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Water quality from artesian wells in the northeastern semi-arid region: A literature review

Calidad del agua de los pozos artesianos de la región semiárida del noreste: revisión bibliográfica

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Abstract: Water is the main survival resource for living beings, however the problems with scarcity of this resource are very present in the northeastern semi-arid region, one of the most used solutions for this problem is the construction of artesian wells and can be defined as sources of water found within the soil/subsoil useful to supply human supply, such sources are obtained by drilling the soil to a certain depth at which the available water is located in the water table or aquifer existing in the place. Water from artesian wells usually has high levels of salinity, a factor in which potability standards must be analyzed in order to ascertain whether it is suitable for human consumption and other activities. The objective of this work was to present studies carried out on the analysis of the quality of water acquired through artesian wells in the northeastern semi-arid region, noting the possibility of using them in adequate conditions for human consumption. Data were collected through a literature review of research already carried out in this area that found results on the physical-chemical and microbiological aspects of water samples in different artesian wells located in different points of the northeastern semi-arid region. Based on the studies carried out, it is clear that in most of the water resources coming from artesian wells in the semi-arid northeast, it is necessary that the appropriate treatment be made for its use, thus making water within the required potability standards. It is concluded that, in view of the results obtained, the water obtained through artesian wells needs treatment before being destined for human consumption.
Keywords: *Water resources; Potability; Underground sources.*

Resumen: El agua es el principal recurso de supervivencia para los seres vivos, sin embargo, los problemas de escasez de este recurso están muy presentes en la región semiárida del noreste, una de las soluciones más utilizadas para este problema es la construcción de pozos artesianos y se pueden definir como fuentes de agua que se encuentran dentro del suelo/subsuelo útiles para abastecer al ser humano, dichas fuentes se obtienen perforando el suelo hasta cierta profundidad donde el agua disponible se localiza en el manto freático o acuífero existente en el lugar. El agua proveniente de pozos artesianos suele presentar altos niveles de salinidad, factor que requiere un análisis de las normas de potabilidad para determinar si es apta para el consumo humano y otras actividades. El objetivo de este trabajo fue presentar estudios realizados sobre el análisis de la calidad del agua adquirida por medio de pozos artesianos en la región semiárida del Nordeste de Brasil, verificando la posibilidad de utilizarla en

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condiciones adecuadas para el consumo humano. Los datos fueron recogidos a través de una revisión bibliográfica de investigaciones ya realizadas en esta área que encontraron resultados sobre los aspectos físicos, químicos y microbiológicos de muestras de agua de diferentes pozos artesianos localizados en diferentes puntos de la región semiárida del Nordeste. Con base en los estudios realizados, se observa que la mayoría de los recursos hídricos provenientes de pozos artesianos de la región semiárida del Nordeste de Brasil necesitan ser tratados adecuadamente para su utilización, de modo que el agua pueda cumplir con los estándares de potabilidad exigidos. Se concluye que, en vista de los resultados obtenidos, el agua obtenida de pozos artesianos requiere tratamiento antes de ser destinada al consumo humano. **Palabras clave:** *Recursos hídricos; Potabilidad; Fuentes subterráneas.*

INTRODUCTION

Drinking water consumption is indispensable for living beings in general, especially for humans, since this element is the main responsible for the survival of species of fauna and flora on the earth's surface. Therefore, in face of the existing problems in several parts of the planet related to the scarcity of this natural resource, it becomes necessary to develop techniques for the population to live with the interference of the lack of water.

According to the Trata Brasil Institute, the planet's aquifers concentrate about 97% of fresh and liquid water. Thus, an alternative to combat the insufficiency of water are artesian wells (or underground sources), which serve as a water supply option for certain families/communities, improving coexistence with the lack of water in these places that have unfavorable climatic conditions for the supply of drinking water for the population (FARIAS et al., 2018).

However, it is worth noting that a qualitative analysis of the water from these sources of supply is necessary in order to determine whether the natural resource extracted from these places has satisfactory properties for consumption by the population, since some studies such as, for example: Silveira (2018) points out the uselessness of these waters due to the lack of basic conditions of potability determined by the Ministry of Health. The relevance of these analyses is explained by the fact that the human body needs the basic components of drinking water to develop its activities, so if this water has changes in its composition this may cause negative impacts on human health (SOUSA et al., 2021).

According to a study conducted in rural areas in the hinterland of the state of Sergipe, it was found that the water from most artesian wells analyzed in the research presented inadequate quality due to the presence of effluents from septic tanks near the artesian wells, as well as the inadequate construction of these systems. Thus, such water that was used in schools in those locations raised suspicions of contamination, which led the population to seek findings about this problem, justifying the research (SIQUEIRA et al., 2022).

Therefore, it is clear that to ensure access to drinking water for the survival of the population it is necessary to perform physical-chemical and microbiological analysis of the water obtained through these

natural sources to determine the possibility of its consumption. Therefore, the objective of this study is to present the results obtained from some research carried out in the semi-arid region of the Northeast about the quality of water from artesian wells.

THEORETICAL FOUNDATION

Water is the most important substance for sustaining life, this element is also extremely important for industrial operation, for agriculture and certainly for economic performance, although the planet is composed 70% by water, only 3% of this resource is available for human use. According to the Ministry of Environment 11.6% of the fresh water existing in springs, are found in Brazil, although the country geographically represents a great abundance with respect to this resource, its distribution among the regions is disproportionate (MOHR and SANTOS 2014).

According to Ferreira et al. (2015) the Brazilian semi-arid region has a low rate of rainfall, the rains occur only in certain months of the year, leaving the population in a state of drought, because it is a dry region, water resources are even more limited, for this reason the need to build alternative sources of supply such as reservoirs to capture surface water and artesian wells for groundwater was triggered. The sources of groundwater supply represent 39% of Brazilian municipalities (SIMÕES et al., 2020).

Sousa et al. (2021), states that it is necessary that the characteristics of groundwater are known, he also adds that it is of utmost importance to know the habits of the population living near the wells, because the lack of basic sanitation can cause contamination in the sources of supply. According to data from IBGE (2011), in the Northeast sewage collection serves only 16% of the population, the lack of sewage collection results in the lack of a place to dispose of human waste and with this the pits, which are built in inappropriate places can contaminate the groundwater (SIQUEIRA et al., 2022).

In the northeastern Sertão, the scarcity of water leads the population to search for means of supply, it is very common to drill artesian wells to supply the need for this resource to the population, this measure is even more present in rural areas, the lack of hydrographic knowledge for the excavation of wells can result in waters with high salt content, making it unsuitable for human consumption and leading to the need for adequate treatment for its use (SOUSA et al., 2021).

According to the United Nations (UN, 2011), each individual needs at least two million liters of water per year to lead a healthy life; however, man has the false idea that water resources are infinite and are constantly contaminating their springs from various sources, offering risks to human health (MIRANDA, 2004; BRASIL, 2013).

Water for human consumption can be obtained from different sources. One of these sources, the underground spring, is a resource used by a large portion of the Brazilian population. Groundwater can be

abstracted from confined or artesian aquifers, which lie between two relatively impermeable layers, making contamination difficult, or from unconfined or free aquifers, which lie close to the surface and are therefore more susceptible to contamination. Due to the low cost and ease of drilling, the capture of water from the free aquifer, although more vulnerable to contamination, is more frequently used in Brazil (SILVA; ARAÚJO, 2003).

Underground springs constitute a source of strategic and alternative water reserves for the supply of current and future demands, since they represent an amount about 100 times greater than surface water worldwide (BORGHETTI et. al, 2004). Currently, this source has been gaining more importance when there is an occurrence of water shortage, as in some regions of the Brazilian Northeast, where there is a predominance of the semi-arid climate, with high temperatures and low rainfall, causing long droughts and drying of much of the surface water sources. The underground well is the result of a drilling with small diameter and great depth, "when the waters flow naturally from the soil in an aquifer called confined (totally filled with water, whose ceiling and floor are impermeable fragments) until reaching the upper level, it is characterized the existence of an artesian well" (ROCHA; LOPES, 2015).

When the well's pressure is not enough to jet the water to its surface and for this the use of pumps is necessary, the well is called semi-artesian. Another classifies both the artesian and semi-artesian wells as technically being called deep tube wells. Both are dug by a type of wells are dug by a drilling machine using a specific drill developed by the oil industry (HIRATA, 2002).

The physical and chemical parameters are determined by the particular characteristics of the watershed - geology, relief and associated soils, climatic conditions and aspects of use and vegetation cover, and, represented by the solids, organic and inorganic matter, present in the water (PAIVA and PAIVA, 2003; VON SPERLING, 2005). Among these parameters are: temperature, dissolved oxygen, biochemical oxygen demand, ammoniacal nitrogen, total phosphorus, solids, turbidity and pH.

According to Von Sperling (2005) and Alves (2006), the parameter Temperature is the measure of the intensity of heat, and its change occurs by natural origins, related to heat transfer by radiation, conduction and convection between the atmosphere and soil, and by anthropic origins, by effluents, by waters from industrial cooling towers, thermoelectric power plants and others.

Oxygen is essential for all forms of life, and in aquatic life directly influences the organisms that perform self-depuration in waterways (VON SPERLING, 2005). According to Freire (2010) the quantification of dissolved oxygen (DO) in water is an expressive indicator of the quality of the water resource.

The dissolved oxygen can be influenced with increased values by water turbulence (natural or artificial), as well as present a lower concentration, caused naturally by temperature - in the case of

warmer waters and with a greater amount of organic matter, and by anthropic influence, in waterways that run through urban centers and receive effluents with large contribution of organic matter (FARIAS, 2006).

The Biochemical Oxygen Demand (BOD) is the ratio of the amount of oxygen available in water that would be necessary to oxidize organic matter to a stable inorganic form (VON SPERLING, 2005). And, according to Bowie et al (1995) BOD is an indirect estimate of oxygen consumption in waterways. BOD is usually defined as the amount of DO consumed over a given period of time at a specific incubation temperature. For the oxidation of organic matter, according to Von Sperling (2005), the BOD5,20 is the amount of DO consumed during a 5-day period at an incubation temperature of 20°C.

The organic matter present in waterways and in effluents is used by microorganisms in their metabolic synthesis, consuming DO. According to Von Sperling (2007), the main organic components are proteins, carbohydrates, fats, urea, pesticides, among others. For Dick and Martinazzo (2006), organic matter can also act as a carrier of contaminants. Thus, the increase in BOD is caused by effluents of predominantly organic origin. It is important to note that BOD is closely linked to DO, because a high concentration of organic matter in water can lead to the complete consumption of oxygen in the water, which causes a direct impact on aquatic life, such as the disappearance of fish and other local species (CETESB, 2008).

Ammoniacal nitrogen is the first compound produced by the degradation of organic matter, being the most reduced form of nitrogen, characterized by showing pollution in its initial stage (VON SPERLING, 2005).

The main source of ammoniacal nitrogen in watercourses, in urban areas, is the discharge of effluents, characterized by the hydrolysis of urea in water, by the decomposition of proteins and amino acids. In rural areas, the sources can be associated with the use of fertilizers in crops, which is carried to waterways by the action of rain. Thus, Silva et al. (2010) showed that there is a relationship between fertilizer use and the concentration of nitrogen forms in surface waters.

Phosphorus is essential for the development of microorganisms responsible for the stabilization of organic matter, and is present in aquatic ecosystems, having natural origin - by dissolution of rocks, soil compounds, decomposition of organic matter - and by anthropic action, by effluents of domestic and industrial origin, by the presence of detergents, fertilizers/pesticides and animal excrements (VON SPERLING, 2005).

Water quality is affected by surface runoff, under natural conditions. Thus, interference in quality depends on the material carried by this runoff, which can be sediment and soil impurities. Thus, according to Von Sperling (2005), the incorporation of solids (in suspension - soil particles resulting from the

dissolution of rocks) occurs even in a natural environment, and what gives the greatest degree of protection against runoff is the vegetation cover and the composition/texture of the soil.

For Merten and Poleto (2006) the quantification of the flow of pollutants transported by suspended sediments plays an important role in the management of water resources. In addition, they point out that the fine granulometry of the solids (silt and clay fraction) is linked to the transport of contaminants.

Turbidity is a photometric measurement, in which suspended matter is analyzed and its ability to interfere with the flow of light energy, i.e., turbidity represents the degree of interference to the passage of light in water, causing a turbid appearance (SINCERO and SINCERO, 2003).

According to Branco et al (1991) the reduction of turbidity in water occurs by the presence of suspended solids, such as soil particles (sand, silt and clay) and organic matter (plankton, bacteria, algae). While Barcellos et al. (2006) describe that some minerals present in soils, such as iron and manganese, confer increased coloration and turbidity to water.

Thus, in periods of intense rainfall, which can generate exacerbated runoff, there is leaching of the soil, influencing the turbidity of waterways. In this context, Freire (2010) and Gorjon Neto (2014) mention that the concentration of turbidity is an effect resulting from the carriage of soil particles by the action of precipitation and runoff. They describe that this parameter is also influenced by the flow of waterways, since, when there is precipitation and changes in the flow, there is the triggering of erosive processes.

According to Iost (2008), pH is one of the most difficult parameters to interpret, since there are a large number of factors that can influence its concentrations, such as dissolved solids, water temperature, oxidation of organic matter and photosynthesis, and also domestic and industrial effluents and sewage.

Thus, according to Collischonn and Dornelles (2013) pH influences the balance of chemical compounds in waterways, and may accelerate the decomposition process of toxic materials, in its acidic condition, as well as increase the concentration of free ammonia (NH3), in basic condition, i.e., it has a direct reach on aquatic ecosystems.

With the exception of Escherichia, the other bacteria of the coliform group, according to Tarelho Júnior (2014), can occur in waters with high levels of organic matter, industrial effluents, as well as in the decomposition of vegetable matter in the soil, i.e., without any obvious pollution by fecal matter.

METHODOLOGY

This study is a literature review, which is a specific method that summarizes past empirical or theoretical literature to provide a more comprehensive understanding of a particular phenomenon. Thus,

integrative review enables the synthesis of several studies already published and allows the generation of new knowledge based on the results presented by previous research (LAKATOS et al., 2010).

After selecting the theme to be understood, a search was made for studies already conducted in academic data platforms, Scientific Electronic Library Online and Dissertations (SCIELO) and Google Scholar (Google Scholar): Choice of the base question; Literature search/establishment of criteria for the inclusion and exclusion of studies; Choice of the points to be used; Critical analysis of the included studies; Interpretation of the results and presentation of the review/synthesis (SOUSA et al., 2017).

Inclusion and exclusion criteria were determined to select the research that provided the theoretical basis for this study, articles with texts present in the area of engineering knowledge. Thus, articles or theses outside the study area were excluded. To choose the data to be extracted from the articles, we used the identification of the articles (author, title and year of publication), together with the objective, type of study and main results (UISI, 2005). Therefore, the inclusion factor was defined as: Papers that address the analysis of water quality from artesian wells. And, as exclusion factors: Papers published in languages other than Portuguese; papers that do not address the studied theme.

From the analyses collected from the studies, a mediation was made between the described objective pointed out in this study and the considerations and data collected by each author, pointing in synthesis, the objective result of this production.

RESULTS AND DISCUSSIONS

Among the articles analyzed based on the established criteria, 5 were chosen because they present suggestions of studies conducted in the northeast region on artesian wells as a source of drinking water.

BOX 01: Summary of the selected articles.

Author/Year/Location	Title	Methodology	Results

SOUSA/2021/BRASIL	Physical-chemical characterization of water from artesian wells in the city of Patos/PB.	Qualitative Descriptive	For the study the parameter tests were performed in relation to PH, which showed satisfactory results, turbidity was satisfactory, electrical conductivity was high and alkalinity was low, so the high values of electrical conductivity, which are outside the standards, can be explained by the presence of chloride ions or free residual chlorine. Thus, it is not indicated the consumption of this water by the communities adjacent to the wells, being indicated the prior treatment of disinfection of these waters, after analysis of determination of these ions.
FORMIGA/2020/BRASIL	Evaluation of the quality of water for human consumption, under the physical-chemical aspects of the city of Juazeiro do Norte - CE.	Qualitative Descriptive	The results of the studies show that most of the wells are not in compliance for the distribution of drinking water for human consumption in the municipality. Therefore, it is up to the public authorities, the public and private sector, and the entire population to ensure the control and quality of the water supply in the municipality, in the certainty that in the near future they will be able to continue to enjoy this renewable resource, but which is capable of becoming exhaustible due to the frequent use of uncontrolled anthropic activities.
SIQUEIRA et. al/2022/BRASIL	Potability of water from artesian wells in rural communities of the agreste region of Sergipe.	Qualitative Descriptive	The results showed that only in three locations the water was free of fecal coliforms. This data is a strong indication that the pits built near the artesian wells are black pits. It is therefore necessary to take a series of measures to remediate the problem, and thus ensure

			that the individuals who depend on the artesian wells have safe drinking water.
GREGÓRIO *et. al*/2020/BRASIL	Microbiological quality of water from artesian wells located in the City of Acari, Rio Grande do Norte.	Qualitative Descriptive	After the collection and laboratory analysis of all the material, it was verified a high number of biological properties in the waters of the artesian wells of Beira Rio and Bico da Arara located in the Rural Zone of Acari, Rio Grande do Norte. The quality of water for human consumption is one of the criteria determined so that the health of the population is not compromised.
FARIAS/2018/BRASIL	Quality of groundwater in the municipality of Olivedos-PB for irrigation purposes.	Qualitative Literature review	In the research, all the samples analyzed from tubular wells in rural communities in Olivedos, PB, were classified as low quality water with very high salinization risk (class C4) according to Richards (1954), with the lowest value of CEa= 4,910 uS cm^{-1} and the highest value of 18,580 uS cm^{-1}.

SOURCE: Survey data (2022).

In accordance with the study carried through in the city of Olivedos - PB, that had for purpose to carry through the qualitative analysis of the underground water for use in irrigation systems, it was verified that such hydric resource did not present adequate properties for use in certain end, since the studied samples presented high index of salt, with risk of salinization. Thus, one suggestion made by the authors was to combine the water from these underground sources with water from cisterns, so that it would be possible to use it in small irrigation systems with a reduced degree of salinity, avoiding the uselessness of this resource. Thus, for this solution to be viable, it is necessary to adjust the proportion to balance the amount of salts in the water.

In a research carried out in the city of Acari - RN, the aspect analyzed in the water obtained from artesian wells in that locality was the microbiological quality. Therefore, through the collection of samples from two artesian wells and after laboratory analysis to detect bacteria, it was observed that due to the presence of high rates of biological properties contained in these waters collected from both wells and through comparisons with the reference values indicated by the ordinances of the Ministry of Health

related to water potability, their consumption should not be performed, because they can cause health risks through their consumption.

Another study conducted in the city of Juazeiro do Norte, in the state of Ceará, showed that almost all parameters of the water from the wells were compliant for use, except for the high electrical conductivity present in them. The presence of this factor indicates that there is a high amount of residual chlorine present in the water, which makes the use of this hydric resource inappropriate until an adequate treatment is performed to make the water potable.

CONCLUSION

Observing the analyses and studies carried out, it can be concluded that a good part of the waters of the phreatic mines in the semi-arid region of the Northeast of Brazil have unsatisfactory parameters regarding the potability of the water, and that its consumption without adequate treatment is almost always inappropriate. Therefore, the water coming from most of these underground sources needs to be treated to achieve adequate levels of potability, avoiding risks to the health of the population through this natural hydric resource.

Thus, as strategies for solving these problems, it is suggested that in addition to the physical-chemical and microbiological analysis of these waters, treatment systems are developed to make them drinkable and suitable for consumption by the population. For this, it is necessary that studies are improved in this line of research to achieve this goal.

Water is one of the natural resources that are indispensable for life, but for human consumption it must meet potability standards determined by legislation. According to the quality standard for drinking water established by the Consolidation Ordinance No. 5 of September 28, 2017 of the Ministry of Health establishes the values for physical-chemical and microbiological characteristics of drinking water.

REFERENCES

[1] BARCELLOS, M. C.; ROCHA, M.; RODRIGUES, L. S. et al; Avaliação da qualidade da água e percepção higiênico-sanitária na área rural de Lavras, Minas Gerais, Brasil, 1999-2000. Caderno Saúde Pública, v.22, n.9, p.1967-1978, 2006. 4.

[2] BORGHETTI, M.R.B.; BORGHETTI, J.R.; FILHO, E.F.R. Aquífero Guarani: a verdadeira integração dos países do Mercosul. Curitiba: Fundação Roberto Marinho/Itaipu Binacional, 2004.

[3] BRANCO, S. M. A água e o homem. In: Porto, R. L. L. (Org.). Hidrologia Ambiental. São Paulo: USP/ABRH, 1991.

[4] COLLISCHONN W.; DORNELLES, F. Hidrologia para engenharia e ciências ambientais. Porto Alegre: ABRH, 2013.

[5] FARIAS, D. S. C. R. *et al*. QUALIDADE DE ÁGUA SUBTERRÂNEA NO MUNICÍPIO DE OLIVEDOS-PB PARA FINS DE IRRIGAÇÃO. In: CONGRESSO TÉCNICO CIENTÍFICO DA ENGENHARIA E DA AGRONOMIA, 18., 2018, Maceió. **Anais [...] .** Maceió: Contecc, 2018. p. 1-5. Disponível em: <https://www.confea.org.br/sites/default/files/antigos/contecc2018/agronomia/200_qd%C3%A1snmdopfdi.pdf>. Acesso em: 26 set. 2022.

[6] FARIAS, M. S. S.; Monitoramento da Qualidade da Água na Bacia Hidrográfica do Rio Cabelo. 2006. 152f. Tese (Doutorado em Engenharia Agrícola). Centro de Tecnologia e Recursos Naturais, Universidade Federal de Campina Grande, 2006.

[7] FERREIRA, K. C. D.; LOPES, F. B.; ANDRADE, E. M.; MEIRELES, A. C. M.; SILVA, G. S. Adaptação do índice de qualidade de água da National Sanitation Foundation ao semiárido brasileiro/ Adapting the National Sanitation Foundation water quality index to the Brazilian semiarid. **Revista Ciência Agronômica**, v. 46, n. 2, p. 277-286, abr-jun, 2015.

[8] FREIRE, R. Monitoramento da Qualidade da Água da Bacia Hidrográfica do Ribeirão Maringá. 2010. 199f. Dissertação (Mestrado em Engenharia Química). Programa de Pós-Graduação em Engenharia Química, Universidade Estadual de Maringá, 2010.

[9] GORJON NETO, A. Monitoramento da qualidade da água na bacia do rio Pirapó. 2014. 177f. Dissertação (Mestrado em Engenharia Urbana). Programa de Pós-Graduação em Engenharia Urbana, Universidade Estadual de Maringá, 2014.

[10] GREGÓRIO, M. G. et al. Qualidade microbiológica da água de poços artesianos localizados na Cidade de Acari, Rio Grande do Norte. Research, Society And Development, [S.L.], v. 9, n. 8, p. 1-9, 4 jul. 2020. Research, Society and Development. http://dx.doi.org/10.33448/rsd-v9i8.5251.

[11] HIRATA, R. VIEIRA, A.; SUSKO, S.; VILLAR, P.C.; MARCELLINI, L. A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento. Instituto Trata Brasil, 2018.

[12] IOST, C. Produção de sedimentos e qualidade da água de uma microbacia hidrográfica rural. 2008. 87f. Dissertação (Mestrado em Engenharia Agrícola). Programa de Pós-Graduação em Engenharia Agrícola, Universidade do Oeste do Paraná, 2008.

[13] MERTEN, G. H.; POLETO, C. Rede de monitoramento e coleta de amostras. In: MERTEN, G. H.; POLETO, C. (Orgs.) Qualidade dos sedimentos. Porto Alegre: ABRH, 2006.

[14] MIRANDA, E. E. A Água na Natureza e na Vida dos Homens. Aparecida: Idéias & Letras., 141 p.,2004.

[15] MOHR, T.; SANTOS, R. S. SAÚDE E QUALIDADE DA ÁGUA: Análises Microbiológicas e Físico-Químicas em Águas Subterrâneas / Health and Water Quality: Microbiological and Physical-Chemi-cal Water Underground. REVISTA CONTEXTO & SAÚDE IJUÍ EDITORA UNIJUÍ v. 13 n. 24/25 jan./jun. 2013 – jul./dez. 2013.

[16] PAIVA, J. B. D.; PAIVA, E. M. C. D. Hidrologia aplicada à gestão de pequenas bacias hidrográficas. Porto Alegre: ABRH, 2003.

[17] ROCHA, J.P.; LOPES, A. POÇOS ARTESIANOS: uma reflexão na perspectiva da sustentabilidade. Revista multidisciplinar, 2015. Disponível em:. Acesso: 10 de julho de 2019.

[18] SILVA, D. F.; ANDRADE, C. L. T.; SIMEONE, M. L. F.; AMARAL, T A. et al. Análise de nitrato e amônio em solo e água, Sete Lagoas: Embrapa Milho e Sorgo, 2010.

[19] SIMÕES, et al. Avaliação da qualidade da água de poços domésticos em comunidades rurais no arquipélago de MARAJÓ – PA/ The evaluation of the quality of the water in the wells in the rural communities of the Archipelago of Marajó island – PA. Revista Brasileira de Geografia Física, [S.L.], v.13, n.05 , p.2462-2475, 03 agosto 2020.

[20] SINCERO, A. P.; SINCERO, G. A. Pysichal Chemical Treatment of Water and Wastewater. London: IWA Publishing, 2003.

[21] SIQUEIRA, C. G. et al. Potabilidade da água de poços artesianos em comunidades rurais do agreste sergipano. Águas Subterrâneas, [S.L.], v. 35, n. 3, p. 1-9, 7 fev. 2022. Lepidus Tecnologia. http://dx.doi.org/10.14295/ras.v35i3.30112.

[22] SOUSA, R. M. et al. Caracterização físico-química da água de poços artesianos no município de Patos/PB / Physical-chemical characterization of water from artesian wells in the city of Patos/PB. Brazilian Journal Of Development, [S.L.], v. 7, n. 8, p. 82116-82122, 17 ago. 2021. South Florida Publishing LLC. http://dx.doi.org/10.34117/bjdv7n8-427.

[23] TARELHO JÚNIOR, O. Monitoramento da qualidade da água das bacias hidrográficas do Paranapanema. 2014. 139f. Dissertação (Mestrado em Engenharia Química). Programa de Pós-Graduação em Engenharia Química, Universidade Estadual de Maringá, 2014.

[24] VON SPERLING, M. Introdução à qualidade das águas e ao tratamento de esgotos. 3ºed. Belo Horizonte: Departamento de Engenharia Sanitária e Ambiental/UFMG, 2005.