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Quality of Roof-Harvested Rainwater for Irrigation of Crops by Family Farmers in Brazil

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Abstract

The efficiency of family farmers irrigation is conditioned by several factors such as good quality water supply. In this context, it was to evaluate the salinity and physical, chemical, and bacteriological characteristics of water harvested from roofs for irrigation of crops by family farmers in Brazil. The experiment was conducted at the Federal Institute Goiano, in Rio Verde, Goiás, Brazil. The rainwater collected on the roofs was sent through vertical and horizontal conductors to the storage tank, which has a capacity of 5000 L. The risk of salinity, pH, turbidity, conductivity, color, total dissolved solids and thermotolerant coliforms during 13 precipitation events was analyzed. Rainwater was classified as water with no salinity problem (EC < 0.7). The variation of the electrical conductivity (EC) and Total Dissolved Solids (TDS) were similar during the collection period, with mean values of 0.05 dS m^{-1} and 29.72 mg L^{-1} for EC and TDS, respectively. The pH of the rainwater presented little variation, presenting a mean of 7.37. The mean value of the color of rainwater was 11.45 PtCo L^{-1}, while the turbidity averaged 4.89 UT. During the period of rainwater harvesting, it was observed absence of thermotolerant coliforms in all samples. It is concluded that rainwater does not present restrictions on the risk of salinity and that all physical-chemical and bacteriological parameters analyzed are within the limits allowed by Resolution 357/2005 of CONAMA, indicating the propensity of this type of water for irrigation.

Keywords: water economy, water consumption, environmental sustainability, precipitation

1. Introduction

Irrigated agriculture has contributed to the economic growth of Brazil. Irrigation is essential not only for the agribusiness but to the subsistence of family farmers (Silva, 2013). However, irrigation consumes more water than any type of use of this natural resource (Bernardi, 2003). Water is a resource that is precious and vital to the existence of all living organisms, but this resource is increasingly being threatened as demand more water of quality for irrigation purposes and economic activities (Yakubu, 2013).

Water is the main input for agriculture; the rational use of water for irrigation increases the productivity of crops (Vasconcelo et al., 2009). The use of rainwater for non-potable purposes is an alternative for small properties of family farmers that depend on or seek an implementation of an irrigation system for crops (Thielke, 2014). Alternative sources of water supply, such as rainwater harvesting, are becoming increasingly important, for a number of different purposes including irrigation, drinking, and domestic use; the roof of a building or house is the obvious first choice for the catchment (TWDB, 2005; Meera & Ahammed, 2006; Schets et al., 2010; Daoud et al., 2011).

As the cost of water continues to increase across the world due to reduced water reliability, rainwater still has the potential for a positive return on investment; however, the system must be designed efficiently, used frequently, and maintained properly to meet that potential (Allison et al., 2017).

The efficiency of agricultural irrigation depends on the quality of the water used (Barroso et al., 2011). The water salinity is important to evaluate the quality of waters intended for irrigation, since this characteristic affects crop yields (Vasconcelo et al., 2009). Water quality analysis must consider physical, chemical, and biological characteristics that define its suitability for irrigation (Almeida, 2010)

In this context, the objective of the present work was to evaluate the salinity and physical, chemical, and bacteriological characteristics of water harvested from roofs for irrigation of crops by family farmers in Brazil.

2. Materials and Methods

The experiment was conducted at the Federal Institute Goiano, in Rio Verde, Goiás, Brazil (17°48′28″ S, 50°53′57″ W, and average altitude of 720 m). The climate of the region is classified as Aw (tropical), according to Köppen and Geiger (1928), with a rainy season from October to May and a dry season from June to September. The region presents mean annual temperature of 20 °C to 35 °C, mean annual precipitation of 1,500 to 1,800 mm, and slightly wavy relief (slope of 6%). Rainwater was harvested from roofs of a building of this institute, which had an area of 60 m², and slope of 30%, using aluminum gutters connected to PVC pipes with diameter of 150 mm. The rainwater was conducted to a storage tank (plastic) with a capacity of 5000 L.

The water quality analysis consisted of physical and chemical evaluations, using 100 mL of the rainwater collected with polyethylene flasks, and bacteriological evaluation using 100 mL of the rainwater collected with glass flasks. The flasks were carefully washed with the same rainwater before collecting the rainwater samples.

Rainwater quality analyzes were carried out from February to March 2018 at the Sanitation and Environment Laboratory, and Water and Effluent Laboratory of the Federal Institute Goiano. The parameters analyzed and analytical techniques used followed the recommendations of the Standard Methods for the Examination of Water and Wastewater (APHA, 2005) (Table 1).

Table 1. Parameters analyzed and techniques used for the analysis of the roof-harvested rainwater

Parameters	Analytical methods	Unit of measurement
Salinity	-	-
pH	LUCA-210P pHmeter	-
Turbidity	HACH-2100P Turbidimeter	UT
Electrical conductivity	Mca-150 Conductivity Meter	dS m^{-1}
Color	Policontrol Aqua Color Fluoride IP67 Colorimeter	mg PtCo L^{-1}
Total dissolved solids	-	mg L^{-1}
Thermotolerant coliforms	Colilert and UV lamp	-

3. Results and Discussion

The water electrical conductivity (EC) expresses its content of dissolved salts, indicating its salinity. The EC found in the rainwater of the 13 precipitation events evaluated are described in Figure 1.

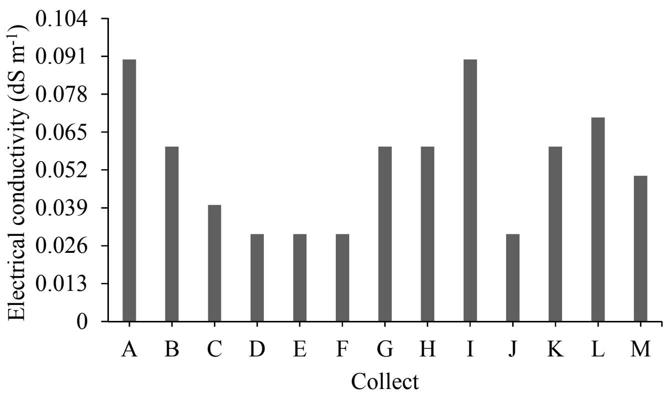

Figure 1. The electrical conductivity of the roof-harvested rainwater during the study period

EC of the rainwaters varied from 0.03 to 0.09 dS m^{-1}, with mean EC of 0.05 dS m^{-1}. According to Ayers and Westcot (1991), EC below 0.7 dS m^{-1} causes no salinity problems to plants. Therefore, the EC of all samples of rainwater evaluated are within the ideal range for irrigation of crops.

Corroborating these results, Marques et al. (2010) found low EC in rainwaters, with mean EC of 0.007 dS m^{-1}, representing a low concentration of ions in the rainwaters.

The results of electrical conductivity (EC) and total dissolved solids (TDS) are shown in Figure 2A and 2B, respectively.

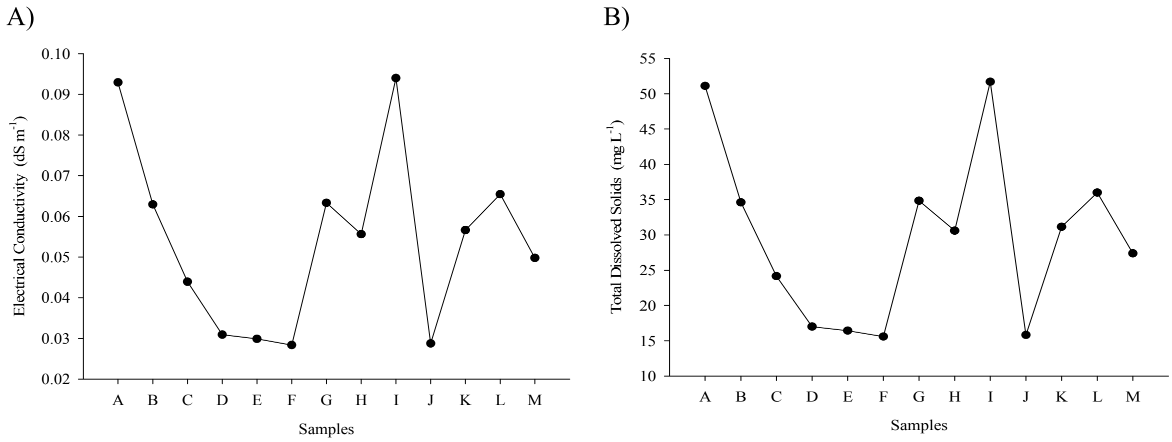

Figure 2. The electrical conductivity (EC) and total dissolved solids (TDS) of the roof-harvested rainwater

EC and TDS had similar variation, with some peaks during the evaluation period. These variations were due to the rainfall intensity, which carries different amounts of material from the roof to the storage tank.

The samples presented TDS of 17 mg L^{-1} to 51.11 mg L^{-1}, and mean TDS of 29.72 mg L^{-1}. This mean was lower than that reported by Tamioso et al. (2007), who found mean TDS concentration of 123 mg L^{-1} in roof-harvested rainwaters. Amponsah et al. (2015) observed conductivity values that ranged from 13.45 to 19.04 µS cm^{-1} with a general mean of 15.75 µS cm^{-1}, these low electrical conductivity concentrations of rainwater show less pollution of the atmosphere with particulate matter.

The results of pH, color, and turbidity were compared with the limits established by Resolution 357/2005 of March 17, 2005 of the Brazilian National Environment Council (Conama), which determines that waters intended for irrigation of vegetable and fruit plants must be at least from the Class 2.

The pH of the rainwater presented little variation during the study period (Figure 3).

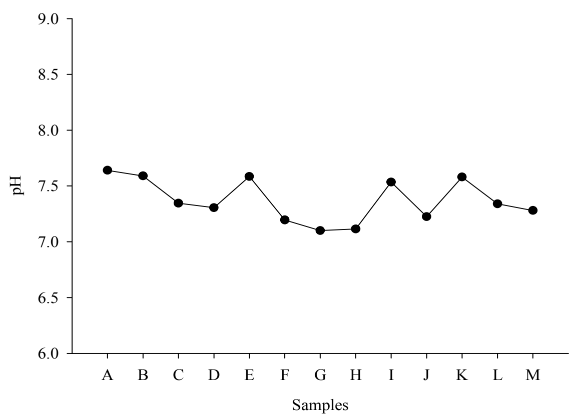

Figure 3. The pH variation during the collection period

All rainwater samples presented pH tending to neutrality, ranging from 7.10 to 7.64, with mean of 7.37. Santos et al. (2016) when evaluating the quality of rainwater harvested using direct and indirect methods; they found mean pH of 7.26 in roof-harvested rainwaters stored in tanks. The pH of rainwater stored in plastic cisterns tends to be slightly acidic with a mean of 6.5, conversely, the rainwater at sites with concrete cisterns was more basic, with a mean of 7.7 (Despins et al., 2009).

Class 2 waters (Conama, Resolution 357/2005) must have pH of 6.0 to 9.0. Therefore, the pH of the rainwater harvested was within the established range.

The color of the rainwater (Figure 4), according to the Platinum-Cobalt Scale (Apha-Hazen Scale), ranged from 4.75 Pt/Co L^{-1} to 24.45 Pt/Co L^{-1}, with mean color of 11.45 Pt/Co L^{-1}. This result denotes the suitability of this water for irrigation, since the Brazilian current legislation (Conama, Resolution 357/2005) establishes a maximum limit of 75 Pt/Co L^{-1} for waters intended for irrigation.

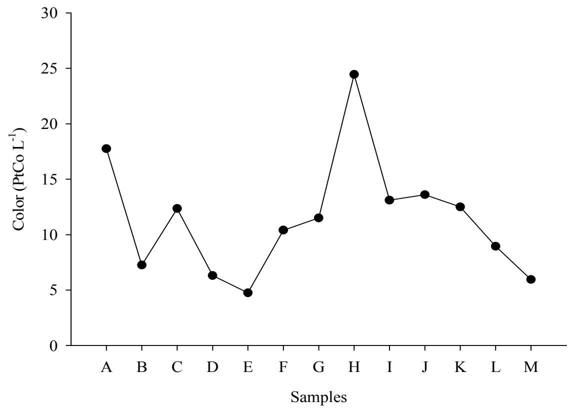

Figure 4. The color variation during the collection period

The mean color of the rainwater was lower than those reported by Guedes (2017), who found mean color of 37.2 mg Pt/Co L^{-1} for raw rainwater stored in reservoirs, and Nakada et al. (2014), who evaluated the quality variability of rainwaters and found mean color of 66.36 mg Pt/Co L^{-1} for roof-harvested rainwater.

The maximum turbidity of Class 2 waters, according to the Conama, is 100 nephelometric turbidity units (NTU). The turbidity of the rainwater evaluated ranged from 2.12 to 10.27 NTU, with mean turbidity of 4.89 NTU (Figure 5).

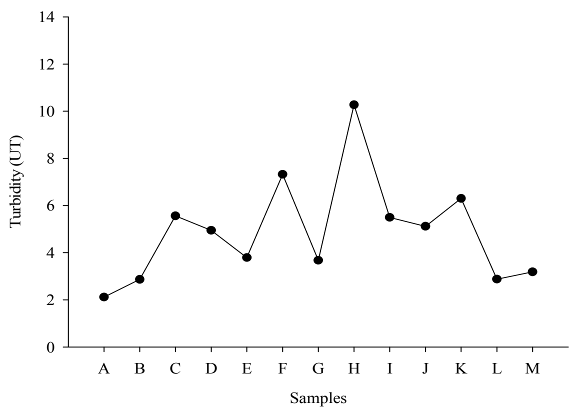

Figure 5. The turbidity variation during the collection period

Pereira (2014) evaluated the quality of rainwaters and found similar results, with mean turbidity of 3.2 NTU, and reported that this result was expected since the dirt present in the roof is carried by the rainwater to the reservoirs. Zhu et al. (2004) found that cisternstored rainwater turbidity was from 3.5 NTU when collected from mortar roofs, whereas the turbidity of rainwater collected from cement-paved courtyards was higher with values up to 6.5 NTU. Bharti et al. (2017) observed that the conductivity of first rain (285 µmho cm^{-1}) was found quiet higher than the second rainwater (195), while total dissolved solids, suspended solids, and turbidity was also found high in first rain *i.e.* 187, 9 and 19 mg L^{-1}, respectively.

The results of the bacteriological analysis of the rainwater are presented in Table 2.

Table 2. Bacteriological analysis of rainwater

	Collection[1]												
Thermotolerant	A	B	C	D	E	F	G	H	I	J	K	L	M
Coliform	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs	Abs

Note. Abs: Absent.

The samples of the roof-harvested rainwater showed absence of thermotolerant coliforms, meeting the standards established by the Conama. The absence of thermotolerant coliforms indicates that the roof area presented little incidence of feces from birds or other animals that could contribute to increase the number of these coliforms (Guedes, 2017). Chubaka et al. (2018) observed no seasonality in bacteria load in samples, however, a moderate relationship was observed between total coliforms and bacteria in samples collected during both winter and summer months, and a difference in bacterial load was observed after a significant period of no rainfall.

4. Conclusions

The roof-harvested rainwaters evaluated presented suitability for irrigation of crops by family farmers. Their salinity and physical, chemical, and bacteriological parameters were satisfactory within the assessed period where within the range established by the Resolution 357/2005 of March 17, 2005, of the Brazilian National Environment Council (Conama) for irrigation waters.

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