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Physicochemical Analysis of Water from Artesian Wells in the Chico Mendes 1 and 2 Settlements in the Municipality of Presidente Médici, RO, Brazil

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Abstract

Water quality is essential for economic and social development, as well as for public health. However, the well-being of a community depends not only on the quantity but primarily on the adequate conditions of the available water resources. While water is a source of life, it can also serve as a vector for diseases and contamination. This study evaluated the physicochemical quality of water from six artesian wells located in the Chico Mendes 1 and 2 Settlements, in the rural area of Presidente Médici, Rondônia, focusing on its suitability for human consumption and aquaculture. Sampling was conducted from December 2016 to May 2017. The results showed that four wells (ART1, ART2, ART3, and ART6) were not in compliance with Ordinance No. 888/2021 of the Brazilian Ministry of Health, particularly regarding hardness, pH, and turbidity. These nonconformities persisted throughout the study period. Hardness was associated with the presence of calcium and magnesium ions, while turbidity was due to suspended particles. Temperature and nitrite were the only parameters that did not show significant variation among the sampling points. Based on these findings, corrective actions are necessary to ensure the water from the four noncompliant wells meets potability standards. Regarding aquaculture, none of the wells were deemed suitable, as at least one parameter exceeded the recommended limits for fish farming in every month evaluated.
Keywords: Artesian wells; Physicochemical parameters; Water analysis.

Análise físico-química da água de poços artesianos dos Assentamentos Chico Mendes 1 e 2 no município de Presidente Médici, RO, Brasil

Resumo

A qualidade da água é essencial para o desenvolvimento econômico, social e para a saúde pública. No entanto, o bem-estar de uma comunidade depende não apenas da quantidade, mas principalmente das condições adequadas dos recursos hídricos disponíveis. A água, embora seja fonte de vida, pode também atuar como vetor de doenças e contaminações. Este estudo avaliou a qualidade físico-química da água de seis poços artesianos localizados nos Assentamentos Chico Mendes 1 e 2, na zona rural de Presidente Médici-RO, com foco no uso para consumo humano e para a piscicultura. As amostragens ocorreram entre dezembro de 2016 e maio de 2017. Os resultados indicaram que quatro poços (ART1, ART2, ART3 e ART6) apresentaram inconformidades com a Portaria nº 888/2021 do Ministério da

Saúde, especialmente nos parâmetros de dureza, pH e turbidez. Essas inconformidades persistiram durante todo o período do estudo. A dureza está relacionada à presença de íons de cálcio e magnésio, enquanto a turbidez se deve a partículas em suspensão. A temperatura e o nitrito foram os únicos parâmetros que não apresentaram variações significativas entre os poços analisados. Diante dos resultados, conclui-se que é necessário adotar medidas corretivas para adequar a água dos quatro poços às normas de potabilidade. Quanto ao uso em piscicultura, nenhum poço foi considerado adequado, já que em todos os meses avaliados houve ao menos um parâmetro fora dos limites recomendados para essa atividade.
Palavras-chave: Análise de água; Parâmetros físico-químicos; Poços artesianos.

1. Introduction

The distribution of water on Earth occurs unevenly, with regions of great abundance and others suffering from severe scarcity. In this context, our planet contains only 2.5% of freshwater, and of this small portion, only about 1% is available in liquid form, comprising river, lake, and groundwater resources; the remaining 97.5% corresponds to saltwater (Unesco, 2021). In Brazil, water distribution is also highly irregular: the Amazon Basin region, which covers approximately 60% of the national territory, holds about 70% of the country's surface water flow, yet houses only about 8% of the Brazilian population (Ana, 2020; Castro & Heller, 2022).

Water scarcity and quality problems have become a global concern, as water consumption tripled during the 20th century, while pollution of water bodies also increased, reducing the availability of water suitable for human consumption (Wwap, 2023). As a result, effective water management is crucial, especially in countries that rely on groundwater as their main source of supply. In southern European regions such as Italy, Spain, Cyprus, and Malta, agricultural irrigation demands often lead to usage conflicts and aquifer overexploitation (Fao, 2022).

Groundwater is an essential resource for ecosystem integrity and population supply, accounting for about 95% of all accessible and available freshwater on the planet (Igrac, 2022). In Brazil, this resource plays a fundamental role in both urban and rural supply, serving households, industries, agriculture, and recreational activities (Hirata et al., 2020). In the Northern Region, especially in the Amazonian states, groundwater is used almost exclusively for human consumption, with industrial and agricultural use estimated at less than 10% of the total extracted volume (Santos, Nascimento & Silva, 2021). In cities like Manaus and Belém, the food, timber, and ceramic industries are the main consumers of groundwater. In Rondônia, recent data indicate that approximately 25% of the water used for public supply comes from aquifers (Brasil, 2021).

This resource is mainly extracted through deep tubular wells, commonly known as artesian wells, which have become an effective alternative in the face of scarcity and contamination of surface water resources. However, in the state of Rondônia, data on the physicochemical quality of this water are still scarce, and further research is needed to support public policies and monitoring actions (Souza et al., 2023). Understanding water quality is essential to ensure human health and the sustainable development of economic activities such as agriculture and aquaculture, which also require high-quality water to ensure the health of organisms and proper management of the production system (Oliveira, Gonçalves & Padilha, 2020).

Given this scenario, the objective of this study was to evaluate the physicochemical quality of water from six artesian wells in the Chico Mendes 1 and 2 settlements, located in the municipality of Presidente Médici, state of Rondônia.

2. Material and Methods

The municipality of Presidente Médici, located in the state of Rondônia (RO), covers an area of 1,758.465 km². According to estimates by the Brazilian Institute of Geography and Statistics (IBGE, 2010), its population in 2017 was 22,124 inhabitants. The municipality borders Ji-Paraná to the north; Castanheira and Nova Brasilândia do Oeste to the south; Ministro Andreazza and Cacoal to the east; and Alvorada do Oeste to the west.

Presidente Médici is located within the Machado River watershed, and the municipal water supply is managed by the Companhia de Saneamento de Rondônia – CAERD (Rondônia Sanitation Company). This study was conducted in the Chico Mendes 1 and 2 Settlements, located in the rural zone of the municipality, approximately 40 km from the urban area. Chico Mendes Settlement 1 was established on May 30, 1997, with 67 settled families, while Chico Mendes Settlement 2 was established on December 9, 1997, with 68 settled families (Incra, 2017).

The two settlements are composed of five agro-villages: three in Settlement 1 (Agro-villages 1, 2, and 3) and two in Settlement 2 (Agro-villages 4 and 5). Each agro-village has its own artesian well, and Agro-village 3 has a public school supplied by a separate artesian well. In this study, the wells were designated ART1 through ART6, with ART6 corresponding to the school's well. Map 1 shows the location of the wells (Figura 1).

The Garmin Global Positioning System (GPS), model etrex, was used to obtain the geographic coordinates of the wells (Table 1). The wells in question belong to homes whose residents agreed to participate in the study. During the collections, the surroundings of the wells were observed to better characterize them. Monthly samples were collected from each artesian well (Figure 1) over a six-month period, from December 2016 to May 2017. The collections were always carried out at the end of each month during the morning. The samples were taken using transparent glass containers with lids, which had been previously sanitized.

Of the six wells analyzed, samples from ART4, ART5, and ART6 were collected through faucets, after allowing the water to run for 30 seconds to flush out the water remaining in the pipes. Samples from ART1, ART2, and ART3 were collected directly from the reservoir (Figure 3), following the methodology proposed by the National Health Foundation (FUNASA) (BRAZIL, 2013). Unlike the other wells, ART6 was recently built to supply the school. Its reservoir is a standard plastic water tank, and the water was collected directly from the well via a faucet installed in the piping system. In February and March, it was not possible to collect water samples from ART2, as the reservoir was empty at the time of sampling. As a result, no parameter analyses were conducted for that period (Figura 2). After sampling, the collected water samples were stored in a Styrofoam box with ice and transported to the Laboratory (LAFQM) at the Federal University of Rondônia Foundation (UNIR), Presidente Médici campus, for the determination of limnological parameters.

Figure 1. Geographical location of the artesian wells where water samples were collected in the municipality of Presidente Médici (RO).

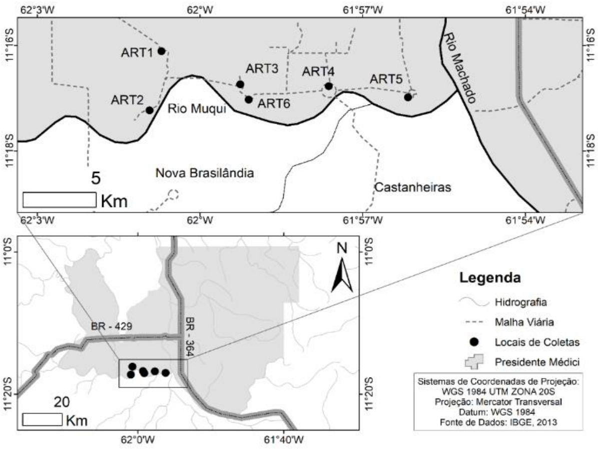


Figure 2. Artesian wells located in the Chico Mendes I and II settlements. A: ART 1; B: ART 2; C: ART 3; D: ART 4; E: ART 5; F: ART 6.

. Temperature measurements were taken directly in the field using a graduated mercury thermometer with 0.1°C precision. The values of hydrogen potential (pH) and electrical conductivity were obtained using a previously calibrated multiparameter probe, model AK88, manufactured by AKSO. Nitrite (NO_2^-) and alkalinity analyses were performed using a MULTIDIRECT benchtop colorimeter. Turbidity values were measured using a TD-300 portable digital turbidimeter from the brand Instrutherm.

The determination of total hardness was only carried out from February 2017 onward, as one of the necessary reagents became available only at that time. For this analysis, the methodology proposed by the Brazilian National Health Foundation (FUNASA, 2013) was followed, based on titration with ethylenediaminetetraacetic acid (EDTA). The volume of EDTA used was applied to the following equation: Total Hardness (mg/L $CaCO_3$) = mL of EDTA × 1000 × Fc / mL of sample, where Fc represents the correction factor of the EDTA and $CaCO_3$ refers to calcium carbonate. The data obtained were initially subjected to descriptive statistical analysis to calculate the mean and standard deviation for each parameter. Subsequently, analysis of variance (ANOVA) was applied, and when necessary, Tukey's test was used to determine whether there were significant differences among the sampling points. All statistical procedures were performed using the Statistica 9.0 software package, considering a significance level of $p < 0.05$.

3. Results and Discussion

The temperature of the wells studied reached a maximum value of 29.5°C and a minimum of 21°C, recorded in wells ART3 and ART6, respectively. The lowest value was observed in May, while the highest occurred in January, February, and March (Table 2), resulting in a thermal variation range of 8.5°C. For every 10°C increase in temperature, the rate of chemical reactions can double or even triple, which is a factor that influences the solubility of gases in water, particularly oxygen (Piveli & Kato, 2005).

When submitted to analysis of variance (ANOVA), no significant differences were found in temperature values among the wells analyzed. Figure 3A shows the means and standard deviations obtained for temperature.

Table 1. Coordinates and characteristics of artesian wells studied.

Artesian wells	**Descriptions**	**Coordinates**	
ART 1	Located in a residence in the center of Agrovila 1, surrounded by low vegetation, with mango trees and cassava plantations nearby. It is approximately 25 meters from the road and has a depth of 72 meters. It was built in 2001.	S	11° 16’ 6.21”
		W	62° 0’ 42.35”
ART 2	Located in the center of Agrovila 2, surrounded by small-sized vegetation, approximately 7 meters from the road. It has a depth of 76 meters and was built in 2001.	S	11°17'13.55”
		W	62° 0'55.52"
ART 3	Located approximately 250 meters from the center of Agrovila 3 in the Chico Mendes 1 Settlement, in a higher area surrounded by pasture, about 20 meters from the road. It is 70 meters deep and was built in 2001.	S	11°16'43.91"
		W	61°59'15.11"
ART 4	Located in the center of Agrovila 4 in the Chico Mendes 2 Settlement, near a church and two sheds, with a bathroom behind the church that has a septic tank located approximately 15 meters from the well. There is grass around the site. It is 60 meters deep and was built in 2001.	S	11°16'46.12"
		W	61°57'37.27"
ART 5	Located in the center of Agrovila 5 in the Chico Mendes 2 Settlement, surrounded by small vegetation and a small cassava plantation nearby, approximately 12 meters from the road. It is 80 meters deep and was built in 2001.	S	11°16'58.71"
		W	61°56'9.73"
ART 6	Located on the grounds of the municipal school in Agrovila 3 of the Chico Mendes 1 Settlement, near the front wall of the school, with no vegetation around it, except for a mango tree about 10 meters away. It has a depth of 60 meters and was built in 2015.	S	11°17'1.27"
		W	61°59'5.74"

Table 1. Monthly temperature values in the studied wells.

	Temperature (ºC)					
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
December	26.5	27	28	27	27	28
January	28.5	29	29,5	27	27	28
February	29	-	29,5	28	27,5	28
March	27	-	29,5	28	27	28
April	28.5	28	28	26	26	27

May	27.5	29	27	28	25	21
Mín.	26.5	27	27	26	25	21
Max.	29	29	29,5	28	27,5	28
Average	27.83	28.25	28,58	27,33	26,58	26,67
SD (±)	0.98	0.96	1,07	0,82	0,92	2,80

Table 2. Monthly pH values in the studied wells.

			pH			
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
December	7.65	7.83	7.43	6.35	6.88	7.42
January	7.61	7.63	6.25	6.47	6.7	7.66
February	7.39	-	5.25	6.07	6.15	7.28
March	7.63	-	5.55	6.18	6.43	7.05
April	7.75	7.51	5.15	6.08	6.46	7.5
May	8.19	8.18	6.46	6.67	6.37	7.68
Min.	7.39	7.51	5.15	6.07	6.15	7.05
Max.	8.19	8.18	7.43	6.67	6.88	7.68
Average	7.70	7.79	6.02	6.30	6.50	7.43
SD (±)	0.27	0.29	0.87	0.24	0.26	0.24

Table 3. Monthly conductivity values in the studied wells.

			Conductivity (μs/cm⁻¹)			
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
December	325.7	245.7	283.1	53.9	74.4	324.8
January	316.7	228.9	35.9	50.2	45	305.7
February	509	-	34.7	64.5	62.7	481
March	522	-	42.4	61.8	65.4	422
April	518	361	35	57	56.5	469
May	534	386	141.1	77.5	67.4	526
Min.	316.7	228.9	34.7	50.2	45	305.7
Max.	534	386	283.1	77.5	74.4	526
Average	454.23	305.40	95.37	60.82	61.90	421.42
SD (±)	103.40	79.59	101.00	9.67	10.14	88.86

Table 4. Monthly nitrite values in the studied wells.

	Nitrite (mg/L)					
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
December	0	0.04	0.09	0	0.04	0
January	0.04	0	0.05	0.03	0.04	0.06
February	0	-	0	0	0	0
March	0	-	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	0	0
Min.	0	0	0	0	0	0
Max.	0.04	0.04	0.09	0.03	0.04	0.06
Average	0.01	0.01	0.02	0.01	0.01	0.01
SD (±)	0.02	0.02	0.04	0.01	0.02	0.02

Table 5. Monthly alkalinity values in the studied wells.

	Alkalinity (mg/L)					
Month	**ART-1**	**ART-2**	**ART-3**	**ART-4**	**ART-5**	**ART-6**
December	277	228	269	119	0	53
January	308	220	22	58	61	284
February	311	-	9	34	36	297
March	301	-	8	21	29	235
April	290	206	7	23	26	280
May	310	237	83	46	52	309
Min.	277	206	7	21	0	53
Max.	311	237	269	119	61	309
Average	299.50	222.75	66.33	50.17	34.00	243.00
SD (±)	13.52	13.15	103.47	36.52	21.46	96.42

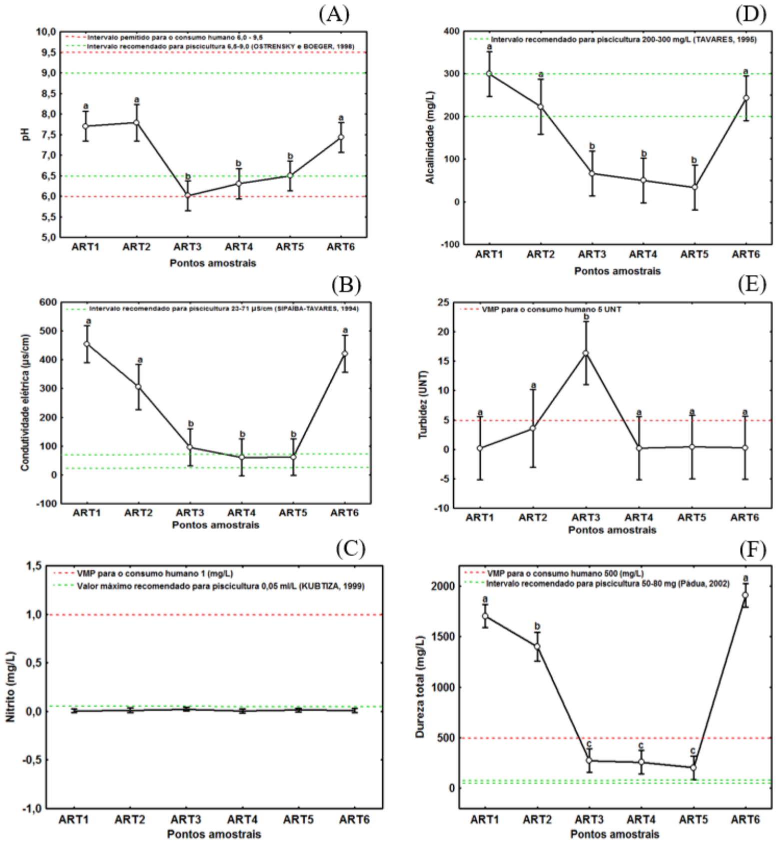
Table 6. Monthly turbidity values in the studied wells.

	Turbidity (mg/L)					
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
December	0	0	2.73	0	0	0
January	0	0	42.4	0	0	1.63
February	0	-	9.6	0	0	0
March	0	-	8.24	0	0	0
April	1.15	0	20.56	1.28	2.45	0
May	0	14.29	14.66	0	0	0
Min.	0	0	2.73	0	0	0
Max.	1.15	14.29	42.4	1.28	2.45	1.63
Average	0.19	3.57	16.37	0.21	0.41	0.27
SD (±)	0.47	7.15	14.11	0.52	1.00	0.67

Table 7. Monthly values of total hardness in the studied wells.

	Total hardness (mg/L)					
Month	**ART1**	**ART2**	**ART3**	**ART4**	**ART5**	**ART6**
February	1936.88	-	437.36	484.22	406.12	2233.66
March	1608.86	-	78.1	156.2	156.2	1608.86
April	1640.1	1374.56	109.34	140.58	124.96	1827.54
May	1624.48	1421.42	468.6	218.68	124.96	1952.5
Min.	1608.86	1374.56	78.1	156.2	124.96	1608.86
Max.	1936.88	1421.42	468.6	484.22	406.12	2233.66
Average	1702.58	1397.99	273.35	273.35	203.06	1905.64
SD (±)	156.72	33.14	208.20	159.80	136.17	260.75

Figure 3. Distribution of average pH (A), electrical conductivity (B), nitrite (C), alkalinity (D), turbidity (E), and total hardness (F) levels and their respective standard deviations, letters with the same value do not differ statistically.



CONAMA Resolution No. 357/2005 establishes a standard of temperatures below 40 °C for fish farming, and in the present study, the maximum temperature recorded was 29.5 °C. However, for fish farming in tropical regions, temperatures between 28 °C and 32 °C are recommended (Kubitza, 1999), meaning that several temperature values were below the minimum recommended by that author.

pH represents the logarithmic activity of hydrogen ions in water, initially resulting from the dissociation of the water molecule itself and subsequently increased by hydrogen from other sources (Piveli, 2005). According to Ordinance No. 888 of May 4, 2021, from the Ministry of Health, the ideal pH values for human consumption should range from 6.0 to 9.5. The pH values ranged between 5.15 and 8.19, with ART3 being the only one outside the ordinance parameters, presenting values below the recommended limit in February, March, and April (Table 3). ANOVA showed that points ART1, ART2, and ART6 had the highest values, statistically differing from points ART3, ART4, and ART5. Figure 3A shows the means and standard deviations obtained for pH. Natural pH changes mainly originate from rock decomposition in contact with water, gas absorption from the atmosphere, oxidation of organic matter, photosynthesis, and the introduction of domestic and industrial waste (Von Sperling, 2005; Alves & Baccarin, 2005). According to ANA (2009), the pH of groundwater generally ranges from 5.5 to 8.5. The main factors determining the pH of water are dissolved carbon dioxide and alkalinity. The desirable pH range for fish farming is 6.5 to 9. Values outside this range can cause stress in fish, potentially leading to death. However, there are species that tolerate large variations in this parameter (Ostrensky & Boeger, 1998).

In ART1, ART2, and ART6, values were suitable for fish farming; in ART3, only December was adequate, with the following months all below the recommended range. In ART4, only May was within the standard; the remaining months were below. In ART5, only December and January were appropriate for aquaculture.

Conductivity is a solution's ability to conduct electric current, depending on the ionic concentration present. Higher ionic concentrations result in higher electrical conductivity, especially due to nutrients such as calcium, magnesium, potassium, sodium, carbonate, sulfate, and chloride (Esteves et al., 2011). This parameter is related to the presence of dissolved ions in the water—electrically charged particles.

The higher the quantity of dissolved ions, the greater the electrical conductivity. The electrical conductivity parameter does not specify which ions are present in a given water sample, but it can help identify potential environmental impacts in the drainage basin caused by the discharge of industrial waste, mining activities, sewage, etc. Electrical conductivity may vary with temperature, pH, and the total concentration of dissolved ionized substances (Martelli, 2008).

Conductivity concentrations ranged from 34.7 to 526 µS/cm, with the lowest value recorded at ART3 and the highest at ART6. A relationship with pH was observed in all wells. ART1, ART2, and ART6, which had pH values above 7, also had higher conductivity values, while ART3, ART4, and ART5 showed low conductivity and pH values (Table 4). ANOVA showed that points ART1, ART2, and ART6 had significantly higher values than the other points (Figure 3B).

According to Kindlein (2010), nitrite is a chemical form of nitrogen typically found in small quantities in surface and groundwater because nitrite is unstable in the presence of oxygen and appears as an intermediate form. Thus, in this study, since the wells are deep and show little variation in oxygen concentration, no variation was observed among the sampling points (Figure 3C).

Values up to 0.05 mg/L are recommended for freshwater fish farming. In this study, concentrations above the recommended value were found in December at ART3 and in January at ART6, which could lead to reduced growth and resistance in fish, potentially causing death (Kubitza, 1999). Chemically, alkalinity is defined as the inverse property of acidity—i.e., the capacity to neutralize acids. In general, the presence of alkalinity raises pH values above 7.0; however, lower pH values (above 4) do not necessarily indicate the absence of alkaline substances in the aqueous medium. The main constituents of alkalinity are bicarbonates, carbonates, and hydroxides (Medeiros Filho, 2013).

It was observed that the values obtained were directly related to pH. Wells ART1, ART2, and ART6 had the highest alkalinity values, while the others had significantly lower values, consistent with their respective pH values. The highest value was 311 mg/L at ART1 in February, and the lowest was 0 mg/L at ART5 in December (Table 6). ANOVA showed the same pattern as pH: points ART1, ART2, and ART6 were statistically different from ART3, ART4, and ART5 (Figure 3D).

Alkalinity in water does not pose a health risk, but it can alter taste. Alkalinity is not part of drinking water standards (Bastos, 2013). Determining and controlling alkalinity is important in water treatment, softening, and preventing internal pipe corrosion (Martins, 2017).

According to Sipaúba-Tavares (1994), values above 20 mg/L are recommended for fish farming, with optimal values between 200 and 300 mg/L. At ART1, only December and April were within the recommended range; at ART2, all months were adequate. ART3 showed suitable values only in December and January, while the following months were far below recommended levels. ART4 and ART6 remained within recommended values throughout the sampling period. At ART5, values from January to May were acceptable; only December was below the standard—and the only month and well with a value of zero.

Water turbidity is an expression of the optical property that causes light to be scattered and absorbed, increasing attenuation (Parron, Muniz & Pereira, 2011). The Ministry of Health's Ordinance No. 888 of May 4, 2021, sets a maximum allowable turbidity of 5 NTU (Nephelometric Turbidity Units) for drinking water.

High turbidity values were observed at ART3, with only December meeting the recommended limit. The highest value was 42.4 NTU in January at ART3, and the lowest was 1.15 NTU at ART1 (Table 7).

ANOVA analysis showed that ART3 was statistically different from the other points (Figure 3E). Turbidity is mainly caused by suspended solids which, aside from making the water visually unpleasant, can pose health risks by sheltering microorganisms from disinfectants like the hepatitis A virus (Pádua, 2007).

According to Bastos (2013), in his study of artesian wells in Cruz das Almas–BA, turbidity values reached up to 36.08 NTU. The author explains that high turbidity may be due to organic matter from nearby septic tanks or plant decomposition in the area. In the current study, it was observed that ART3 has a long distance between the well and the reservoir. If the pipeline is damaged, environmental particles may enter, increasing turbidity. The pipeline should be inspected, and if it is the cause of high turbidity, it must be replaced.

In aquaculture, turbidity is measured by water transparency, with recommended values between 30 and 45 cm (Ostrensky & Boeger, 1998). Hardness is primarily caused by the presence of calcium and magnesium, as well as other cations such as iron, manganese, hydrogen, etc., associated mainly with carbonate and sulfate anions, in addition to others like nitrate, silicate, and chloride. The four main compounds contributing to water hardness are calcium bicarbonate, magnesium bicarbonate, calcium sulfate, and magnesium sulfate (Piveli, 2005).

Water hardness is the measure of its ability to precipitate soap (surfactant), meaning the soap forms insoluble complexes and does not foam until the process is exhausted (Perpetuo, 2014). Hard water can cause undesirable effects such as unpleasant taste, high soap demand, hygiene difficulties, salt deposits in cooking pots or heating elements, and stained dishes (Medeiros Filho, 2013).

Ordinance No. 888 of May 4, 2021, from the Ministry of Health establishes a maximum value of 300 mg/L for human consumption. The results showed that values at ART1, ART2, and ART6 were well above the legal limit. The remaining wells had values within the maximum allowable limit (MAL). The lowest value was at ART3 in March, with 78.1 mg/L, and the highest at ART6 in February, with 2233.66 mg/L (Table 3E).

Hardness was found to influence electrical conductivity, with both parameters increasing and decreasing together in all months analyzed. ANOVA showed significant differences between ART6 and ART3, ART4, and ART5, with no differences among the remaining points (Figure 3F).

ART1 and ART6 had the highest values compared to the others. According to Vasconcelos and Silva (2006), water hardness can be classified as follows: I) <50 mg/L $CaCO_3$ – soft water, II) 50 to 150 mg/L $CaCO_3$ – moderately hard water, III) 150 to 300 mg/L $CaCO_3$ – hard water, and 300 mg/L $CaCO_3$ – very hard water. The average values showed that ART1, ART2, and ART6 fall under the very hard water category, while ART3, ART4, and ART5 are classified as hard water.

The results explain why residents of some rural communities complain about the taste and difficulty in forming lather with this water. In areas where wells had high hardness, residents preferred shallow wells for better water quality. In ART1, ART2, and ART6, treatment is unfeasible, as reducing hardness requires softening techniques with large-scale equipment installed at water treatment and distribution stations.

Fish farming develops best in soft water, around 50–80 mg $CaCO_3$/L (PÁDUA, 2002). On the other hand, Kubitza (1999) recommends values of 30 mg/L. According to Pádua's recommendation, only ART3 in March was within limits; under Kubitza's standard, none of the wells had adequate hardness levels for fish farming

4. Conclusões

Dentre todos os poços analisados, somente ART4 e ART5 apresentaram todos os parâmetros de acordo com a legislação para consumo humano. Apenas a dureza no ART1, ART2 e ART6, e a turbidez a partir do mês de janeiro no ART3, apresentaram valores fora dos padrões recomendados para consumo humano.

Com exceção da temperatura e nitrito, houve diferença significativa entres os poços para os demais parâmetros. Recomenda-se o tratamento das águas dos poços ART1, ART2 e ART6 quanto aos níveis de dureza, e a água do ART3 em relação à turbidez e pH para que atendam a legislação da potabilidade da água.

Entre relação à atividade de piscicultura, a água de nenhum poço é recomendada para esse fim, pois em todos os meses, em todos os poços, sempre foram constatados valores em desconformidade aos recomendados em pelo menos um dos parâmetros, tornando-se inviável sua captação para esse fim.

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