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GROUNDWATER ASSESSMENT IN WATER RESOURCES MANAGEMENT AT NUCLEAR AND ENERGY RESEARCH INSTITUTE - BRAZIL

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ABSTRACT

To comply with the guidelines for environmental control and legal requirements, the Nuclear and Energy Research Institute (IPEN/ CNEN - Brazil/ SP) performs the Environmental Monitoring Program for Chemical Stable Compounds (PMA-Q) since 2007, in attendance to the Term for the Adjustment of Conduct (TAC) signed between IPEN and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). The PMA-Q program includes the assessment of the IPEN's wastewater released in water body, and the groundwater assessment, which is carried out in nine monitoring wells. In groundwater is analyzed, by ion chromatography, species regulated by CONAMA 396/08 [01] fluoride, chloride, nitrite-N, nitrate-N, sulfate, sodium, potassium, ammonium, magnesium and calcium, besides other parameters. Furthermore, based on legal requirements, each year the program is reviewed and improvement actions are planned and implemented. Therefore, the integrated monitoring of groundwater should provide information on the quality and dynamics of the aquifer compared to seasonal variations and anthropogenic effects. Thus, this study intends to evaluate the chemical features of the institute groundwater, evaluating the database of the monitoring program from 2011 to 2014, for the ions chloride, nitrate-N, sulfate, sodium, potassium, magnesium, calcium and bicarbonate, using these information diagrams will be developed for the characterization of the wells. This assessment will be essential to support the control actions of environmental pollution and the management of water resources. Making possible the establishment of groundwater Quality Reference Figures (QRF), according to the CONAMA 396/08 [01] rating, in order to demonstrate that the activities developed at IPEN are not affecting on the aquifer features.
Keywords: Ion Chromatography, Environmental Monitoring.

1. INTRODUCTION

The Nuclear and Energy Research Institute (IPEN/ CNEN - Brazil/ SP) is a nuclear and radioactive facility in charge of several industrial, pharmaceutical and educational activities. In 2012, the Environmental Management System (EMS) was implemented in order to monitor regulated environmental activities together with IBAMA. The EMS complements nuclear licensing actions according the CNEN Resolution 112/2011. In addition, several actions are performed in the EMS, like the PMA-Q the Stable Compounds Environmental Monitoring Program, that states safety and security to life and property and it is yearly revised.

Since 2006 the PMA-Q is performed in the Centro de Química e Meio Ambiente – CQMA, monitoring groundwater and wastewater released by IPEN at public sewer system. Every two months groundwater is collected and several physical and chemical parameters analyzed as part of PMA-Q [2].

One of these program main goals is to identify any pollutant source that might affect the monitored aquifer. Piper diagrams are a useful tool that allows identifying water mixtures. Piper diagrams considered conservative substances to evaluate hydrological mixtures of different aquifers, rainwater recharge and pollution flows that may reach the monitored aquifer. These diagrams are an alternative to meteorological and hydrodynamic methods.

In this paper, the database of the conservative species present in groundwater and the data presentation as Piper diagrams help the identification of the main water sources that affect IPEN's groundwater composition. The database was constructed with 7 species monitored in a minimum of 10 (PM-09 and PM-10) that were opened in 2013 and a maximum of 17 collection's to all other wells from 2011 to 2014. IPEN's groundwater preliminary results [3] were discussed before. However as IPEN is located in a high vulnerability area, more data was gather in the present paper.

2. MATERIAL AND METHODS

2.1. Instrumental

All analyses were performed by Ion Chromatography (model DX120, DIONEX Corp) in accordance with APHA 4110 method [4]. An autoregenerative suppressed, conductivity detection mode, with 100uL injection loop, with Chromeleon 6.8. Software was used.

2.2. Groundwater Sampling

Water collection (with bailers) and sample preservation was performed as per CETESB [5] and APHA [4] procedures. All samples were filtrated on 45um paper filter (Unifil, diameter 15 cm), kept under refrigeration and analyzed up to 48hs from collection. The geographical coordinates from each of 9 wells are presented at Table 1. The wells distribution inside IPEN's campus are presented at Figure 1.

2.3. Database

All cation and anion results from each well between 2011 and 2014 were stored in a MS-Excel spreadsheet.

2.4. Piper diagram

The freeware software QUALIGRA [6], version 2014, developed by Departamento de Recursos Hídricos da Fundação Cearense de Meteorologia e Recursos Hídricos – FUNCEME was used to construct wells Piper diagrams.

TABLE 1: Geographical coordinates corresponded to each Wells location

PM	Latitude	Longitude
01	23°33'43.51"S	46°44’13.87”W
02	23°33’59.66”S	46°44’4.58”W
03	23°33’40.76”S	46°44’27.90”W
04	23°33’40.00”S	46°44’26.58”W
05	23°33’36.67”S	46°44’33.07”W
06	23°33’58.39”S	46°44’7.43”W
08	23°33’36.51”S	46°44’32.98”W
09	23°33’37,3”S	46°44’33,1”W
10	23°33’38,4”S	46°44’08,1”W

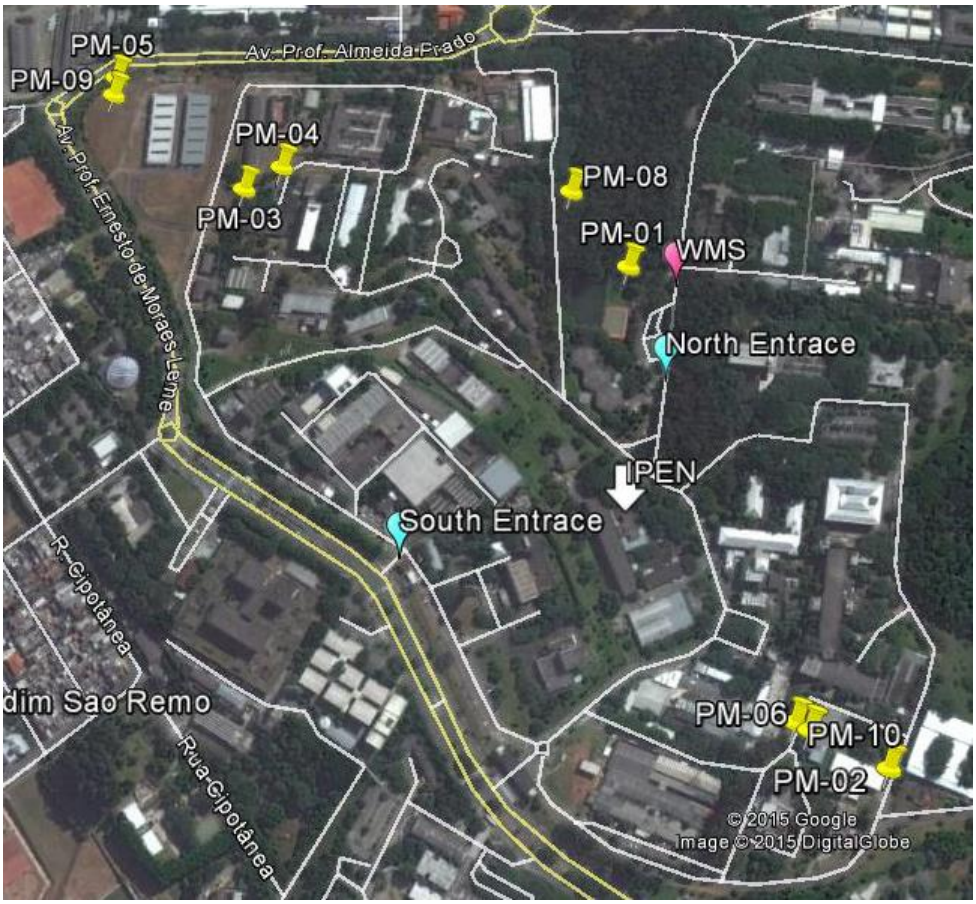

Figure 1: Monitoring well distribution inside Ipen’s facility.

*WMS:Wastewater Monitoring Station

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Table 2: Average concentration, Standard deviation and RSD of major ions on each monitoring well, from 2011 to 2014

Monitoring Well	Statistcs	Cl^- (mg/L)	SO_4^{-2} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	Mg^{+2} (mg/L)	Ca^{+2} (mg/L)	HCO_3^- (mg/L)	Sum major inorganic content (mg/L)
PM-01	Average	3,3	0,8	2,8	6,9	14,0	58,1	167,9	253,8
	STD	0,8	0,9	0,8	3,7	3,3	18,0	42,3	
	RSD	25%	109%	30%	54%	24%	31%	25%	
PM-02	Average	4,5	1,6	7,6	1,0	0,3	1,3	6,7	23,1
	STD	1,0	1,1	2,5	0,9	0,1	0,4	2,4	
	RSD	22%	67%	33%	86%	43%	32%	36%	
PM-03	Average	12,2	4,6	10,3	5,5	2,2	15,7	27,3	77,8
	STD	4,6	3,8	4,7	3,4	0,5	3,9	7,6	
	RSD	38%	84%	46%	62%	23%	25%	28%	
PM-04	Average	6,0	10,0	5,5	4,1	0,8	6,2	12,2	44,8
	STD	2,4	3,8	1,5	3,4	0,3	2,3	7,2	
	RSD	40%	38%	27%	83%	32%	37%	59%	
PM-05	Average	6,4	9,9	5,6	3,9	1,1	3,2	14,4	44,5
	STD	2,1	1,8	2,4	2,9	0,2	2,9	9,2	
	RSD	32%	19%	44%	74%	22%	91%	64%	
PM-06	Average	4,2	2,6	3,2	3,0	0,9	6,6	14,1	34,5
	STD	0,7	4,0	0,7	2,2	0,7	8,4	18,1	
	RSD	16%	156%	23%	74%	82%	126%	129%	
PM-08	Average	5,9	1,2	7,8	1,2	0,5	1,1	12,6	30,2
	STD	3,0	1,7	4,2	1,0	0,1	0,4	18,7	
	RSD	50%	145%	53%	88%	26%	33%	148%	
PM-09*	Average	8,0	0,2	15,4	8,7	9,4	26,2	233,8	301,7
	STD	1,0	0,2	3,6	1,6	1,0	8,9	20,3	
	RSD	12%	90%	24%	19%	11%	34%	9%	
PM-10*	Average	5,0	0,2	14,1	18,7	9,3	23,2	6,9	77,4
	STD	0,7	0,2	4,9	29,1	1,0	12,4	6,5	
	RSD	14%	103%	35%	155%	11%	53%	95%	

* Wells opened on March 2013.

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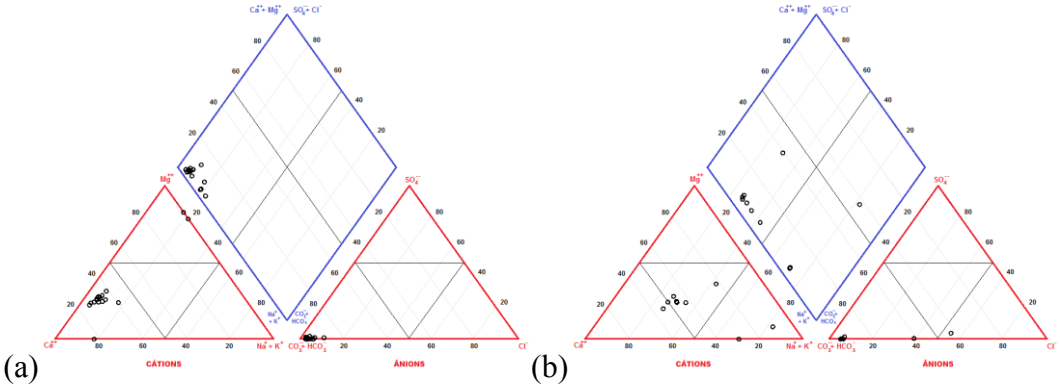
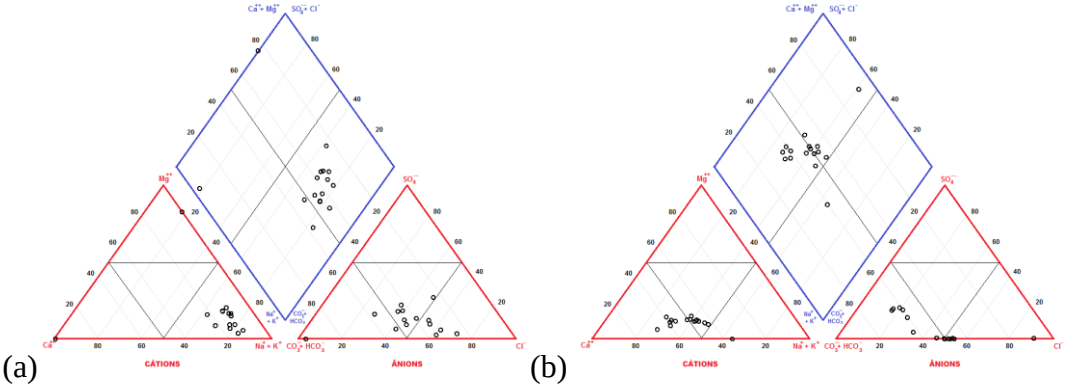
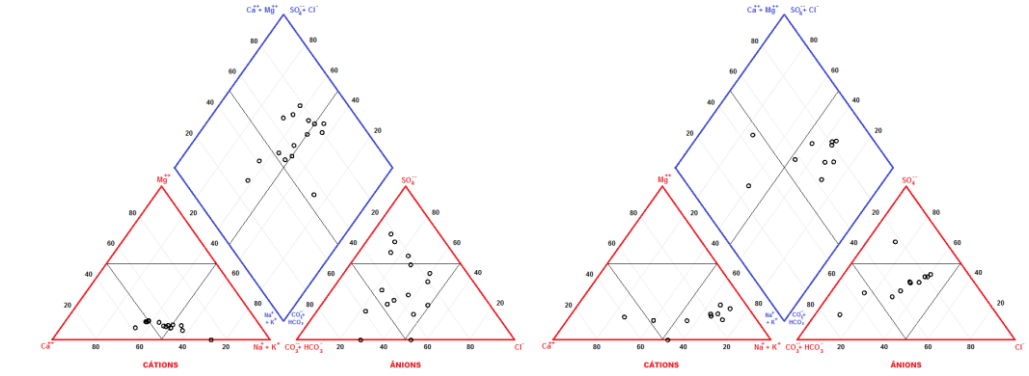


(a) (b)

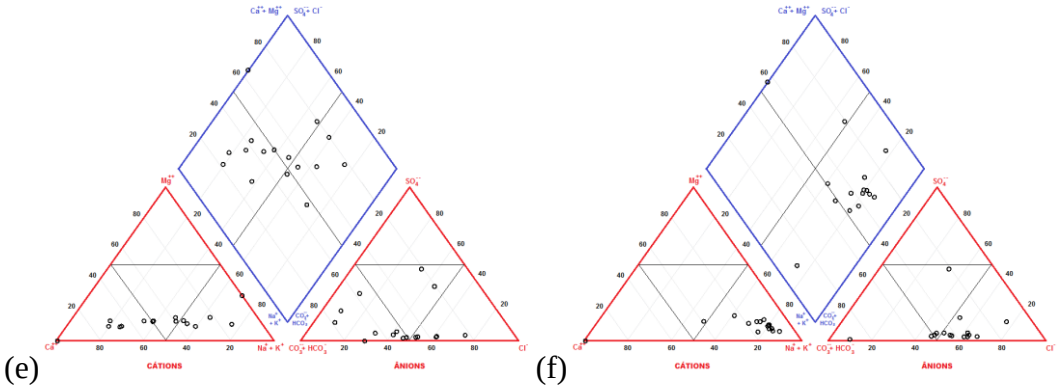
Figure 2: Piper diagrams for PM-01(a) and PM-09 (b).



(a) (b)



(c) (d)



(e) (f)

Figure 3: Piper diagrams of PM-02(a), PM-03 (b), PM-04 (c), PM-05(d), PM-06 (e) and PM-08 (f).

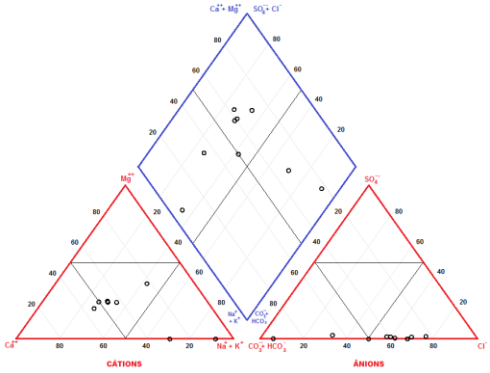


Figure 4: Piper diagrams of PM-10.

2.5. Results

Monitoring wells PM-01 and PM-09 were classified as Bicarbonated calcic waters as presented on Figure 2 (a) and 2 (b). Monitoring wells PM-02, PM-03, PM-04, PM-05, PM-06, PM-08 and PM-10 are considered to have mixed waters either from the cation or from the anion, as presented on Figure 3a-f and on Figure 4. This behavior is also observed on data from Table 2, because PM-01 and PM-09 have also a higher content of inorganic compounds (sum of inorganic content >250 mg/L), due mainly to bicarbonate contribution.

The change observed in monitoring wells PM-03, PM-04, PM-05 and PM-06 from the major composition of sodium + potassium to calcium can be explained by rainwater recharge. Depending on the rain regimen, more or less of each cation can be observed. No other flow or contribution is considered to these wells because of the low salt content present.

3. CONCLUSIONS

According to the Piper Diagram, the wells are chemically classified as:

- Bicarbonated Waters: PM-01 and PM-09
- Low salt content Mixed Waters: PM-02, PM-04, PM-05, PM-06 and PM-08.
- Mixed water: PM-03 and PM-10.

Piper diagrams are helpful to identify flow mixtures, pollution sources or the rain water recharge effect. IPEN's facility is located in a high populated area and can be exposed to different sources of pollution or infiltration, so this tool will be continuously used in order to identify any possible contribution to groundwater composition.
IPEN's Environmental Monitoring Program for stable compounds (PMA-Q) assessed groundwater status, by using Piper diagrams. Now on, PMA-Q will also be able to manage safely any eventual inorganic contribution that may change groundwater relative composition.

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