 0.31 and 0.75 mS/cm, critical conductivity between 0.76 mS/cm and 2.25 mS/cm, high conductivity between 2.26 mS/cm and 4.5 mS/cm, and very high conductivity when it is superior to 4.5 mS/cm (DA SILVA; ALMEIDA; FERNANDES, 2002).

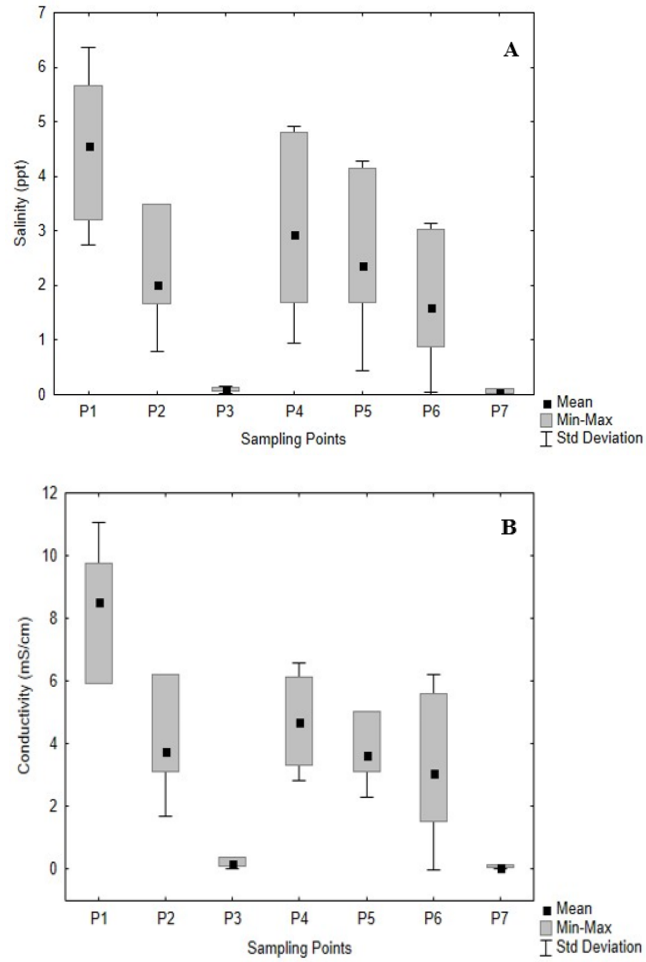

Figure 14 – A) Salinity distribution (ppt) and B) electrical conductivity in the wells.
Source: Barbosa et al (2025).

The study conducted by Koley et al. (2024) assessed water quality after the conventional treatment process and demonstrated that there is a correlation between electrical conductivity and the salinity of the water with concentrations of sodium and chlorine, and between electrical conductivity and water hardness with the presence of calcium and magnesium. Therefore, the drop in electrical conductivity is associated with the removal of these total dissolved solids. Therefore, it is possible to understand the decrease in electrical conductivity at points P3 and P7. In the study performed by Souza (2019), it was verified that 57% of the water samples analyzed presented a salt rejection rate superior to 90%, resulting in a significant reduction in electrical conductivity. This discovery reinforces the importance of water treatment in mitigating salinity and improving overall water quality.

Figure 15 shows the values obtained for colors in the studied wells. The same scenario can be observed: both at point P3 and at point P7, the values obtained for color were smaller than at points P2 and P6 before passing through the filter. This shows this process can also retain particles dissolved in the water and, consequently, decrease their coloration. According to the Ordinance N° 888 of the Ministry of Health (BRASIL, 2021), the organoleptic standard for the apparent color of water for human consumption must not exceed 15 uH (Hazen unit), when there is sensory stimulus, but not causing damages to health; thus, under this aspect, the waters are suitable for human consumption.

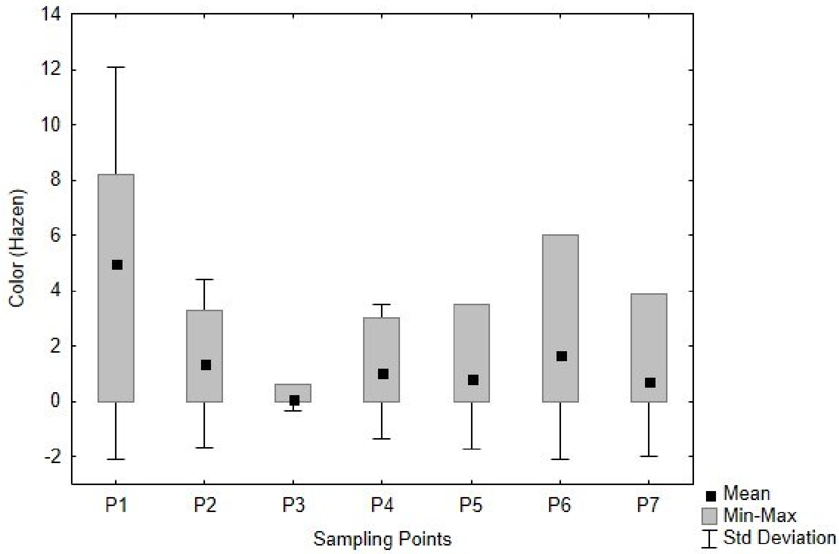

Figure 15 – Color distribution in the water samples from the wells.
Source: Barbosa et al (2025).

3.6 Turbidity

Regarding the parameter turbidity, the Ordinance N° 888 of the Ministry of Health (BRASIL, 2021) provides that the values cannot exceed 0.5 NTU in 95% of the samples for groundwater with disinfection. Figure 10 presents the turbidity data of the waters from the studied wells, which do not undergo any disinfection methods. Still, regarding this criterion, all samples were in accordance with the Ordinance, since they presented mean values that are inferior to the recommended.

Almeida et al. (2020) evaluated the efficiency of a pilot system for brackish water desalination. Desalination by reverse osmosis was conducted, where the system presented a turbidity removal of 27%. A similar result can be observed in P3, according to Figure 16, which demonstrates a reduction in the turbidity indices. Nevertheless, this behavior was not observed in P7, where the scenario presents a difficulty in removing suspended particles, since this sample already has low turbidity.

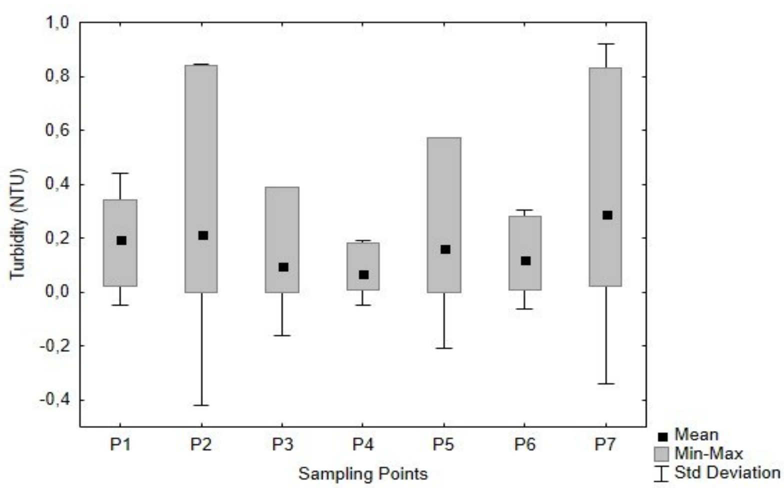

Figure 16 – Turbidity distribution (NTU) in the water samples from the wells.
Source: Barbosa et al (2025).

4. Final considerations

All wells analyzed presented a parameter outside the limits established by the Brazilian legislation. Thus, the collected samples are not appropriate for public supply without adequate disinfection and filtration.

The presence of total coliforms and *Escherichia coli* was detected in disagreement with regulatory standards in all samples. In particular, the samples of the collection points P2, P4 and P6, derived from wells B, C and E, registered the highest concentrations of these pathogens, which represents a significant risk to public health in the absence of treatment by disinfection. Therefore, water chlorination is an essential measure, economically feasible, and effective in eliminating these microorganisms prior to distribution.

In relation to total hardness, points P1, P2, P4, P5 and P6 exceeded the limits established by the Brazilian legislation, presenting superior values to the allowed. Nonetheless, none of the samples presented detectable levels of calcium hardness. Regarding the parameters of turbidity, pH and color, all samples were in compliance with current criteria, with favorable results.

For the parameters of alkalinity, salinity and electrical conductivity, the Brazilian legislation does not establish specific limits for potability. It is observed that points P1, P2, P4, P5 and P6 presented considerable alkalinity levels. Regarding salinity, the waters were classified as brackish because of the high concentration of salts, which is reflected in high electrical conductivity, since these factors are directly correlated to the presence of dissolved salts.

The presence of desalination units in wells B and E resulted in significant alterations in the parameters analyzed. The comparison between the samples collected upstream and downstream of the desalination units revealed an expressive reduction in the levels of total coliforms, *Escherichia coli*, total hardness, alkalinity, salinity and electrical conductivity, with values tending to zero. Regarding color, only a slight decrease was observed.

Given the results obtained, the need for a plan to improve water quality in the region becomes evident, focusing on disinfection methods, such as chlorination and a broader use of desalination units in wells with high levels of salinity and coliforms.

As a proposal for future works, studies focused on the problem of disposal of the desalination waste are recommended, aiming at identifying environmentally safe alternatives. Furthermore, the investigation of geological factors, as well as of aspects related to soil use and occupation, may significantly contribute to the understanding of the variations in groundwater quality in the region. The expansion of sampling is also suggested, with the inclusion of a larger number of wells in different areas of the municipality, in order to evaluate possible differences in water quality, especially in less inhabited regions, where there may be less anthropogenic interference and, consequently, better potability conditions.

References

AISH, A. M. *Water quality evaluation of small scale desalination plants in the Gaza Strip, Palestine*. Department of Geology, Faculty of Science, Al Azhar University, P.O. 2010.

Almeida, J. et al. Eficiência de um sistema piloto de dessalinização de água salobra. *Engenharia sanitária e Ambiental*, v. 25, p. 107-114, 2020.

ANA. Agência Nacional de Águas e Saneamento Básico. Centro de Gestão e Estudos Estratégicos. *A questão da água no Nordeste. Brasília*, DF: CGEE, 2012. 391 p.

Aoueryagel, I. et al. Assessment of Water Treatment Processes and Quality Parameters at the Al Hoceima Desalination Plant. *BIO Web of Conferences*. EDP Sciences, 2024. p. 01007.

APAC. Agência Pernambucana de Águas e Clima. *Série histórica do município de Passira. 2025.* Disponível em: http://old.apac.pe.gov.br/meteorologia/monitoramento-pluvio.php. Acesso em: 15/14/2025.

Baird, R. B. et al. *Standard methods for the examination of water and wastewater*. American Public Health Association, 2012.

BOVAROTI, T. *Avaliação de um sistema de dessalinização de água salobra em escala piloto.* 2018, 74f. Dissertação (Mestrado em Engenharia Sanitária e Ambiental), Universidade Estadual de Ponta Grossa, Ponta Grossa, 2018.

BRASIL. Ministério da Ciência, Tecnologia e Inovação. Centro de Gestão e Estudos Estratégicos (CGEE); Agência Nacional de Águas (ANA). *A Questão da Água no Nordeste*. Brasília: CGEE/ANA, 2012.

BRASIL. Ministério da Saúde. *Portaria GM/MS N° 888, de 04 de maio de 2021.* Brasília, 2021. Disponível em: https://www.in.gov.br/en/web/dou/-/portaria-gm/ms-n-888-de-4-de-maio-de-2021-318461562. Acesso em: 28/08/2022.

BRASIL. Ministério de Minas e Energia. Projeto de Cadastro de Fontes de Abastecimento por água subterrânea: *Diagnóstico do Município de Passira*. 2005. Disponível em: https://rigeo.cprm.gov.br/jspui/bitstream/doc/16555/1/Rel_Passira.pdf. Acesso em: 13/10/2022.

BRASIL. Ministério do Desenvolvimento Regional. Secretaria Nacional de Saneamento. Sistema Nacional de Informações sobre Saneamento: *diagnóstico dos serviços de água e esgoto* – 2019. Brasília: SNS/MDR, 2018. Disponível em: http://www.snis.gov.br/. Acesso em: 17/09/2024.

BRASIL. Ministério do Meio Ambiente. Conselho Nacional do Meio Ambiente (CONAMA). *Resolução nº 357, de 17 de março de 2005.* Disponível em: http://www.mma.gov.br/port/conama/res/res05/res35705.pdf. Acesso em: 02/10/2022.

Britto C.; Melo J. G.; Silva, F. M. Aspectos da salinização das águas do aquífero cristalino no estado do Rio Grande do Norte, Nordeste do Brasil. *Revista Águas Subterrâneas*, v.20, n.1, p.67-82, 2006.

Buzanello, E. et al. Determinação de coliformes totais e termotolerantes na água do Lago Municipal de Cascavel, Paraná. *Revista Brasileira de Biociências*, v. 6, n. S1, 2008.

CRUZ, V. et al. *Análise físico-química da qualidade da água de poços artesanais no município de Itumbiara-GO*. 2014.

FUNASA. Fundação Nacional de Saúde. *Manual prático de análise de água*. 4. ed., Brasília, DF, 2013. Disponível em: http://www.funasa.gov.br/site/wp-content/files_mf/manual_pratico_de_analise_de_agua_2.pdf. Acesso em: 28/08/2022.

G1. *Cerca de 70% da área de PE está sob seca extrema, aponta relatório*. 2016. Disponível em: https://g1.globo.com/pernambuco/noticia/2016/05/cerca-de-70-da-area-de-pe-esta-sob-seca-extrema-aponta-relatorio.html. Acesso em: 23/02/2022.

GASPARINI, N. *Conheça as doenças causadas por água contaminada*. Mega Imagem, 2020. Disponível em: https://www.megaimagem.com.br/blog/conheca-as-doencas-causadas-por-agua-contaminada/. Acesso em: 23/02/2022.

GRIESINGER, D. *Maior reservatório de água do agreste pernambucano entra em colapso*. Agência Brasil, 2016. Disponível em: https://agenciabrasil.ebc.com.br/geral/noticia/2016-09/mairo-reservatorio-de-agua-do-agreste-pernambucano-entra-em-colapso. Acesso em: 23/02/2022.

HIRATA, R. *A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento*. São Paulo: Instituto Trata Brasil. Disponível em: https://repositorio.usp.br/directbitstream/e7d9e125-7b22-4706-915b-a397f8a91784/2928658.pdf. Acesso em: 23/02/2022.

IBGE. Instituto Brasileiro de Geografia Estatística. *Censo Brasileiro de 2010*. Rio de Janeiro: IBGE, 2022.

IBGE. Instituto Brasileiro de Geografia Estatística. *Censo Brasileiro de 2020*. Rio de Janeiro: IBGE, 2022.

IBGE. Instituto Brasileiro de Geografia Estatística. *Censo Brasileiro de 2021*. Rio de Janeiro: IBGE, 2022.

Kaczmarek, N. et al. Water quality, biological quality, and human well-being: Water salinity and scarcity in the Draa River basin, Morocco. *Ecological indicators*, v. 148, p. 110050, 2023.

Koley, S. et al. Identification and Assessment of Critical Parameters Affecting Drinking Water Quality: A Case Study of Water Treatment Plants of India. *Groundwater for Sustainable Development*, p. 101221, 2024.

LANXESS. *Product information LEWABRANE® RO B085 FR 4040*. 2018. Disponível em: https://www.rotatek.com.tr/Uploads/GenelDosya/lewabrane-ro-b085-fr-4040-3114-d.pdf. Acesso em: 07/05/2023.

Luna, R.; Campos, J.; Studart, T. Tipologia de acesso à água no semiárido do Nordeste do Brasil: estudo de caso da Bacia do Rio Curu. In: *Simpósio dos países de expressão portuguesa*, 7., 2005, Évora.

Macedo, T.; Rempel, C.; Maciel, M. Análise físico-química e microbiológica de água de poços artesianos em um município do Vale do Taquari-RS. *Tecno-Lógica*, v. 22, n. 1, p. 58-65, 22 jan. 2018.

Molion, L.; Bernardo, S. Uma revisão da dinâmica das chuvas no nordeste brasileiro. *Revista Brasileira de Meteorologia*, v. 17, n. 1, p. 1-10, 2002.

PASSIRA. Secretaria de Agricultura. *Dados do município de Passira*. 2022.

CPRM, *Projeto Cadastro de Fontes de Abastecimento por Água Subterrânea do município de Passira.*, 2005. Disponível em: https://rigeo.sgb.gov.br/jspui/bitstream/doc/16555/1/Rel_Passira.pdf. Acesso em: 15/04/2025.

SILVA, L. C. et al. Aspectos socioambientais e qualidade da água de dessalinizadores no semiárido brasileiro. *Revista Ambiente & Água*, vol. 15, no. 6, 2020.

Silva, F.; Araújo, A.; Souza, R. Águas subterrâneas no Ceará – poços instalados e salinidade. Rev. *Tecnol. Fortaleza*, v. 28, n. 2, p. 136-159, dez. 2007.

Silveira, K. et al. Contaminação no lençol freático por fossas rudimentares. *Caderno Progressus*, v. 3, n. 5, p. 40-47, 2023.

Simões, M et al. Avaliação da qualidade da água de poços domésticos em comunidades rurais no Arquipélago de Marajó-PA. *Revista Brasileira de Geografia Física*, v. 13, n. 5, p. 2462, 2020.

Souza Antas, F. et al. Analysis of recovery by desalination systems in the west of Rio Grande do Norte, Brazil. *Desalination and Water Treatment*, v. 138, p. 230-236, 2019.

VILLELA, S. *Maior reservatório de água do agreste pernambucano entra em colapso*. Agência Brasil. 2016. Disponível em: https://agenciabrasil.ebc.com.br/geral/noticia/2016-09/mairo-reservatorio-de-agua-do-agreste-pernambucano-entra-em-colapso. Acesso em: 23/02/2022.

Von Sperling, M. *Introdução à qualidade das águas e ao tratamento de esgotos.* Editora UFMG, 1996.

Zerwes, C. et al. Análise da qualidade da água de poços artesianos do município de Imigrante, Vale do Taquari/RS. *Revista Ciência e Natura*, v. 37, n. 3, p. 651-663, 2015.