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Proposal groundwater quality index for irrigation in rural land, Eastern Amazon, Brazil

The research proposes the implementation of the Water Quality Index for Irrigation from an underground source, in order to assess the quality of the Apéu River microbasin in rural areas. 88 water samples were collected from September 2018 to August 2019 in a rural area of the municipality of Castanhal-PA. To assess water quality, SAR and EC were used with a reference value corresponding to 0.7 dS m-1. The physicochemical variables evaluated were pH, DO, TDS, EC, SAL, and the metals Al, Fe, Ba, K, Ca, Mg, Na, Zn. Furthermore, the WQI for irrigation was determined through an equation that relates the standardized value of the variable analyzed with the number of characteristics assessed, where the proposed method of IWQI allowed to satisfactorily classifying the quality of water for irrigation. Although different waters qualities was observed, the predominance was of excellent quality.

Keywords: Agriculture; Heavy metals; Salinity; Water quality.

Proposição do índice de qualidade da água subterrânea Para irrigação em ambiente rural, Amazônia Oriental, Brasil

A pesquisa propõe à implementação do Índice de Qualidade da Água para Irrigação a partir de uma fonte subterrânea, a fim de avaliar a qualidade da microbacia do Rio Apéu em área rural. Coletou-se 88 amostras de água de Set/2018 a Agost/2019 em área rural do município de Castanhal-PA. Para avaliar a qualidade da água utilizou-se a RAS e a CE com valor de referência correspondente a 0,7 dS m-1. As variáveis físico-químicas analisadas foram: pH, OD, STD, CE, SAL, e metais Al, Fe, Ba, K, Ca, Mg, Na, Zn. No mais, determinou-se o IQA para irrigação por meio de uma equação que relaciona o valor padronizado da variável analisada com o número de características avaliadas, onde o método proposto de IQAI permitiu classificar satisfatoriamente a qualidade da água para irrigação. Apesar de terem sido observadas águas de diferentes qualidades, a predominância foi de excelente qualidade.

Palavras-chave: Agricultura; Metais pesados; Qualidade da água; Salinidade.

Topic: **Engenharia Ambiental**

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INTRODUCTION

The importance of studying the quality of groundwater for all biomes in Brazil contributes to solving problems involving the alteration of quality by human actions, under conditions to be used in irrigation. Therefore, proposing to monitor its qualitative variables, such as salt concentration, becomes a necessary tool for the planning and management of water resources for this consumptive use activity.

The use of water in irrigation is the consumptive use practice that spends the most water in the world ANA. For Singh et al. (2018), high quality irrigation water leads to good yields, since it is directly correlated with the soil and plant ecosystem. Considering this context, it is necessary to assess possible changes in the composition of water (MEGUID, 2019). Bortolini et al. (2018), describe water irrigation problems due to the risk of salinity, as high levels of salts reduce water availability, affect crop yield.

Currently, there are international water quality guidelines related to irrigated agriculture, and several countries adopt the guidelines proposed by the Food and Agriculture Organization of the United Nations – FAO, these guidelines were created to support the management of water resources and not define maximum values allowed for each use (AYERS et al., 1999). And in Brazil, to assess the quality parameters of groundwater for irrigated agriculture, CONAMA Resolution 396/2008.

The Water Quality Indexes-WQIs are tool, which emerged with the aim of presenting a single value for the quality of water by a given source, has been widely used by the National Sanitation Foundation - NSF, USA (ABBASI et al., 2012). In the assessment of water quality observed by Tripathi et al. (2019), it could be more feasible and economical due to the drastic reductions in time and cost required to monitor samples for a large number of parameters.

The application of an index for the Amazonian biome makes it possible to propose regional parameters to assess the quality of water in function of environmental characteristics in accordance with the conditions of each location and use, since there is a very large difference for each water body, due to the size of the country. The land IWQ considers a more real classification, according to the resources to which the water is destined, since most of the proposed indexes are conditions only for public supply activities.

From this perspective, this research proposes the implementation of the Water Quality Index for Irrigation (IWQI) from an underground source, in order to assess the quality of the Apeú River microbasin in a rural area.

MATERIALS AND METHODS

Study site

This study was carried out with water from underground abstraction in the Apeú River watershed, specifically in the community of Iracema (rural land), of the municipality of Castanhal-PA. The study area comprises the geographic coordinates 01°07’19.4” S and 48°01’48.2” W, and 01°06'04.3" S and 48°06'29.6" W (Figura 1).

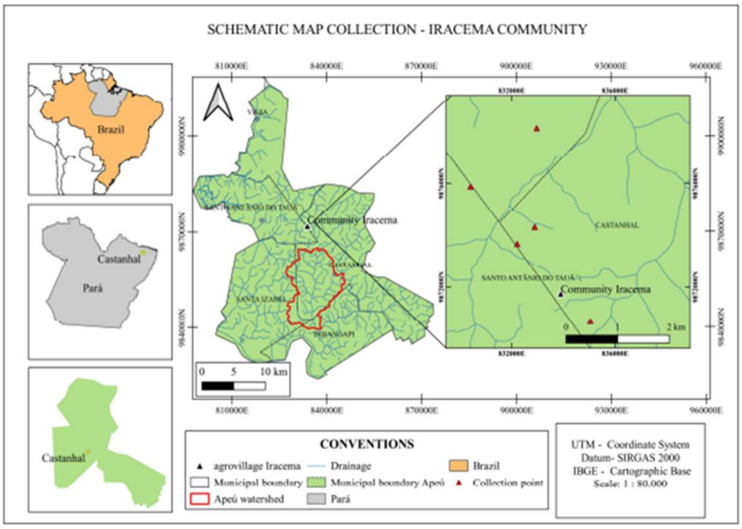

Figure 1: Location of the study area and collection points. Source: Adapted from Google Earth (2020).

Sampling

The Northeastern Pará State is the mesoregion with the highest rainfall throughout the year, with average annual values ranging from 2000 to 2500 mm (SILVA et al., 2020). According to Koppen's classification, the climate of the region is Af – Humid Tropical, with precipitation every month of the year and no defined dry season (ALVARES et al., 2013). The rainiest period is concentrated from December to May, and the least rainy period is concentrated from June to November (CORDEIRO et al., 2017).

Eleven campaigns of groundwater (from well) collection were conducted in the Apeú River microbasin, considering eight sampling points. That is, six collections between September to November/2018 and June to August/2019 (least rainy period) and five collections during the rainy period from January to May/2019.

Samples were collected in 0.5 L polypropylene bottles previously washed with 50% HNO_3 and double deionized water, and acidified with 5 mL of HNO_3. The collected samples were transported in ice boxes to the laboratory for analysis within 24h after collection and kept in a refrigerator at 4ºC until analysis (BRANDÃO et al., 2011).

Physicochemical analysis and determination of metals

The physicochemical parameters considered in this study were: pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Salinity (Sal), Electrical Conductivity (EC), exchangeable Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg), and Total Iron (Fe), Aluminum (Al), Barium (Ba), Chromium (Cr), Copper (Cu), Manganese (Mn), and Zinc (Zn).

To determine the physicochemical parameters: pH, DO, CE, TDS and Sal, the equipment of Bante 900p Instruments brand multiparameter was used, with an automatic calibration solution, measured in situ, according to the methodology described by the *American Public Health Association* - APHA (2012).

The determinations of trace elements were carried out in the laboratory of the Evandro Chagas Institute, and the samples were filtered using a Whatman 42 filter (pore size 2.5 µm) and acidified with NHO_3

at pH<2. The metals were analyzed using the technique of Optical Emission Spectrometry with Induced Plasma (ICP-OES, Perkin Elmer Optima 5300), determined according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

Sodium Adsorption Ratio (SAR)

According to Queiroz (2018), the determination of the sodium adsorption ratio is expressed in equation (1):

$$SAR = \frac{Na}{\left(\frac{Ca+Mg}{2}\right)^{0.5}} \qquad (1)$$

Where: SAR represents the sodium adsorption ratio, in which Na, Ca and Mg are concentrations contained in irrigation water, in mg L^{-1}.

Queiroz (2018), proposed a classification based on the Sodium Adsorption Ratio, where: low sodicity, S1 (SAR < 10); medium sodicity, S2 (SAR between 10–18); high sodicity, S3 (SAR between 18–26); and very high sodicity, S4 (SAR > 26).

Determination of the Groundwater Quality Index for Irrigation (IWQI)

Based on the descriptive statistics and the calculation of the standard deviation of each analyzed parameter in relation to the reference value, considering the normal distribution equation, the data were standardized according to equation (2):

$$Zi = \frac{x-\bar{x}}{\sigma} \qquad (2)$$

Where:
Zi = standardized value of the analyzed characteristic;
x = average value observed in the laboratory analysis for each parameter;
$\bar{x}$ = Limit established by the standard reference class;
σ = standard deviation of the evaluated characteristic in the reference population

According to the study carried out by Maia et al. (2012), the classification proposal considered the calculation of the water quality index of each evaluated characteristic of the sample (QIi), that is, for the analyzed parameters, as well as for the samples as a whole, which was called the irrigation water quality index (IWQI). QIi and IWQI were calculated based on equations (3) and (4), respectively:

$$QIi = \sqrt{Zi^2} \qquad (3)$$

$$IWQI = \frac{\sum_{i=1}^{n} QIi}{N} \qquad (4)$$

Where:
QIi = water quality index for the evaluated parameter
IWQI = irrigation water quality index
Zi = standardized value of the evaluated characteristic
N = number of evaluated characteristics.

The equation (3), which determines the QIi, it also corresponds to the modulus of the standardized value of the analyzed characteristic (Zi), which means the standardized error. The IWQI is a dimensionless number that varies from 0 to 100, according to its importance.

The determination of the water class values proposed for this study took into account the interquartile values, with a probability of 95% of the values in that area. Following the methodology adapted by Maia et al. (2012), the interquartile range was used to divide the data set into groups, in which the first quartile (25% of the variable results) corresponds to the range of Qi values less than 30, the second quartile (50% of the variable results) corresponds the range 31 – 60, and the third quartile (75% of the variable results) corresponds to values between 61 – 90 (Table 1).

Table 1: Proposed classification of the water quality index for irrigation activity (IWQI). Pará, UFRA, 2021.

CLASSES	CONDITIONS
I (Excellent)	IWQI ≤ 30
II (Good)	31 < WQI ≤ 60
III (Average)	61 < IWQI ≤ 90
IV (Poor)	IWQI > 91

RESULTS AND DISCUSSION

The analytical results of the physicochemical parameters, metal contents, mean value and standard deviation of the water quality parameters are summarized in Table 2 and 3.

Table 2: Analysis of physicochemical parameters of groundwater during the rainiest season and standard deviation.

	Parameters																
Unit	pH	EC	DO	TDS	SAL	Al	Fe	Ba	Zn	Cu	Cr	Mn	K	Mg	Ca	Na	SAR
	-	dS m^{-1}	mg L^{-1}														
Collection 1 (September 2018)																	
Average	4.89	0.35	5.20	210.03	0.17	0.69	0.23	0.03	0.19	0.01	0.02	0.04	4.65	2.49	8.34	12.56	5.40
SD	0.28	0.17	0.50	69.95	0.10	0.43	0.20	0.004	0.03	0.002	0.01	0.01	2.76	0.73	1.18	1.70	0.44
Collection 2 (October 2018)																	
Average	4.81	0.33	4.90	225.00	0.14	5.25	0.16	0.03	0.19	0.01	0.05	0.08	2.43	1.94	7.36	10.80	4.96
SD	0.48	0.15	0.66	220.95	0.10	0.59	1.16	0.004	0.03	0.001	0.02	0.01	1.92	0.79	1.18	1.84	0.45
Collection 3 (November 2018)																	
Average	5.39	0.61	5.48	382.29	0.31	3.33	0.27	0.03	0.16	0.01	0.02	0.05	1.96	1.73	6.21	10.31	5.20
SD	0.42	0.31	1.01	130.96	0.15	0.45	0.26	0.003	0.01	0.003	0.003	0.006	1.18	0.69	1.14	1.69	0.63
Collection 9 (June 2019)																	
Average	4.78	0.43	5.27	383.00	0.24	8.96	0.38	0.03	0.27	0.01	0.04	0.07	2.49	2.19	8.59	13.19	5.69
SD	0.11	0.27	0.61	130.81	0.14	1.30	0.18	0.003	0.07	0.001	0.08	0.01	1.20	0.69	2.00	2.66	0.7
Collection 10 (July 2019)																	
Average	4.56	0.48	5.11	280.14	0.16	10.19	0.32	0.03	0.27	0.01	0.02	0.07	3.08	2.35	7.90	12.01	5.28
SD	0.39	0.27	0.35	148.60	0.17	2.55	0.18	0.01	0.07	0.001	0.01	0.01	1.63	1.14	1.84	3.47	0.79
Collection 11 (August 2019)																	
Average	4.66	0.04	4.31	261.00	0.02	7.35	0.26	0.03	0.19	0.01	0.02	0.06	2.06	1.89	7.33	11.11	5.16
SD	0.66	0.02	0.54	171.96	0.02	1.41	0.20	0.003	0.03	0.001	0.001	0.01	1.15	0.53	1.10	2.04	0.50

Legend: SD – Standard deviation.

Table 3: Analysis of physicochemical parameters of groundwater during the dry period and standard deviation.

Parameters																	
Unit	pH	EC	DO	TDS	SAL	Al	Fe	Ba	Zn	Cu	Cr	Mn	K	Mg	Ca	Na	SAR
	-	dS m^{-1}	mg L^{-1}														
Collection 4 (January 2019)																	
Average	4.49	0.04	4.86	21.05	0.03	7.78	0.39	0.04	0.19	0.01	0.03	0.09	2.25	2.25	8.18	14.68	6.41
SD	0.44	0.02	0.42	11.45	0.01	4.09	0.29	0.005	0.02	0.001	0.01	0.01	1.19	0.54	0.99	2.82	0.90
Collection 5 (February 2019)																	
Average	4.43	0.05	5.65	26.01	0.03	5.35	0.22	0.08	0.17	0.01	0.03	0.08	2.42	2.08	7.82	13.55	6.10
SD	0.74	0.03	0.35	14.33	0.01	0.36	0.15	0.13	0.01	0.00	0.01	0.01	1.02	0.54	1.18	1.44	0.22
Collection 6 (March 2019)																	
Average	5.57	0.42	4.80	306.96	0.19	6.44	0.27	0.03	0.19	0.02	0.03	0.08	5.06	2.25	7.65	13.73	6.20
SD	0.12	0.16	0.98	163.90	0.11	0.60	0.20	0.01	0.02	0.02	0.01	0.01	5.94	0.84	1.22	1.48	0.43
Collection 7 (April 2019)																	
Average	4.89	0.05	5.14	22.43	0.09	7.55	0.27	0.04	0.18	0.01	0.02	0.08	2.40	2.22	8.11	14.50	6.39
SD	0.72	0.02	0.52	11.52	0.12	1.00	0.21	0.004	0.03	0.001	0.01	0.01	0.79	0.48	0.74	1.67	0.69
Collection 8 (May 2019)																	
Average	5.47	0.31	4.96	382.93	0.30	9.03	0.32	0.03	0.20	0.01	0.01	0.07	2.20	2.05	7.94	12.62	5.64
SD	0.13	0.24	0.49	216.72	0.22	2.16	0.16	0.00	0.03	0.001	0.01	0.01	0.77	0.56	1.22	2.09	0.59

Legend: SD – Standard deviation.

Physicochemical parameters

The analysis of groundwater in the study area revealed that the average pH value was 4.43 in the dry season, while it was 4.37 in the rainy season. These results are below what the FAO establishes for use in irrigation, which must be alkaline and comprised between 6.5 – 8.4 (AYERS et al., 1999). The low pH values of Amazonian waters reflect the common characteristics of organic matter decomposition, associated with other climatic and geological/mineralogical factors, which cause a decrease in water pH (MATTA et al., 2010).

The concentration of DO, in the rainy season (5.48 mg L^{-1}) and in the dry season (5.65 mg L^{-1}), and does not have maximum allowed value (MAV) for use in irrigation. However, according to WHO (2012), high levels of DO can aggravate the corrosion of pipes and metallic structures, damaging the groundwater subtraction and irrigation system.

The mean values of EC measured in groundwater were between 0.61 dS m^{-1} and 0.42 dS m^{-1} in the dry and rainy periods, respectively. According to FAO (AYERS et al., 1999), irrigation water must have a content of up to 3.0 dS m^{-1}, with potential for use without restrictions on salinity.

Therefore, several studies were performed to classify water, in order to measure the concentration of salts as a function of EC. Rhoades et al. (2000), to identify water salinity levels for irrigation, proposed: non-saline water – Class 1 (EC < 0.7 dS m^{-1}); slightly saline – Class 2 (EC between 0.7–2.0 dS m^{-1}); moderately saline – Class 3 (EC between 2.0–10 dS m^{-1}); highly saline – Class 4 (EC between 10-25 dS m^{-1}); and excessively saline – Class 5 (EC between 25-45 dS m^{-1}).

The water collected for irrigation in the study area has a low concentration of dissolved salts (salinity) in both sampling periods (table 1 and 2), classified as C1, and that the water does not present restrictions for use in this activity.

The mean value of TDS in the two seasonal periods was approximately 383 mg L^{-1}. The acceptable limit for irrigation purposes, according to FAO, is up to 2.000 mg L^{-1}. CONAMA Resolution No. 396/2008 describes that TDS must be below 1.000 mg L^{-1} in groundwater to be used for irrigation (CONAMA, 2008). In the Municipality of Salinópolis, Northeastern Pará state, Silva et al. (2018), found concentrations of up to 120 mg L^{-1}, values close to the data of the present study.

The average level of salt found in the study was 0.30 mg L^{-1} (rainy and dry season). It is noteworthy that this is a parameter indicative of the degree of salinity, not presenting thresholds established by FAO and CONAMA Resolution No. 396/2008. High salinity causes plant cell lysis (breakdown of the membrane) and cell death (SRIVASTAVA, 2019).

Sodium Adsorption Ratio (SAR)

For Kiremit et al. (2016), SAR is the relative concentration of Ca, Mg and Na, indicating the effect of concentrations of the two cations on sodium accumulation in the soil. Thereby, high Na and low Ca contents can reduce the amount of water in the root zone.

It is noticed that the results presented in tables 2 and 3 show SAR values < 10, which can be classified as a low ratio between Ca/Mg, that is, with low sodicity, classified as S1, in which there is no restriction for use in irrigation.

Metal Contents

The content of Fe in the water collected during the seasonal period had the highest average of 0.39 mg L^{-1}. For Al, the average concentration was 10 mg L^{-1} in the rainiest season and 9 mg L^{-1} in the least rainy period. It is noteworthy that the Fe and Al contents in groundwater potentially usable for irrigation purposes have a reference level of up to 5 mg L^{-1}, established by FAO (AYERS et al., 1999) and by CONAMA Resolution 396/2008.

Iron is a common element in groundwater, its origin is through the leaching of soils, industrial contaminants, and the contact of water with metallic pipes. The concentrations of the Al vary widely in groundwater, depending directly on geological and physicochemical factors (PARRON et al., 2011). The elements Fe and Al present in this study, easily reflect the relationship of the regional formation of the Barreiras aquifer system (RODRIGUES, 2016).

The Barium is introduced into the environment through well drilling using drilling mud, and agricultural defensives (PARRON et al., 2011). The tolerance level of Ba in drinking water according to WHO (2012) is 0.7 mg L^{-1} and does not have a maximum value allowed for use in irrigation. In this study, the average contents found in the seasonal periods were approximately 0.03 mg L^{-1}. Abreu et al. (2012) showed the absence of toxic effects in plants grown in Ba contaminated soils.

The presence of chromium in groundwater is associated with anthropogenic contamination. However, chromium can also be generated from natural processes, associated with minerals from the aquifer's matrix rock (FREDDO FILHO, 2018).

The concentration of Cr in groundwater to be used in the irrigation system for both CONAMA Resolution 396/2008 and FAO is 0.10 mg L^{-1}. In the waters of the region studied, the mean values of Cr ranged from 0.02 mg L^{-1} to 0.05 mg L^{-1} in the rainiest season, and from 0.01 mg L^{-1} to 0.03 mg L^{-1} in the least rainy season, indicating that the values found were well below the threshold established by the aforementioned recommendations.

Copper occurs in natural waters at small concentrations in the form of chalcopyrite ($CuFeS_2$), among other minerals, and can be released into groundwater through the solubilization of these minerals, which is directly influenced by the water pH, and the respective acidity will determine a greater or lesser solubilization/precipitation of this metal (FREDDO FILHO, 2018).

FAO recommendations and CONAMA Resolution 396/2008 established that the level of Cu in groundwater acceptable for irrigation purposes is 0.20 mg L^{-1}. The average content of Cu in the water collected during the two seasonal periods was 0.01 mg L^{-1}, which is well below the acceptable level to be used in the irrigation system.

The presence of manganese in drinking water is similar to iron, it almost always occurs as a bivalent manganese oxide, which oxidizes in the presence of air, giving rise to black precipitates, and can lead to accumulation in the abstracted water distribution system (WHO, 2012).

The highest average content of Mn in the rainy season was 0.08 mg L^{-1}, while in the less rainy periods was 0.09 mg L^{-1}, which can be acceptable when compared to FAO (AYERS et al., 1999), and the CONAMA Resolution 396/2008, in which the acceptable limit for the use of water to be used in irrigation is 0.20 mg L^{-1}.

The Zinc element can be present in water through leaching of rocks, corrosion of galvanized iron pipes, and contamination by industrial effluents (PARRON et al., 2011). The presence of zinc in water at high levels confers undesirable astringent taste (WHO, 2012).

The mean concentration of Zn ranged from 0.16 mg L^{-1} to 0.27 mg L^{-1} in the rainy season, while it was from 0.17 mg L^{-1} to 0.20 mg L^{-1} in the dry season. Thus, the MAV of Zn in groundwater to be used in irrigation is 2.0 mg L^{-1}, as established by CONAMA Resolution 396/2008 and FAO (AYERS et al., 1999).

The potassium is easily absorbed by clay minerals and, as well as in agricultural runoff. Potassium contents in groundwater are less than 10 mg L^{-1}, with higher occurrence of values between 1 mg L^{-1} and 5 mg L^{-1} (PARRON et al., 2011).

Regarding potassium, mean values found in groundwater in this study corresponded to 4.65 mg L^{-1} in the rainy season and 5.06 mg L^{-1} in the dry season. These values are much lower than the limit established by the FAO, of 78 mg L^{-1}, for use in irrigation (AYERS et al., 1999).

Elaboration of IWQI

In the study of the concentration of physicochemical parameters and metal contents in groundwater, the results did not reveal seasonal variability, however, to propose the elaboration of the IWQI, all parameters were used, since there is no interference of the results with the monitoring period. Thus, the proposal is the beginning of decision-making aimed at improving water in the region, since it is used for human consumption and irrigation activities.

The purpose of this study presented the classes for groundwater defined below: IWQI ≤ 30 (class I) and indicates no restriction (NR) for use, to which the water has excellent quality; 31< IWQI ≤ 60 (class II) classifies the water as good, indicating low restriction (LR); 61< IWQI ≤ 90 (class III), in which water is classified as regular, with medium restriction of use (MR); IWQI ≥ 91 (class IV) classifies water as undesirable, with high restriction for use (HR).

The recommendations for the classes, according to restriction for use, were followed according to Meireles (2010), as follows: NR: in soil, it can be used for the majority with low probability of causing salinity and sodicity problems; in plant, it can be used without risk of toxicity and contamination by *Escherichia coli;* LR: it is recommended for use on irrigated soils with light texture or moderate permeability; avoid in plants sensitive to salinity, as well as in vegetables consumed raw, with fruits that grow close to the soil and that are eaten raw; MR: it can be used in soils with moderate to high permeability values, with moderate salt leaching; plants with moderate tolerance to salts can be grown; it is unsuitable for vegetables consumed raw, from fruits that grow close to the soil and are eaten raw, without skin removal, as well as for vegetables in general and fruit plants; HR: it can be used in soils with high permeability, without compact layers, however, an irrigation schedule must be adopted for EC above 2000 mg L^{-1} and SAR above 7.0. Irrigation can be used for plants with moderate to high salt tolerance. It is not recommended to irrigate raw vegetables and fruits, fruit plants, tree crops, cereals and forages.

The values adapted from irrigation water quality guidelines are described in Table 4. The classes of the IWQI, taking into account the risk of salinity problems and the evaluation of parameters regarding the risk of water contamination, are shown in Table 5. Therefore, it was possible to compare the proposed classes and verify that, in general, the waters do not present restrictions for irrigation purposes (NR) in the study area during the assessed period.

The QIi results are found in table 4 and the classifications of the groundwater samples (from well) may be observed in table 5. For IWQI, it was possible to conclude that there are different qualities for the same water source (well), according to the parameters presented, and that planning should exist to assist in the best use of these waters.

Table 4: Values of water quality indices for chemical characteristics (QIi).

	CLASSIFICATION (QIi)												
PERIOD	**pH**	**TDS**	**EC**	**Ca**	**Cu**	**Cr**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**Zn**	**SAR**
Sep/18	2.8	11.2	10.6	289.3	34.6	2.7	11.4	31.2	82.7	9.0	249.6	35.4	12.2
Oct/18	3.1	11.4	10.8	289.6	35.0	1.8	9.7	32.1	82.9	6.8	250.1	35.3	12.7
Nov/18	1.9	10.8	9.5	290.9	35.2	3.0	11.3	32.4	83.8	8.7	250.5	36.1	12.4
Jan/19	3.5	12.3	11.8	289.4	35.4	2.4	11.0	32.3	83.1	6.3	248.7	35.5	10.9
Feb/19	3.6	12.3	11.8	289.7	35.4	2.4	11.4	32.2	83.3	6.7	249.2	35.9	11.3
Mar/19	1.6	11.1	10.3	289.8	34.0	2.4	11.3	31.1	83.1	6.8	249.1	35.5	11.1
Apr/19	2.8	12.3	11.8	289.5	35.2	2.8	11.3	32.2	83.1	6.7	248.8	35.7	10.9
May/19	1.8	10.1	11.1	289.6	35.3	3.1	11.2	32.3	83.4	7.3	249.6	35.2	11.8
Jun/19	3.0	11.2	10.3	289.1	35.1	2.0	11.0	32.2	83.1	7.2	249.4	33.8	11.8
Jul/19	3.3	11.4	11.0	289.6	35.3	2.9	11.1	31.9	82.9	7.4	249.8	33.8	12.3
Aug/19	3.2	12.3	11.8	290.0	35.3	2.8	11.3	32.3	83.6	7.6	250.2	35.5	12.5

Table 5: Values of Water Quality Indexes for Irrigation (IWQI), according to the classification for underground water (from well) with EC < 0.7 dS m^{-1}.

	CLASSIFICATION (IWQI)													**IWQI**
PERIOD	**pH**	**TDS**	**EC**	**Ca**	**Cu**	**Cr**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**Zn**	**SAR**	**(Overall)**
Sep/18	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Oct/18	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Nov/18	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Jan/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Feb/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
May/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Apr/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
May/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Jun/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Jul/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I
Aug/19	I	I	I	IV	II	I	I	II	III	I	IV	II	I	I

Even though most samples are of excellent quality, there are still waters in undesirable classes, which can be used in the irrigation system, either in isolation, mixed or alternated. The normal values of calcium and magnesium in irrigation water should be 400 mg L^{-1} for Ca, 60 mg L^{-1} for Mg and Na for 620 mg L^{-1} (AYERS et al., 1999). High water hardness can also be limiting for fertigation. Values above 100 mg L^{-1} of Ca and 43 mg L^{-1} of Mg considerably increase the risk of precipitation of phosphate fertilizers inside the pipes (KAFKAFI et al., 2011).

Considering the analyzed samples, a certain degree of restriction was observed for the elements Ca and Mg (index IV), with values of 290 and 250, respectively, for the QIi. However, by comparing the average values analyzed for these parameters described in Tables 2 and 3 with the reference values for these elements Ca, and Na, it can be seen that these are still within the limit established by FAO.

For well water samples, SAR presented QIi equal to I. This characteristic is relevant, as it works as an indicator of the risk of water sodification. The SAR value is much more relevant when the Ca/Mg ratio is less than the unity, because the lower this ratio, the greater the risk of sodicity. Sodium toxicity is often modified and reduced if calcium and magnesium are also present. Moderate amounts of calcium can reduce damage and larger amounts can prevent it. The reasonable assessment of the toxicity potential of irrigation water is possible using the SAR value (ZHANG et al., 2012).

Waters with high Na content can be used with restriction in localized irrigation, as it may present a risk of carbonate precipitation. For some crops, soils with high Mg content present low productivity, or also when these crops are irrigated with waters that have high levels of this element (AYERS et al., 1999).

The Figure 2 shows the index IV, in the samples analyzed for Ca and Na, respectively, and the index III for Mg, classes different from most of the parameters that were framed between indexes I and II.

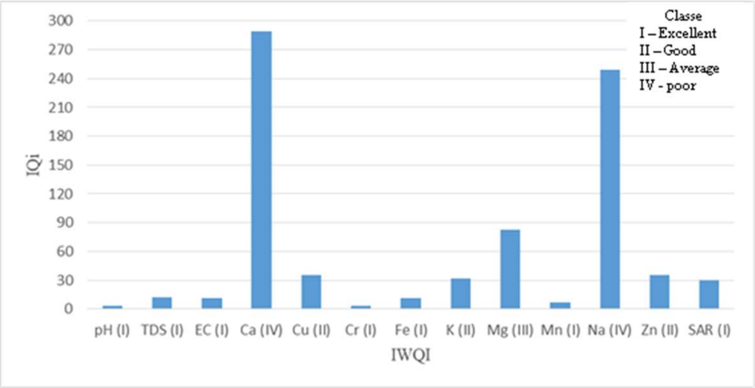

Figure 2: Classification of indices based on chemical characteristics (QIi) and for irrigation water (IWQI) considering samples with EC < 0.7 dS m^{-1}.

However, the IWQI demonstrates efficiency as a function of certain parameters for some irrigation modalities, which have much greater relevance. It is important to identify and determine specific treatments for each quality of water to be used in micro-irrigation systems, where the susceptibility to problems, especially the obstruction of emissions, is greater (ZAMBERLAN et al., 2013).

For Siqueira et al. (2012), variations in water quality indices may have different origins, studying the same hydrographic basin of the Paraupaebas River (State of Pará), in which differences were found due to the distinct anthropogenic actions.

This differentiation in the preparation of water quality indices only reinforces the importance of localized studies, since waters can be influenced by different geogenic and anthropogenic sources. Therefore, the control/monitoring can subsidize and facilitate the integrated management of this water resource.

CONCLUSIONS

In the study area, the exploited underground water presents good physicochemical quality in relation to the values established by the aforementioned CONAMA Resolution, and by the FAO recommendation. However, it is known that the monitoring/control of water quality for several consumptive and non-consumptive uses are preponderant for maintaining a balanced environment.

However, regarding the classification of water as a function of saline and sodicity control, it was observed that these can also be used without restrictions in irrigation, as well as the proposed methodology to prepare the IWQI to be used in irrigation. Although waters of different qualities were observed, waters of excellent quality predominated, with index I.

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