Webology (ISSN: 1735-188X)
Volume 19, Number 6, 2022

"Harvesting Clouds". Rainwater For Buildings In The Special District Of Medellin, Colombia. "Pedagogical Strategy For Technical, Economic, Legal And Environmental Feasibility Of Rainwater Use."

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Summary

Rainwater harvesting is an alternative to minimize pressure on water resources and optimize water management. This article investigates a case study in a building of the Naranjal Partial Plan, in the city of Medellin, Colombia, which demonstrates the technical, economic and legal feasibility of the implementation of techniques and technologies for rainwater harvesting for non-potable uses, as well as its environmental contribution. The objective was to identify the feasibility of rainwater harvesting in multifamily buildings with a combined system of potable water from conventional aqueducts and rainwater for non-potable use. Among the results achieved are: the contextualization of the methodology of the Pan-American Center for Sanitary Engineering and Environmental Sciences for the pluviometric index of cities in the tropics, the positive adaptation of sustainable water supply networks to technical regulations, and their good performance in terms of costs and budgets for the execution of works. It can be concluded that it is possible to build smaller tanks than those stipulated in the CEPIS methodology according to the daily correlation carried out, which is viable for all strata.

Keywords: sustainable construction; climate change; stormwater; feasibility.

1. Introduction

Climate change and rapid population growth put pressure on natural resources; being the water resource, one of the most affected by changes in precipitation and dry periods (Almeida et al., 2021); due to this, and environmental pollution, available water supply sources are decreasing globally causing scarcity (Adugna et al., 2018). Water use has been increasing by 1% per year, driven by population growth, socioeconomic development, and changing consumption patterns, so scarcity levels will continue to increase as water demand grows and the effects of climate change intensify (WWAP, 2019).

The greatest consumption of water in a residential, commercial or educational building is not used for potable water, but for activities such as washing clothes, emptying toilets, cleaning the building, among others, which consume more than 50% (Cano, E.; 2010). Additionally, the water sources that supply the cities are distant, due to the fact that the local ones do not have the capacity to supply the growing demand, implying costs of drinking water production, transfer, connections and infrastructure (González, 2018). Medellín is one of the municipalities in Colombia that faces problems associated with water resource management, due to the municipality's dependence on external sources of supply and contamination in the main water courses (Alcaldía de Medellín, 2020).

There are two main categories of solutions to optimize water management: consumption reduction, which promotes changes in consumption habits together with the adoption of water-saving devices and the identification of new sources such as rainwater harvesting for buildings (Silva et al., 2015). This rainwater harvesting has been used in countries with humid climates and in sustainable construction for its adequate and intelligent use, especially for non-potable use (Campos Cardoso et al., 2020); However, it is important to emphasize that buildings have greater technical and possibly economic feasibility than small domestic environments for installing rainwater harvesting systems (Ward et al., 2010).

Buildings with different consumption profiles and higher water demands generate the possibility of implementing rainwater harvesting systems to meet the demand for non-potable purposes, avoiding future water stress and adequate consumption of the resource. The objective of this article is to identify the feasibility of rainwater harvesting in multifamily buildings in Medellin from the architectural design, a combined system of drinking water from conventional aqueduct and rainwater for non-potable use.

2. Materials and Methods

The district of Medellín, capital of the department of Antioquia, is located in the geographic center of the Aburrá Valley, on the central mountain range of the Andes. The climate and atmospheric phenomena are determined by its location in the area of influence of the intertropical convergence zone and the altitudinal and geographic conditions of the territory, aspects that affect the spatial and temporal distribution of precipitation (Alcaldía de Medellín, 2020).

The research was carried out in a building of the Naranjal Partial Plan located at Carrera 65 and 44ª, which has eight towers of 30 apartments, 15 stories high and a possible catchment area of 2,000 m2 in its two facades and terraces. The analysis was developed taking into account the history of daily rainfall in the southwest area of Medellín, with data obtained from the rainfall station of the Olaya Herrera airport of IDEAM.

Figure 1. Double pipe for rainwater harvesting at height.
Source: Authors.

With this information, the average was calculated and the climatological phenomena that alter the behavior of precipitation, known as "El Niño and La Niña", were taken into account. For this case study of rainwater harvesting for non-potable use and according to the Colombian technical standard NTC 1500 of 2014, the use of non-potable water for toilets, garden irrigation, house cleaning and car washing will be quantified (Table 1).

Table 1. Use of non-potable water for domestic buildings, NTC 1500.

Domestic activities	Percentage of water use (%)	Percentage of non-potable use (%)
Laundry	19,9	
Sanitary	27,2	27,2
Shower	20,9	
Dishwasher	15,5	
Housekeeping	4,9	4,9
Own consumption	3,9	
Hand washing	3,7	
Car wash	1,5	1,5
Garden irrigation	1,9	1,9
Plant irrigation	0,6	0,6
Total	100	36,1

The sizing of the rainwater catchment area and the reservoir must be carefully designed according to the specific characteristics of use and occupancy of the building (Almeida et al., 2021). The projected population is 120 inhabitants with an endowment of 34 liters/day of water consumption per person; its consumption for non-potable use would be 8.19 m3/day and 245 m3/month, taking into account toilets, housekeeping and irrigation.

Rainwater harvesting systems consist of three components: catchment, conveyance and storage (Abdulla & Al-Shareef, 2006), where catchment and use require an engineering technique (Palacio Castañeda, 2010). In this research, the technique used by the Pan-American Center for Sanitary Engineering and Environmental Sciences (CEPIS) was used, which is based on the difference between the accumulated supply and the accumulated demand. The storage volume (VA) is defined as the sum of the accumulated water supply per year minus 1 (OA) and divided by the 365 days of the year (DA), this value is multiplied by the number of days of the month.

$$VA = \left(\left(\frac{OA - 1}{DA}\right) * 30\right) * ef \qquad \text{Ecuación (1)}$$

VA = (((OA –1)/ DAM)*30)*ef.; ecuación (1)

VA = storage volume (m3);
OA = (cumulative water supply of year -1) (m3);
DA = Days per year (m3).
Ef = Efficiency.

Figure 2. Rainwater harvesting and treatment system
Source: Authors.

The rainwater was subjected to a physical-chemical analysis based on Colombian technical standards for water sampling techniques, collection, handling and preservation of samples: NTC-ISO 5667-3. These samples were analyzed by the Analtec laboratory in the city of Medellín, under the following parameters: a) pH, b) temperature, c) total hardness, d) carbonates, e) total alkalinity, f) bicarbonates, g) chlorides; these results provide the criteria for determining whether the water is of good quality for use in toilets, washing floors, and irrigation.

3. Results

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

Table 2. Laboratory analysis

Parameters	Method	Results	Allowable value
Total iron (mg Fe/L)	Atomic absorption	<0,022	Less than 0.3
pH at 25 °C	Electrometric	6,64	Between 6.5 and 9.0
Turbidity (NTU)	Nephelometric	5,81	Less than 2
Apparent color (UPC)	Photometric	55,8	Under 15
Chlorides (mg Cl/L)	Argentometric	<4,00	Less than 250
Total alkalinity (mg CaCO/L)	Titulometric	7,15	Less than 200
Total hardness (mg CaCO/L)	EDTA Titrimetric	17,5	Less than 300
Sulfates (mg (SO4)2)	Turbidimeter	6,11	Less than 250

For the building of the sector of study of stratum 5 and for a tank of 247 m3, the investment would be $72,371,500, which would take 8 years to recover. Taking into account the parameters the Ministry of Housing and Environment, in resolution 0549 of 2015, establishes 5 years or less for it to be viable, which would not apply economically for all strata of high-rise housing; however, when analyzing a tank with 50% of what CEPIS requests to make it economically viable (table 3), it is observed that it would be viable for strata 4, 5 and 6 according to the 2015 and current rates for the city of Medellin.

Table 3. Feasibility with 50% CEPIS tank.

Table of collected water value by stratum					125 m3 tank	
Drinking water value		**Medellin**	**2015**		**Investment $ 321,882/m3**	
WATER RAIN		**2,221**	**Drainage value**		**full**	**40,235,250**
STRATUM	**VALUE M3**	**VALUE**			**Return on investment per year**	
Stratum 1	454,6	1009777	686,35	1524549	2534326	16
Stratum 2	681,89	1514643	1029,52	2286813	3801455	11
Stratum 3	994,43	2208869	1501,38	3334928	5543797	7
Stratum 4	1136,49	2524419	1715,45	3810474	6334893	6,351
Stratum 5	1704,73	3786618	2573,8	5717032	9503650	4,23
Stratum 6	1818,38	4039062	2745,39	6098175	10137237	3,97
commercial	1704,43	3785951	2573,8	5717032	9502983	4,23
industry	1477,43	3281729	2230,63	4954769	8236498	4,88
officer	1136,49	2524419	1715,47	3810474	6334893	6,35

Verifying the behavior of the 125 m3 tank for each month, it is determined how much water needs to be injected from the municipal aqueduct and the water discharged to the sewer system as ecological flow. The difference between the 50% tank and the tank with CEPIS methodology indicates only 99 m3 of difference in water to be taken out of the system between the tanks, with a value of $424,255 per year. The difference of $35,746,000 in the tanks means that the larger volume of the tank with CEPIS methodology takes 84 years to pay the difference with the current water value. But, when performing a daily analysis as is normal for a system and not by monthly averages, the tank is not as large as evidenced in the CEPIS methodology, as it never exceeds 24 m3. This ratio indicates that the tank can be made smaller, recommending 1.5 times, which indicates the maximum value to have a larger margin when the "La Niña" phenomenon occurs (36 m3) (Table 4).

Table 4. Feasibility with proposed average daily rainfall.

Table of collected water value by stratum				**tank volume**	**385000**		
Drinking water value		**Medellín**	**2016**	**tank volume**	36	**Investment**	**inject**
WATER RAIN		**3,101**	**Drainage value**		**full**	**13,860,000**	-1468,7
STRATUM	**VALUE M3**	**VALUE**			**Return on investment per year**		value of water
Stratum 1	644,91	1,999,805	680,94	2,111,530	4,111,335	3	$(1,947,224)
Stratum 2	967,36	2,99,692	1021,24	3,166,768	6,166,460	2	$(2,920,579)
Stratum 3	1410,74	4,374,571	1501,38	4,655,637	9,030,208	2	$(4,276,916)
Stratum 4	1612,27	4,999,496	1715,47	5,319,510	10,319,006	1	$(4,887,321)
Stratum 5	2418,41	7,499,260	2573,8	7,981,110	15,480,370	1	$(7,331,863)
Stratum 6	2579,16	7,997,730	2745,39	8,513,194	16,510,924	1	$(7,819,958)
commercial	2418,41	7,499,260	2538	7,981,110	15,480,370	1	$(7,331,863)
industry	2095,31	6,497,358	220,63	6,916,972	13,414,330	1	$(6,353,338)
officer	1612,37	4,99,806	1715,47	5,319,510	10,319,316	1	$(4,887,468)

4. Conclusions

This study analyzes the feasibility of a rainwater harvesting system for a building in the Naranjal Partial Plan and identifies that there are sufficient and complete legal and environmental regulations for the use of rainwater in buildings.

The results indicate that the volume of the tank with CEPIS methodology to ensure continuity and efficiency in the service, does not make economically viable the use of rainwater for non-potable use in high rise housing of any socioeconomic stratum of the city of Medellin, therefore, to be economically viable for strata 4, 5 and 6 the tank should be 50% of that proposed by CEPIS.

It can be concluded that it is possible to build smaller tanks than those stipulated in the CEPIS methodology according to the daily correlation carried out, which is feasible for all strata, taking into account that most of the Colombian population are strata 1, 2 and 3 according to DANE, so they require economic subsidy and training from the state to implement rainwater storage tanks for non-potable use.

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