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Rainwater harvesting roofs: insights of water quality and potential usage in rural areas

Água de chuva de telhados: perspectivas da qualidade de água e potencial uso em áreas rurais

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ABSTRACT

Rainwater can be harvested from different roofs of rural buildings, which can be stored for multipurpose depending on its quality. This technical note describes rainwater quality collected directly from the atmosphere and after passing through four types of roofs that are: French ceramic (roof1/Agronomy school building), fiber cement (roof2/farm machinery shed), or French ceramic (roof3/sheep housing), and French ceramic (roof4- swine housing) located inside Agroveterinary School Campus (CAV/UDESC) in Lages, Santa Catarina state, Brazil. The parameters analyzed were pH, color, turbidity, dissolved oxygen, total coliforms, and thermotolerant coliforms. Results showed that pH "*in natura*" rainwater was variable and below 7.0 with an average of 6.02. However, after passing through the roof, there was an increase in the pH (average) to 6.34 (roof1), 6.90 (roof2), 7.14 (roof3) and 6.50 (roof4). The rainwater also presented variations in the parameters of turbidity, dissolved oxygen, and coliforms after passing through roofs. Thus, the rainwater can potentially be used for non-potable purposes, being then advised of their use without treatment for cleaning of nearby environments of these rural buildings, as well as the irrigation of trees and ornamental plants, among others.

KEYWORDS: environmental factors; particulates; pollution; animal housing.

RESUMO

Água da chuva pode ser captada de diferentes telhados de construções rurais e esta pode ser armazenada para múltiplos propósitos dependendo de sua qualidade. Esta nota técnica relata a avaliação da água da chuva coletada diretamente da atmosfera e após passar por quatro tipos de telhados que são: de cerâmica francesa (telhado1/prédio da escola de Agronomia), de fibrocimento (telhado2/galpão de máquinas agrícolas), de cerâmica francesa (telhado3/instalação para ovinos) e de cerâmica francesa (telhado4/instalação para suínos), localizados no Centro de Ciências Agroveterinárias, Lages/SC. Os parâmetros analisados foram pH, cor, turbidez, oxigênio dissolvido, coliformes totais e termotolerantes. Os resultados mostraram que o pH da água da chuva "*in natura*" foi variável e abaixo de 7,0 com pH (médio) de 6,02, que após passar pelos telhados houve aumento do pH (médio) para 6,34 (telhado1), 6,90 (telhado2), 7,14 (telhado3) e 6,50 (telhado4) e com variações também nos parâmetros turbidez, oxigênio dissolvido e de coliformes. Desta forma, a água de chuva apresenta potencial em ser utilizada para fins não potáveis, sendo então aconselhado seu uso sem tratamento para limpeza dos ambientes próximos destas construções rurais, bem como a irrigação de árvores e plantas ornamentais, entre outros.

PALAVRAS-CHAVE: fatores ambientais; particulados; poluição; instalações para animais.

Rainwater harvesting is an alternative source that can be considered as the most alternative solution to solve the problem of water scarcity and sustainable development (MELVILLE-SHREEVE et al. 2016, ZAVALA et al. 2018, OTHMAN et al. 2020, ANABTAWI et al. 2022, SÁ et al. 2022). The global supply of available freshwater is more than adequate to meet all current and foreseeable water demands, however, its both spatial and temporal distributions are not what demand research in water management (COSGROVE & LOUCKS 2015, OTHMAN et al. 2021, TEREZO et al. 2022). NICHOLLS & CROMPTON (2018) shows in their research the importance of evaluating the water quality, which generally provides convincing evidence on property values.

Thus, this preliminary study evaluates different water quality parameters such as pH, turbidity, color, dissolved oxygen, and concentration of coliforms in the rainwater collected directly from the atmosphere and the different roofs of rural buildings. These rural buildings are found in the municipality of Lages (Southern Brazil), inside the Agroveterinary College of the Santa Catarina State University (UDESC) (27°47'S and 50°18'W and show an average elevation above sea level of 884 m). So far, there are no similar reported studies in this field. The roof's position is indicated by numbers placed over a Google Earth print (Figure 1).

Figure 1. Spatial distribution of the collected points for water harvesting.

The number 1 (henceforth, Roof1) is placed in the Agronomy main building, and has a surface area of 196 sq meters, and is predominantly of old ceramic clay tiles (of French type with 20 mm thick). Roof2 is located in the farm machinery shed, has a surface of 67.21 sq meters, and is predominantly made of old fiber cement tiles (5 mm thick). Roof3 is located in the sheep housing and shows a surface area of 122.74 sq meters and is predominantly made of old ceramic clay tiles (of French type with 20 mm thick), and roof4 belongs to the swine housing and has a surface area of 134.42 sq meters and is predominantly of old ceramic clay tiles (of French type with 20 mm thick). All the roofs presented an average inclination of 40%, and point 5 shows the position where rainwater was collected directly from the atmosphere. It is an open area without buildings or tall trees nearby. It is also important to mention that the maximum distance between points is less than 400 m.

The predominant Koeppen climate type in Lages, Santa Catarina, is Cfb (temperate, humid, without a dry season, with a cool summer) with an average annual temperature of 15.7 °C. Consequently, April, May, and June are less rainy and January, February, March, and September are rainier. As a result, the average annual rainfall in the region of 1,556 mm, and moderate northeasterly winds commonly occur (WREGE et al. 2012, CARDOSO et al. 2014).

In this study, rainwater sampling was performed directly from the vertical descent plastic pipe, at diurnal periods, between 5 and 10 minutes after it began. In some rainfall events, this time could have been longer, and in that time, initial disposal may have occurred due to the presence of impurities such as small tree branches and leaves as well as sand particles most probably previously accumulated over the tiles and washed with the water falling on the roof. However, it also changed according to the characteristics of the rain, mainly on the intensity and duration aspects. Sterile plastic bags were used to avoid contamination and were sent to the Laboratory of Food Technology (NUTA) inside the campus to analyze the water quality parameters described above. The rainwater collected in point 5 used a reservoir plastic with a capacity of 30 liters. The results in this study were compared with the guidelines proposed by the Consolidation Ordinance 5/2017 of the Ministry of Health (Ministry of Health 2017); National Environmental Council resolution number 357 (CONAMA 2005), and the Brazilian National Standards Organization resolution number 15527 (ABNT 2019).

The rainwater samples were collected in following dates 04th of June in 2008 with a precipitation record of 25.6 mm (henceforth ec1), 2th of September in 2008 with a precipitation record of 42.1 mm (ec2), 2th of October in 2008 with a precipitation record of 44.1 mm (ec3), 9th of august in 2011 with a precipitation record of 113.3 mm (ec4), and 22th of September in 2013 with a precipitation record of 46.5 mm (ec5). The rainfall data of the region were provided by the Meteorological Brazilian Database for Education and Research (BDMEP/INMET/2016). BDMEP houses daily meteorological data in digital form, from historical series of the various conventional meteorological stations of the National Institute of Meteorology (INMET) network of stations with millions of information, referring to daily measurements according to the international technical standards of the World Meteorological Organization.

Interestingly, the amount of initial water discarded is still controversial. NAKADA & MORUZZI (2014) described in their research that it is widely known that the first amount of water must be disregarded to improve the water parameters quality of the stored water. However, the adequate amount or height (mm) to be discarded is still controversial, requiring additional efforts in costs and time, being beyond the scope of this research.

The water parameter analysis was conducted with the following devices previously calibrated: benchtop pH meter PG1800 (Gehaka instrumentation, Brazil) to measure pH; the apparent color of rainwater by the value obtained on the disc color pattern; Microprocessor Turbidity Meter Plus II (Alfakit instrumentation, Brazil) to measure turbidity; Microprocessor Oximeter AT 160 SP (Alfakit instrumentation, Brazil) to measure dissolved oxygen. In addition, total coliforms and fecal coliforms were obtained with Brilliant Green Bile Broth 2% and EC broth, respectively. The determination of the presence of total and thermotolerant coliforms was the Most Probable Number (MPN) method.

We describe average, minimum and maximum pH values, turbidity, color, dissolved oxygen, and total and fecal concentration coliforms based on the records. The results were reported on different days and compared with the literature. Insights on water usage and eventual alternatives were also discussed.

Results show that turbidity and dissolved oxygen presented different values according to roof type, building finality, and rainfall events (Table 1). Nevertheless, the values were similar to those reported by NAKADA & MORUZZI (2014), ZERBINATTI et al. (2011), and HAGEMANN & GASTALDINI (2016). However, the studies of these researchers focus mainly on urban areas, and specific studies conducted in rural areas are still scarce.

Table 1. The maximum turbidity values, color, and dissolved oxygen parameters according to the roof type and rainfall event (ec).

Sample point	Turbidity (NTU)	Color (µH)	Dissolved oxygen (mg/L)
Roof1- (clay ceramic tile)	1,12 (ec 4)	0	10,40 (ec 5)
Roof2- (fiber cement tile)	2,20 (ec 4)	0	9,60 (ec 5)
Roof3- (sheep housing)	1,61 (ec 4)	0	9,80 (ec 5)
Roof4- (swine housing)	2,10 (ec 4)	0	11,00 (ec 5)
Directly from atmosphere	0,42 (ec 2)	0	N/A

Note: NTU - Nephelometric turbidity units; µH – Color Hazen units; OD – Dissolved oxygen (mg/L).

Several causes can be attributed to the low turbidity values and color parameters (Table 1). Some of these aspects are most probably related to the release of polluting elements from industries. For example, TORRES et al. (2013) described that the rainwater drained from different surfaces suffers both temporal and spatial variations, reflecting on their quantities and qualities, making it imperative for the case-by-case analysis. Similarly, KUS et al. (2013) described factors that influence the quality of the pluvial water, such as the intensity of vehicle traffic, air pollution, and specific urban or rural localization characteristics.

Figure 2 shows pH values according to roof type and rainfall events (ec) where the more considerable gradient to pH was to rainwater from the atmosphere while roof3 (sheep housing) presented the slightest difference between the maximum and minimum pH. The maximum value found was on the roof2, pH = 7.78, and the minimum was found on the roof1, pH = 5.83.

HAGEMANN & GASTALDINI (2016) reported in their study realized in the city of Santa Maria, Rio Grande do Sul state, Brazil, that the pH values obtained from direct rainwater, i.e., directly from the atmosphere, ranged from 4.5 to 7.0, which is in agreement with the present study. Interestingly, the obtained results are also likely strongly related to those reported by ZERBINATTI et al. (2011), performing a study in the city of Inconfidentes, Minas Gerais state, Brazil; and KUMAR et al. (2014) that realized a study in New Delhi, India. Similarly, CALHEIROS et al. (2014) realized in Itajubá city, Minas Gerais, Brazil, and PINHEIRO & ARAÚJO (2016) in Natal city, Rio Grande do Norte, Brazil. However, the pH equal to 6.0 is the lower limit established by the guidelines proposed by the Brazilian legislation described above.

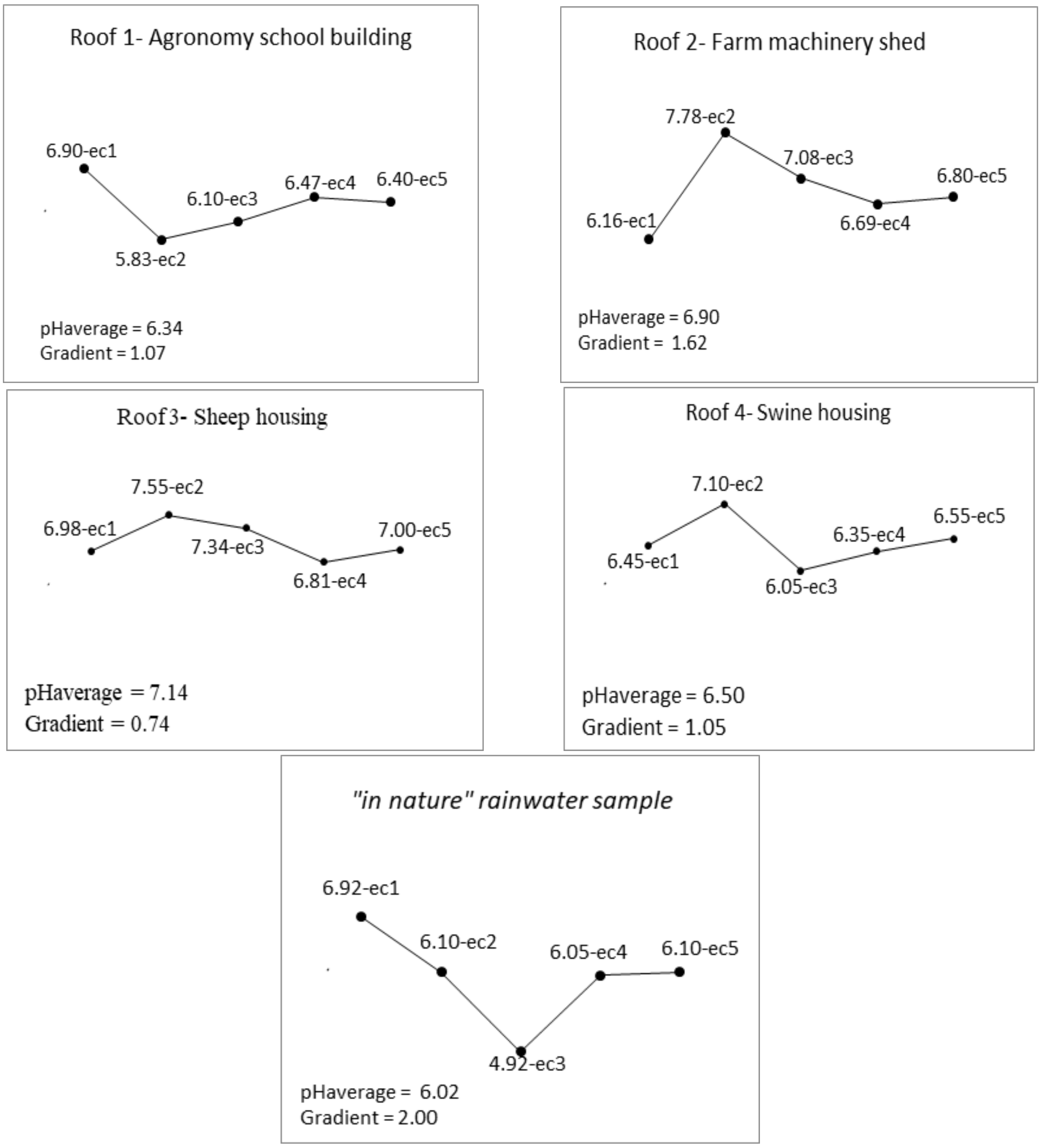

Figure 2. pH average and difference between maximum and minimum pH (gradient) according to the roof type and rainfall event (ec).

Table 2 shows the most probable number per 100 mL (MPN/100 mL) of total coliforms and thermotolerant coliforms, with combinations of positive results using three tubes, each one with volumes of 10, 1.0, and 0.1 mL.

Table 2. The most probable number (MPN/100 mL) results of total coliforms and *Escherichia coli* according to the roof type and rainfall events (ec).

Sample point	Total coliforms					*Escherichia coli*				
	ec1	ec2	ec3	ec4	ec5	ec1	ec2	ec3	ec4	ec5
Roof1	5,1 (2/0,1)	N/A	N/A	6 (2/0,1)	39 (3/10+1/0,1)	3	N/A	N/A	N/A	16
Roof2	16 (3/1+2/0,1)	N/A	N/A	3 (2/01)	16 (1/1+2/0,1)	9,2	N/A	N/A	3	9,2
Roof3	16 (3/1+2/0,1)	16	N/A	11 (1/10+2/0,1)	16 (3/1+2/0,1)	16	N/A	N/A	7,3	16
Roof4	15 (1/10+3/0,1)	3 (1/1)	3 (2/0,1)	7,3 (1/10+1/1)	3 (2/01)	3	3	3	6,2	3
Directly from atmosphere	16 (3/1+2/0,1)	N/A	N/A	N/A	N/A	16	N/A	N/A	N/A	N/A

N/A means the absence of these microorganisms.

In some rainfall event (ec), the samples presented coliforms limiting direct use to humans and animal confinement production indicated by the Brazilian standards. Furthermore, *Escherichia coli* indication was higher at samples collected from roofs than those collected directly from the atmosphere. Most probably, the presence of nearby birds and other animals may have landed on the tiles before the precipitation event.

Overall, the quality of the rainwater observes great potential to be used for non-potable purposes, especially considering the high rainfall rates (intensity and duration) that occur with a certain frequency in the region. This resource offers economic, social, and environmental benefits, solves sporadic water scarcity problems, and promotes economic and sustainable development.

This preliminary study showed that rainwater presents variations in the parameters of pH, turbidity, dissolved oxygen, and concentration of coliforms after passing through roofs. Even so, rainwater can be used without treatments for various activities, such as cleaning, washing, and irrigation of trees and ornamental plants, among other uses. Therefore, additional studies are suggested using other collection methodologies for rainwater storage to show the influence of the history of rainfall prior to collection on the rainwater quality after passing through roofs. Interestingly, it would assess the influence of the heating of the tiles and the wind on the quality of rainwater and even verify the possible use of the rainwater in animal confinement production or even in irrigation of vegetable crops after some simple water disinfection treatment.

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