2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

SURFACE AND GROUND WATERS EVALUATION AT BRAZILIAN MULTIPROPOSED REACTOR INSTALLATION AREA

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ABSTRACT

This study evaluates six surface and ground waters physicochemical characteristics on the area of the future Brazilian Multipurpose Reactor (RMB), at Iperó/SP. One of the main goals is to establish reference values for future operation monitoring programs, as well as for environmental permits and regulation. Considering analyzed parameters, all collection points presented values within CONAMA Resolution 396/08 and 357/05 regulation limits, showing similar characteristics among colletion points.Only two points groundwater (RMB-005 and RMB-006) presented higher alkalinity, total dissolved solids and conductivity. The studied area was considered in good environmental conservation condition, as far as water quality is concerned.

1. INTRODUCTION

In recent decades, population growth and consequent increase in industrial activities have contributed to environmental deterioration [1], thus generating great consequences for population, such as water resources pollution leading to water scarcity, elevated costs for water treatment, among others. For this reason, Environmental Licensing actions has become essential for cities continuous growth and for water quality control [2].

Alteration of surface and ground waters quality could occur through sanitary effluent discharges, contaminated wastewater, oils, greases or chemicals spills or leaks, directly into the soil or receiving water bodies. Thus affecting these water bodies quality. Therefore, environmental impact assessment methods, one Environmental Licensing tool, aim to identify, evaluate and synthesize a given project or program effect over a given enterprise environmental influence area. For this purpose, surface and ground water quality monitoring are crutial.

Brazilian Multiproposed Reactor - RMB is the project of a research nuclear reactor that will be installed in the contiguous area of the Aramar Experimental Center of the Marinha Technological Center in São Paulo (CTMSP) located in the city of Iperó, São Paulo. Some of its purpose are to contribute to the acquisition of knowledge, experience and training of human resources, as well as to produce services in several areas, such as scientific, technological, economic and social [3]. For RMB installation and operation, both environmental licensing by IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) required by Brazilian regulation law n^0 6.938/1981 and CONAMA

Resolution n^0 237/97, and also nuclear licensing to be carried out by Comissao Nacional de Energia Nuclear (CNEN), are required.

Therefore, also a periodic monitoring plan is required to ensure environmental water resource quality, this study has the motivation to evaluate surface water and groundwater by means of physical and chemical parameters, In order to obtain reference values of these waters for futu re studies, comparing them with environmental legislation and serving as a tool for the install ation license, in the area of influence of a new project, RMB.

2. OBJECTIVE

The present work aims to evaluate surface and ground water quality at the area of the future Brazilian Multipurpose Reactor-RMB.

3 METHODOLOGY

3.1 Identification and collection of samples

The sampling points for surface and ground water were the same as those adopted by the National Nuclear Energy Commission [4] in the environmental radiological monitoring program, in order to study and provide information for environmental licensing. Thus, six sampling points for surface water and four for groundwater were selected, are presented in Table 1.

Procedures for collecting and field parameters measurement were performed with the assistance of IRD and CDTN team. Physical and chemical parameters measured in the field are an integral part of the Environmental Radiological Monitoring Program - Phase: Pre-Operational - Brazilian Multiproposed Reactor - RMB, coordinated by Dr. Sueli da Silva Peres/IRD.

Table 1: Location of sample collection points

SAMPLE	IDENTIFICATION OF THE POINT	LOCATION	GEOGRAPHICAL COORDINATES (UTM)
SURFACE WATER	001RMB	Ribeirão do Ferro, upstream of the development	23°24'17.49"S 47°37'30.19"W
	002RMB	Ribeirão do Ferro, downstream from the development	23°23'18.71"S 47°37'0.93"W
	003RMB	Rio Sorocaba, downstream of the discharge point of the Ribeirão do Ferro	23°21'55.76"S 47°36'54.27"W
	004RMB	Rio Sorocaba, upstream of the discharge point of the Ribeirão do Ferro	23°21'39.40"S 47°36'1.05"W
	009RMB	Farm São Benedito (Lake)	23°22'8.56"S 47°37'22.05"W
	010RMB	Rising brook Ibama	23°23'25.00"S 47°37'30.59"W
GROUNDWATER	005RMB	Control point of the Ipanema farm – well pond	23°22'8.56"S 47°37'22.05"W
	006RMB	Control point of the Ipanema farm – wel nurseries	23 25 37 S 47 35 57 W
	007RMB	Downstream from the development farm São Benedito	23°22'8.56"S 47°37'22.05"W
	008RMB	Water entrance on SABESP/Sarapuí	23°38'35.76"S 47°49'40.47"W

Sampling points were numbered from 1 to 10, according to their study area location (Fig. 1).

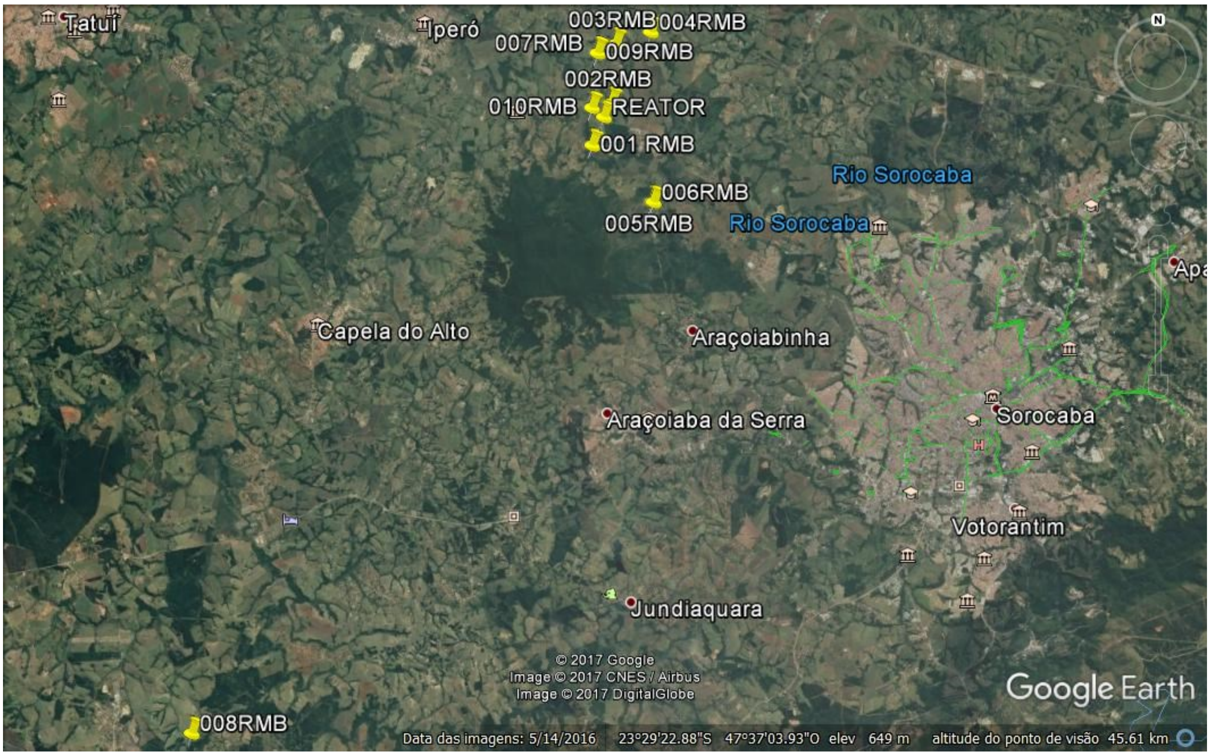

Figure 1: Sample point location in the study area

In April, June, September and December 2015, in four field campaigns, 38 samples were collected (in the month Of April, RMB-005 and RMB-006 were not collected), and 350 trials per campaign (except in the month of April that were 280 trials), totaling 1330 trials.

Samples of surface water samples were collected using a plastic container. Still in the field, they were transferred to polyethylene bottles by means of a funnel. The groundwater samples were collected in water collection wells installed in the region. In these wells the water is pumped and collected in a tap directly from the well.

The samples were collected and stored as recommended by CETESB/ANA [5] and Standard Methods [6], with appropriated bottle, volume and sample preservation to carry out each parameter analysis.

3.2 Water sample analysis

Temperature, pH, electrical conductivity, alkalinity, total dissolved solids and total metals, according to the analysis method and analytical technique were performed as presented in Table 2 [6;7,8,9,10,11,12 and 13].

Quality standards established by CONAMA Resolution 357/05 [14] as Class 2 were adopted to surface water, the same as Rio Sorocaba is classified [15]. CONAMA Resolution 396/08 [16] classification as Class 1, was adopted to groundwater, since the main water use is for human consumption.

Table 2: Method of analysis and analytical technique used in the samples

Parameters	Analysis method	Analytical technique
pH (*)	SM4500H+B	Potentiometer
Temperature (*)	SM2550B	Thermometer
Conductivity (*)	SM2510B	Conductivity meter
Alkalinity	ABNT NBR 13736	Titulometry
Total Dissolved Solids	ABNT NBR 10664	Gravimetry
Total Metals (Ag, Al, Ba, Be, Co, Cr, Ca, Cd, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sn, Sr , Ti, V e Zn e semi metals (B e Si)	EPA3015A (preparation) EPA6010C (analysis)	ICP OES
Arsenic	EPA 7062	AAS - Forno de Grafita (GF-AAS)
Mercury	EPA 7470A	AAS – Geração de vapor frio (CV-AAS)
Selenium	EPA 7741A	AAS - Forno de Grafita (GF-AAS)

(*) – Parameters determined in the field by the team of the Environmental Radiological Monitoring Program - Phase: Pre-Operational - Brazilian Multipurpose Reactor - RMB.

4 RESULTS AND DISCUSSION

4.1 pH

In 2015, six surface water and 4 groundwater pH values (Fig. 2) indicate a neutral character of waters (pH = 7.00), with surface waters maximum of 7.51, minimum of 5.00 and average of 6.57, and with groundwaters maximum of 7.93, minimum of 4.50 and average of 6.77.

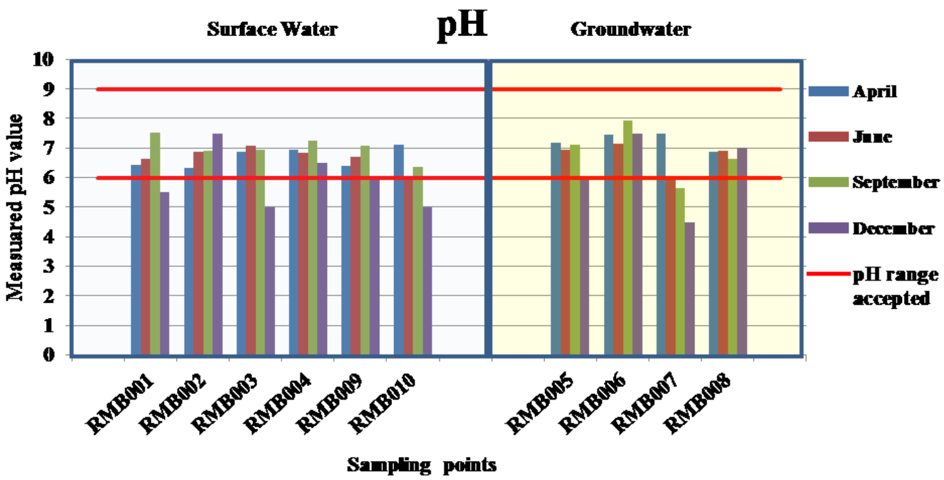

Figure 2: 2015 pH values surface and ground water results.

According to CONAMA Resolution 357/05 [14], pH should range should from 6 to 9, which was not observed to all collection points in December 2015 and at RMB-007 in September .

Low pH values in December was related to a high rainfall period, according to Fig.3. However, this behavior was not observed at points RMB-002, 006 and 008, which presented more constant values of pH.

According to Von Sperling [17], the climate interferes with water quality from precipitation, which provides surface infiltration, which is responsible for loading soil particles (increasing suspended solids), nitrogen compounds, organic carbon, substances present or ions from the dissolution of rocks into bodies of water.

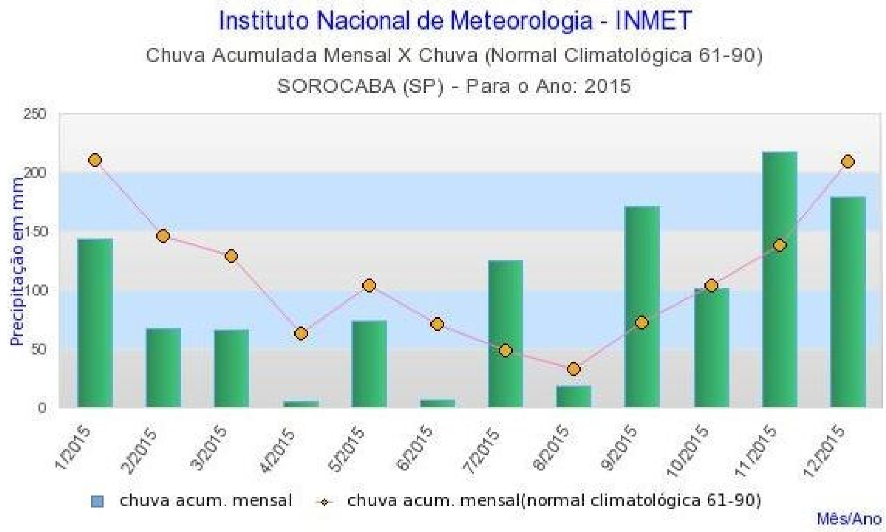

Figure 3: 2015 monthly rainfall in Sorocaba region.
Fonte: INMET [18]

The pH values are related to a number of factors, both natural (absorption of atmospheric gases, oxidation of organic matter, photosynthesis), and anthropogenic (domestic and industrial sewage disposal, acid washing of industrial processes, fertilizers), so the RMB -007 point showed a decrease in pH from April to December, due to the influence of some of these factors [17].

4.2 Temperature

Temperature presented a similar behavior within points and months. In December, the highest temperature values were measured in all points, except for RMB-007 and RMB-009, both located at farm São Benedito (Fig.4). With a maximum of 26 ° C, minimum of 13 ° C and average of 20 ° C for surface waters and maximum of 32 ° C, minimum of 12 ° C and average of 21 ° C for groundwater.

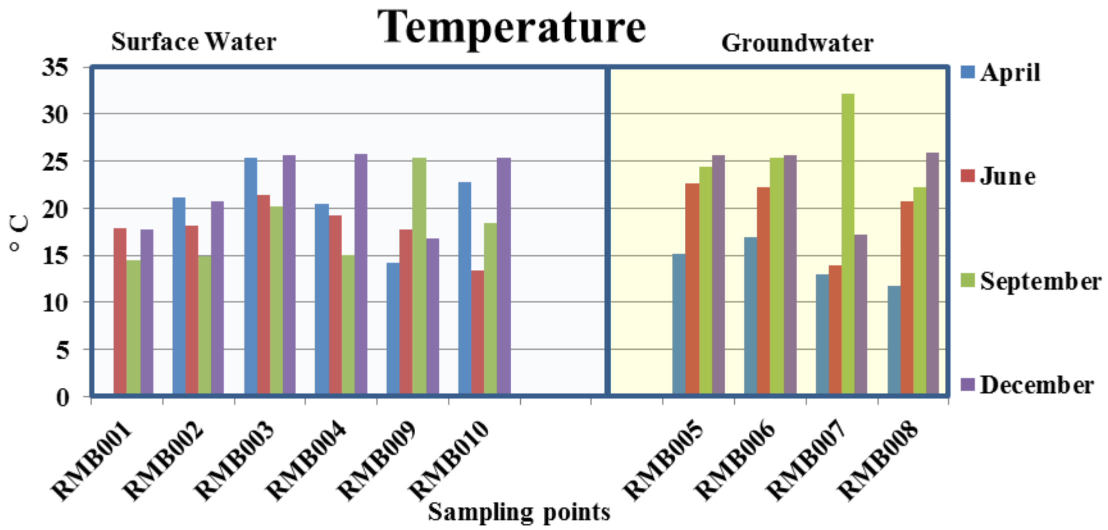

Figure 4: 2015 temperature values at points from future RMB facilities.

According to CETESB [19], several factors influence water temperature such as latitude, altitude, season, period of the day, flow rate and depth.

4.3 Alkalinity

There is no alkalinity limit in water established by Brazilian legislation. Most of the natural waters present values of alkalinity in the range of 30 to 500 mg.L^{-1} of CaCO3 [20]. Fig. 5 presents alkality values on surface and groundwater collection points.

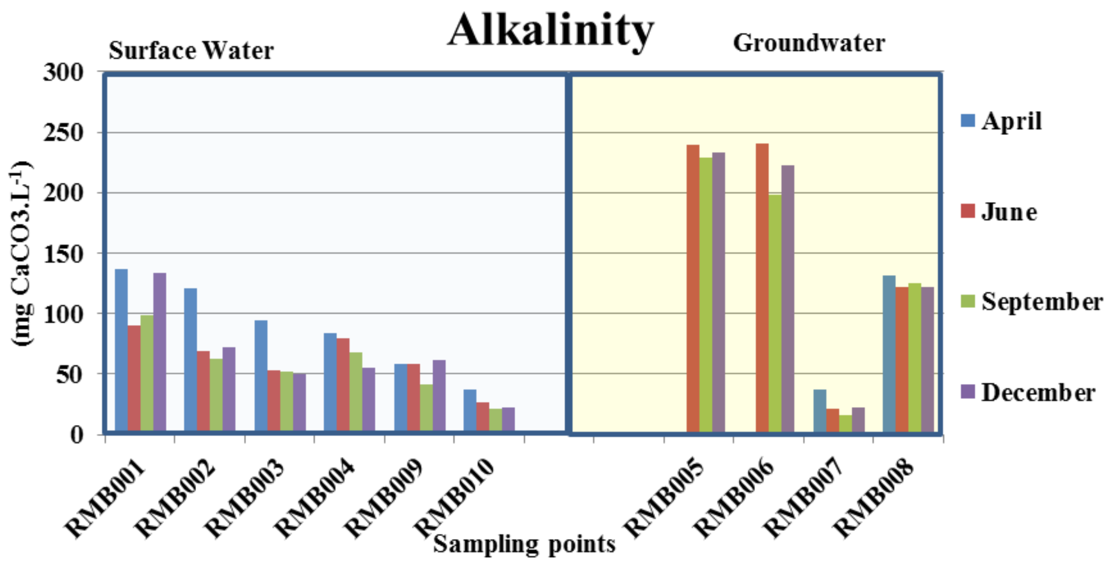

Figure 5: 2015Alkalinity values at water collection points around future RMB facilities.

RMB-005 and RMB-006 wells are located on the Ipanema Farm, comes from two artesian wells on the lakeside of FLONA, with from 120 and 100 m depth respectvely. Both presented a high alkalinity value when compared with other samples. This high alkalinity values can indicate samples mixture with high organic matter content, coming from residential village, and its subsequent oxidation, leading to carbonate and bicarbonate increase in groundwater.

4.4 Conductivity

Six surface water points presented an average of 152 µS.cm-1, maximum of 258 µS.cm-1 and minimum of 27 µS.cm-1. Four groundwater points had an average of 257 µS.cm-1, maximum of 400 µS.cm-1 and a minimum of 90 µS.cm-1 (Fig. 6). Both ranges are considered low to average conductivity results [21]. Resolution 357/05 of CONAMA does not establish conductivity limits.

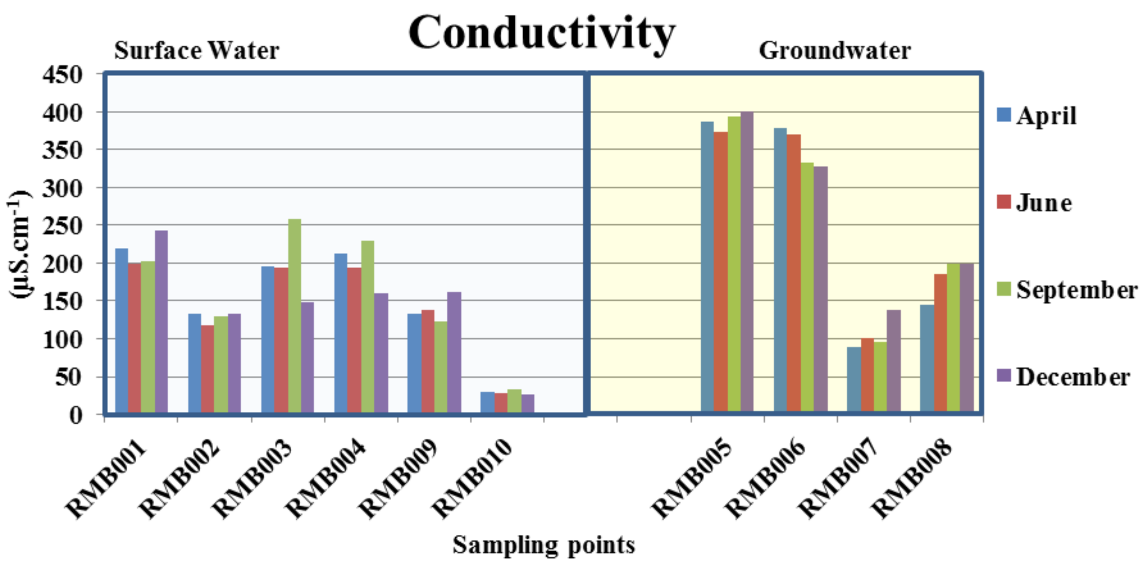

Figure 6: 2015 Conductivity values at 10 collection points around future RMB facilities.

RMB-005 and RMB-006 groundwater had the highest conductivity values related to total dissolved solids, alkalinity, hardness and also with the presence of ions such as calcium and magnesium.

4.5 Total dissolved solids

For surface fresh waters, classified as class 2 according to CONAMA Resolution 357, and for groundwater for human consumption, according to CONAMA Resolution 396, the maximum total dissolved solids value is 500 mg.L-1 and 1000 mg. L-1 respectively.

All sampling points showed values below the regulated maximum value, but RMB-005 and RMB-006 wells had the highest total dissolved solids content, that could be related to the well construction and also to agricultural activities near sampling sites (Fig.7).

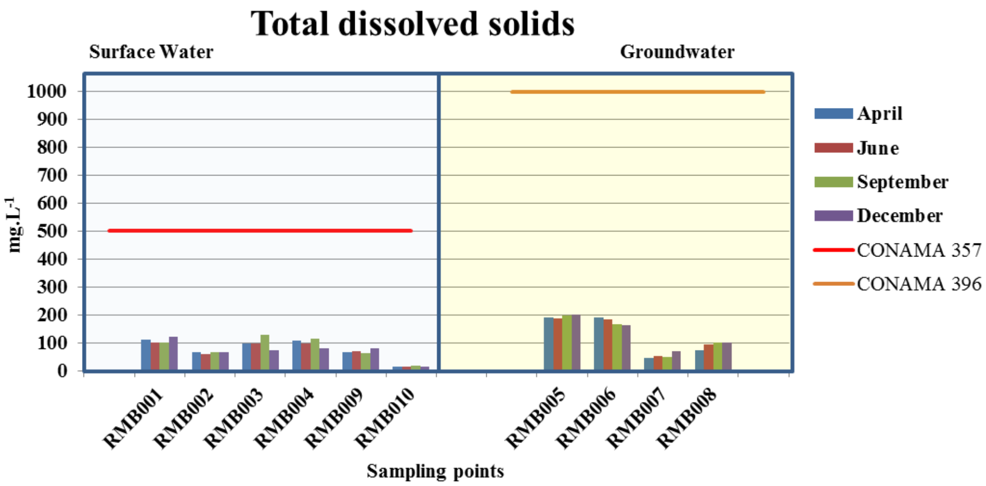

Figure 7: 2015 total dissolved solids values at the collection points around future RMB facilities.

The total dissolved solids parameter is directly related to the conductivity, and the more dissolved solids are present in the water, the higher the conductivity. With the comparison of the results, it was possible to observe that the concentration of total dissolved solids was practically half of the conductivity.

4.6 Total metals and trace elements

In all sampling points, metals and total metals were lower than Maximum Allowable Value (VMP) established by CONAMA 357/05 [14] and CONAMA 396 [16], except to zinc, manganese and iron (Table 3). Table 3 shows average values as well as elements distribution range and legislation limits.

Table 3: Elemental average and range in surface and groundwater samples with legislation limits.

Element	Groundwater average (mg.L^{-1})	Groundwater Concentration range (mg.L^{-1})	CONAMA 396/2008 Groundwater Human Consumption (mg.L^{-1})	Surface water average (mg.L^{-1})	Surface water Concentration range (mg.L^{-1})	CONAMA 357/2005 Water bodies CLASS 2 (mg.L^{-1})
Ag	< 0.020		0.10	< 0.020		0.01 total
Al	0.029	0.010 – 0.175	0.20	0.078	0.010 – 0.422	0.1 Al dissolved
As	<0.006		0.01	<0.006		0.01 total
B	<0.200		0.50	< 0.200		0.5 total
Ba	0.159	0.058 – 0.369	0.70	0.064	0.01 – 0.156	0.7 total
Be	< 0.020		0.004	< 0.020		0.04 total
Ca	16.15	3.71 – 23.5	-	12.744	1.49 – 35.3	-
Cd	0.002	0.0015 – 0.002	0.005	0.002	0.0015 – 0.002	0.001 total
Co	0.011	0.010 – 0.012		0.011	0.010 – 0.012	0.05 total
Cr	< 0.040		0.05	< 0.040		0.05 total
Cu	< 0.020		2.00	0.026	0.020 – 0.164	0.009 dissolved
Fe	<0.0500		0.30	0.257	0.050 – 0.991	0.3 dissolved
K	2.621	2.09 – 3.57	-	3.52	1.03 – 5.78	-
Ni	< 0.01		0.02	< 0.01		0.025 total
Mg	5.136	1.09 – 10.06	-	4.01	0.050 – 10.04	-
Mn	0.033	0.02 – 0.09	0.10	0.173	0.020 – 1.978	0.1 total
Pb	<0.004		0.01	<0.004		0.01 total
Se	<0.004		0.01	<0.004		0.01 total
V	< 0.020		0.05	0.021	0.020 – 0.026	0.1 total
Zn	0.056	0.010 – 0.165	5.00	0.033	0.01 – 0.21	0.18
Li	0.012	0.010 – 0.016	-	< 0.010		2.5
P	0.161	0.042 – 0.276	-	0.233	0.02 – 0.596	0.030 in lentic environments 0.050 in intermediate environments
Na	24.161	8.428 – 43.227	200.00	12.789	2.622 – 50.5	-
Sn	< 0.010		-	< 0.010		-
Sr	0.405	0.029 – 1.00	-	0.225	0.011 – 1.59	-
Mo	< 0.020		-	< 0.020		-
K	2.621	2.091 – 3.570	-	3.519	1.033 – 5.78	-
Si	12.219	5.483 – 17.300	-	7.77	0.179 – 16.6	-
Ti	< 0.01		-	0.044	0.01 – 0.1	-

The elements with no maximum value established by legislation were represented by "-" and the points represented by the symbol "< " presented values below the quantification limit of the methodology used [22].

In April 2015, RMB003 and RMB009, both with concentration of 0.21 mg.L-1 were above legislation limit for zinc of 0.18 mg.L-1.

Manganese with 0.10 mg.L-1 legal limit presented at the RMB002 only in April 2015 a value of 1.978 mg.L-1 (Fig.8).

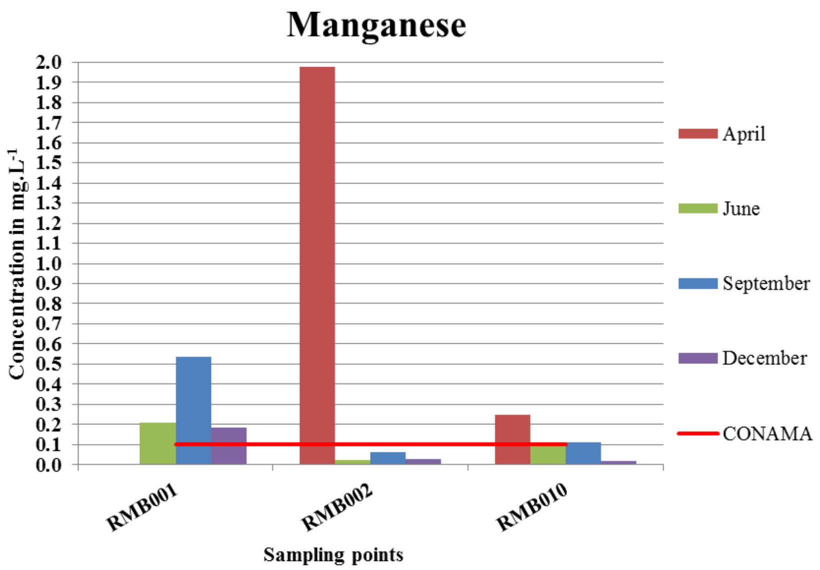

Figure 8: 2015 manganese results in mg/L

Iron legislation limit is 0.3 mg.L-1, and in june 2015, RMB010 had 0.991 mg.L-1 of Fe (Fig.9). RMB002 and RMB010 presented values above Iron limit established by CONAMA 357, for 3 months, while RMB001 and RMB004 had only one exceeding value, in different months.

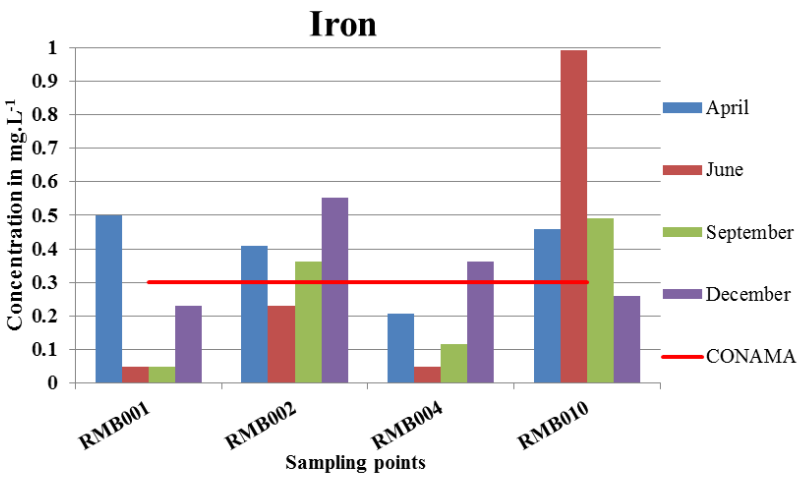

Figure 9: Iron concentration at points in the RMB that exceeded the limit established in the legislation

Iron and manganese legislation limits were set due to consumption objection to turbidity, color and taste, not impeding the use of water after adequate treatment, nor conferring health risk. Iron and manganese are found in abundance as natural constituents of tropical climates and in many cases are present as suspension in surface waters and in ground waters due to well construction issues.

5 CONCLUSIONS

• pH values obtained at all points indicate neutral waters, within the ideal range for aquatic organisms. pH established by CONAMA 357/05, was met except to RMB-007;
• Temperature values indicate an equilibrium in the environment, directly influenced by seasons;
• RMB-005 and RMB-006 presented the highest alkalinity;
• Electrical conductivity were relatively low, indicating little salt and solid dissolution. RMB-005 and RMB-006 had EC values related to total dissolved solids, alkalinity and hardness and calcium and magnesium. No limitation is set by CONAMA Resolution 357/05 for this parameter.
• RMB-005 and RMB-006 presented the highest TDS;
• Metal concentrations found throughout the sample period are in accordance with the limits of resolution 396/08 for groundwater and 357/05 of CONAMA for class II surface water, except for iron and manganese but no toxicity is related to this elements.
• RMB-005 and RMB-006 presented values within the limits established by the legislation in all parameters, but presented the highest values in the parameters alkalinity, conductivity and total dissolved solids;

Therefore, both surface and ground waters in the studied area, considering physical chemical parameters herein presented, are well preserved, thus providing subsidies for the installation stage of the RMB environmental licensing and establishing reference values for future studies. However, continuous water monitoring is necessary to ensure its quality and conservation.

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