Chapter 70

Technical and Economic Feasibility Study of rainwater use system in communities in Jardim Gramacho- RJ

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Paula Iglesias Ribeiro
Department of Civil Construction, Polytechnic School, Federal University of Rio de Janeiro, Brasil

Mayara Amario
Department of Civil Construction, Polytechnic School, Federal University of Rio de Janeiro, Brasil

Carina Mariane Stolz
Department of Civil Construction, Polytechnic School, Federal University of Rio de Janeiro, Brasil

Mohammad Najjar
Department of Civil Construction, Polytechnic School, Federal University of Rio de Janeiro, Brasil

Elaine Garrido Vazquez
Department of Civil Construction, Polytechnic School, Federal University of Rio de Janeiro, Brasil

ABSTRACT
Many Brazilian communities are in a situation of extreme vulnerability, with a lack of decent housing and water supply network, a fundamental element for survival. This article presents the feasibility analysis of the implementation of the rainwater use system designed by the ceiling (social organization that acts to reduce poverty) in the houses built by it in the Rampinha and Chatuba communities, in Jardim Gramacho, through the study of Demand, supply, sizing of reservoirs and prospecting for materials. The results showed that the project is able to supply 67% of the demand for non -potable purposes with a Payback of up to 2.8 years, thus reducing the lack of water on site.

Keywords: Capture, Storage, Supply, Rain water, Reuse.

1 INTRODUCTION

Art. 2 of the Universal Declaration of Water Rights, published in 1992, states that water is the essential condition of life of all living beings and that the right to its access is one of the fundamental rights to the human being, as it results in the right to life [1]. Among the sustainable development objectives, which are part of an international protocol, signed by 193 countries, at the United Nations General Assembly, it includes number 6, which consists in ensuring the availability and sustainable management of water and sanitation for all and all [two].

However, by the end of 2019, the covid-19 pandemic emerged in China, which became one of the biggest sanitary challenges on a global scale of the century [3]. Given the inequality of access to services in Brazil, a disproportionate effect of this disease on the most vulnerable population in the country was already expected to be expected. During the pandemic, the problems of access to water in the outskirts of large cities were aggravated when WHO determined constant hygiene as a measure of containment of the virus. This fact is clear in the analysis of the indicators: in May 2021, the proportion of deaths in the favelas of Rio de Janeiro reached the value of 9.80% [5], while in the state were confirmed 5.90% of cases that resulted in death [6].

In order to reduce existing social inequalities, the ceiling social organization was created in 1997 in Chile and is present in 19 Latin American and Caribbean countries, having formally established in Brazil, based in São Paulo, in 2007. It is a non -profit foundation that works in precarious communities by connecting volunteering and residents to generate concrete solutions to improve living conditions in these places and overcome poverty. It acts mainly with the construction of emergency housing, but also develops other projects, whose priority is determined by residents [7].

The organization began its activities in Rio de Janeiro in 2013, in Jardim Gramacho, with the aim of denouncing the situation of extreme poverty in which families live [7]. The Jardim Gramacho neighborhood is located in the municipality of Duque de Caxias, Rio de Janeiro, and is known for having great pockets of misery and has housed the largest dump in Latin America for over three decades, and its activities have been closed in year 2012 [8].

After the deactivation of the old dump, which is why the situation of residents, which was already precarious, was strongly aggravated, since about 60% of residents of the region depended directly or indirectly on the economic activity arising from this, and therefore lost lost its subsistence source. The population of the region began to live with the aid of the "Bolsa Familia", actions carried out by NGOs and donations of religious institutions operating on site [3].

Faced with the COVID-19 pandemic, the ceiling updated its urgent definitions to continue supporting the communities as best as possible, organizing new action plans. In 2020 they began to focus their efforts on developing projects that fostered access to water and sanitation, food safety and community training, always in accordance with residents' demand. In 2020, for example, community washbasins, rainwater capture stations, modular bathrooms with biodigesters, community gardens and new community headquarters [7] were built.

The objective of this paper is to present the analysis of the technical and economic viability of the construction and implementation of a rainwater use system, developed by the ceiling organization, in the 193 emergency houses and at the community headquarters built by the organization in the communities of Rampinha and Chatuba, in Garden Gramacho - RJ.

2 STUDY METHODOLOGY

The study methodology was divided into seven steps presented below.

a) delimitation of the area of study and climate characterization;

b) make a study of water resource forecast for non -potable purposes in the region;

c) Calculate the estimate of the supply of rainwater on site;

d) Check the space available for reservoir installation on housing land and make the use of usable volume;

e) prospect the materials that make up the water capture, conducting and storage system;

f) Understand the current solution found by residents to supply the region and make their budget for comparison purposes;

g) Calculate Project Payback to understand its viability.

2.1 DELIMITATION OF STUDY AREA

In the Jardim Gramacho neighborhood there are older communities that already have a consolidated urban infrastructure, such as Cohab, with supply networks and paved streets, and more recent occupations, such as chatuba and rampinha, which are completely devoid of any type of service or installation [9].

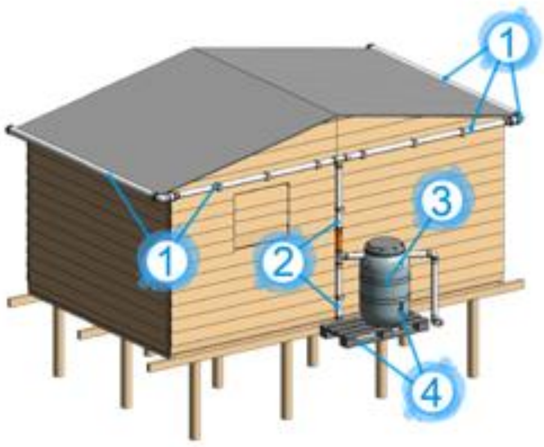
According to Carcamo [10] it is possible to divide Garden Gramacho into 3 subareas based on vectors such as infrastructure, services and sanitation situation: central subarea, landfill subarea and expansion subarea, as shown in Figure 1. The worst indicators are located in the subarea From the landfill, which did not have public investment at the time of its creation and expansion, being done precariously by residents and workers in this region [10]. The communities of Rampinha and Chatuba, both considered at work, are located in the landfill subarea [11].

Figure 1: Delimitation of the central subareas, landfill and expansion (adapted from Google Earth, 2022).

In recent years, the organization, together with residents, has been playing strongly in the communities of Rampinha and Chatuba in Jardim Gramacho, having built, until May 2021, 193 emergency housing.

Faced with the COVID-19 pandemic, the ceiling updated its urgent definitions to continue supporting the communities as best as possible, organizing new action plans. In 2020 they began to focus their efforts on the development of projects that fostered, for example, access to water and sanitation, such as rainwater capture and storage systems, using the emergency housing roofs as a capture area (Figure 2) [12].

Figure 2: Rainwater capture system for ceiling emergency houses: 1) collection and conduct system, 2) filtering system, 3) reservoir and 4) necessary accessories. (Ceiling, 2018).



One of the main solutions found in the neighborhood to combat the absence of water supply systems is the Pipa truck service [13,14]. However, one of the most effective and economical ways to reduce the dependence on water supply from distribution concessionaires is the implementation of supply systems through alternative sources. On Fernando de Noronha Island, for example, almost 100% of water consumption for non -potable purposes is supplied by storing rainwater in cisterns [14].

2.2 CHARACTERIZATION OF CLIMATE AND RAINFALL

The gramish garden area, according to the climate model of Koëpen, is classified as a tropical climate without dry season and is conditioned by two dynamic factors: the Atlantic tropical mass, originated by humid and hot maritime air, and the Atlantic polar mass of origin Cold and dry that, upon contact with tropical air, causes torrential rainfall [15].

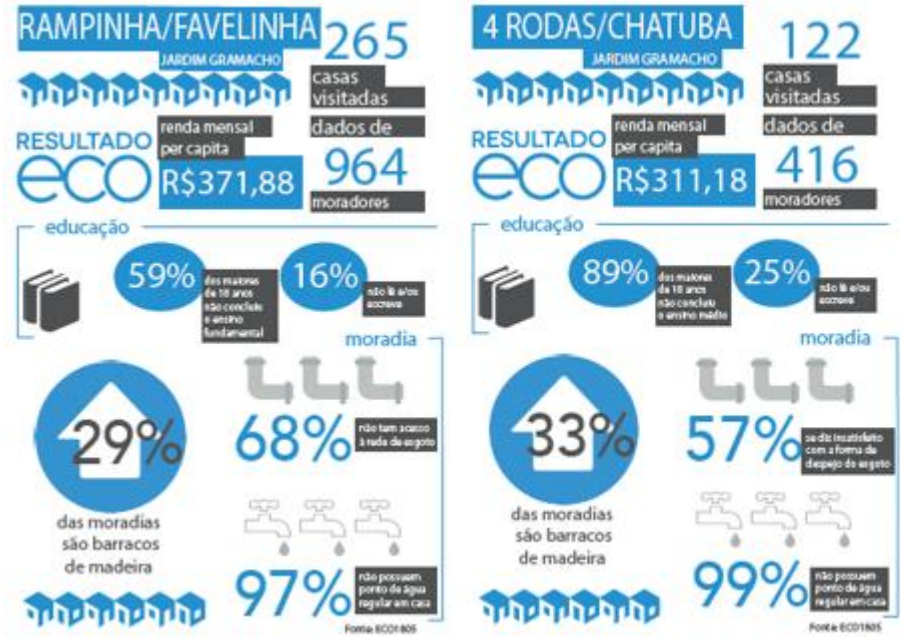
The mountainous relief of Serra do Mar, located around, also influences the atmospheric instability of the region, as it serves as a natural barrier for the moist winds from the sea, which favors the formation of orographic rainfall, making the municipality of Duque de Caxias a of the regions with the highest rainfall in the state of Rio de Janeiro [15].

2.3 WATER DEMAND ESTIMATION

For the calculation of the demand, the information of the information compiled obtained through the polls applied in 2018 in the region, through the event “Listening to Communities” of the ceiling organization, where 265 homes were mapped in Rampinha and 122 in Chatuba, as shown. Through the figures it was also possible to understand the vulnerability of the study site, since 97% of ramp dwellings have no regular water point at home and, in chatuba, this percentage is 99%, and per capita monthly income does not exceed the $ 400 in neither communities [11].

In Jardim Gramacho it is stipulated that on average 30 liters per day per villagers are used to satisfy the needs of non-drinking use of residents in relation to the resource in question, such as washing of clothing, dishes and personal sanitation, varying according to the number of residents in Housing [16].

Figure 3: Compiled of the information of the polls applied in Rampinha and Chatuba (ceiling, 2018).



The calculation of demand is equal to the average demand of 30 liters per housing multiplied by the number of houses in each community and, as used for the calculation of the next items the annual value, for 365 days. The values obtained were 2.9 million liters in Rampinha and 1.3 million in Chatuba per year, totaling 4,237,650 liters/year.

2.4 WATER SUPPLY ESTIMATE

For the supply calculation a study was done to determine the average annual rainfall of the site. In order to obtain more accurate data, data obtained from the nearest rainfall stations to the study site for the period between August 2020 and July 2021, obtained through the CEMADEM platform (National Center for Monitoring and Natural Disasters Alerts, obtained through the Platform of CEMADEM.) [17]. For this were selected three rainfall stations: Sarapuí, Jardim Metropolis and Jardim Olavo Bilac, whose locations are indicated in Figure 4. For each day of the year, the data of the season that obtained more records were considered, and among the days 01/08/2020 and 13/09/2020 no measurement was identified in the rainfall, having been considered zero in this period. Through the monthly data obtained, the graph of Figure 5 was elaborated, which shows the rainfall month by month and the monthly average of 90.40 mm. For the study in question, therefore, it was considered the annual rainfall of 1,084.76 mm, which consists of the sum of rainfall in the months considered in the study.

Figure 4: Location of rainfall near Jardim Gramacho (CEMADEM, 2021).

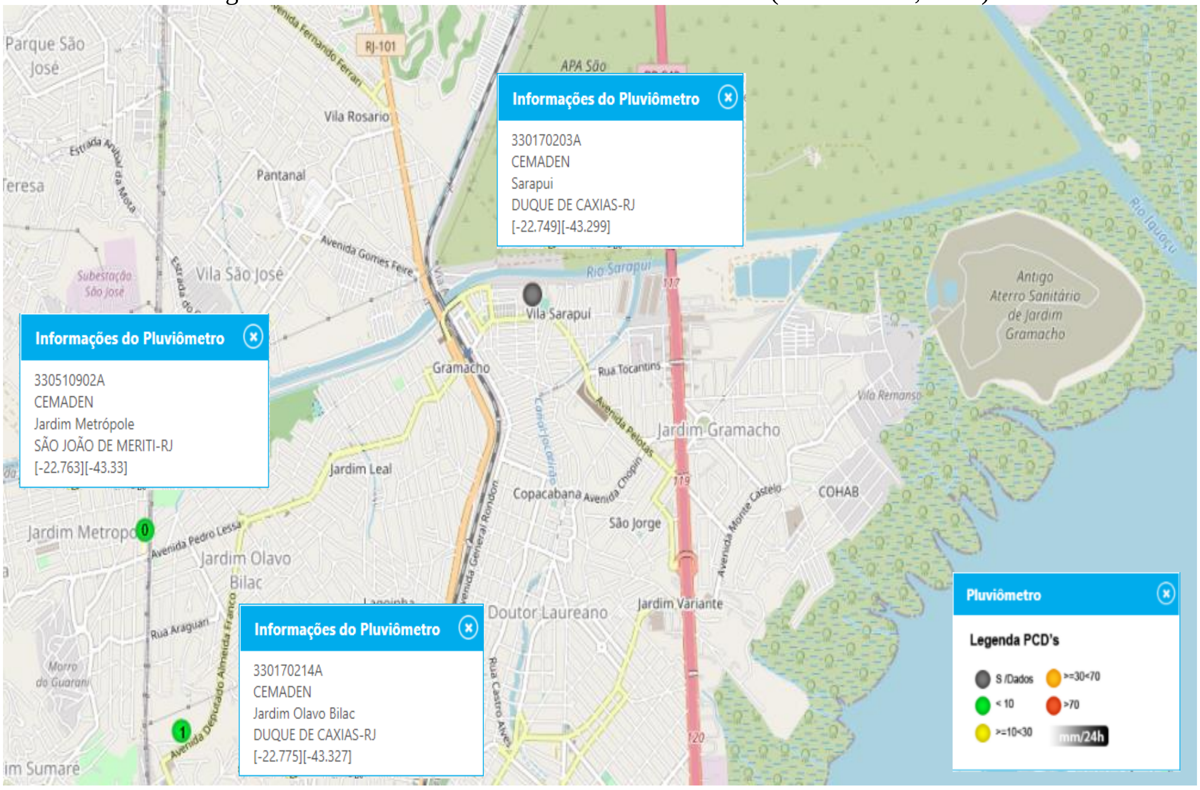
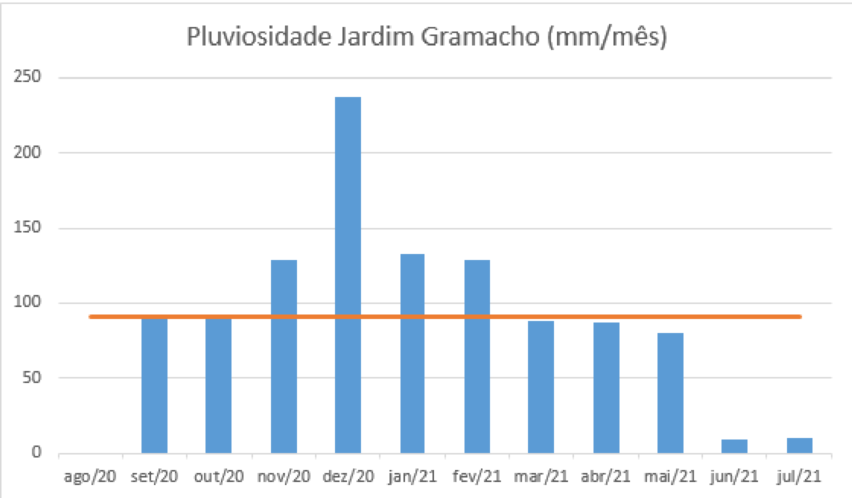


Figure 5: Monthly rainfall in Jardim Gramacho



For the calculation of total use area of capture, the proportion of 15 and 18 m² houses in the communities was stipulated, as the organization does not have this control. For this it was an estimate based on the number of tiles bought for each typology in three mass construction events between 2018 and 2019 (Table 1). Based on the data obtained, the percentage of 30% of houses was estimated to be 15m² and 70% of 18m².

Table 1: Calculation of the average relationship between 15 and 18 m² houses

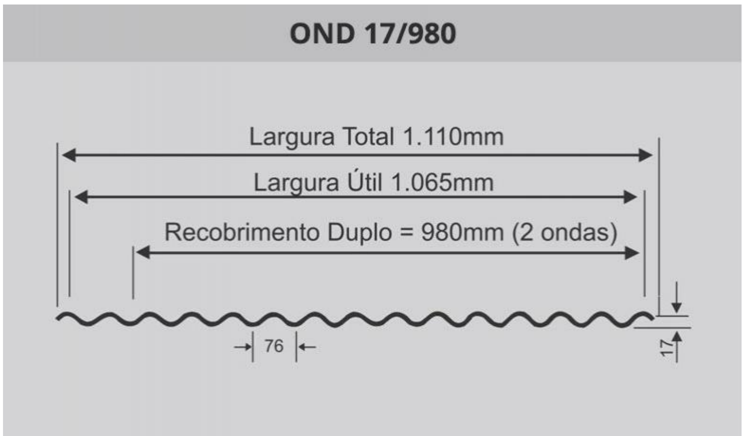
Date Construction	Tiles Houses 15 m²	% Houses 15 m²	Tiles Houses 18 m²	% Houses 18 m²
April 2019	48	33%	96	67%
March 2018	36	27%	97	73%
July 2018	24	12%	174	88%

Subsequently, the roofing area was calculated, subtracting the intersections between the tiles. In the longitudinal intersection, it was considered the value of 60 cm, considering the length of the indicated fold of the housing construction manual [18], and for transverse was considered the intersection of a and a half wave, also indicated in the manual (Figure 6) .

Figure 6: Handling of the tile according to the Construction Manual of the ceiling organization (ceiling, 2017)

The transverse measure of the intersection was obtained through the specifications of the galvalume steel tiles used (Figure 7). Considering that a wave has a width of 76 mm [19] and that the intersection is a wave and a half, the value of the intersection is obtained by multiplying 1.5 waves by length of 76 mm, which is approximately 0.12 m.Obrga

Figure 7: Specifications of Galvalume Steel Tile Width Measurements - And 17/980 (Açotel, 2021)



The calculation of the final areas, subtracting the intersections, is specified in Table 2.

Table 2: Calculation of the average ratio between 15 and 18 m² houses

Typology	Nº Tiles/ Typology	Measures (m)/ Roof tiles	Useful Area (m²)/ Housing	Quant./ Tip.	Useful Area (m²)/ Tip.	Total useful area (m²)
Houses 15m²	6	1,0 x 3,0	14,90	58	864,43	
Houses 18m²	6	1,0 x 3,6	18,22	135	2.459,16	3.359,16
Library	12	1,0 x 3,6	35,64	1	35,64	

3 RESULTS AND DISCUSSION

3.1 DIMENSIONING OF RESERVOIRS

There are two emergency housing sizes built by the ceiling organization: 15m² and 18m², based on the area available for construction. Therefore, a determining factor for choosing the reservoir volume is the space available for its deployment.

Through the “Google Earth” platform were located the land that contains emergency villas of the ceiling in Jardim Gramacho and the measurement of the space available through the platform itself (Figure 8) was obtained. When consulting Table 3, it is possible to verify that most land holds reservoirs of up to 2,000 liters, being limited to 1,000 liters in some cases. Since the 15 m² dwelling ground is lower, the 1,000 liters reservoir was considered for this, while for 18 m², the 2,000 liters reservoir was considered. For Community Headquarters/ Library (Figure 9) there is room for a larger reservoir.

Figure 8: Dimension available for reservoir implementation on land containing villas built by the ceiling (Google Earth, 2022).

Table 3: volume and diameter of prospective reservoirs.

V(L)	D with lid (m)
1.000	1,52
2.000	1,89
3.000	2,28
5.000	2,45
6.000	2,22

Figure 9: Dimension available for reservoir implementation in the community headquarters (Google Earth, 2022)

Finally, among the methods available in ABNT NBR 15527: 2007, the simulation method was chosen, because it is one of the most recommended and because this is arbitrated a volume and it is possible to follow month by month the volume of excess water and the demand for water, being possible to evaluate the efficiency of the system. Moreover, it is not considered a simplistic method, such as English and German practical methods, and for not having a history of overdone, such as the Azevedo Neto method.

Through the calculations it was possible to verify that for the community headquarters there is no difference in results between the 5,000 liters reservoirs and the 6,000 liters, so it will be considered the first.

In the simulation method, water evaporation will not be taken into account. For each month the continuity equation will apply to a finite reservoir, through equations 1 and 2 below.

$$S_t = Q_t + S_{(t-1)} - D_{(t)} \qquad \text{Eq. 1}$$

$$Q_t = \text{C x } P_{(t)} \text{ x A} \qquad \text{Eq. 2}$$

Being that: $0 \leq S_t \leq V$

Where:
$S_t =$ Volume of water in the reservoir in time t;
$S_{t-1} =$ Volume of water in the reservoir at time t -1;
$Q_t =$ Volume of useful rainfall in time t;
$D_{(t)} =$ demand or consumption in time t;
V = reservoir volume;
C = runoff coefficient;
$P_{(t)} =$ rainfall in time t;
A = catchment area.

For each month were calculated: the volume of surplus rainwater, as there will be water extravasation in the months (T) is greater than the volume determined to the reservoir; the volume in deficit, which corresponds to the empty volume of the reservoir; and the final volume of water in the reservoir.

The volume served was calculated through equation 3:

$$V_{atendido} = \sum Q(t) - \sum Excedente \qquad \text{Eq. 3}$$

The results obtained are presented in Table 4. The annual volume used by the system in question is equal to the sum of the last column: 2,850.201.78 liters.

Tabela 4: Volume atendido pelo sistema de captação e armazenamento de água da chuva.

Typology	V (L)	∑ Q (L)	∑ Surplus	V utmost (L)	Quant.	V Total Used (L)
Houses 15m²	1.000	12.934	761,96	12.171,85	58	705.868
Houses 18m²	2.000	15.808	153,50	15.654,49	135	2.113.356
Head office	5.000	30.929	50,31	30.878,37	1	30.878

3.2 PROSPECTING MATERIALS

The materials needed to build the rainwater use system projected by the ceiling for a two -water roof are presented in Figure 10, extracted from the organization's construction manual, and were prospected. Considering the best price for each item, it was reached the total amount of R $ 114,937.24 for the systems of the 193 housing and community headquarters, disregarding the reservoirs, whose prices are presented in Table 5.

Figure 10: Materials of the ceiling rainwater use system, extracted from the Construction Manual (ceiling, 2018)

MATERIAIS

11 MATERIAIS

Materiais	Quantidade	Exemplo	Materiais	Quantidade	Exemplo
Barra Tubo 100mm - 6m	2		Tê 75mm	2	
Barra Tubo 75mm - 6m	2		Abraçadeira U para Tubo de 75mm	8	
Caps 100mm	2		Luva 75mm	1	
Caps 75mm	1		Flange para Caixa d'água DN25	1	
Joelho 90º 100mm	2		Filtro para Sólidos	1	
Joelho 90º 75mm	4		Folha Lixa para Ferro 120	4	
Redução 100x75mm	2		Adesivos Plásticos para PVC	1	

MATERIAIS

11 MATERIAIS

Materiais	Quantidade	Exemplo	Materiais	Quantidade	Exemplo
Torneira de Jardim	1		Arame	0,5Kg	
Cadeado para Torneira	1		Niple Roscável 3/4	1	
Tela Mosquiteira	1		Cap Roscável 3/4	1	
Fita Veda Rosca	1		Bombona de 220L	1	
Lâmina para Arco de Serra	1		Pregos, Parafusos.	Var.	
Retalho de Pano para Limpeza de Tubos	1				

Table 5: Reservoir prospecting.

Typology	Quant./ Typology	V (L)	Value/ reservoir	Total Value/ Typology	Amount
Houses 15m²	58	1.000	R$ 399,90	R$ 23.194,20	
Houses 18m²	135	2.000	R$ 1.043,90	R$ 140.926,50	**R$ 166.819,70**
head office	1	5.000	R$ 2.699,00	R$ 2.699	

3.3 PIPA TRUCK SERVICE BUDGET

The supplier found and serving the study region gave the budget of R $ 0.035/L. Thus, the annual volume served by the project under study, of 2,850.201.78 L, would have a cost of R $ 99,757.06 L if acquired through this solution.

3.4 PAYBACK

The following was the calculation of Payback, which is a financial indicator that represents the period of return on estimated investment, in order to compare the project studied with the current solution used by residents. Compared the amount that will be saved in the purchase of water by the Pipa truck service with the investment to install rainwater use systems considering the following scenarios:

a) Scenario A: Purchase of reservoirs and all components;

b) Scenario B: Purchase only the components and use of reservoirs already present in the community or obtained through donation.

Payback calculation is given by equation 4 below and was calculated in Table 6 for both scenarios.

$$\textit{Payback}\ \text{simples} = \frac{\text{Investimento inicial}}{\text{Saldo médio do fluxo de caixa no período}} \qquad \text{Eq. 4}$$

Table 6: Payback calculation in years.

Scenario	*Payback*
A	R$ 281.756,94 / R$ 99.757,06 = 2,82
B	R$ 114.937,24 / R$ 99.757,06 = 1,14

4 CONCLUSIONS

In the study, two difficulties were found, the first consists of estimating the value of rainfall in the study region, due to the lack of nearest rainfall stations to the site and the inconstancy of these measurements. An important factor to consider is the relationship of the water cycle with climate change, whose standard can be changed, making it more difficult to have more accurate predictions of rainwater supply and, therefore, the actual efficiency of the studied project. And the second was the sizing of reservoirs through the standard, since ABNT NBR 15527: 2007 was reviewed and the sizing methods were removed due to the dispersal of the results.

Nevertheless, it was possible to achieve the specific specific objectives, through which it was possible to understand how the project would impact the community and its cost.

The forecast of demand for non -potable purposes at study sites, considering the daily use of 30 liters per housing, is 4,237,650 liters/year. The offer of this resource obtained with the installation of rainwater use systems in the mentioned buildings is 2,850.201.78 liters. Therefore, the systems meet 67% of the demand.

It is estimated that after the installation of the system the water purchase economy by the kite truck service is approximately R $ 100,000.00 per year for the communities. Considering the 387 houses described earlier, the economy is almost R $ 260.00 per family, significant value taking into account the great pockets of misery in the region, where the average per capita monthly income is less than R $ 400.00.

By calculating Payback, the return period of investment in the project is a maximum of 2.8 years, and may be reduced to 1.1 if reservoirs are already used in the place or donated.

The result found was satisfactory and the project is considered viable because it has a relatively low cost, is simple and easy to implement and is already being used in some communities and presenting proper functioning. In addition, the systems contribute to the reduction of soil erosion, the runoff and flood problems, issues that are aggravated due to soil contamination of the study site.

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