Princípios de Química

Carmen Lúcia Voigt
(Organizadora)

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APRESENTAÇÃO

Química é a ciência que estuda a estrutura das substâncias, a composição e as propriedades das diferentes matérias, suas transformações e variações de energia. A Química conquistou um lugar central e essencial em todos os assuntos do conhecimento humano, estando interligada com outras ciências como a Biologia, Ciências Ambientais, Física, Medicina e Ciências da Saúde.

Pesquisas na área da Química continuam evoluindo cada dia, sendo benéficas devido maior conscientização de como usar os conhecimentos químicos em prol da qualidade de vida e do desenvolvimento da sociedade; prezando pelo meio ambiente, surgindo assim processos e novas tecnologias com menor agressão e impacto.

Muitas são as fontes degradadoras da natureza, porém os resíduos químicos são considerados os mais agressivos. Ao longo dos anos inúmeros tipos de contaminantes foram lançados no meio ambiente, causando contaminação e poluição em diversos tipos de compartimentos ambientais como solos, rios e mares. O avanço e crescimento industrial no mundo é uma das principais causas da poluição excessiva e liberação de resíduos químicos.

Devido estudos na área da Química é possível realizar remoção de poluentes por diversos processos e o desenvolvimento de técnicas e materiais é abordado neste volume, que trata de processos como adsorção para retirada de contaminantes da natureza. Além destes processos, este volume também trata de novos materiais para aplicação em substituição aos polímeros convencionais, como os biopolímeros, produzidos a partir de matérias-primas de fontes renováveis, ou seja, possuem um ciclo de vida mais curto comparado com fontes fósseis como o petróleo o qual leva milhares de anos para se formar.

Fatores ambientais e sócio-econômicos estão relacionados ao crescente interesse por novas estratégias que buscam alternativas aos produtos e processos convencionais. Neste enfoque, os trabalhos selecionados para este volume oportunizam reflexão e conhecimento na área da Química, abrangendo aspectos favoráveis para ciência, tecnologia, sociedade e meio ambiente.

Boa leitura.

Carmen Lúcia Voigt

SUMÁRIO

CAPÍTULO 24

MANAGEMENT AND CLASSIFICATION OF PHYSICOCHEMICAL AND MICROBIOLOGICAL PARAMETERS OF GROUNDWATER

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ABSTRACT: This pioneer study aims at management the groundwater quality consumed by a segment of the rural population in the state of Paraná, Brazil, in addition to identify the physicochemical and microbiological parameters. The water quality was monitored from nine months. Three sites distributed throughout the rural environment were sampled. The water quality was evaluated based on the determination of 16 physicochemical and microbiological parameters. According to these parameters and the Decree Nº.2.914 of December 12th, 2011 of the Ministry of Health (2006), and also the Decree Nº. 518 of March 25th, 2004, it was possible to classify the water quality for use in agriculture and household use. Microbiological analyzes of the presence and absence of microorganisms were carried out, as well as the pH physicochemical analysis (hydrogenation potential), electrical conductivity, turbidity, dissolved oxygen, fluorine, nitrites, nitrates, phosphates, acidity, alkalinity, chloride, hardness, potassium, dissolved and total solids. According to the results, all the parameters were in accordance with the standards established by the Ministry of Health, except for the presence of phosphate and conductivity. The findings showed the importance of monitoring water intended for consumption and use in agriculture, as well as its quality and supply that may affect the health and well-being of the population.

KEYWORDS: classification, groundwater, monitoring, water quality.

RESUMO: Este estudo pioneiro teve como objetivo avaliar a qualidade da água subterrânea consumida por um segmento da população rural no estado do Paraná, Brasil e identificação dos parâmetros físicos, químicos e microbiológicos. A qualidade da água foi monitorada durante o período de novembro de 2012 a julho de 2013. Três pontos distribuídos por todo o ambiente

rural foram amostrados para um total de 15 amostras. A qualidade da água foi avaliada com base na determinação de 16 parâmetros físico-químicos e microbiológicos. De acordo com esses parâmetros e de acordo com acordo com o Decreto 2.914, de 12 de dezembro de 2011 o Ministério da Saúde (2006) e também o Decreto nº 518 de 25 de março de 2004 foi possível classificar a qualidade da água. Foram realizadas análises microbiológicas de presença e ausência de microrganismos e físico-química de pH (potencial hidrogeniônico), condutividade elétrica, turbidez, oxigênio dissolvido, flúor, nitritos, nitratos, fosfatos, acidez, alcalinidade, cloreto, dureza, potássio, sólidos dissolvidos e totais. De acordo com os resultados, todos os parâmetros estavam dentro dos padrões estabelecidos pelo Ministério da Saúde, com exceção da presença de fosfato e condutividade. Os resultados mostraram a importância do monitoramento da água destinada ao consumo bem como a qualidade e fornecimento afetar a saúde e o bem-estar da população.
PALAVRAS-CHAVE: classificação, monitoramento, poço artesiano, qualidade da água.

1 I INTRODUCTION

Water is the most abundant chemical component of the planet Earth, and it is of fundamental importance for all forms of life, however, only about 2% is in safe condition for consumption, that is, fresh and potable water (JIN et al., 2016).

Managing the diffuse pollution in drainage basins is an important issue to meet water quality standards[1], since according to the Decree Nº. 518 of the Ministry of Health potable water is that intended for human consumption, whose microbiological, physical, chemical and radioactive parameters meet drinking parameters and do not put health at risk (BRASIL, 2004).

With the formation of urban and industrial areas, the water demand for both domestic and industrial consumption has been increasing; however, the anthropogenic emissions of nutrients such as nitrogen and potassium have been quantitatively more than the natural emissions from soil leaching and atmospheric deposition, which changes the composition of water bodies, introducing eutrophication and contamination of the biota (BRICKER et al.,1999).

Groundwater is an essential natural resource for life and the integrity of ecosystems; it has been used to serve a wide range of publics, such as industries, municipalities, domestic water supply and irrigation (PALMIER, 2010; CHANG et al., 2017). The artesian wells represent more than 95% of the exploitable fresh water reserves in the world, and more than half of the world's population depends on groundwater for their survival, especially Brazil, where the groundwater reserve is significant (CHANG et al., 2017).

In the rural environment, water contamination is mainly related to agricultural activities, which have different levels of impacts to the environment according to the technology adopted (NARVAEZ et al., 2017).

The intensive use of the soil for agricultural purposes has raised concern due to the high degree of pollution caused to the environment, especially with respect to the contamination of water resources through agricultural materials such as pesticides and nutrients (RIBEIRO et al., 2013; XUE et al., 2017). Pollution through pesticides may also be related to the irregularity of rainfall and the low quality of available water resources, whereas in urban areas this problem is mainly associated with the rapid and disorderly growth of the world population (FREITAS and PORTO, 2006).

The lack of water quality has historically been associated with development models based on the irrational use of natural resources in Brazil. Therefore, there was a water crisis in the late twentieth century, which motivated the search for solutions concerning the rational use of natural resources. Under these circumstances, the environmental management of water has shown great importance in the public policies of several countries, including Brazil (XUE et al., 2017; MAGALHAES and NETTO, 2003). In addition, some historical facts have also shown that some of the most widespread epidemics that have already afflicted human populations have their origins in water distribution systems.

1.1 Water Treatment Processes

Water resources work as a direct and indirect vehicle for the propagation of diseases. Therefore, their quality deserves attention and constant monitoring. The combination of natural and anthropogenic factors directly interferes with water characteristics, assigning them a specific character in each place. Thus, these interventions change the physicochemical and microbiological properties, compromising the potability when it is related to the water intended for public supply (LUIZ et al., 2012).

According to the Decree N^{o}. 2.914 of December 12th, 2011, there are parameters that must be followed to verify the potability of water resources, and these have maximum values allowed according to the type of source. Some considerations on the parameters addressed in this study are shown as it follows. (BRASIL, 2011; BRASIL, 2006).

Initially, considering water turbidity, which is one of the most relevant parameters regarding the quality and visual appearance for commercialization, that is, measuring the difficulty that a light beam crosses the sample, comparing the scattering of light when passing through the sample with another, with the same intensity that it passes through a pattern, is caused by solid materials suspended in water resources, such as clays from soil leaching, colloids resulting from the action of detergents, organic matter in suspension, among others (GREGORY, 1998).

There are several processes for removing the turbidity from water, such as filtration, coagulation/flocculation, decantation and the action of oxidants. The use of coagulants or flocculants for removing the turbidity, color and organic matter, is widely used in Brazil and has great efficiency in the treatment of surface water for producing drinking water. As an example, the aluminum sulfate is widely used in water treatment because of its low cost, easy handling and optimum efficiency) (HUANG et al., 2000; LOCK et al., 2016). Turbidity sensors can provide constant monitoring for the identification of resurgence groundwater areas and in the treatment of water supply as well (LOCK et al., 2016).

The presence of ions dissolved in an aqueous medium, generates the electrical conductivity of the water, caused by the presence of dissolved substances, mainly salts, coming from the contact of the water medium with soils, sediments and rocks, which dissociate in anions and cations, translate the water capacity to conduct the electric current, characterizing the presence of minerals that, when following the limits established by resolutions, such as CONAMA 357 and updated by CONAMA 430, for example, may guarantee water of excellent quality (CONAMA, 2011; CONAMA, 2005; LIU et al., 2018; MIRLEAN et al., 2002; MIRLEAN et al., 2005).

The pH value, defined as the hydrogen ion activity, expressed as the negative logarithm of its concentration, determines the acidity or the relative basic character of a medium (GREGORY, 1998; MABILDE et al., 2017). This parameter is fundamental so that the water for consumption has an ideal quality, being dependent on the geological and historic factors of the region; as well as the type of soil in which drainage, climate and geomorphology basins occur, in addition to the geochemical condition, and especially the anthropic activities (NUR et al., 2016).

Dissolved oxygen (DO), in turn, is critical for assessing natural conditions and detecting environmental impacts, such as eutrophication and organic pollution. In cases of eutrophication, for example, the action of men generally intensifies the natural phenomena that accelerate the abnormal enrichment process of water in nutrients, mainly phosphorus and nitrogen, increasing the population of species that may consume oxygen (NUR et al., 2016). Another parameter that deserves attention, that is, the dissolved solids, which encompass all the soluble substances in water, may be influenced by climatic changes, common in prolonged droughts, which contribute to the load of solids in the water resources. This fact is more common in surface waters, subject to intense evaporation processes; on the other hand, the eutrophication processes also contribute to the increase of the load of solids (MABILDE et al., 2017).

The total acidity, which represents the free carbon dioxide content, the presence of mineral acids and salts of strong acids, which by dissociation results in hydrogen ions in the water body, (MIRLEAN et al., 2002; MIRLEAN et al., 2005) may generate corrosion caused by both the carbon dioxide (found in natural water) and the mineral acids (found in industrial effluents). The effect of acidity on water bodies is controlled by the pH value.

The water alkalinity, in turn, which is the ability to neutralize an acid, is mainly characterized by the carbonate and bicarbonate ions and it does not necessarily mean that the pH of the medium must exceed 7, even in groundwater. These ions contribute to the alkalinity of water bodies, unlike the chloride, sulphate and nitrate ions. Alkalinity has no sanitary significance for drinking water, however, at high concentrations may provide the water with a bitter taste (VON SPERLING, 1996; SANTOS et al., 2009).

According to Nur et al. (2016), the phosphate, another parameter seen in this study, in addition to agricultural products, mainly fertilizers and fertilizers, contains a high concentration of phosphorus, which is one of the three main components for the growth of plants, and one of the components used in the composition of household and industrial detergents. In the case of detergents, the inorganic phosphates have the function of neutralizing certain metal ions found in water, such as the calcium and magnesium, reducing the water hardness, and, thus, maintaining the alkaline medium, preventing the dirt from re-fixing in the tissues (SOUZA et al., 2010).

The nitrogen, usually found in wastewater, especially the water of urban origin with considerable levels, influences several forms and states of oxidation. The main forms found in water resources are: organic nitrogen, ammoniacal nitrogen, nitrite and nitrate. According to Hussar et al. (2005), together with phosphorus, they are important nutrients in the photosynthetic processes; the eutrophication is among the main problems caused to the high concentration of these compounds in surface water, but it is essential for the growth of plants in general. Therefore, in order to minimize the impact caused by both, nitrogen and the phosphorus from effluents of compound treatment systems only through anaerobic reactors, such effluents are used to irrigate crops and pasture areas (HUSSAR et al., 2005).

The presence of chloride ion in the water, another parameter, may bring restrictions to the flavor, and, in several cases, the water may be rejected by the consumer, in addition, this ion also has a laxative effect in some cases when it is associated with calcium, magnesium, sodium and potassium. The presence of calcium and magnesium, whose concentrations are normally higher than the ones of other ions found in natural water, may provide the water with hardness (SRINIVASAN and SRINIVAS, 2015).

This is normally expressed as the equivalent number of milligrams per liter of calcium carbonate, and such a characteristic generates difficulty in dissolving soap (foaming) when washing hair, which may be damaged. In industrial activities the problem is more serious when it is associated to thermal processes that generate incrustations in boilers and pipes due to the chemical precipitation of carbonates and hydroxides through the presence of calcium, magnesium and other elements, such as iron, manganese, copper and barium (YOUSEFI et al., 2017).

Alkali metals found in rocks, and in structures of many minerals, such as the potassium, are mainly used in fertilizers, being essential for the growth of plants, which, together with sodium, regulates the water balance in organisms. In urban areas, the sewage has potassium, since most of these elements consumed by the human beings are excreted by urine, which together with nitrogen and phosphorus is a macronutrient found in water resources, favoring the development of the eutrophication process (PROCHNOW and PROCHNOW, 2009). In underground resources the sodium concentration may vary with the depth of the well and reach higher concentrations than in surface water. The removal of these substances is very expensive and it is not common in conventional water supply treatment processes.

The fluoride analysis also deserves attention in groundwater, since such groundwater generally has fluoride compounds in higher concentrations than the surface water, depending on the nature of the rock formation, the rate at which water passes over these rocks beyond its porosity at the local temperature. Therefore, it is important to point out that the excess of fluoride, above 1.40 ppm according to the current legislation, may cause dental fluorosis (HARRISON, 2005).

Detecting microorganisms in water is another important parameter evaluated in this study. The relation between water quality and waterborne diseases has been observed since antiquity, and was only scientifically verified in 1854 by John Snove, who confirmed that the cholera epidemics in London occurred by this means (ALMEIDA et al., 2006). The microorganisms seen in water medium reflect the terrestrial conditions, revealing the effects of domestic, agricultural and industrial practices that lead to the water quality degradation (PELCZAR Jr et al., 1997).

The microbial population that is found in aquatic medium is determined by the physical and chemical conditions that occur in such medium; these conditions widely vary from one place to another. Some factors, such as temperature, precipitation, luminosity, pH, nutrient and the presence of animals influence this population growth. Some species of microorganisms are native in specific ecological areas, whereas others are transient and emerge from human activities, for example, in water that receives domestic sewage with a large amount of organic nutrients; bacteria of the coliform group may be found, such as *Escherichia coli*, indicating, thus, a serious potential risk to health, since it comes from the large intestine of both, men and warm-blooded animals, characterizing fecal contamination (GREENBERG et al., 1992; MARCUS, 1997). This group is defined as Gram-negative bacilli, in the form of facultative aerobic or anaerobic rods, which are non-spore formers, lactose fermenters that form gas in 24-48 hours after incubation in lactosate broth at 35-37°C (ENGSTRÕM et al., 2015). Fecal or heat tolerant coliforms are able to develop and ferment lactose with acid and gas production at a temperature of 44.5°C in 24 hours (CETESB, 1991).

All these parameters were evaluated in this study in order to classify the groundwater of an artesian well and the residual water in Apucarana city – PR. Such parameters are of extreme importance to determine possible risks to both, the public health and the environment, in addition to show the mutual knowledge by adapting the local technology to the standards established by norms, laws, and resolutions in general.

2 I MATERIALS AND METHODS

Fifteen groundwater samples were collected in Apucarana city, southeast region of the state of Paraná, in a farm where there is no intense agricultural activity, but with a community of approximately 20 people who depend on this source of supply in three sites: at the direct exit of the artesian well (S1) 23º62'55.2''S/51º62'94.0''W and 599m high; from a faucet inside one of the residences that uses the artesian well water (S2) 23º62'54.0''S/51º52'93.9''W and 601m high; and another faucet outside the residence (S3) 23º62'55.1''S/51º52'96.0''W and 601m high.

In order to carry out the physical-chemical parameters, the samples were collected in 500 mL glass vials, after two rinses with the sample itself. They were packed in an ice-containing thermal box and sent to the laboratory of chemistry of UTFPR-campus of Apucarana.

For determining the pH, a properly calibrated Instrutherm pHmetro-2000 was used. For analyzing the Dissolved Oxygen, a selective oxygen electrode was used with a microprocessor system, zero calibration, and fine salinity adjustment (Quimis, Q758P). For conductivity, a benchtop conductivity meter with a standard calibration of 146.6 µS cm^{-1} (MCA-150) was used. The nitrite determination was carried out in accordance with the recommendations of CLESCERI et al. (1989), with spectrophotometer measurements (DR2800 (HACH) at 540 nm) (CLESCERI et al., 1989). These parameters were performed immediately after the collections. For verifying other parameters, such as the fluoride, it was used a benchtop fluorometer (Tecnopon-MS with SPADNS reagent), with a sensitivity of 0.1ppm, microprocessed. For detecting turbidity through diode at specific wavelength, it was used a benchtop turbidimeter (Policontrol- A02000 iR), with certified calibration standards of 0.02, 110 and 1000 NTU. The total alkalinity, acidity and phosphate determination were performed by using the methodology proposed by Silva (1977); and the nitrate determination was carried out according to Horwitz's method (1980) (SILVA and ÁLVARES, 1977; HORWITZ, 1980). These parameters were measured in the maximum time interval of one week after water collection. The chloride analysis[39] and the determination of hardness, total and dissolved solids, (Clesceri, 1989) and potassium were carried out by using a flame photometer (ANALYSER, TKS 910M, microprocessed) with an automatic calibration of zero and automatic selection of the wavelength. These parameters were determined in a maximum of fifteen days after the collection. For the microbiological analyzes, the samples were collected in sterile glass vials of 200 mL, conditioned in an ice-containing thermal box and immediately sent to the laboratory of microbiology of UTFPR – campus of Apucarana.

Before opening the vials, the samples were homogenized and the external area cleaned with 70% alcohol to avoid contamination. The culture medium used was prepared by using the method according to Cetesb, (1991); Brasil, (2005), which is based on the inoculation of volumes of 100mL of the sample into suitable vials containing 50mL of the presumptive medium (sodium lauryl sulfate broth) in triple concentration. The inoculation was performed at 35ºC for 24/48 hours and after the time of 24 hours. It was observed if the acidification of the medium occurred through the change in coloration, from purple to yellow, either with or without gas production, which is considered a positive result for coliforms. Otherwise, the vial was incubated for more than 24 hours. This result was confirmed by transferring an inoculum of the positive presumptive cultures to a bright green lactosate broth and bile at 2%. The production of gas in this medium after 24/48 hours of incubation at 35ºC was the confirmatory result for the total coliforms (multiple tube technique). For determining the thermotolerant coliforms (*Escherichia coli*), a positive presumptive culture inoculum was transferred to the EC medium (HIMEDIA), which was incubated at 44.5°C for 24 hours. The gas production at this temperature was considered to be positive for this subgroup of bacteria.

The rainfall data (figure 1) were obtained with SIMEPAR (Meteorological System of Paraná), for the seasonal verification in the periods in which the samples were collected.

3 I RESULTS AND DISCUSSION

The results obtained for total and thermotolerant coliforms were compared with the parameters determined by the Decree 2.914 of December 12th, 2011 of the Ministry of Health. Table 1 indicates the results of a microbiological analysis (with a series of five test tubes), which was performed at the three sites of collection, but without any type of asepsis when collecting the samples, as a comparison with the samples collected according to the resolution Alpha, (2012), Brasil, (2011) the importance of asepsis in the collection was also seen, and the result of the presumptive test was positive for all the samples.

Sites of collection	Bright green lactosate broth			NMP100mL^{-1}	Reliability Limit of 95% higher/lower
	10mL	1mL	0,1mL		
S1	5	0	0	23	9 – 80
S2	5	5	5	>140	>60 - >360
S3	5	2	2	90	40 – 250

Table 1. Series of the most prospective number (NMP), without any asepsis of the samples collected

S1: direct exit of the artesian well; S2: faucet inside the residence; S3: faucet outside the residence. NMP100mL^{-1}: the most prospective number in 100mL of the sample.

Table 1 shows three groups of tubes, each group containing five tubes. Each tube from the first group of five tubes received 10 mL of the sample with a positive result in the presumptive test. Each tube of the second group of five tubes received 1mL of the sample, and the third group received 0.1mL of the sample. This procedure was carried out for each sample collected from the three sites, where it was possible to observe that all the five tubes of the first group at all the collection sites showed bacterial growth, that is, a positive result, demonstrating the existence of microorganisms.

In the second group, which received only one tenth of the inoculum (1mL), all the five tubes of S2 and only two tubes of S3 showed positive results. In the third group, which received one-hundredth of the inoculum (0.1mL), the result was the same as the previous one. Regarding the thermotolerant coliforms, the tubes of the three groups did not show a positive result.

For the samples performed with the recommended asepsis in all months and at all sites of collection, the result of the presumptive test (lactose broth) was negative.

Drinking water must comply not only with microbiological analyzes, but also with the standard of chemical substances according to the Decree Nº. 2.914 of December 12th, 2011, which means a risk to health. (Brasil, 2011; Brasil, 2006).

Table 2 shows the results obtained compared to the standards established by the Decree Nº. 2914 of 2011, resolution 357 of 2005, whose parameters evaluated for fluorides, chlorides, nitrates and nitrites comply with the standard that is allowed; however this does not occur for the phosphate levels, which may be associated with the use of fertilizers in the region, since the biodegradation process of this nutrient is slow, allowing its permeation to the well (MIRLEAN et al., 2005; DE ASSIS et al., 2017; MARQUES et al., 2017). In relation to human consumption, only an excessively high amount of phosphate may cause some public health problems (SANTOS et al., 2009; NUR et al., 2016). The chloride concentration levels are also low, so the addition of active chlorine in the form of hypochlorite, for example, would be interesting to guarantee the long-term decontamination, as well as the hardness, which is also within the standards stipulated by the same Decree, dispensing attention and not impeding the consumption in relation to this factor.

However, the conductivity, a parameter not mentioned in the Decrees regarding minimum or maximum limits, encompassing all the ionic species of the sample, does not show any variation at the sites sampled, considering the respective deviations, as well as potassium (Table 2).

Parameters Evaluated	Sample sites			Limits
	S1	S2	S3	
Fluoride ($mg\ L^{-1}$)	0,31±0,24	0,29±0,35	0,26±0,31	(1)1,5 $mg\ L^{-1}$
Nitrate ($mg\ L^{-1}$)	5,16±4,2	4,96±2,7	4,90±4,2	(1)10,0 $mg\ L^{-1}$
Nitrite ($mg\ L^{-1}$)	0,010±0,003	0,014±0,01	0,014±0,01	(1)1,0 $mg\ L^{-1}$
Phosphate ($mg\ L^{-1}$)	0,054±0,03	0,058±0,02	0,058±0,02	(2)0,020mg L^{-1}

Chloride (mg L^{-1})	5,07±0,68	4,52±0,96	3,41±0,64	(2)250 mg L^{-1}
Hardness (mg $CaCO_3$ L^{-1})	177,4±24,5	185,7±37,7	193,9±49,7	(2)500 mg L^{-1}
Conductivity (μS cm^{-1})	256,6±27,31	259,4±21,85	260,7±20,64	(3) *
Potassium (mg $200mL^{-1}$)	0,80±0,55	0,67±0,35	0,70±0,45	(2) 175

Table 2. Results of the physicochemical analyses carried out in the three sample sites during the period evaluated

(1) Standard established by the Decree 2.914 of December 12th, 2011. (2) Standard established by the Resolution 357 of 2005. (3) There is no specific reference. The results are expressed as mean ± standard deviation.

Table 3 shows the results obtained of the other parameters evaluated, with less impact on water quality, but not less important. In relation to the total dissolved solids, it is observed that in all the sites analyzed the values are within the established standards; and, considering the deviation, there is no significant difference among the sites, observing that the presence of these solids may cause stains in objects, incrustations in plumbing and taps, in addition to make the use detergents and soaps difficult. This may be extended to the pH values, which within the established limits, offers a pleasant taste and a better protection to the metallic systems in contact with water, minimizing corrosion problems.

Parameters Evaluated	Sample sites S1	S2	S3	Limits
pH	7,28±0,28	7,29±0,27	7,47±0,36	(1) 6,0 a 9,0
Total dissolved solids (mg L^{-1})	391,2±37,2	296±76,9	312,6±97,0	(2)1000 mg L^{-1}
Turbidity (NTU)	0,02±0,00	0,02±0,00	0,02±0,00	(3) 5,0 NTU
Alkalinity (mg L^{-1})	146,7±3,36	145,7±1,92	144,9±1,71	(4)*
Acidity (mg L^{-1})	26,2±5,14	22,2±5,18	21,3±7,21	(2)250 mg L^{-1}
Dissolved oxigen (mg $CaCO_3$ L^{-1})	8,3±0,6	8,3±0,8	8,7±0,8	(2) 5,0 mg L^{-1} (min)

Table 3. Results of the physicochemical analyses carried out in the three sample sites during the period evaluted

[(1)] Standard established by the Decree 2.914 of December 12^{th}, 2011. [(2)] Standard established by Resolution 357 of 2005. [(3)] NTU: Nephelometric Turbidity Unit. [(4)] There is no specific reference. The results are expressed as mean ± standard deviation. The means are of five replicates.

For turbidity (Table 3), the results indicate that the samples were extremely clear and free of suspended material. It is important to see that the water in the well does not receive any preliminary treatment. This fact may be related to the depth of the well (60m) where a higher percolation is possible and, consequently, a higher natural filtration, but with a higher amount of dissolved ions as confirmed by the conductivity (Table 2).

In Table 3 it is also possible to observe that the alkalinity is in agreement with de Angelis et al., (1998), because there is no norm that determines the maximum amount allowed, where, according to the author, most natural water shows alkalinity values from 30 to 500 mg L^{-1} of $CaCO_3$. A good average concentration of dissolved oxygen is also seen, and although the level of potassium is very low, considering the current legislation, there is water of good acceptance for human health (DE ANGELIS et al., 1998; NUR et al., 2016).

3.2 Rainfall Data

During the period studying the samples (from November, 2012 to July, 2013), according to SIMEPAR (Meteorological System of Paraná), 2012/2013, there was a huge seasonal variation when collecting (figure 1); in July (2013) the climate was very dry, with a below-average precipitation index; in February and June (2013), on the other hand, it was extremely rainy, and in May (2013) and November (2012) the precipitation index was within the average. This is the reason why the standard deviation of most analyzes was not considered satisfactory (MAGALHAES JR and NETTO, 2003; MARQUES et al., 2017).

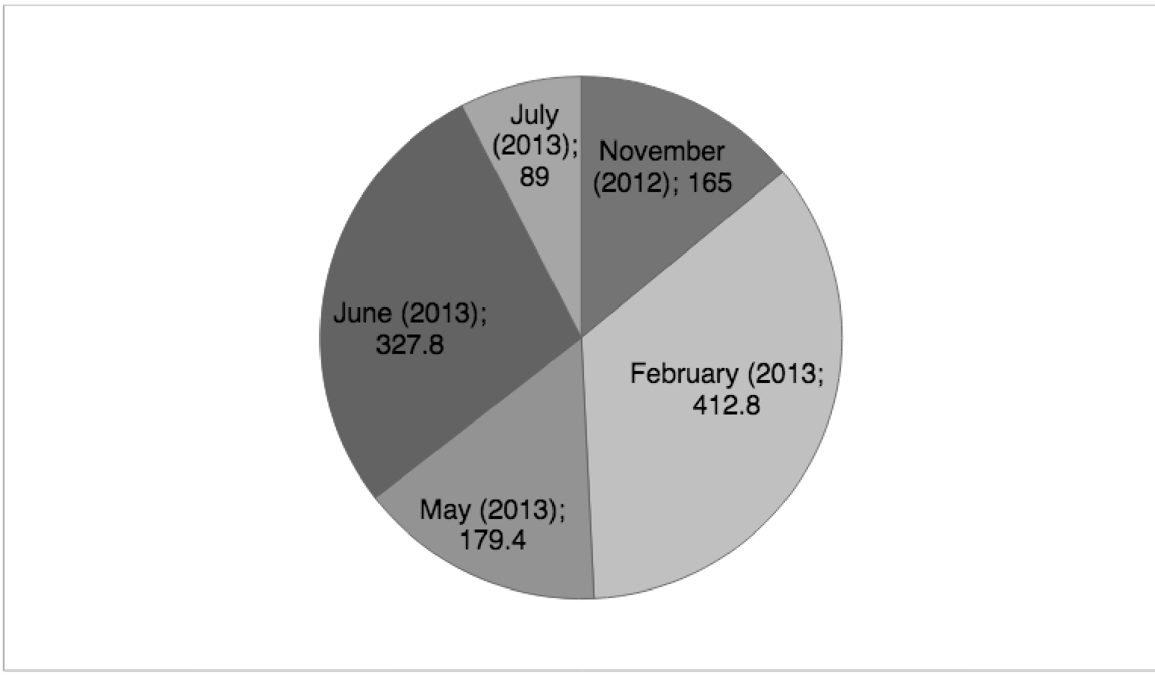

Figure 1. Rainfall data (mm) of Apucarana city – PR. Source: Self-published, 2017

4 I CONCLUSIONS

In general, the groundwater quality of the artesian well under study is considered adequate for human consumption. The concern and need to determine both physicochemical and microbiological parameters are important, since due to the industrial growth and the proliferation of new sources of groundwater pollution, currently monitoring the quality of these water resources is becoming increasingly necessary.

During the period studied, the microbiological characteristics of the groundwater showed to be potable when compared to the Decree Nº. 275 of September 2005 (BRASIL, 2005). Through the analysis in the presence and absence of microorganisms, it was possible to see that both the artesian well and other collecting sites did not show any microbiological contaminant.

On the other hand, the monitoring of physicochemical parameters shows that the artesian well water complies with the Decree Nº. 2.914 of December 12th, 2011, in addition to other resolutions and authors, except for the phosphate, which is an inorganic contaminant that was out of the pre-established limits, probably due to the local soil composition.

The high deviations may be explained by the seasonal variations in the study period due to the wide rainfall amplitude, according to SIMEPAR data (2012/2013). On the other hand, considering all the results obtained in this study, it is possible to state that the water in the well in question is in excellent condition for human consumption, without previous treatment.

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