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MONITORING TIME AND SPATIAL CHANGES IN GROUNDWATER SALINITY IN RECIFE COASTAL PLAIN

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ABSTRACT

Recife, capital city of Pernambuco State, in Northeast Brazil, is built over a sedimentary low plain about 2.0m meters of average height above sea level, surrounded by small hills. Due to over-exploitation and to presence of point sources of contamination, groundwater is subjected to degradation and salinization.

This work presents the analysis of a monitoring program for the groundwater salinity in Recife Coastal Plain, aiming to assess the occurrence of seawater intrusion in the Cabo Aquifer. Mainly deep wells have been investigated, but few shallow wells have been included in the monitoring program. From May 1999 to August 2002, 18 campaigns have been undertaken, evaluating electrical conductivity of 86 wells, with individual frequency, in Boa Viagem beach near the coast. During this period others ions have been analysed in selected wells and periods and ionic ratios have been calculated looking for evidences of seawater intrusion. Although in some points the salinity has increased during the monitoring program, the results do not fully confirm the occurrence of groundwater contamination in the Cabo Aquifer from seawater intrusion.

INTRODUCTION

Groundwater has been historically used in Recife Metropolitan Region, in the Northeast Coast of Brazil, as a complementary source. However, recent shortage on water supply, due to droughts, besides problems related to losses in the water supply system, has led part of the population to look for guaranty on water supply, drilling private wells. Facing difficulties due to population growth and increasing water consumption, COMPESA (the agency in charge for the water supply) has also increased the number of public operating wells. The aquifer system in the area is composed of two confined aquifers, Cabo and Beberibe, overlined by an unconfined formation, the Boa Viagem Aquifer. The Cabo Aquifer in Recife Coastal plain has been the most intensively exploited. The Boa Viagem Aquifer is the most directly exposed to contamination, since it is connected to mangroves and rivers estuaries. The impact of urbanization, leading to a decrease in natural recharge and over- exploitation conditions and the risk of seawater intrusion has been posing the aquifer system under severe threat of degradation.

Many academic and technical studies have been undertaken aiming to issue elements for groundwater management in the area]. One of the most critical areas identified is in Boa Viagem beach, a residential and touristic area with high population density. According to one of the studies, which has issued a management plan incorporated in the State Groundwater Law, in part of the area, denominated “Zone A”,

drawdowns in the piezometric levels of more than 50m have been observed in some wells, for the past 25 years [Costa et al., 1998].

A research program has been established in May 1999 to investigate the temporal and spatial variation in groundwater quantity and quality, specially salinity and infer the salt intrusion risk.

GEOLOGY

The aquifers in the RMR are classified according to the geomorphological domain in: 1) Basement rocks plain (fractured aquifer); 2) Northern Sedimentary and Recife Coastal plains (porous aquifer). The Recife Coastal plain occupies an area of 112 km^2. The Cabo aquifer occurs in the Recife Coastal plain, and comprises sandstones, siltstones and mudstones, with average thickness of 90m. The Beberibe aquifer occurs in the Northern Sedimentary plain, with average thickness of 100m of sandstones with intercalations of mudstone. Both Beberibe and Cabo aquifers are semi-confined formations. The Boa Viagem aquifer, an unconfined formation, overlies both the Beberibe and Cabo aquifer and comprises sand, silt and clay, with an average thickness of 40m. Although the Beberibe aquifer is the most important formation in terms of water storage, the Cabo aquifer is the most exploited. The Boa Viagem aquifer is the most vulnerable formation in terms of water quality. Since the area is highly urbanized, recharge from rainfall is decreasing throughout the years.

MONITORING PROGRAM

A monitoring program funded by the Brazilian Federal Government through a research project has been established for investigating the groundwater salinity levels in the Cabo aquifer in the most exploited areas. One hundred and seven wells have been monitored since May 1999 to August 2002, with individualized frequency, and comprising 18 monitoring surveys. The main foccus of the monitoring program has been a sample of wells located alongside the coast in a region approximately 10 km long and 300m wide with more than 500 deep wells operating and where salinity levels had caused some wells to be abandoned. Most of the monitored wells extract water from the Cabo aquifer but some shallow wells extracting water from the upper formation, the Boa Viagem aquifer have also been included, to infer an evidence of the difference in salinity pattern between the two formations.

For the total 568 samples analyzed during the monitoring program, the electrical conductivity ranged from 0.10 to 36 dS/m. Figure 1 shows the frequency distribution of electrical conductivity in the monitoring wells, from May 1999 until August 2002.

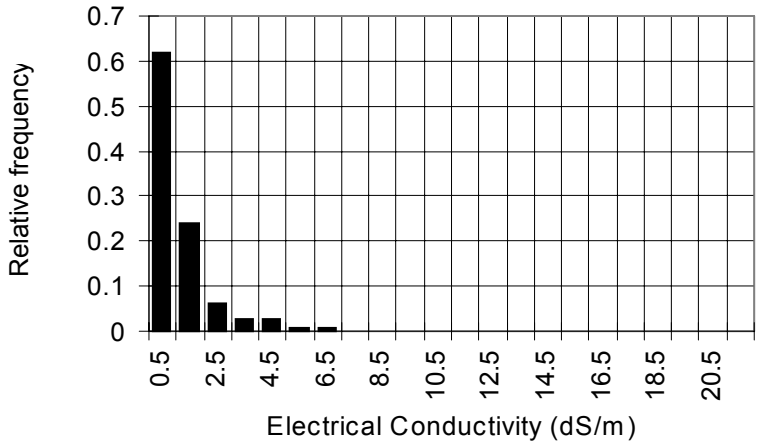

Figure 1- Frequency histogram of Electrical Conductivity in the monitoring wells (May 1999 to August 2002).

It can be verified that more than 60% of the readings are related to electrical conductivity lower than 1 dS/m. It can be instructive to examine the aquifer response to rainfall. Figure 2 exhibits the behavior of the mean electrical conductivity and the standard deviation of the electrical conductivity in time, together with the monthly rainfall.

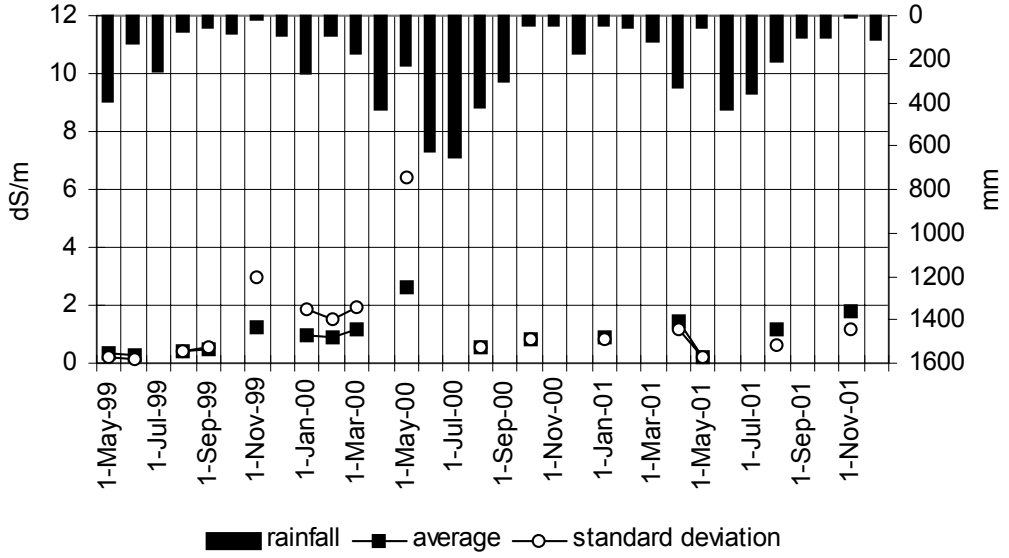

Figure 2- Average electrical conductivity, standard deviation of electrical conductivity in time, and rainfall.

Figure 2 highlights that after the end of a dry year (1999),(less than 40% of the historic mean) when a groundwater over-exploitation scenario has occurred, both the mean and the dispersion of the electrical conductivity has increased, as for example for November 1999. By then the occurrence of monthly rainfall higher than 200mm has

diluted salinity and, at the same time, reduced the over-pumping behavior. Figure 3 presents the statistical distribution of the electrical conductivity for November 1999 and January 2000.

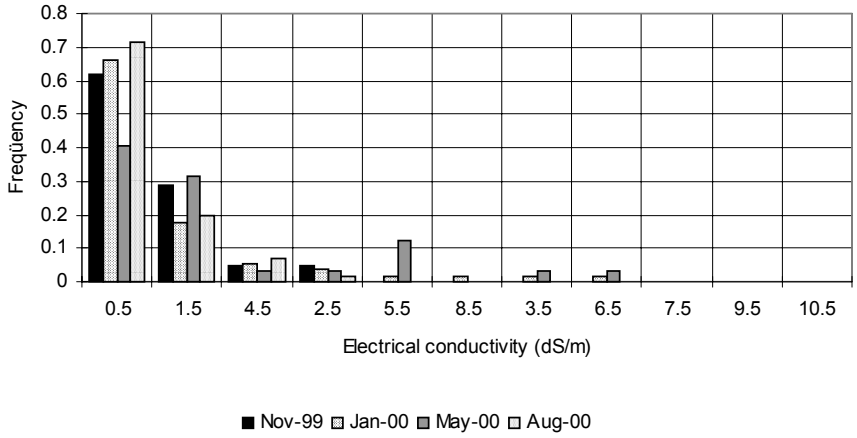

Figure 3- Electrical Conductivity dilution in the monitoring wells, in November 1999-January 2000; .and in May-2000- Aug-2000

It can be verified from Figure 3 that the main dilution has occurred for the electrical conductivity range from 1.0 to 2.0dS/m. Another important dilution can be verified between May 2000 and August 2000, as a result of monthly rainfall higher than 600mm. Again, the main dilution has occurred for wells exhibiting electrical conductivity in the 1.0-2.0dS/m range, but also for the range between 4.0 and 5.0 dS/m (Figure 3).

An important criteria to analyse the salt intrusion risk is to assess the ionic ratios between chlorine and bicarbonate (greater than 20 for seawater), and between Magnesium and Calcium (greater than 5 for seawater). Figure 4 presents the results for the case study, for March 2002. Thirty locations have been analysed.

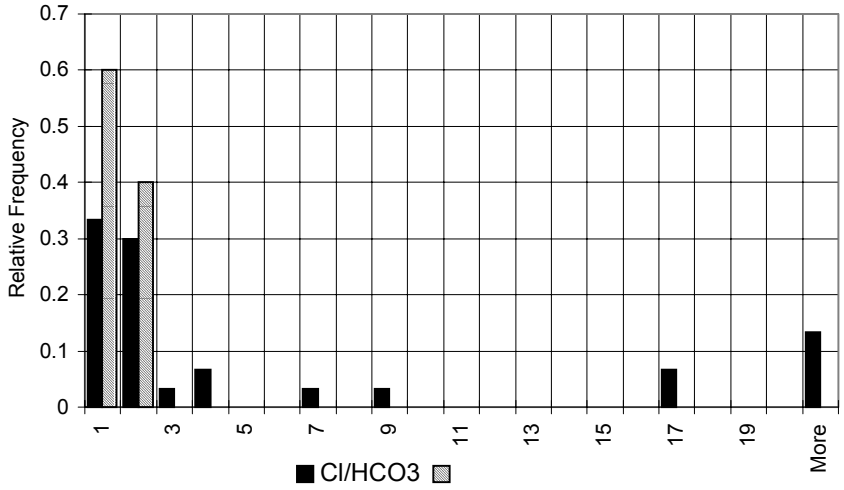

Figure 4- Ionic ratios $rCl/rHCO_3$ and rMg/rCa.

In order to investigate the spatial pattern of electrical conductivity variation, the mean value for each monitoring well has been analysed. It can be verified that about 60% of the monitoring network exhibits electrical conductivity lower than 1,0dS/m (Figure 1). After sorting the mean values and assessing the experimental cumulative frequency, it can be verified that the data shows a log-Normal behavior. To assess spatial variability of electrical conductivity, the classical semivariogram has been estimated. Figure 5 presents the experimental semi-variogram and the adjusted Gaussian model. It can be observed large range of spatial dependence, greater than 300.00m.

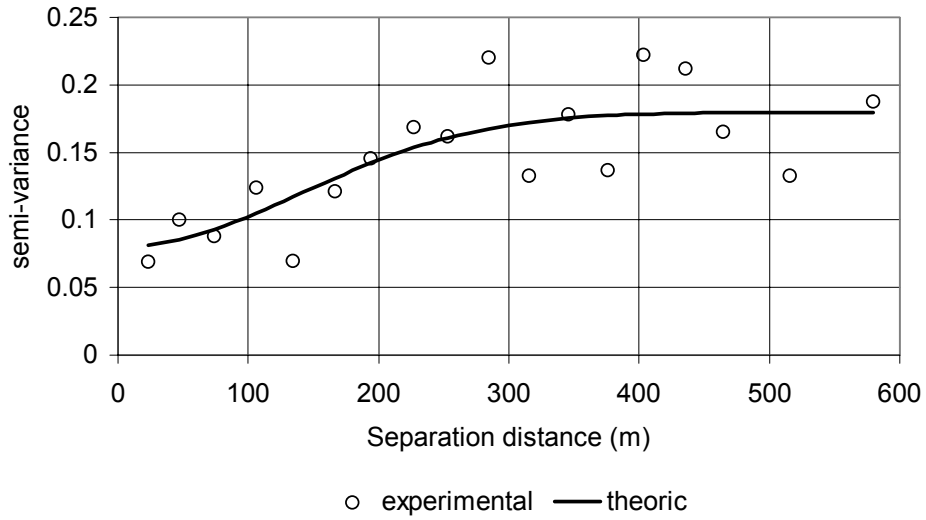

Figure 5- Spatial dependence of log(CE) for the monitoring network.

FINAL CONSIDERATIONS

Even though the results reveal areas where the salinity is high, the occurrence of seawater intrusion has not been clearly identified. Ionic ratios between chlorine and bicarbonate, and Magnesium and Calcium suggest that at some points contribution from seawater to groundwater is likely to occur. Rainfall is an important factor towards controlling salinity patterns. For the considered network, the electrical conductivity is lognormally distributed and exhibits a high spatial correlation length.

ACKNOWLEDGMENTS

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