SECULAR EVALUATION OF PHYSICAL CHEMICAL CARACTERISTICS OF WATERS USED IN THE CACHOEIRA II IRRIGATED PERIMETER, SERRA TALHADA/PE BRAZIL

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ABSTRACT - Brazil’s Northeastern region, so even possess one high potential for agriculture, is harmed by the uneven distribution of rains, having promoted great risks of salinization in irrigated areas. This risk is related to the climate, relief and parent material of the soils, and leaves salts in the profile of the ground which are propagated by water used in the irrigation. The objective of the work was to carry through an evaluation of waters’ characteristics used for irrigation in the Cachoeira II Irrigated Perimeter, as well as making a survey of the quality of these waters. The study area corresponds to the Cachoeira II Irrigated Perimeter, with 37 lots, located at Serra Talhada city, Pernambuco, Brazil. Each three months, water samples were collected at water sources of the perimeter, being grouped in: group I - Pajeú River water, group II - Cachoeira Streamlet water, and group III - Main reservoirs and wells waters used in the Perimeter; to all, 76 water samples had been collected. In these water samples, they had been carried pH and electrical conductivity (EC) analysis, Ca^{2+} and Mg^{2+} concentration by atomic absorption spectrophotometry, Na^+ and K^+ by flame photometry, and Cl^-, HCO_3^- and CO_3^{2-} by titration. It was calculated the sodium adsorption ratio (SAR) for waters classification and its variations in the studied period. The results had been analyzed by descriptive statistics. It was observed the predominance of sodium chloride waters, varying at waters sources (groups I, II and III) and year period. The waters used in irrigation at perimeter had presented salinization risk and it contains high levels of sodium and chloride salts. The values of pH had been inside of the normal limits (6.5 the 8.4) in the studied period. But the wells waters presented Cl^- values higher than 3 $mmol_c\ L^{-1}$, with average values of 19.53 $mmol_c\ L^{-1}$, the biggest average values of the SAR had been found in the third collection of waters, collected at December (2006). The waters of the wells had been the ones that had presented higher values of EC in all the collections, leaving salinity risk for many cultures of economic value.

Key-words: Salinity, sodicity, space variability.

INTRODUCTION

The semi-arid Northeast region of Brazil, has a high potential for agriculture, but is damaged with irregular rain regime and great rate of evaporation, promoting a high risk of salinization in soils. This risk is related to the naturally occurring salts in the soil profile and conducted by irrigation waters used in these areas, as well as the capillary rise of salts from underground waters to the soil surface. Irrigation development in these areas, typically, is associated with a high risk of salinization, often compromising the quality of water's reserves available. Thus, management alternatives that mitigate the evaporation of water from soil and the techniques that reduce total applied volume water are desirable (Lima et al., 2006).

The presence of salts in waters is related to the substrate's characteristics (nature and type of soil) in contact with it, leaving their concentrations in the dependence of the evaporation rate. During the process of weathering, the salts are naturally solubilized and transported by water to underground water tables (Hoffman, 1997; Santos, 2000).

The groundwater importance in the salinization process is related by Fernandes (2005) and Bernstein et al. (2006) showing that, when the water is accumulated in the subsoil at depression areas, the concentration of salts happen because the rocks weathering, which are carry and deposited in these reservoirs. Those waters use and exploitation disorderly can cause serious damage to crops and the soil, depending on the management and quality of water used.

Irrigation management can lead the process of leaching, contributing to the removal of soluble salts to deeper soil layers. If been complete the leaching, the salts in soil solution will be deposited at saturated profile, causing water table electrical conductivity increase. Won't to occur this increase in electrical conductivity, incomplete leaching can be done, so, the sheet will deposit the salts in a layer between the root zone and the water table (Andrade Junior et al., 2006).

Water quality used for irrigation may influence several factors, such as water availability to plants, specific ions toxicity, excessive vegetative growth, plant fallen down and equipment corrosion. According Cruz and Melo (1969) and Oliveira (1997), crystalline waters presents high levels of electrical conductivity (EC), with values over 1.4 dS m^{-1}, often reaching 4.5 dS m^{-1} or above this, also presents itself limitation of flow around 4.0 m^3 h^{-1} in most of wells drilled in this geological formation. To use these waters in irrigation, it is necessary proper irrigation and drainage management, and the use of tolerant plants to these salinity levels.

The use of quality water indicators allows correlating the changes in drainage basin, both anthropogenic and natural origin, trying monitoring the possible deterioration of water quality in time. For an ecological interpretation of this phenomenon, it's necessary to establish a checking system and simple methods use that produce objective and interpretable information (Toledo & Nicolella, 2002).

Taking into consideration that the water is a crucial factor in crop production and that in semi-arid regions, the concentration of salts in the irrigation waters varies with the evaporation rate and the chemical composition of the rocks and soils where these waters moving, the lack of information concerning their quality could lead to inappropriate use of water, with consequent adverse effects on the physicochemical properties of soil (Costa & Gheyi, 1984).

It's possible to observe that the irrigation water quality, especially in semi-arid regions, can cause soil degradation, changing their hydraulic behavior. In experiments with Pernambuco's state reference soils, in Brazil, Freire et al. (2003a) found that increasing the sodium adsorption ratio (SAR) of irrigation water resulted in hydraulic conductivity (Ko) decrease, especially in cases where irrigation water EC was lower and SAR higher, encouraging the dispersion of the soil colloids.

According Ayers and Westcot (1991), the leaching is the practical method to control the accumulation of salts in the root zone and can be used to prevent or correct salt accumulation from irrigation water. For the effective salinity management it is necessary both to drainage in order to control and stabilize the level of the water table, such as leaching, to avoid excessive accumulation of salts in the soil profile, particularly in alluvium areas of the arid and semi-arid regions, with the occurrence of surface water table.

This study aimed to conduct an assessment of spatial and temporal characteristics of the water used for irrigation in the Cachoeira II Irrigated Perimeter, at Serra Talhada, Pernambuco, Brazil, with a waters quality survey in the course of a year of observations.

MATERIALS AND METHODS

The study area includes the Cachoeira II Irrigated Perimeter, composed by 37 lots, located at Serra Talhada city, in the semi-arid region of Pernambuco (Brazil), region of the High Pajeú. The perimeter is located in the geographical coordinates: 7º 58' 54" to 8° 01' 36" South latitude and 38° 18' 24" to 38° 21' 21" West Longitude, downstream of Cachoeira Dam, which semi-perpetuates the Cachoeira streamlet, one of the tributaries of the Pajeú River.

According to the Köppen classification, adapted in Brazil, the area is located at climate area Bsw'h', very hot and semi-arid. This climate is characterized by presenting a rainy season from summer to autumn, average annual rainfall of 720 mm and an average annual temperature of 27.0°C (DNOCS, 1999).

Each three months, water samples were collected at water sources of the perimeter, being grouped in: group I - Pajeú River water, group II - Cachoeira Streamlet water, and group III - Main reservoirs and wells waters used in the Perimeter. In all, 76 samples were collected from water resources. Beyond these samples were also collected samples of water in the Jazigo Dam, which controls the flow of the Pajeú River and Cachoeira Dam, which controls the flow of Cachoeira Streamlet, these samples were used for the purpose of comparison with other waters.

The number of samples varies from one to another collection as well as the place of collection on the basis of high levels of pollution found in the waters used for water supply at Cachoeira II Irrigated Perimeter.

These samples were taken: a measurement of pH and EC, setting up the levels of cations Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometry, and Na^{+} and K^{+} by flame photometry, and anions Cl^{-}, HCO_3^{-}, CO_3^{2-} by titration, according to Richards (1954) recommendations. It were calculated also the SAR for the water classification and its variations over the studied period.

The water classification proposed by United States Salinity Laboratory (USSL) of the Agriculture Department was made, using the EC as a salinity indicator and SAR as sodicity indicator (Richards, 1954).

Obtained data from water chemical characteristics were analyzed using descriptive statistical techniques.

RESULTS AND DISCUSSION

The results concerning the average variability of chemical characteristics of water allow them in C3 Class, which correspond to high salinity (Table 1). However, there is a natural variation over the year with respect to water classification for irrigation, and in view the existence of the variation in water quality due to natural phenomena, especially the high evaporation existing in the region. So, there is a direct influence on the water classification. Thus, taking into account the average value for water classification, they are framed as not recommended waters for plant irrigation and sensitive soils with poor drainage. Looking three sources and four times of water samples collect, the electrical conductivity of irrigation water ranged from 200 to 4,580 μ S cm^{-1} (Figure 1) and is considered water with increasing risk of salinization, according California University (1975).

The EC is a measure of total soluble salts, in principle all waters and soils contain salts and even when the areas used for irrigation have reduced salt concentrations, there is a salinization potential in conditions of rain and poor drainage. Therefore, prevention of salinity is as important as the corrective actions after finding it in soils.

Table 1: Classification[1] of irrigation water used at Cachoeira II Irrigated Perimeter, Serra Talhada, Pernambuco, Brazil

Water group and collect	Class	Location and Collection	Class	Location and Collection	Class
Streamlet June/2006	C2S1	Well June/2006	C3S1	River June/2006	C2S1
Streamlet September/2006	C2S1	Well September/2006	C3S1	River September/2006	C2S1
Streamlet December/2006	C3S1	Well December/2006	C3S2	River December/2006	C3S2
Streamlet March/2007	C3S1	Well March/2007	C4S3	River March/2007	C3S1

[1] Based on the water classes from Richards (1954).

In addition, the tracking or systematic evaluation of irrigation water is essential for the proper development of crops explored and to determination of adopted management. There were changes in the water classification occurred during the year in some water sources used for irrigation, especially after the rainy season, as noted by Costa and Gheyi (1984), in their studies on the monitoring of the irrigation water at Catolé do Rocha region, Paraíba, Brazil.

It is likely that the way a reservoir receives its waters, influence particularly on the water quality being used. If the reservoir receives water at rainy season through surface runoffs, water repressed, probably, presents itself low salt concentrations, while if it receives the water through a natural soil drainage, having gone through deeper layers of the substrate, the situation becomes completely different from the previous one, with a higher probability of salts transport and, consequently, increased risk of salinity, as observed by Molinier et al. (1989). This explains the variations found in the dates presented in Table 5, as well as information provided by Ribeiro et al. (2005), that the electrical conductivity of the water varies with the time of sampling the water, type of source and soil of the site.

Evaporative demand at semi-arid Northeast of Brazil reaches annual average levels of the order of 2,000 mm (Fernandes, 2005). This means that, every day, are evaporated around 6 mm of water, corresponding, in turn, a 500 mm or 0.5 m at 3 months. In inadequate irrigation systems, this can promote, the capillary rise of saline water and consequent salts levelling to the surface, promoting soil degradation and preventing the cultivation of many agricultural species.

There were a natural variation between the four sampling and three different sources of water for the values of pH (Figure 1A). The highest average values of pH (7.84) were found in the second collection for streamlet waters, the waters of wells also had the highest average value in the second collection (7,92), and for the waters from the Pajeú River, the highest average value of pH (7.8) occurred in the third collection. The Cachoeira Streamlet and Pajeú River showed the lowest average values of pH in the fourth collection, possibly, because the rain that felt in the first months of the year (Figure 1A), providing a minimum flow of water at streams.

The pH values of irrigation water were within normal limits (6.5 to 8.4) established by Ayers (1977), so, there is no need to investigate problems related to this. However, Nakayama (1982) cites that there is no restriction to pH water below 7, with moderate restriction for pH water between 7 and 8 and severe restriction for pH above 8, in relation to obstruction of issuers of trickle irrigation.

The highest average concentrations of EC were observed in the third collection for the waters of the Cachoeira II Streamlet and Pajeú River. The salinity was higher at well waters than the other sources, with high EC values in all samples (Figure 1B), showing the highest average (3.276,00 μS cm^{-1}) in the fourth collection of water. It is believed that this is because of the high rate of evaporation from reservoirs and the constant use of the waters of the same, with the consequent lowering of the volume, the content of salts tend to be higher in the case of wells when the first rains have carried part of soluble salts to the soil water table that feeds these wells.

So, the electrical conductivity of these waters is in the risk range to many economic value cultures, as illustrated in the studies by Campos (2001) in tomato, and by Gurgel (2001), with acerola, indicating that the saline waters with electrical conductivity between 0.5 to 5.5 dS m^{-1} hinder the germination of these species, as for the mamona culture. Cavalcanti et al. (2005) found that the stress caused by salt water, electrical conductivity up 4.7 dS m^{-1} doesn’t affect the percentage of germination of castor-oil plants. Thus it is important to observe what crops to be explored and what the sources of water to be used, to won’t present future problems with plants.

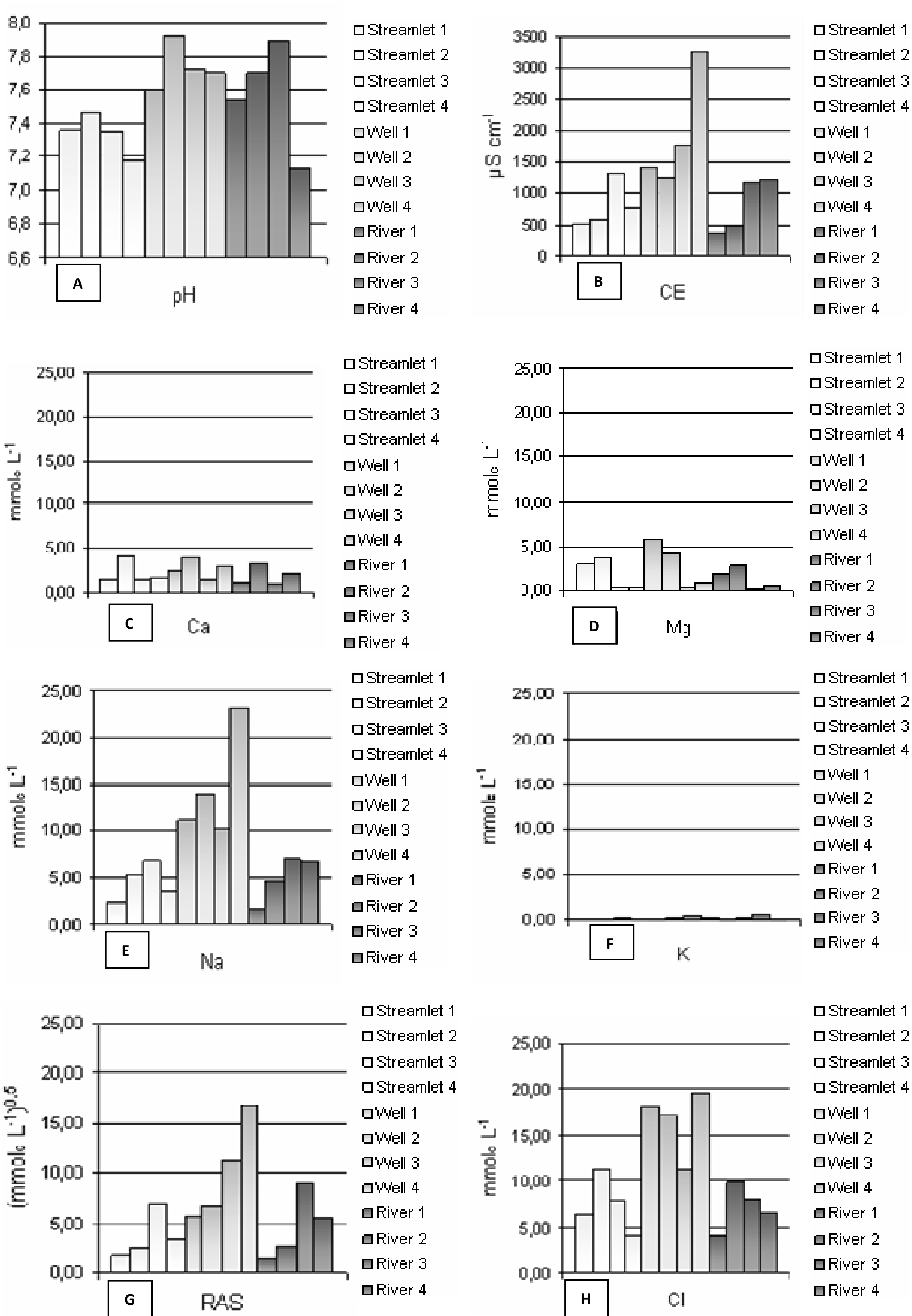

Figure 1: Average values of pH (A), EC (B), Ca^{2+} (C), Mg^{2+} (D), Na^+ (E), K^+ (F), RAS (G) and Cl^- (H) of the Cachoeira Streamlet, Pajeú River and well waters used for irrigation at Cachoeira II Irrigated Perimeter (Serra Talhada - PE), in the months of junho/2006, setembro/2006, dezembro/2006 and março/2007.

The waters of the studied sources showed the highest and lowest values of Ca^{2+} levels at second and third collection, respectively (Figure 1C), and the well waters the highest levels of Ca^{2+} in all collections. For the variable Mg^{2+} (Figure 1D) the lower average levels were found at third collection for the different sources of water and among the three sources. The well waters presented the highest values of all collections, being recorded in first collect the value of 5.8 $mmol_c$ L^{-1}. The limits recommended by Ayers & Westcot (1985) are of 2.0 $mmol_c$ L^{-1} for calcium and 5.0 $mmol_c$ L^{-1} for the magnesium, that has been exceeded only on the first collection of water from well.

According to Ayers and Westcot (1991), plants respond better with the increase in the Ca^{2+} proportion and Na^+ fall of the irrigation water. It's possible to observe inverse behavior in Figure, with increase at Na^+ concentration and decline of Ca^{2+}, which is a negative factor, because the use of these irrigation waters can cause greater Na^+ saturation of the soil colloids, promoting their sodification, and inducing infiltration problems in the soil (Freire et al., 2003a, b), in addition to the toxic effects in plants. This fact has been established in practice by farmers, who note that during dry season of the year, when this ratio increases, the development of the plant is damaged, according to the placement of them.

Noting the Figure 1E, it's clear that the Na^+ is the dominant cation in waters, giving emphasis up in the waters of wells, especially in the fourth collection (23.1 $mmol_c$ L^{-1}). Ayers and Westcot (1985) features a limit of 3.0 $mmol_c$ L^{-1} for the concentration of Na^+, on the sprinkler irrigation, in which the toxicity becomes was potential for the opportunity to increase the absorption by leaves.

It's believed that the rains at beginning of the year have caused the decrease in the concentration of this element in the River and Streamlet waters, and also have conducted the soluble salts, accumulating them in the water table, later providing them to the well waters. However, the K^+ content (Figure 1F) was the lowest in all samples in the different water sources. Costa and Gheyi (1984), working at Catolé do Rocha homogeneous micro-region, in Paraíba (Brazil), noted that there is variation at irrigation water quality, especially with regard their chemical characteristics after the rainy season, a fact that corroborate with the results from this work.

The highest average values of the waters' SAR (Figure 1G) of the Streamlet and River were the third collection, at 2006 December, while at well waters, the largest SAR was recorded in the fourth sampling, at 2007 March, with a mean value of (16.72 mmol $L^{-1})^{0.5}$. Since SAR is a relationship between the content of sodium and the square root of the sum of the amounts of calcium and magnesium, when there is sodium displacement it doesn't imply in a higher SAR because depends on the concentration of calcium and magnesium, this explains in part the results unevenness of this variable between collections.

The sodification risk can't be assessed only by the concentration of sodium present in the water; the relationship between this variable and the concentration of calcium and magnesium must be observed, represented by SAR. In addition, other factors can interfere in the process, as the concentration of anions able to react with the calcium to form salts of low solubility, precipitating the calcium and changing the SAR, to promote greater action on the sodium in the system. Another important aspect is that the salinity of the water, represented by the EC, contributes to the flocculation of colloidal particles, minimizing the effect of sodium dispersive, increasing infiltration (Freire et al., 2003a). Maia et al. (1999), working with recovery of sodium saline soils in irrigated perimeter of Itans-Sabigi in Rio Grande do Norte also observed this effect in relation to the SAR and EC.

In relation to Cl^- concentrations (Figure 1H), it is observed that none of the three sources of water had values below 3 $mmol_c\ L^{-1}$, with the largest average value found in the fourth collection of water in the wells (19.53 $mmol_c\ L^{-1}$). Macêdo and Menino (1998), working with the tracking of salts in water and soil irrigated project Vereda Grande - PB, found that the Na^+ ion constituents and Cl^- present specific toxicity of 3 $mmol_c.L^{-1}$, above that may limit the absorption of water by the plant through the xylem (sap gross) and phloem (sap drafted), how ever increasing, mainly because of the type of irrigation system used (spraying). Thus, it is possible that losses in production reported by irrigantes may be linked to this factor.

Studies by Fernandes et al. (2005) found that the potassium ion, from KCl, used as fertilizer in agriculture in the Chapada do Apodi - Ceará, it's easily assimilated by soil-plant system, while the chloride ion, which is conservative, it's carried to the aquifer, making up source of salinization of the water. In Cachoeira II Irrigated Perimeter there are many cultures for production of onion seed that use NPK formulations not based on soil analysis, and this is repeated for all crops commercially exploited, which apparently may be contributing to the high value of chloride in the water.

Thus, only with a rational fertilizers application system, based on soil analysis, associated with a continuous monitoring of the waters of the aquifer, it will be possible to maintain the salts balance, minimizing the secondary salinization in the soil-water-plant systems.

The CO_3^{2-} and HCO_3^- concentration in water used for irrigation is of high importance in the evaluation of soil sodification risk since these anions, when combined with calcium cation, form the calcium carbonate salt, with low solubility (Yaron, 1973). The precipitation of calcium carbonate cut part of the calcium from the solution, interfering with the sodium adsorption ratio, and increasing sodium activity. In the study area, none of the sources of water samples taken in the search along one year presented restriction on the carbonate concentration, whose values were below 0.1 $mmol_c\ L^{-1}$.

Andrade Júnior et al. (2006), working with underground water in irrigation, warning that the use of waters with CO_3^{2-} and HCO_3^- concentrations higher than mentioned, can cause precipitation of calcium and magnesium, leading to clogging or malfunction of the irrigation system.

Thus, it appears that, in general, the water used for irrigation in lots of Cachoeira II Irrigated Perimeter are classified as sodium chlorine, with predominance of Cl^- anion and Na^+ cation and can promote soil salinization and sodification with inadequate irrigation management, problems detected in most lots. There is a pressing need for a constant monitoring these lots, in order to maintain the balance of Perimeter soils and waters salts and the environment as a whole.

CONCLUSIONS

According to studies conducted with the sources of water used for irrigation in the Cachoeira II Irrigated Perimeter, it's possible say that:

- The water used for irrigation showed salinity risk and contains high levels of sodium and chloride;
- There are predominance of sodium and chlorine in waters, regardless of the water salinity level, places and sources of origin;
- The concentration of carbonate was low, with values below 0.1 $mmol_c\ L^{-1}$ in the three sources of water, not reaching the level of restriction for this ion on the water irrigation use;
- The waters of wells showed higher values of EC, cations and anions studied, accounting for the higher salinization and sodification risk;
- There was elevation in salt levels at dry season of the year for all water sources studied;
- It's necessary carry out the monitoring of the irrigation water quality in the Cachoeira II Irrigated Perimeter to prevent soil degradation.

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