



Environmental diagnosis of the aquifer free of the north zone of Aracaju - Sergipe through metal, ions and BTEX concentrations

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Abstract

Groundwater is a large percentage of sweet easily accessible water and is often the only option for drinking water supply. In general, it possesses better quality due to interactions with the ground during percolation. The aim of this study was to evaluate the contamination of the unconfined aquifer in the North Zone of Aracaju, SE, through the analysis of metal, ions and BTEX compounds of water samples from shallow wells, relating to potential sources of contamination, evaluating the effects of seasonality and comparing them to the limits of potability of Decree No. 2,914 / 2011 of the Ministry of Health.

Keywords: groundwater, water quality, potability standards.

1. INTRODUCTION

Groundwater generally has good quality for human consumption, requiring less treatment costs than surface water, which makes it more accessible to the public (LAVOIE et al, 2015). Although a significant portion of Brazilian municipalities use groundwater to supply, there are few studies about the resource, its water potential and quality, and most of these are focused on specific issues in the characterization of contaminated sites (ANA, 2007; IBGE, 2010).

According to Araujo (2009), regions with sandy soil and sedimentary rocks, such as Aracaju, are potential suppliers of underground water by porosity and high permeability of this formation, allowing exploration of significant flows.

By being more superficial, the unconfined aquifer is the most exploited by population, and is highly susceptible to contamination (E SILVA ARAUJO, 2003; LIBANIO, 2005; Silva et al, 2014). The contamination of these aquifers is reflected in an important public health problem, since the human consumption of drinking water is one of the biggest ways to prevent disease (E ARAUJO SILVA, 2003).

According to data published by IBGE (2010), only 26 municipalities in Sergipe have sewage, and, out of these, only 07 perform some kind of treatment. The lack of



an efficient environmental sanitation system requires the use of tank-filter-sink, contributing to groundwater contamination, naturally high in sandy soils (FRANCE 2011). Garcia et al (2011) identified contaminated areas in the greater Aracaju associated with domestic and industrial effluents untreated, from trace metals analysis in sediments of rivers, potential contamination of the aquifer.

CETESB reported in 2014 that 5,148 contaminated areas, of which 74.3% related to gas stations and 16.74% industries. Fuels have compounds such as Benzene, Toluene, Ethylbenzene and Xylene, which have high toxicity and carcinogenic potential, directly affecting the central nervous system. Once present in the aquifer, decontamination procedures are needed, usually with high implementation costs.

The current order of the Ministry of Health regarding to the standards of potability of water for human consumption is the Ordinance No. 2,914 / 2011 (BRAZIL, 2011). In addition to this, CONAMA Resolution no. 396/2008 presents Maximum Values Allowed (MVA) parameters to the main uses, i.e., human consumption, watering livestock, irrigation and recreation (CONAMA, 2008), and CONAMA Resolution No. 420/2009 sets out guiding values of the quality for substances in the soil and the ground water as well as guidelines to the management of contaminated areas (CONAMA, 2009).

The aim of this study was to evaluate the contamination of the unconfined aquifer in the North Zone of the municipality of Aracaju / SE, through the analysis of metals, ions and BTEX compounds in water samples from shallow wells, relating to human activities and potential sources contamination, comparing the results to the limits of potability of Decree No. 2,914 / 2011 of the Ministry of Health.

2. MATERIALS AND METHODS

2.1. Study Area

The study area is located the north of the city of Aracaju and in the east of Sergipe, being part of the basin of the Sergipe and Vaza Barris Rivers (Figure 1). Data published by the IBGE (2016), the estimated population of Aracaju in 2015 was of 632,744 inhabitants, the most populous city in the state. The climate is megathermal sub-humid, with an average monthly temperatures ranging from 24.65° C to 27.32° C, rainy season between April and August, and the dry season between September and March. The predominant aquifer is the granular one, formed by sedimentary rocks of the surface formations of the Cenozoic Era, with good storage capacity and water supply due to primary porosity and high permeability of sandy soils (PINTO et al, 2000; ARAUJO, 2009; SERGIPE, 2012; JESUS, 2015 INMET, 2016).

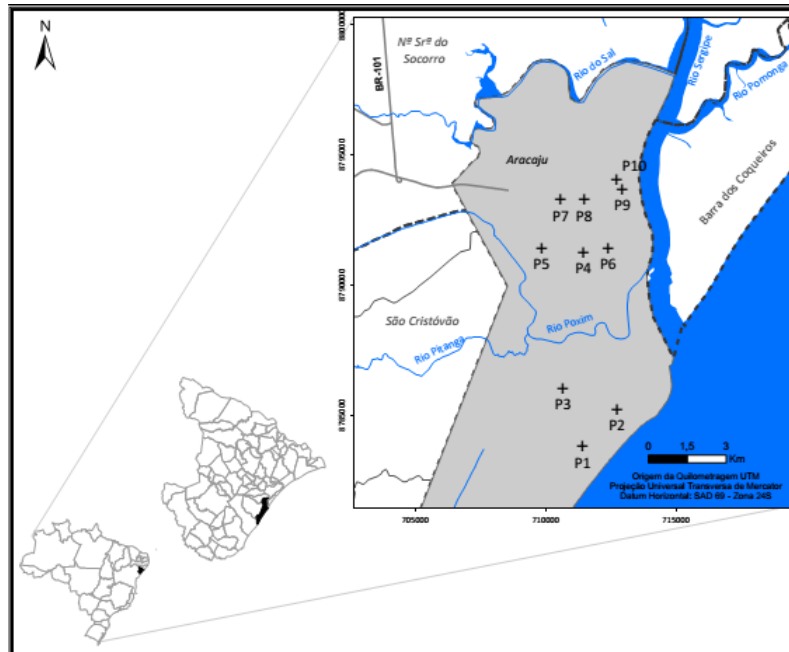


Fig.1 Study area and location of sampling points
Source: Sergipe (2012).

2.2. Methodology

For this work, 10 shallows monitoring wells (up to 8 m deep) were selected to collect, all of them already existing, manually drilled with auger and located in the unconfined aquifer in the North Zone of Aracaju. The sample size was established at the cost of analysis and the twells available for collection. The samplings were carried out in May (rainy season) and in November and December 2015 (dry season), evaluating the seasonal effect for the concentrations of metals (Al, As, Ba, B, Cd, Co, Cr, Cu, Fe, Li, Mn, Ni, Sr, Zn) ions (calcium, magnesium, potassium, sodium, sulphate, chloride, fluoride) and BTEX (benzene, toluene, ethylbenzene and xylenes), and when appropriate, compared to the maximum permissible values of Decree n° 2,914/2011 of the Ministry of Health, CONAMA 420/2009 and CONAMA 396/2008 to characterize the quality of groundwater for potable purposes.

Samples were taken with a sampler bailer manual of double valve, disposable, and immediately transferred to containers appropriate for each analysis, properly identified with tags, and preserved in ice. The valve in the bailer allows the sample to be transferred to sample containers with less loss of volatiles compounds (ASTM, 2010). The collection forms were filled with the data on the collected sample (place, date, sample number, time condition), and the static level of the well.

The preservation of the samples and analysis of the parameters followed the analytic method described in Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The first sample was designed to analysis of BTEX, to preserve the concentration of these volatile (EPA 1986). Analyses were performed at the Environmental Analytical Chemistry Laboratory - LQA - in the Federal University of Sergipe, except total and fecal coliforms, which were analyzed at the Technological Institute and Research of the State of Sergipe - ITPS.

The results were analyzed for dry and rainy season, and when appropriate, compared to the maximum permissible values recommended by Decree N°.

2,914/2011 of the Ministry of Health, and the CONAMA 420/2009 in order to characterize the quality of the underground water for potable purposes.

3. RESULTS AND DISCUSSION

The presence of high levels of metals in groundwater may be related to the release of industrial effluents or leaching of industrial waste, particularly heavy metals such as As, Cr, Cu, Pb, which, in addition to being toxic, have a cumulative effect in the body (Libânio, 2005; FARIAS, 2006). Among metals which have limits of potability (Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni and Zn), only Cd and Mn extrapolated the boundaries (Table 3). Co and Cr were not detected in any of the studied points.

The As was found at all points, exceeding in 9 of them a concentration of 0.01 mg L⁻¹ defined by Decree No. 2,914/11, in at least one of the campaigns. This compound is related to industrial waste, burning coal, mineral smelting activities and insecticides (SON, 2000). The highest value was found in P10, equal to 0.0436 mg L⁻¹ in the dry season.

The Cd concentrations were similar in most samples, with higher values in the dry season, except for P01 and P04. Four points were more critical regarding to the limit of potability (0.005 mg L⁻¹): P02 with 0.0050 mg L⁻¹ in the dry season; P04 with 0.0049 mg L⁻¹ in the rainy season; P09 with 0.0048 mg L⁻¹ in the dry season; and P10 with 0.0077 mg L⁻¹ also in the dry season. The Cd is highly toxic to human health, and the excess can cause anemia, hypertension and death (SANTOS, 2000).

Mn is widely used in the industry for the manufacture of metal alloys, batteries, paints, varnishes, fireworks and fertilizer (FARIAS, 2006). Whereas the limit for human consumption is 0.1 mg.L⁻¹, the concentrations were elevated in 4 out of 10 analyzed points (P01, P02, P08 and P10). P02 was the one which surpassed the research value set by CONAMA n° 420/2009, which is 0.4 mg L⁻¹, requiring environmental research to assess the risk that the presence of this compound may represent to human health.

An acidic pH increases the solubility of the water-metal (CHUAN et al 1996; Yabe and Oliveira, 1998; Jimenez et al, 2004), which may explain the high levels of As, Cd and Mn detected in P10, as well as in other metals such as Al, B, Ba.

Studies by Ahmed et al (2006) in surface soil samples and groundwater an old launch area of industrial effluents in Singapore / SE identified the presence of metals such as Cu, Cd, Zn, Pb, Ni, Cr and Mn. Part of these metals - such as Cu, Cd, Zn, Ni and Mn - was also detected in this study, at least one sample, with emphasis on Cadmium and Manganese concentrations presented above potability standards. Fernandes et al (2013) examined several parameters in shallow wells in the municipality of Quissamã/RJ, and detected concentrations of Al, Fe, Mn and Ni above the maximum allowable limits.

Ions content as calcium and magnesium are very important in the environmental assessment, as they are the main representatives of the water hardness. Hard water can cause fouling of pipes, reduce foaming, increase the consumption of soap and hinder the cooking of foods (LIBANIO, 2005; SANTOS, 2000). The calcium content in the samples ranged from 14.06 to 143.61 mg L⁻¹ in the rainy season and from 8.73 to 88.50 mg L⁻¹ in the dry season. The magnesium concentrations, in turn, ranged from 0.64 to 7.96 mg L⁻¹ in the rainy season and from 0.50 to 9.29 mg L⁻¹ in the dry season. Both showed higher concentrations during the rainy season for most points.

All samples were below 200 mg L⁻¹ sodium, maximum limits by the Ministry of Health and by CONAMA No. 396/2008 for human consumption. Sodium concentrations ranged from 3.97 to 45.59 mg L⁻¹ in the rainy season and from 4.71 to 55.85 mg L⁻¹ in the dry season, with higher values in P06.

Table 1 Total concentration of metals in the rainy season in groundwater

Site	Al mg.L ⁻¹	As mg.L ⁻¹	B mg.L ⁻¹	Ba mg.L ⁻¹	Cd mg.L ⁻¹	Co mg.L ⁻¹	Cr mg.L ⁻¹	Cu mg.L ⁻¹	Fe mg.L ⁻¹	Li mg.L ⁻¹	Mn mg.L ⁻¹	Ni mg.L ⁻¹	Sr mg.L ⁻¹	Zn mg.L ⁻¹
P01	0,0328 ±0,0032	0,0091 ±0,0032	0,0281 ±0,0003	n.d.	0,0041 ±0,0005	n.d.	n.d.	n.d.	0,0005 ±0,0003	0,0163 ±0,0011	0,3824 ±0,0057	n.d.	0,5356 ±0,0040	0,0367 ±0,0056
P02	0,0041 ±0,0010	0,0104 ±0,0039	n.d.	n.d.	0,0040 ±0,0004	n.d.	n.d.	n.d.	0,0025 ±0,0004	0,0227 ±0,0020	0,4069 ±0,0028	n.d.	0,1635 ±0,0023	0,0454 ±0,0020
P03	0,0444 ±0,0092	0,0221 ±0,0019	n.d.	n.d.	0,0034 ±0,0003	n.d.	n.d.	n.d.	0,0392 ±0,0039	0,0162 ±0,0018	0,0429 ±0,0024	n.d.	0,1196 ±0,0047	0,0457 ±0,0058
P04	0,0206 ±0,0071	n.d.	0,0094 ±0,0056	n.d.	0,0049 ±0,0002	n.d.	n.d.	n.d.	n.d.	0,0167 ±0,0017	0,0262 ±0,0038	0,0014 ±0,0002	0,2372 ±0,0039	0,0335 ±0,0022
P05	0,0555 ±0,0037	0,0254 ±0,0038	0,0192 ±0,0037	n.d.	0,0033 ±0,0005	n.d.	n.d.	n.d.	0,0132 ±0,0012	0,0164 ±0,0020	0,0213 ±0,0025	n.d.	0,1040 ±0,0050	0,1706 ±0,0066
P06	0,0262 ±0,0061	0,0078 ±0,0025	0,0280 ±0,0054	n.d.	0,0035 ±0,0006	n.d.	n.d.	n.d.	0,0132 ±0,0003	0,0164 ±0,0019	0,0167 ±0,0030	0,0011 ±0,0004	0,4619 ±0,0062	0,0331 ±0,0014
P07	n.d.	0,0186 ±0,0047	n.d.	n.d.	0,0035 ±0,0004	n.d.	n.d.	n.d.	n.d.	0,0167 ±0,0018	n.d.	n.d.	0,1403 ±0,0032	n.d.
P08	n.d.	0,0279 ±0,0042	0,0015 ±0,0003	n.d.	0,0033 ±0,0002	n.d.	n.d.	n.d.	0,0086 ±0,0002	0,0167 ±0,0018	0,1447 ±0,0038	n.d.	0,1950 ±0,0028	0,0138 ±0,0053
P09	0,0968 ±0,0083	0,0146 ±0,0019	n.d.	n.d.	0,0045 ±0,0005	n.d.	n.d.	n.d.	0,0512 ±0,0004	0,0169 ±0,0015	n.d.	n.d.	0,0493 ±0,0027	n.d.
P10	n.d.	0,0071 ±0,0065	0,0090 ±0,0004	n.d.	0,0036 ±0,0003	n.d.	n.d.	n.d.	0,0430 ±0,0003	0,0163 ±0,0018	0,0042 ±0,0007	n.d.	0,3759 ±0,0019	n.d.

n.d. Not detected

Table 2 Total concentration of metals in the dry season in groundwater

Site	Al	As	B	Ba	Cd	Co	Cr	Cu	Fe	Li	Mn	Ni	Sr	Zn
	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹
P01	0,0447 ±0,0033	0,0183 ±0,0049	0,0252 ±0,0045	n.d.	0,0020 ±0,0002	n.d.	n.d.	n.d.	0,0148 ±0,0036	0,0162 ±0,0016	0,1091 ±0,0022	0,0001 ±0,00001	0,3691 ±0,0041	0,0261 ±0,0014
P02	n.d.	0,0057 ±0,0040	0,0153 ±0,0059	n.d.	0,0050 ±0,0003	n.d.	n.d.	n.d.	0,0983 ±0,0026	0,0201 ±0,0011	0,1074 ±0,0061	0,0021 ±0,0003	0,1141 ±0,0023	0,0355 ±0,0057
P03	0,0092 ±0,0009	0,0052 ±0,0033	n.d.	n.d.	0,0044 ±0,0002	n.d.	n.d.	n.d.	0,0375 ±0,0061	0,0163 ±0,0013	0,0494 ±0,0045	0,0019 ±0,0007	0,0747 ±0,0044	0,0448 ±0,0032
P04	0,0083 ±0,0008	0,0182 ±0,0016	n.d.	n.d.	0,0034 ±0,0001	n.d.	n.d.	0,0006 ±0,0001	n.d.	0,0180 ±0,0015	0,0209 ±0,0055	n.d.	0,3989 ±0,0031	0,0768 ±0,0037
P05	0,0207 ±0,0083	n.d.	n.d.	n.d.	0,0040 ±0,0004	n.d.	n.d.	n.d.	0,0602 ±0,0026	0,0165 ±0,0020	0,0140 ±0,0065	n.d.	0,0366 ±0,0062	0,0746 ±0,0017
P06	0,0205 ±0,0078	n.d.	0,0252 ±0,0011	n.d.	0,0036 ±0,0005	n.d.	n.d.	n.d.	0,0369 ±0,0050	0,0161 ±0,0019	0,0467 ±0,0030	n.d.	0,3622 ±0,0038	0,0175 ±0,0017
P07	n.d.	n.d.	0,0066 ±0,0022	n.d.	0,0039 ±0,0004	n.d.	n.d.	n.d.	n.d.	0,0175 ±0,0014	0,0089 ±0,0042	n.d.	0,2199 ±0,0021	n.d.
P08	n.d.	n.d.	0,0026 ±0,0014	n.d.	0,0042 ±0,0006	n.d.	n.d.	n.d.	0,0343 ±0,0015	0,0168 ±0,0021	0,0068 ±0,0015	n.d.	0,1899 ±0,0050	n.d.
P09	0,0121 ±0,0033	n.d.	n.d.	n.d.	0,0048 ±0,0001	n.d.	n.d.	n.d.	0,0276 ±0,0012	0,0161 ±0,0015	0,0027 ±0,0005	n.d.	0,1016 ±0,0054	n.d.
P10	0,0162 ±0,0012	0,0436 ±0,0039	0,0825 ±0,0054	0,6202±0,031 0	0,0077 ±0,0002	n.d.	n.d.	n.d.	0,0128 ±0,0029	0,0251 ±0,0021	0,1633 ±0,0034	0,0286 ±0,0026	0,1724 ±0,0046	0,0482 ±0,0032

n.d. Not detected

Potassium was detected in all samples, with little variation between the rainy and dry periods, ranging from 2.77 to 16.88 mg L⁻¹ in the first, and from 2.08 to 16.85 mg L⁻¹ in the second one. The law does not define a maximum value for potassium concentrations, and its toxicity to humans is not well known, since in general health risks are related to people who already have some susceptibility, such as renal and cardiac diseases, hypertension, diabetes and others. (WHO, 2011).

As regards to the sulfate ion, this one may be related to the discharge of domestic and industrial effluents, which for human consumption should be at a maximum concentration of 250 mg L⁻¹; above that, it has laxative effects (PIVELI AND KATO, 2005). All samples were below this value, and therefore fit for human consumption. The highest concentrations were found in the dry season, with maximum value in P06, equal to 40.18 and 41.84 mg L⁻¹ in the rainy and dry, respectively; and minimum value in P02, equal to 1.79 and 1, 93 mg L⁻¹ in the rainy and dry seasons, respectively.

The presence of chlorides in groundwater is very common, and may be the result of the dissolution of salts, saline intrusion and also the release of domestic and industrial effluents (LIBANIO, 2005). Chloride concentrations were detected in all samples and none of them exceeded the limit of 250 mg L⁻¹ of Decree No. 2,914/11. The samples collected in the dry season showed higher concentrations, as a result of lower water demand period, and therefore less dilution.

Fluoride is most commonly found in the environment by applying fluoride in the treatment plants as a preventive dental caries (BRAZIL, 2013). In groundwater, may also be present by the decomposition of soil and rocks, and in higher concentrations may be harmful, causing tooth decay (LIBANIO, 2005). It was detected in all samples below the limit of 1.5 mg.L⁻¹.

Table 3 Total concentration of ions in the samples analyzed in the rainy season

Site	Ca mg.L ⁻¹	Mg mg.L ⁻¹	Na mg.L ⁻¹	K mg.L ⁻¹	SO ₄ mg.L ⁻¹	Cl mg.L ⁻¹	F mg.L ⁻¹
P01	143,61 ±0,17	7,816 ±0,011	24,847 ±0,190	11,821 ±0,012	32,888 ±0,204	54,61 ±0,14	0,280 ±0,025
P02	60,20 ±0,10	2,544 ±0,011	26,881 ±0,143	8,564 ±0,012	1,793 ±0,111	58,90 ±0,08	0,462 ±0,035
P03	37,81 ±0,06	2,985 ±0,006	8,602 ±0,187	3,323 ±0,019	12,431 ±0,121	14,33 ±0,07	0,047 ±0,003
P04	57,52 ±0,15	2,429 ±0,019	19,145 ±0,179	5,938 ±0,006	25,311 ±0,163	26,95 ±0,15	0,237 ±0,035
P05	33,85 ±0,13	1,234 ±0,013	9,918 ±0,173	2,770 ±0,019	7,071 ±0,135	15,65 ±0,10	0,042 ±0,003
P06	111,81 ±0,16	7,963 ±0,012	45,588 ±0,197	16,885 ±0,009	40,179 ±0,154	72,77 ±0,09	0,156 ±0,028
P07	25,85 ±0,11	0,674 ±0,020	3,970 ±0,060	3,374 ±0,006	5,356 ±0,200	5,30 ±0,06	0,076 ±0,009
P08	54,84 ±0,15	3,726 ±0,009	27,364 ±0,182	10,448 ±0,017	33,584 ±0,156	47,18 ±0,19	0,250 ±0,039
P09	14,06 ±0,08	0,758 ±0,014	5,170 ±0,088	4,589 ±0,006	5,253 ±0,204	8,27 ±0,05	0,023 ±0,005
P10	92,30 ±0,19	5,843 ±0,006	35,292 ±0,095	15,233 ±0,007	12,608 ±0,182	55,05 ±0,10	0,146 ±0,036

Table 4 Total concentration of ions in the samples analyzed in the dry season

Site	Ca	Mg	Na	K	SO ₄	Cl	F
	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹	mg.L ⁻¹
P01	83,38 ±0,11	9,297 ±0,018	25,136 ±0,060	5,863 ±0,016	36,825 ±0,139	54,81 ±0,14	0,330 ±0,046
P02	34,73 ±0,18	2,541 ±0,013	30,104 ±0,194	5,644 ±0,009	1,931 ±0,181	61,19 ±0,06	0,485 ±0,024
P03	19,86 ±0,08	2,327 ±0,014	10,110 ±0,207	7,443 ±0,018	14,930 ±0,159	14,87 ±0,21	0,052 ±0,021
P04	65,08 ±0,13	4,494 ±0,011	22,693 ±0,093	8,462 ±0,009	26,829 ±0,144	30,13 ±0,06	0,250 ±0,041
P05	8,73 ±0,06	0,508 ±0,008	10,665 ±0,137	2,077 ±0,009	7,496 ±0,097	17,12 ±0,10	0,051 ±0,001
P06	88,50 ±0,17	8,466 ±0,017	55,854 ±0,106	11,815 ±0,013	41,841 ±0,097	74,56 ±0,09	0,179 ±0,036
P07	41,60 ±0,18	2,007 ±0,009	4,710 ±0,086	4,865 ±0,015	5,786 ±0,135	5,64 ±0,08	0,083 ±0,007
P08	48,38 ±0,10	3,735 ±0,009	31,639 ±0,084	7,300 ±0,015	33,604 ±0,141	54,21 ±0,21	0,272 ±0,050
P09	28,24 ±0,12	2,343 ±0,010	6,253 ±0,072	4,411 ±0,007	6,156 ±0,135	9,89 ±0,13	0,028 ±0,005
P10	77,41 ±0,13	2,026 ±0,012	42,447 ±0,147	16,845 ±0,020	15,062 ±0,166	61,39 ±0,12	0,165 ±0,022

BTEX compounds are monoaromatic hydrocarbons used as fuel for contamination indicators, specifically gasoline, being the most soluble fraction of it (BARROS and PORTO, 2009). Seven of 10 points analyzed showed some type of contamination related to fuels, results related to the existence of gas stations in the vicinity of all points.

Regarding to benzene, the most toxic of BTEX compounds (Mariano, 2006), P01, P02 and P10 had significantly higher values, above those permitted by law (0.005 mg L⁻¹). The long-term exposure to benzene can cause chronic effects such as a change in the bone marrow, in the chromosomes in the immune system, cancer, damage to the central nervous system and irritation to the skin and mucous membranes (ARCURI et al, 2012).

Toluene has a limit equal to 0.17 mg.L⁻¹ and may be found in addition to gasoline, in household products, such as cleaners and adhesives (Forster et al, 1994), in the manufacture of adhesives, printing inks, solvents, pharmaceuticals or cosmetic additives (E PIVELI KATO, 2005). This substance was found in 6 points in concentrations exceeding the established legal value. Only P08 in the rainy season, presented below, equal to 0.016 mg L⁻¹. The toluene exposure affects the central nervous system causing excitation or depression, tremor, depression, hallucinations, convulsions and coma, may also cause problems in the liver and kidneys (PIVELI and KATO, 2005).

The ethylbenzene was detected in 5 points, in very high concentrations in P01 and P02 points, as the limit of 0.2 mg L⁻¹ of Decree No. 2,914/11. The values in the rainy season were 7.69 and 5.17 mg L⁻¹ for P01 and P02 respectively, increasing the dry period to 20.12 mg L⁻¹ in P01 and 7.35 mg L⁻¹ in P02. Only P09 showed values below the legal limits. Finotti et al (2001) reports that this compound is toxic, but does not bioaccumulate and is not carcinogenic, such as benzene, which has stricter values.

The total represents the sum of xylene isomers ortho, meta and para-xylene, and are present in gasoline and solvents in the manufacture of paints. These degrade rapidly in the atmosphere by photo-oxidation; and in water, m-xylene and p-xylene degrade easily under aerobic or anaerobic conditions, while the o-xylene is more persistent (PIVELI and KATO 2005). In Legislation, the ceiling for human consumption is presented as a total xylene equal to 0.3 mg L⁻¹. In the five points presented xylene

concentrations, all above 0.3 mg L⁻¹, the values ranged from 1.33 to 1.42 mg L⁻¹ in the rainy season and from 0.34 to 4.22 mg L⁻¹ in the dry season. It is noteworthy that the o-xylene was not detected in any of the samples, and only the presence of m-xylene and p-xylene may indicate a more recent contamination.

The highest values in the dry season may represent a new contamination between periods, but may also be a result of the lower volume of water in the dry season, as noted in the study by Silva et al (2002).

Additionally, the presence of dissolved oxygen and nitrate in the water may have contributed to the biodegradation of BTEX compounds in the analyzed wells (Silva et al, 2002). In the case of P01, the reduction in the concentration of benzene and toluene between the rainy and dry seasons may indicate biodegradation of these compounds, since the reduction of oxygen levels to zero. In the point P02 the absence of dissolved oxygen and the increase of nitrate concentration does not represent evidence of biodegradation of the compounds, in accordance with the increase of the concentration of benzene, ethylbenzene and xylene. Thus, the observed reduction of the toluene concentration in this sample (P02) may have been due to natural volatilization of the compound.

The biodegradation of petroleum hydrocarbons may generate acidic by-products which reduce the pH of the medium, and consequently slow down microbial activity (Andrade et al, 2010). The toluene degradation, for example, releases CO₂ into underground water, which increases the acidity of the medium (Mariano, 2006). This may explain the reduction in pH, dissolved oxygen consumption and increasing concentrations of BTEX in P10 in the dry period.

Among the results, the concentrations of BTEX compounds diagnosed a serious situation for contamination by fuel, out of 10 points analyzed, 7 exceeded the limits of potability for any of these parameters in at least one of the campaigns. The limits of the turbidity, nitrite, sodium, sulfate, fluoride, chloride, aluminum, barium, copper, iron, nickel and zinc parameters are not exceeded in any of the samples performed.

Table 5 Total concentrations of BTEX in the samples

Site	Rainy				Dry			
	Benzene mg.L ⁻¹	Toluene mg.L ⁻¹	Ethylbenzene mg.L ⁻¹	Total xylene mg.L ⁻¹	Benzene mg.L ⁻¹	Toluene mg.L ⁻¹	Ethylbenzene mg.L ⁻¹	Total xylene mg.L ⁻¹
P01	23,940 ± 1,077	0,460 ± 0,058	7,690 ± 0,988	1,330 ± 0,037	17,569 ± 0,957	n.d.	20,120 ± 1,089	3,238 ± 0,088
P02	6,990 ± 0,997	0,260 ± 0,038	5,170 ± 0,769	1,420 ± 0,076	15,753 ± 0,927	n.d.	7,349 ± 0,781	4,219 ± 0,091
P03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
P04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
P05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0,212 ± 0,038	1,246 ± 0,087
P06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
P07	n.d.	n.d.	n.d.	n.d.	n.d.	0,232 ± 0,072	n.d.	0,874 ± 0,024
P08	n.d.	0,160 ± 0,034	n.d.	n.d.	n.d.	0,350 ± 0,029	n.d.	n.d.
P09	n.d.	0,200 ± 0,026	n.d.	n.d.	n.d.	0,548 ± 0,082	0,127 ± 0,035	n.d.
P10	n.d.	0,280 ± 0,019	0,110 ± 0,076	n.d.	2,173 ± 0,027	0,658 ± 0,106	0,343 ± 0,035	0,342 ± 0,039

n.d. Not detected.

4. CONCLUSIONS

Aracaju has vulnerabilities which allow us to infer a poor quality of the unconfined aquifer, because besides the existence of the various impacts inherent to urban areas, the predominance of sandy soils provides conditions favorable for contamination. The results diagnosed that water is unfit for human consumption in 09 of 10 analyzed points, in at least one of the campaigns..

The detection of BTEX compounds show greater concern for these toxicity at high concentrations, even it is highly volatile, suggesting greater attention to these parameters in potability assessments.

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