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PHYSICAL QUALITY OF SUBTERRANEAN WATERS IN URBAN AREAS OF CITIES ON THE NORTHEAST COAST: THE CASE OF APICUM-AÇU - MA

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ABSTRACT
The research identified the potability conditions of the subterranean waters utilized by the urban population of Apicum-Açu - MA. To achieve the proposed goals it was analyzed the water levels of physical quality from the analysis of physical parameters: Potential Hydrogen(pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Salinity, and Turbidity. The samples were obtained in 49 tubular wells and waterholes inside the urban zone of the municipality and analyzed by a portable Aquaread AP800 multiparameter. To the ascertainment of the physical quality levels from the samples utilized, it was used the determined parameters defined by the Brazilian law in the patterns of water potability to human consumption established by the Normative Resolution in CONAMA 357/2005. The results found had identified that the pH shows itself as slightly acid to basic, the salinity in the majority of the wells presents at a low of 0,5% as well as other indexes of EC, TDS, and Turbidity found themselves inside the water quality levels of human consumption established by the CONAMA 357/2005. As such, it was possible to classify the subterranean water, inside the urban zone of the municipality of Apicum-Açu as potable, indicated to consumption, with caveats and recommendations that can contribute to maintaining and improving the levels of its potability.
Keywords: Apicum-Açu; groundwater; physical analysis.

QUALIDADE FÍSICA DAS ÁGUAS SUBTERRÂNEAS EM ÁREAS URBANAS DE CIDADES DO LITORAL NORDESTINO: O CASO DE APICUM-AÇU – MA

RESUMO
A pesquisa identificou as condições de potabilidade das águas subterrâneas utilizadas pela população urbana de Apicum-Açu - MA. Para atingir os objetivos propostos foram analisados os níveis de qualidade física das águas a partir da análise dos parâmetros físicos de: Potencial Hidrogeniônico (pH), Condutividade Elétrica (EC), Sólidos Totais Dissolvidos (TDS), Salinidade e Turbidez. As amostras foram obtidas em 49 poços de poços tubulares e cacimbas dentro da zona urbana do município e analisados por uma sonda multiparâmetro portátil da marca Aquaread AP800. Para determinação dos níveis de qualidade física das amostras foram utilizados os parâmetros determinados pela legislação brasileira nos padrões de potabilidade da água para consumo humano estabelecidos pela Resolução Normativa da CONAMA 357/2005. Os resultados encontrados identificaram que o pH se apresenta levemente ácido a básico, a salinidade na maioria dos poços apresenta-se abaixo de 0,5% e os outros índices de EC, TDS e Turbidez encontram-se dentro dos níveis de qualidade de consumo humano estabelecidos pela Resolução

CONAMA 357/2005. Foi possível assim classificar que a água subterrânea, dentro da zona urbana do município de Apicum-Açu é potável, indicada ao consumo, com ressalvas e recomendações que podem contribuir para manter e melhorar os níveis de sua potabilidade.

Palavras-chave: Apicum-Açu; águas subterrâneas; análise física.

INTRODUCTION

The water is a substance composed of three atoms (H20), fundamental to the manutention of all life forms on the Planet, being the essential support to all ecosystems. It's present in the major part of human activities, indispensable to mankind's survival, utilized for consumption, food preparation, personal hygiene, and socioeconomic activities, and potentially acquired from rivers and lakes or other subterranean sources, through the drilling of wells.

With the cities' urbanization process, the economic activities and the development of urban areas are influenced and driven to attend to the human population necessities. Although, the population and economic growth processes happen in a disorganized and badly-planned manner, without taking into consideration the natural potential of a location, the prime example of this being the current environmental problems, develop in a proportionate growth to the demographic and economic of this region.

Amid the many environmental issues caused by the urbanization process, it must be mentioned the issue of the loss of water potability, influenced by the contamination process of order both human and natural, be it the shallow waters like rivers and lakes - more susceptible to contamination since they are more accessible, as well as subterranean waters that, although in a certain way may be protected since they are contained in aquifers, can be contaminated and its process of decontamination is much more onerous and prolonged.

The subterranean waters are formed by the exceeding of rainwater that travels layers underneath the soil's surface and fills the empty spaces between the rocks, originating aquifers that are classified into three types: fractured, porous, and karst. Thus, the aquifers are water that is reserved underneath the soil that fills up the rivers, lakes, and wells.

The sources of human contamination of subterranean waters are, in general, related to irregular disposal of domestic effluents, industrial waste, irregular dumps that produce leachate and infiltrate the soil and contaminate groundwater. In addition to the drilling of tubular wells or of cacimba irregularly, without proper knowledge of the area and the legislation, which may cause contamination of aquifers and interfere with the quality of subterranean waters.

It is known that water is an essential element of human existence and that no other liquid can replace it. Therefore, the quality of water intended for human consumption is very important, being a public health issue. Ingestion of contaminated water or it being outside the minimum standards of potability seen in resolutions of the Ministry of Health and water quality regulatory agencies can cause serious health problems, as they contain microorganisms harmful to health and damaging chemicals, leaving them unsuitable for use in human consumption.

Water quality is determined from chemical and microbiological studies and analysis in the laboratory, identifying the presence of altered chemical substances, and pathogenic microorganisms harmful to human health, in addition to physical analysis, in the laboratory or instantly through the use of multiparameter equipment specific for this purpose in the field. The potability of water is determined by comparing it with the standards and norms established by the Ministry of Health and water quality regulatory bodies.

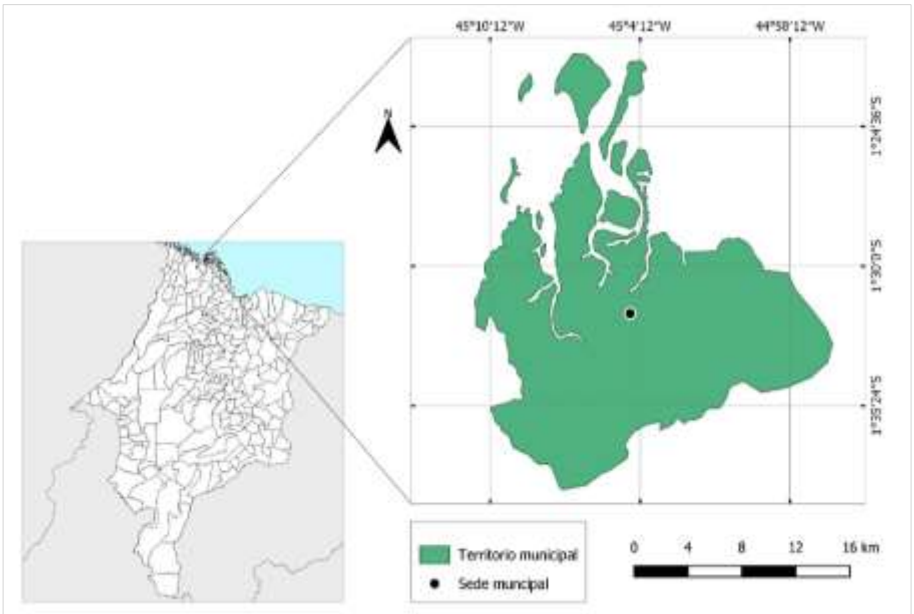
The research identified the groundwater's physical quality of tubular wells and cacimba in the urban area of the municipality of Apicum-Açu, state of Maranhão, analyzing the following physical parameters: Hydrogenonic Potential (pH), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity and Salinity. It was searched as well as how to identify possible environmental problems of natural or human order, that may be influencing the physical subterranean water quality of the studied areas.

The research was conducted in the urban area of the municipality which is located in the North Mesoregion of Marnhão, West Coast Microregion, composing the Environmental Protection Area of the Western Coast of Maranhense, with a population of 14,959 inhabitants and a population density of 42.36 hab./km² (IBGE, 2010).

LOCATION AND CHARACTERIZATION OF STUDY'S AREA

Apicum-Açu is one of the 217 municipalities in Maranhão and is located in the North Mesoregion of the State, within the Microregion of the Western Coast of Maranhense, with a territorial area of 353.2 km² (Cidade-Brasil, 2019), being the 195th municipality in extension. territorial area of the state (Figure 1). It has an estimated population of 17.413 habitants (IBGE, 2020) and a demographic density of 45,38 hab./km2 (Atlas Brasil, 2013). The municipality of Apicum-Açu has borders between the North of the Atlantic Ocean, the South, and the West with the municipality of Bacuri and with the East in the municipality of Cururupu (Cidade-Brasil, 2019). The municipal main office has the following geographic coordinates: -01º27'36 of South Latitude and -45º06' of West Longevity. The urban zone is composed of the following neighborhoods: Center, Tabatinga, Magueirão Nambu, Novo Apicum, Campelos, Turirana, Caruaru e Alto Alegre (Municipal Law 271/71). According to IBGE data (2010), 9.162 habitants, around 61,25% of the population, live in the urban zone.

Figure 1 – Localization map of Apicum-Açu in the state of Maranhão.



Source: IBGE (2010). Organization: Souza, J. F. M (2020)

GEOLOGY AND GEOMORPHOLOGY

The municipality is part of the Parnaíba Sedimentary Basin, which, according to Bandeira (2013, p. 23), "is a sedimentary basin that has a certain peculiarity in the sedimentation of its lithotypes". A part of these sediments was deposited in the Paleozoic era, during the formation of the Pangea. In the Mesozoic era, with the fragmentation of this large continental mass, the deposition of these rocks originated formations such as Mosquito, Pastos Bons, Itapecuru, and even the formation of the Brazilian coastal basins.

The area of the municipality has characteristics of the Barreira do Tertiário Group, "mainly composed of silty-clay sandstones, sandy-silty clays, and conglomeratic rivers, with a predominance of reddish and whitish colors". Quaternary, Fluviomarine Deposits "flat relief, cut by the mouth of water courses, subject to frequent flooding of salt water". And Water Deposit "consisting of quaternary sediments, essentially sandy, typical of beach and wind marine environments, with predominantly silty and clayey sediments". (CPRM, 2011, p. 20; 21).

In addition to the Coastal Tablelands of São Luís and Alcântara-Guimarães, present between the Gulf and northwest of Maranhão, "tabular landforms, with extensive flat tops, with a predominance of pedogenesis processes and the formation of thick, well-drained soils" (BANDEIRA, 2013, p. 42).

The soil of the municipality is formed by fluvial and fluvial-marine plainlands, with a predominance of flat and slightly undulating areas, cut by channels of circulation of brackish water that form apicuns, with an altitude of 0 to 27 meters on average in the higher regions. The types of soils found in the municipality are Yellow Latosol, Plintosol, Gleissolos, and Neossolos. (CPRM, 2011, p. 19).

CONAMA water quality standards and resolutions

According to Resolution 396/2008, subterranean waters are those that "occur naturally or artificially in the subsoil" (Article 2, item I), being these stored in aquifers that are "a hydrogeological body capable of accumulating and transmitting water through its pores, cracks or spaces resulted from the dissolution and carrying of rocky materials". (Section III).

The Resolution mentioned, in its Article 3, in items I to VI, classifies groundwater by classes, which are called: Special, 1, 2, 3, 4, and 5. Given the considerations about each of these, it is highlighted class 2, for its definitions can relate to the reality of groundwater studied and analyzed in this research. The text is transcribed below:

> Article 3, item III: water from aquifers, a collection of aquifers or a portion thereof, without altering their quality by human activities, and which may require adequate treatment, depending on the predominant use, due to their natural hydrogeochemical characteristics. (CONAMA, 2008).

The Resolution 357/2005 in Article 2, determines parameters for classifying water as fresh, brackish, and saline. Being fresh water, those with salinity equal to or less than 0.5%o. Brackish water, salinity higher than 0.5% and less than 30%. And saline waters, with salinity equal to or greater than 30% (items I to III).

Article 3 establishes that "fresh, brackish and saline waters in the national territory are classified according to the quality required for their predominant uses". Article 4 classifies fresh water by classes according to its purposes, being recommended for human consumption only water from special class up to 3, after simplified, conventional, or advanced treatment according to the class to which they are categorized. (Items I to IV).

The saline waters are classified from special class to 3, and none of these are recommended for use for human consumption, only for other activities with less demanding quality parameters (Article 5, items I to IV). Article 6 classifies brackish water from special class up to 3, recommending for human consumption only class 1 brackish water after conventional or advanced treatment. (Section II, item d).

In Article 14, conditions and quality standards are established for class 1 of freshwater, for which there must be no "floating materials, including unnatural foams, oils, and greases, substances that communicate taste or odor, dyes from human sources and waste objectionable solids" (item I, items b, c, d, e, f). The turbidity allowed is up to 40 Nephelometric Turbidity Units - UNT. And the pH from 6.0 to 9.0. (Section I, paragraphs j and m).

For class 2 of fresh waters, the same standards and conditions as for class 1 are followed, in addition to not allowing the "presence of dyes from human sources, which are not removable by conventional coagulation, sedimentation, and filtration processes". And the turbidity is up to 100 UNT (Article 15, items I and IV). Class 3 fresh water follows the same conditions as class 1 and 2 water, with a pH of 6.0 to 9.0 and turbidity of 100 UNT. (Article 16, items l and n).

Saline waters will observe the following conditions: "no verification of chronic toxic effect to organisms, according to the criteria established by the competent environmental agency...", the inexistence of oils, greases, unnatural foams, substances that produce odor and turbidity, dyes from anthropic sources, objectionable solid waste, having a pH between 6.5 to 8.5 (Articles 18 to 20).

Class 1 and 2 brackish waters will comply with the conditions of the non-existence of chronic toxic effects to organisms, according to the criteria of Organs responsible bodies, greases, oils, unnatural foams, and substances that produce color, odor, or turbidity. Presenting a pH of 6.5 to 8.5 (Articles 21 and 22). Class 3 brackish waters will comply with class 1 and 2 criteria, plus "easily sedimentable substances that contribute to the silting up of navigation channels: virtually absent", and pH 5.0 to 9.0 (Article 23, item VI).

Article 42 establishes that in places where there is no evidentiary study that establishes the class of water, fresh water will be classified as class 2. Except when its characteristics and quality are sounder, falling within the strictest classes and before this.

MATERIAL AND METHOD

The method adopted in the realization of the research was quantitative, which is justified by the measurement of the indices of the physical parameters obtained in the analysis of the water of the researched wells. It also adopted a qualitative method, evidenced by the analysis and description of the collected data. The deductive method was also used, which is characterized by the considerations developed from the observed, researched, and analyzed parameters, which made it possible to draw a profile of the physical quality of the groundwater in the studied area.

To execute the research, fieldwork was carried out with the undergraduates of the Geography course at the Apicum-Açu Pole, at the Federal University of Maranhão (UFMA), for observations, water collections, and measurements of physical parameters of subterranean water in the city of Maranhão. Apicum-Açu - MA, from wells of the private cacimba and tubular type, which is located in the urban area of the municipality.

For the collection of water samples from the wells, 500 ml pet bottles (polyethylene containers) of mineral water were used, two bottles for each well, one of which would be used to wash the Aquaread Multiparameter Probe before performing the analysis and to others for the physical analysis of water through the Probe. (Figure 2).

Figure 2 - Aquaread AP800 multiparameter probe

Source: Field research collection: Apicum-Açu - MA, 09/15/2019

It's also emphasized the obtainment of the georeferenced location of the wells by the GPSMAP 78 Garmin device. There were collected and performed physical analyzes of 49 groundwater samples from private cacimbas and tubular wells within the urban area of the municipality.

RESULTS AND DISCUSSION

The municipality of Apicum-Açu is inserted in the Parnaíba Sedimentary Basin, with small and mostly perennial rivers and streams in its territory. It presents a hydrogeological domain with characteristics of a porous or intergranular aquifer, resulting from the consolidated sediments of the Barreiras group and the unconsolidated sediments of the Fluviomarine and Coastal Deposits (CPRM, 2011, p. 20; 22).

The water consumed in the municipality of Apicum-Açu's headquarters mostly comes from tubular wells of the public water distribution system managed by SAAE in partnership with FUNASA, serving a considerable part of the population. However, the supply system does not meet everyone's needs in the same proportion and is not accessible to all neighborhoods, with the need to install private wells of the tubular and cacimba types, especially in areas not served by the regular distribution system of water.

It is known that pure water is colorless, odorless, and tasteless, however, as it is a great natural solvent and a very active chemical substance, it is capable of incorporating large amounts of elements when in contact with the minerals that make up the soil and rocks, where circulates and is stored. Beyond the addition of exogenous particles from anthropic action.

The physical characteristics of water are aesthetic and of high value and some of these can cause some discomfort when ingested, as well as health problems from drinking water outside of potability standards. In view of these considerations, the research collected for analysis of groundwater a total of forty-nine samples in 49 private wells of the tubular and cacimba types within the urban area of the municipality of Apicum-Açu.

To organize and develop the work, the research divided the urban area of the municipality of Apicum-Açu into four collection areas, to be known:

Area 1: Tabatinga neighborhood (9 wells – being 6 wells and 3 tubular);

Area 2: western portion of the Tabatinga neighborhood (14 wells - 1 being tubular and 13 wells);

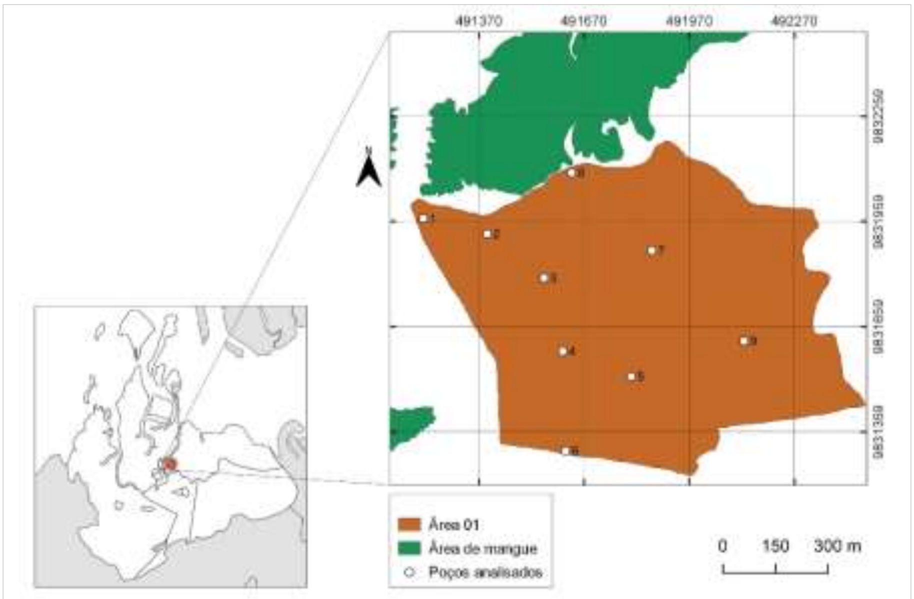
Area 3: Centro (west), Mangueirão, Campelos, and Novo Apicum (16 wells - 12 tubular and 4 wells);

Area 4: Nambu neighborhood and a small strip of the eastern portion of Novo Apicum neighborhood (10 wells, 7 of the cacimba type, and 3 tubular).

Physical quality of groundwater in Area 1

Since the Tabatinga neighborhood is the largest in the municipality, it was divided into areas 1 and 2, aiming at greater efficiency in the collection of research data. The area 1 refers to the eastern portion of the neighborhood, where samples were collected from 9 wells – 6 wells and 3 tubes. Starting near the port region until the limits with the Nambu neighborhood, in the north/south direction. (Figure 3).

Figure 3 - Location map of the analyzed wells in Area 1 - Apicum-Açu



Source: Database: IBGE (2010). Prepared by: Souza, J.F.M. (2020)

The area is partially urbanized, with a few paved streets, masonry buildings, commercial points, and urban equipment (schools), especially the region closest to the main avenue. In the eastern portion, there is a social disparity, a peripheral region popularly known as "Morro", started as an invasion, which over time grew in terms of housing, but did not receive the same public attention as the others.

The area has much more sandy soil than the other surveyed environments, concerning the mangrove region, establishing direct contact to the north, whereas in the northwest, west, and southeast the contact is farther from the inhabited region. The water samples were collected in private wells located on the streets: Benedito Lopes, do Sol, Joaquim Amado, Alto Alegre, and Avenida Gregório Castro, with the results shown in Table 01:

Table 01 - Results of physical analysis of groundwater in Area 1

PARÂM.	UND	P1	P2	P3	P4	P5	P6	P7	P8	P9	CONAMA/ FUNASA
pH	–	5,37	4,84	4,35	4,31	4,63	4,35	4,90	4,11	4,90	6,0 a 9,0
EC	µS/cm	462	268	124	196	122	308	229	1012	16	10 - 100
TDS	mg/L	300	164	80	127	79	199	148	659	11	≤1000
TURB	UNT	0	0	0	0	0	0	0	0	0	≤100
SALIN	‰	0,15	0,09	0,04	0,06	0,04	0,10	0,07	0,48	0,01	≤ 0,5‰
GEO/REF	UTM	491211 9831967	491393 9831924	491555 9831798	491609 9831589	491804 9831517	491617 9831305	491863 9831876	491634 9832098	492126 9831618	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P).
Fonte: Pesquisa de campo: Apicum-Açu - MA, 15/09/2019

After analyzing water samples from the 9 wells, pH indices were obtained for the groundwater in area 1, values that range from 4.11 to 5.37 as shown in graph 1, indicating that all wells in this area are outside the potability standards of water for human consumption, classifying them as acidic, which may be an indicator of contamination. None of the samples reached the minimum established by CONAMA Resolution 357/05 and FUNASA (2014), which is 6 for class 2 waters.

Such changes may come from several factors, such as: proximity of some of these wells to the mangrove, irregular construction form - no protective coating for some, domestic effluents disposed of irregularly, in addition, most of the wells are installed in the lowest part of this area that has a certain slope, that is, all the material carried from the highest part is deposited in the lowest part.

As shown in table 1, the electrical conductivity values obtained in area 1 range from 16 to 1,012 µS/cm, that is, with the exception of well 9, which was the only one that showed a value below 100µS/cm, being within the standards established by FUNASA (2014) for natural water, all other wells present values outside the established limits, indicating possible contamination, with a high concentration of dissolved salts.

The reasons for these changes are similar to those in Graph 1, with an important fact: in well 8, which has the most expressive value, there is a particular phenomenon that contributes to this scenario, the saline intrusion, according to the owner, in periods of high tides. , there is direct contact of seawater with the well, which has no protection, being at ground level and close to the mangrove area.

Although some TDS values may be altered, with emphasis on well 8, which is a special case, for reasons explained above, all 9 wells are within the potability standards of water for human consumption, being below the established limit.

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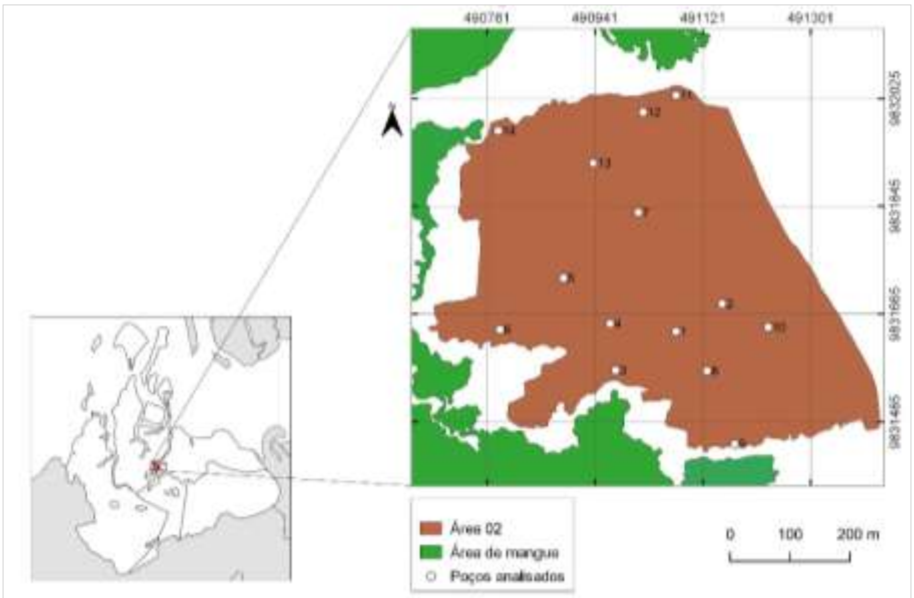
The salinity level recorded in well 8 stands out, it is associated with the particular characteristics of this area, already mentioned above (saline intrusion). The well is not coated with cement and its water has a yellowish color, and, according to the owner, it is used for consumption, especially in the rainy season, in the dry season, only when it is cleaned. It is also used for other purposes such as washing fishing tools, watering plants, and personal hygiene.

Physical quality of groundwater in Area 2

Area 2 corresponds to the western portion of the Tabatinga neighborhood, where groundwater samples were collected from 14 wells, 1 being tubular and 13 cacimbas. The place is well populated and urbanized, with some paved streets and others without paving (be it laterite or sand), the buildings are mostly masonry, commercial points, and urban equipment (health center). This area establishes direct contact in the north, northwest, west, southwest, and south with mangrove areas. (Figure 4).

Figure 4 - Location map of the analyzed wells in Area 2 - Apicum-Açu



Source: IBGE / Google Earth, Organization: Souza, J.F.M. (2020)

The samples for physical analysis of the water in area 2 were collected in private wells of residences located in the streets: do Sol; Airport; from the Landfill; Pedro Neiva de Santana; of Freedom; from Matinha; Travessas do Porto and Bom Milagre, with the permission of the owners. After a physical analysis of the 14 samples, the following results were obtained and expressed below. (Tables 2 and 3):

Table 02 - Results of physical analysis of groundwater in Area 2

PARÂM.	UND	P1	P2	P3	P4	P5	P6	P7	CONAMA/ FUNASA
pH	–	4,84	4,86	4,47	6,04	6,24	6,83	4,40	6,0 a 9,0
EC	µS/cm	323	130	0	372	372	93	236	10 - 100
TDS	mg/L	207	0	0	242	241	60	154	≤1000
TURB	UNT	0,0	0,0	0,0	0,0	0,0	0,0	0,0	≤100
SALIN	‰	0,10	0,04	0,09	0,12	0,12	0,03	0,08	≤ 0,5‰
GEO/REF	UTM	0491076 9831636	0491153 9831682	0490975 9831571	490966 9831649	0490888 9831725	0490782 9831639	0491013 9831835	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P)Fonte: Base de dados: IBGE (2010). Prepared by: Souza, J.F.M. (2020)

Table 03 - Results of physical analysis of groundwater in Area 2

PARÂM.	UND	P8	P9	P10	P11	P12	P13	P14	CONAMA/ FUNASA
pH	–	4,47	4,80	4,28	7,26	7,57	7,42	7,54	6,0 a 9,0
EC	µS/cm	350	400	248	282	274	319	61	10 - 100
TDS	mg/L	228	260	161	183	178	209	39	≤1000
TURB	UNT	12.60	12,0	0,0	0,0	0,0	0,0	0,0	≤ 100
SALIN	‰	0,11	0,13	0,08	0,09	0,09	0,10	0,02	≤ 5‰
GEO/REF	UTM	0491128 9831570	0491174 9831448	0491230 9831643	0491076 9832030	0491021 9832002	0490938 9831917	0490779 9831971	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P)Source: Database: IBGE (2010). Prepared by: Souza, J.F.M. (2020)

Of the 14 water samples analyzed from area 2, the indices obtained for pH range from 4.28 to 7.57, indicating according to CANAMA Resolution 357/2005 that half of the analyzed wells have slightly acidic to alkaline water and the other half have water acidic, as they present values below 6.

Waters with indexes between 6 and 7 meet the potability requirements established by the Resolution, with a pH favorable to water suitable for consumption. On the other hand, waters with values a little above 4, are outside the potability standards, which may be an indication of alteration in their properties and possible contamination, not being indicated for consumption.

Although most of these wells are close to mangrove areas, the difference in their results is related to the care of conservation, construction, and the location where they were installed, since the wells with the best pH, even close to these areas, are at a higher level relative to sea level than wells with low pH.

The results obtained for the electrical conductivity in area 2 ranged from 0 to 400 µS/cm, although in the legislation there is no consensus for the allowed values, but, taking into account the guidelines of FUNASA (2014, p. 20), most of the wells showed rates above those indicated for natural water, ranging from 10 to 100 µS/cm. The wells that presented values above 100 µS/cm would have a certain level of pollution, possibly from domestic effluents and residues from human activities observed at the site.

Although most of the wells presented values above those indicated for natural water, it is necessary to emphasize some conditions that may have influenced these changes, the salinity largely present in this area, the geological formation, and the dry period, which reduces the dilution of salts, in addition to the water temperature, which in this research was not taken into account.

The wells analyzed in this area showed TDS contents, attributing to the environment where they are inserted, close to the mangrove, and the way of construction of these wells, without proper protection to organic elements and erosion processes, in addition to residues by anthropic activities, except for the tubular well, which in theory would be more protected. However, all wells are within the standards indicated for human consumption, ranging from 0 to 260mg/L, well below the maximum allowed limit of 1,000 mg/L.

According to the analyses, only two wells showed a small turbidity index, 8 with – (12.6 UNT) and 9 – (12 UNT). In this case, justified by two circumstances, in one of the wells the water level (N.A.) was remarkably low, to the point of looking at the bottom of the well, so movements in the water provide suspension of particles, causing turbidity levels, although seemingly, the water was transparent.

In the other well, there were palm tree roots, causing the impression of a dark coloration in the water at the bottom of the well, deducing that with the movement to remove water, particles disperse in the water from the roots, increasing the turbidity, although it was also colorless.

There is also the proximity of both wells to the mangrove swamp and the way of construction (mouth higher than ground level), not guaranteeing a certain protection to the elements coming from the environment, in addition, of course, to the sandy characteristics of the soil. The other wells indicated values below 0. However, all of them are within the potability parameters established for class 2 water up to 100 UNT.

The salinity percentages obtained from the analysis of the 14 wells ranged from 0.02%o to 0.13%o, permitting the determination that the groundwater in this area has a fresh characteristic, with a higher incidence in well 8, which is close to the area of mangrove, is of the unlined waterhole, and its upper limit is at ground level.

Even with having proximity to the mangroves and being located in an environment with marine influence, these characteristics did not attribute significant values of salts in the water. Attributing acceptable percentages of salinity to these wells, within the potability standards recommended by Resolution 357/2005, despite the particular characteristics of the environment in which they are inserted.

Physical quality of groundwater in Area 3

Area 3 refers to the districts: Centro (west), Mangueirão, Campelos, and Novo Apicum, where water samples were collected from 16 wells, 12 of the tubular type and 4 waterholes (Figure 5). The places are well populated and urbanized, in the Center, all the streets are paved, and in the other neighborhoods, only a few are paved, with the exception of the Campelos neighborhood where the public roads are made of laterite (slate) or sand.

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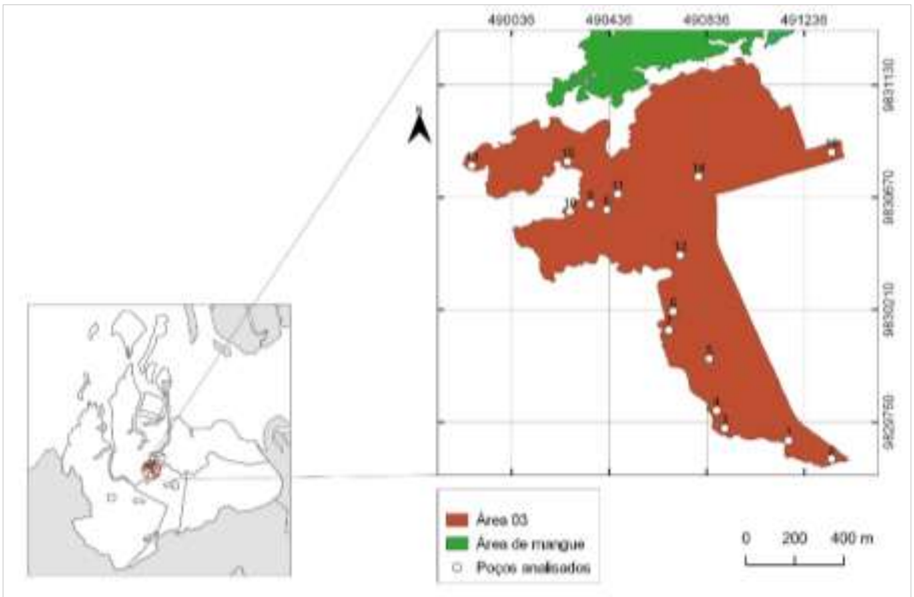
Figure 5 - Location map of the analyzed wells in Area 3 - Apicum-Açu



Source: Database: IBGE (2010). Prepared by: Souza, J.F.M. (2020)

The buildings are practically all masonry, there is a large commercial flow (shops, shops, pharmacy, fruit store…), urban facilities (schools, hospital, health center, police station, radio…). Except for the Center, where the vegetation cover is very reduced due to urbanization, in the other neighborhoods, there is still a reasonable afforestation, with the presence of rivers or lakes, as in Mangueirão and Novo Apicum.

Contact with the mangroves in conditions of greater proximity is established by the northern and northwest portions of the Centro, Mangueirão, and Campelos districts. As in the other 3 areas, the predominant soil is Latosol, with the occurrence of Gleissolo and Neosol in some specific locations. After proceeding with the analysis of the 16 samples of the water collected, the following results were obtained for each standard, shown in tables 04 and 05.

Table 04 - Results of physical analysis of groundwater in Area 3

PARÂM.	UND	P1	P2	P3	P4	P5	P6	P7	P8	CONAMA/ FUNASA
pH	–	6,21	6,21	6,07	5,87	5,43	4,81	4,55	4,89	6,0 a 9,0
EC	µS/cm	33	55	97	51	112	153	131	507	10 - 100
TDS	mg/L	21	35	63	33	73	99	85	330	≤1000
TURB	UNT	0	0	103	0	0	0	0	0	≤ 100
SALIN	‰	0,01	0,02	0,03	0,02	0,04	0,05	0,04	0,21	≤ 5‰
GEO/REF.	UTM	491171 9829675	491347 9829600	490909 9829725	490876 9829798	490845 9830010	490698 9830204	490680 9830127	490427 9830620	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P). Prepared by: Souza, J.F.M. (2020)

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Table 05 - Results of physical analysis of groundwater in Area 3

PARÂM.	UND	P9	P10	P11	P12	P13	P14	P15	P16	CONAMA/ FUNASA
pH	–	4,63	5,14	4,43	4,86	4,24	4,85	5,04	5,23	6,0 a 9,0
EC	µS/cm	198	147	86	42	57	147	70	484	10 - 100
TDS	mg/L	128	95	56	27	37	96	45	317	≤1000
TURB	UNT	0	0	0	0	0	0	0	0	≤ 100
SALIN	‰	0,06	0,05	0,03	0,01	0,02	0,05	0,02	0,16	≤ 5‰
GEO/REF.	UMT	490359 9830643	490275 9830613	490471 9830684	490727 9830434	489873 9830801	490802 9830756	490265 9830817	491347 9830856	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P)µS/cm); Parts per thousand (%o); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P)
Prepared by: Souza, J.F.M. (2020)

In relation to pH, the results of the analysis indicate values that ranged from 4.24 to 6.21, demonstrating that only 3 of these wells are within the established potability standards and most of them have water classified as acidic, as they are below the minimum indicated. for human consumption which is 6.

The wells with the best pH are located close to water bodies and shallow areas, in a place that is still reasonably wooded, and are of the tubular type. The one that indicated the lowest pH is of the cacimba type, situated in a sandy environment, characteristics that possibly contribute to better or worse water quality.

Of the 16 samples analyzed, half are within the conductivity limit established by the FUNASA report (2014) for natural waters, which is 100µS/cm, classifying them as suitable for human consumption. However, 8 wells present indexes above the allowed, indicating possible contamination of the water and concentration of salts, coming from domestic effluents, since they are in a residential area, with great urbanization.

Stand out wells 8 and 16 with the greatest changes to EC, associated with some relevant factors for this result, beyond those already mentioned in the previous paragraph, they are located in an area with little vegetation and bare soil, favoring deposition of particles transported by the winds, in addition to the problem of irregular disposal of solid waste, which with the rains can be carried to the lowest places where they are installed.

According to Graph 11, even with changes with higher TDS indices in wells 8 and 16, all are well below the limit established by Resolution 357/2005, which is 1000 mg/L, indicating that although there are solids dissolved in the water, are not so expressive values that could change its quality or physical structure, in relation to this parameter under analysis. A characteristic that possibly contributes is the fact that most of these wells are of the tubular type, assuming that they would be more protected from exogenous circumstances.

Concerning samples 8 and 16, which indicated higher values, they are associated with the characteristics of the environment where they are inserted, as mentioned above, in addition to the fact that well 16 is close to a temporary river in the process of silting, polluted by the disposal of domestic effluents, which in rainy periods increase their volume of water, flooding nearby areas.

In relation to turbidity, almost all samples indicated negative values, considering them as 0, as they presented values irrelevant to the research, except well 3, which presented a value of 103UNT, being slightly above the potability index established by CONAMA Resolution 357, This result is associated with its own characteristics and the place where it is installed.

The well is of the cacimba type, which is even coated with brick, the material itself in contact with water can release particles, in addition, there is no protection at the top, being subject to fragments transported by the wind. It is located in a sandy area, with little vegetation and close to an unpaved public road, characteristics that can contribute to turbidity.

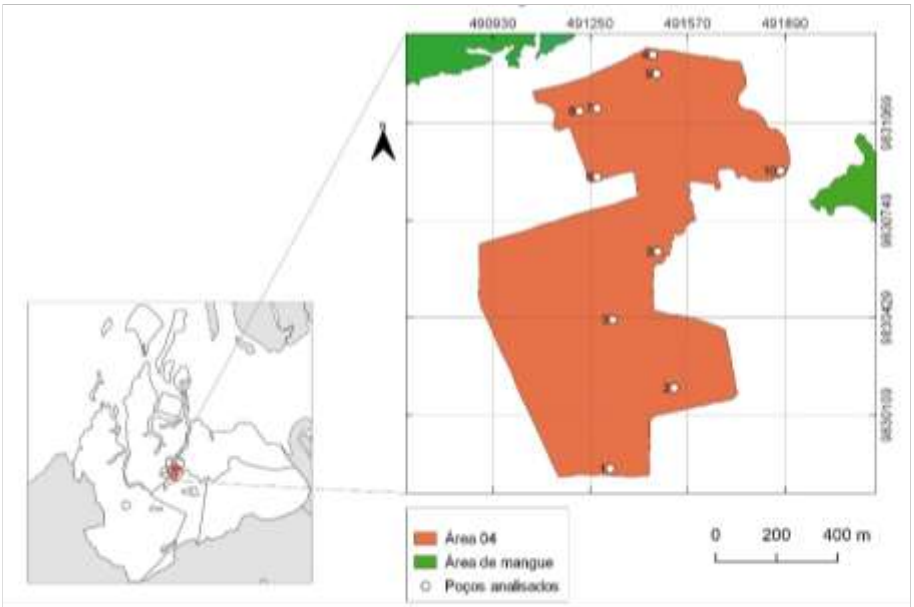
All wells in area 3 indicated acceptable percentages of salinity for water suitable for human consumption, as shown in graph 12, with variations from 0.01%o to 0.21%o, making it possible to classify them as fresh water, as no sample exceeded the maximum value allowed by Resolution 357/05, which is 0.5%. The highest indices are recorded in wells 8 and 16, these being the ones that showed changes in all parameters, without a doubt the conditions of these, already mentioned above, contribute to the degree of salinity recorded.

One of the reasons why the wells in this area do not show great changes in salinity, even in a municipality with marine influences, where some neighborhoods establish contact with the mangroves, is their location, as they are installed in an area far from these areas, so even with the contribution of these elements, they do not change the levels of salts present.

Physical quality of groundwater in Area 4

Area 4 is related to the Nambu neighborhood and a small strip of the eastern portion of Novo Apicum, in addition to the places popularly known as Portelinha and Santo Antônio neighborhoods, although the Municipal Legislation still considers them an integral part of Nambu, where they are inserted. In these places, water samples were collected from 10 wells, 7 of the cacimba type and 3 of the tubular ones. (Figure 6).

Figure 6 - Location map of the analyzed wells in Area 4 - Apicum-Açu



Source: Database: IBGE (2010). Prepared by: Souza, J.F.M. (2020)

Nambu is the most recently inhabited neighborhood, with housing development in recent years, largely due to the beach population that migrated to the municipality's headquarters, occupying areas hitherto uninhabited in this place, as well as Morro, located in the Tabatinga neighborhood.

The characteristics of this area are mostly masonry buildings, small shops, some streets with asphalt paving, and urban equipment (school), the contact with the mangrove region is made by the eastern and northwest portions, however a little distant from the inhabited area. After analyzing the water from the wells in the area, the following results were obtained. (Tables 06 and 07).

Table 06 - Results of the Physical Analysis of Groundwater in Area 4

PARÂM.	UND	P1	P2	P3	P4	P5	CONAMA/ FUNASA
pH	–	4,23	7,46	7,60	7,66	7,77	6,0 a 9,0
EC	μS/cm	89	34	133	120	224	10 - 100
TDS	mg/L	57	22	86	78	145	≤1000
TURB	UNT	134	247	0	0	0	≤100
SALIN	‰	0,03	0,01	0,04	0,04	0,07	≤ 0,5‰
GEO/REF.	UTM	0491316 9829932	0491526 9830197	0491324 9830423	0491456 9831294	0491472 9830646	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (µS/cm); Parts per thousand (‰); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P).
Prepared by: Souza, J.F.M. (2020)

Table 07 - Results of the Physical Analysis of Groundwater in Area 4

PARÂM.	UND	P6	P7	P8	P9	P10	CONAMA/ FUNASA
pH	–	7,69	7,72	7,81	7,88	7,92	6,0 a 9,0
EC	μS/cm	172	192	39	33	254	10 - 100
TDS	mg/L	112	124	22	21	165	≤1000
TURB	UNT	0	135	197	0	0	≤100
SALIN	‰	0,06	0,06	0,01	0,01	0,08	≤ 0,5‰
GEO/REF.	UTM	0491273 9830892	0491273 9831118	0491215 9831108	0491468 9831231	0491875 9830912	–

Note: Hydrogenonic Potential (pH); Electrical Conductivity (EC); Total Dissolved Solids (TDS); Turbidity (TURB); Salinity (SALIN); Milligram per liter (mg/L); Microsiemens per centimeter (μS/cm); Parts per thousand (‰); Georeferences (Geo/Ref); Nephelometric Turbidity Units (UNT); Well (P).
Prepared by: Souza, J.F.M. (2020)

Of the 10 water samples analyzed, 9 are within the legal parameters of pH, classifying them as neutral to slightly alkaline, as they presented values a little above 7. These results, which are possibly related to the predominant soil type in this area, being much more clayey than sandy, favoring better filtering of impurities from the environment, unlike the other researched areas, with the presence of vegetation and proximity to water bodies.

Only well 1 had a lower pH value, indicating that its water is acidic, possibly due to the location where it is installed, a deforested area and close to a lake polluted by the deposition of solid waste by the local population, which in the rainy season tends to increase its water level, flooding nearby areas and the floods carry the discarded materials in inappropriate places, such as domestic effluents, and deposit them in lower areas, where the wells are usually installed.

The wells that have water with a higher pH are of the cacimba type, some coated with cement, installed in wooded areas, such as the one that indicated 7.92 located in the middle of the vegetation, close to a preserved river, without so much human interference, being inserted in a soil possibly of the gleissolo type, characteristics that contribute to the positive results in relation to the pH of these samples.

Regarding electrical conductivity, only 4 wells showed values below 100 μS/cm, typical of natural waters conducive to human consumption, the remaining 6 wells indicated values slightly above this index, suggesting that there may possibly be a small degree of contamination or concentration of salts a little out of the ordinary.

The highest EC indices recorded in wells 5, 7, and 10 are associated with their characteristics and the places where they are inserted, with 1 tubular located near a river that has been silted up, with deposition of solid waste and 2 wells that, although lined with brick, have no protection at the top, being then subject to particles transported by the wind, contributing to the concentration of salts in the water and a reasonable change in conductivity.

The values indicated for TDS in the water samples from the 10 wells were not so altered, as can be seen in graph 15, being well below the limit indicated by the water regulatory bodies, indicating that although there are dissolved solid constituents, these changes are not so forthright to the point of modifying the physical characteristics and compromising the quality of the water referring to this parameter.

The greatest changes in TDS were recorded in the same wells that indicated higher rates in the previous standard, with a correlation between both, as they refer to salts and solids dissolved in the water, so these results, even within the normal range, are related to the characteristics and situations of these wells – proximity to a degraded river and subject to deposition of particles transported by the wind, as it does not have protection at the top.

The indices for Turbidity showed abnormality in only 4 wells of the 10 samples analyzed, being 1 (134UNT), 2 (247UNT), 7 (135UNT), and 8 (197UNT) all with values slightly above those indicated by resolution 357/2005. The others showed negative values, considering them as 0, although some of them have similar characteristics, so it is considered that the suspended solids in most of the wells are of very low levels.

The 4 wells that showed values above the indicated for turbidity, have similar characteristics, are of the cacimba type, without protection at the top - subject to deposition of particles transported by the wind, installed close to sandy or laterite streets, and even those that are coated with cement, release particles upon contact with water.

The salinity percentages resulting from the 10 analyzes are very low for all the wells, none of which approached the maximum limit allowed for water suitable for human consumption, which is 0.5%, making it possible to classify all of this area as fresh water, indicated by the consumption. According to residents, 9 of these wells are used for this purpose, in addition to other activities.

One of the reasons why the salinity percentages of these wells have shown very low values compared to other areas is the greater distance between these wells and the mangrove regions. Even with some marine influence, due to the local characteristics, the salinity levels are low, not altering the water quality in relation to this parameter due to this peculiarity of the environment.

Anthropogenic factors acting on groundwater quality

In general, in all the areas surveyed, one of the major factors that are contributing to certain changes in the physical properties of the groundwater in the municipality's headquarters is the environmental degradation related to deforestation, greatly intensified by the urbanization process, realizing that the most deforested areas are usually the ones with the greatest changes in groundwater quality.

Another factor of great impact on the quality of these waters is the issue of solid and liquid waste, irregularly discarded – on the streets, in water bodies, close to wells, and mangrove areas, although there is a collection service offered by the government. public, which does not serve all neighborhoods in the same proportion. During the rainy season, these solid residues are carried to lower areas, and even into the wells, in the case of cacimba-type wells, without protection above ground level, being more susceptible to pollution.

It was also noticed that there is no control by the Public Power in the drilling of wells, with the proper granting of a concession, as provided for in the legislation, leaving it at the discretion of the population in the face of their water demands, to install their wells, in any location and from the convenient way, not taking into account the peculiarities of the environment in which it is inserted. This was very evident from the location of some wells, as they were close to or within the coastal plain.

In any case, these wells are installed in an environment where it is easier to obtain water, however, due to the lack of guidance from government agencies and responsible bodies, and even from the knowledge of their owners, one may be consuming water outside the standards established, which certainly in the short or long term, will bring certain health problems related to water, as is the case of well 8 in area 1, which its users possibly have or will have kidney, gastric, or hypertension problems, largely due to the brackish water they are consuming.

There are many problems identified in the field that are contributing to changes in the potability of groundwater in the municipality, from the deposition of solid waste in any location - close to a water source, to the lack of information and guidance on how and where these wells can be used. be pierced. There is no control, being at the discretion of the population according to their needs.

This makes it then necessary for a greater responsibility on the part of the public authorities to put into practice what the municipal laws establish about the preservation and supply of drinking water to the population, because although it is a coastal municipality, where the marine influence is constant, they are not natural factors are the biggest contributors to certain potability changes, but the conditions and situations of the wells.

To this end, it is necessary that the public authorities carry out periodic analyzes of the artesian wells that distribute water - as provided for by municipal law, and disseminate the results so that everyone can become aware of the potability conditions of the water they are consuming and adopt the necessary measures that are necessary for healthier and more suitable water for consumption.

If these periodic analyzes took place as provided for in Municipal Legislation, it would be possible to determine the real physical, chemical, and bacteriological conditions of all the analyzed wells, since most of them are close to public water distribution stations, and many related health problems to water consumption could be avoided.

However, there is no control of potability either by the Public Power - even though there are laws that guarantee this right to the population or to the owners of wells - in many cases due to a lack of conditions and information that such care is essential for a quality water that meets potability standards.

Making a general analysis of all the results obtained in the four researched areas, the best indicators of potability are the waters of area 4 - Nambu neighborhood, for some reasons peculiar to the place, vegetation cover is still reasonably present and the predominance of a more fertile clay soil, being more effective in filtration, retaining impurities, and protecting the groundwater.

The worst potability indicators are from the wells in area 1 - Tabatinga neighborhood, which obtained results below or above those indicated by Organs regulatory agencies, as it is a drier area, with few trees and predominance of more sandy soil, being less effective in filtration, allowing exogenous substances to reach groundwater more easily.

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CONCLUSION

The results obtained with the physical analysis of groundwater in the urban area of the municipality of Apicum-Açu - MA were of great importance, both in terms of learning acquired and in obtaining data on the real physical conditions of the water being used by the population, making it possible to identify which areas have a better potability condition and which environmental or structural factors are contributing to this.

Given the results, it is concluded that the groundwater of the municipality's headquarters is of the fresh type in all neighborhoods, even though there are records of changes in salinity in the areas closest to the mangrove region, but nothing as relevant as was assumed, because it was dealing with an environment with marine influence.

Except in one of the wells in area 1, classified as slightly brackish water, due to the salinity level, it is practically above the permitted level, as it is located very close to the mangrove, in a coastal plain, being susceptible to environmental pollution, as well as the entrance of the seawater in the well, very frequent at high tides. In addition to the saline intrusion problem, which is certainly occurring at this location, the water is brackish even in periods when the tide does not reach the well.

Regarding the pH, it is possible to determine that the groundwater is slightly acidic to basic, with reservations for some wells that indicated values from 4 to 5, requiring a little more attention and care, since ingesting water with a certain degree of acidity in the long term can cause health problems. The wells with better pH results are also highlighted, due to the more clayey pedology, suggesting care so that other factors do not minimize this quality.

With the indices obtained for each parameter: pH, EC, TDS, Turbidity, and Salinity, which are directly associated with the environment in which these wells are located, how they are built and maintained, it is considered that the water in most of the wells is relatively specific to human consumption, in relation only to the physical aspects, since the biggest changes are punctual for some areas.

However, it should be noted that no chemical or bacteriological analysis of the water was carried out, although there are parameters in the research that are chemical, such as pH. Therefore, it is not possible to ensure with complete clarity that the water in the wells is free from pathological microorganisms or chemical contamination. But the physical results are already an indication of the potability of most of these wells.

In view of the results, it is suggested as a suggestion to improve the potability of underground water in the municipality, greater control, and care, whether by the government or the residents, in the drilling and conservation of wells, taking into account the proximity to the marine environment. , the location concerning septic or black forces - which can cause water contamination, if they are in the same flow as the groundwater.

It is recommended the construction of wells with coating and protection above the ground level of at least 1 meter, preventing accidents and certain contamination, resulting from both natural events and anthropic activities. In addition to the periodic maintenance and cleaning of the tubular wells and waterholes, thus reducing the concentration of dirt on the slopes and the accumulation of salts and suspended solids.

It is also suggested that the population demands from the public power the implementation of the environmental and water potability laws. However, responsibility for oneself, with others, and with the environment is necessary, because, if in fact, the public power leaves much to be desired, not offering what the laws provide, the population also does its part, discards solid waste in any form and any location, drills the wells without proper care and protection, deforests and burns, without realizing that all this is directly interfering with the quality of the water that is consumed.

It is necessary to have quality water that complies with potability standards, a joint action, the environment with its peculiarities, Public Power exercising and applying legislation authentically and responsibly and a population sensitized and committed to nature because it offers what is offered to you.

Finally, it is hoped that this work can produce even more knowledge and sensitize the population to better care with the subterranean water, raising more attention and concern with groundwater, for greater preservation and better health conditions for the population of Apicum-Açu, be it current and future.

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