

## Rainwater Use in the FAMETRO Manacapuru Unit for Non-Potable Purposes

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### Abstract

Water is the fundamental element for the existence of life on earth is one of the essential natural resources used by humans. The use of alternative sources of water in public and private bodies has been the most constant form in recent years, this time aiming to reduce the demand for drinking water. The management of water use and the search for alternative sources of supply such as rainwater use fall within the context of sustainable development, which proposes the use of natural resources in a balanced way and without harming future generations. Thus, the design of the reservoir for the use of rainwater at the Manacapuru Metropolitan Faculty of Manacapuru - UEA, by the methods provided by the NBR 15527/2007 guidelines were satisfactory. With ten-year rainfall data from 04/2008 to 12/2017, in the municipality of Manacapuru, the volume found for the reservoir to meet the analyzed rainwater demand was 37.17 m<sup>3</sup>, with a supply of approximately 80% of non-potable water consumption at Manaus Metropolitan Faculty Manacapuru unit. Thus the economic advantages, the implementation of this sustainable system can bring benefits to the environment, so all the water collected will help to minimize the occurrence of floods and the improper consumption of treated water.

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# Rainwater Use in the FAMETRO Manacapuru Unit for Non-Potable Purposes

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## Abstract

*Water is the fundamental element for the existence of life on earth is one of the essential natural resources used by humans. The use of alternative sources of water in public and private bodies has been the most constant form in recent years, this time aiming to reduce the demand for drinking water. The management of water use and the search for alternative sources of supply such as rainwater use fall within the context of sustainable development, which proposes the use of natural resources in a balanced way and without harming future generations. Thus, the design of the reservoir for the use of rainwater at the Manacapuru Metropolitan Faculty of Manacapuru - UEA, by the methods provided by the NBR 15527/2007 guidelines were satisfactory. With ten-year rainfall data from 04/2008 to 12/2017, in the municipality of Manacapuru, the volume found for the reservoir to meet the analyzed rainwater demand was 37.17 m<sup>3</sup>, with a supply of approximately 80% of non-potable water consumption at Manaus Metropolitan Faculty Manacapuru unit. Thus the economic advantages, the implementation of this sustainable system can bring benefits to the environment, so all the water collected will help to minimize the occurrence of floods and the improper consumption of treated water.*

**Keywords:** Rainwater, reuse of water, Use of rainwater;

## 1. Introduction

Water is the fundamental element for the existence of life on earth. It has no smell (odorless), no color

(colorless), no taste (tasteless) and is formed by two gases: hydrogen (H) and oxygen (O<sub>2</sub>). All living beings depend on it to survive and ensure the permanence of the species. The average human body needs, on average, four liters of water a day to stay healthy, acting, along with other body functions, to exchange substances, acting on approximately 70% of its body mass. The aqueous solution has the responsibility of transporting the mineral salts of substances, both inside and outside the cell, and other functions such as body temperature regulation [1].

In addition, water is also indispensable for meal preparation, essential for personal and environmental hygiene. Thus, it is everyone's duty not to allow any kind of waste and to guarantee a pure and crystal-clear quality water, since the water makes it possible to quench the thirst, it is used in agriculture, industries, restaurants and in every house. Water is also indispensable for energy generation, transport, recreation, health and employment of the population.

Drinking water found in nature is one of the most essential resources for the growth and multiplication of living organisms that inhabit planet Earth. The dissemination of information regarding the risk of water scarcity has increased the population's awareness regarding the use of this resource [2]. Nowadays this natural resource is increasingly limited due to the population growth which as a consequence consumes more than nature can replenish.

Thus, the search for alternative sources of water supply such as rainwater use is of utmost importance to reduce drinking water consumption and thus contribute to sustainability.

Rainwater harvesting is a new technology that is being used in recent years to collect and store rainwater for human use through gutters that are deployed on roofs, roofs, which are on the earth's surfaces, applying more accessible techniques like buckets, jugs and basins, as well as engineering techniques.

Thus, this work aims to design a system for the use of rainwater to save water and reduce environmental impacts and use for noble purpose in the Manaus Metropolitan Faculty Manacapuru-AM unit. With the specific objective of diagnosing and estimating the volume of non-potable water use and applying methods according to the guidelines NBR 15527/2007 to determine the preliminary design of the system for the storage of rainwater in the Faculty.

## **2. Theoretical References**

### ***2.2 Use of Rainwater Use Throughout History***

The use of rainwater is not a new practice, there are reports of this type of activity millions of years ago. Rainwater utilization has been practiced for over 4,000 years through the temporal and spatial variability of rainfall. It is an alternative source of water in many places where there is no conventional type of water supply system, so of utmost importance in places where water is of good quality, surface or underground. The rainwater harvesting system has been in use since ancient times, and there is evidence of rainwater harvesting systems dating back to the early Roman times [3].

Rainwater harvesting systems are also found in pre-Columbian civilizations. Mexico as a whole is rich in ancient and traditional rainwater harvesting technologies dating from the Aztec and Mayan times. To the south of the city of Oxkutzcab, at the foot of Mount Puuc, one can still see the achievements of the Mayans. In the tenth century, there was an agriculture based on rainwater collection. People lived on the slopes and

their drinking water was supplied by cisterns with a capacity of 20,000 to 45,000 liters. These cisterns had a diameter of approximately 5 meters and were excavated in the limestone basement, lined with waterproof plaster. Above them was a catchment area of 100 to 200 m<sup>2</sup>. Other rainwater harvesting systems were used in the valleys, such as watery (artificially dug rainwater reservoirs with a capacity of 10 to 150 million liters) and Aquadites (small artificial reservoirs for 100 to 50 thousand liters) [4].

With the introduction of modern supply technologies that were emerging, the collection and use of rainwater lost strength. Nowadays, due to the need to search for alternative sources of water, the use of rainwater has become a reality and is a widespread technique mainly in European countries.

### **2.3 Availability of water resources in the world**

We consider the planet on which we came as planet water, since its surface is mostly composed of this substance. It is estimated that 97.5% of the world's water is salty and not suitable for our direct consumption or irrigation.

Of the total volume of water on the planet, it is estimated that only 2.5% is potable water or simply fresh water, and much of this volume is not easily accessible. Only 0.266% of this total is found in lakes, rivers and reservoirs, the remainder being distributed in biomass and in the atmosphere as steam. Thus, it is estimated that only 0.007% of all freshwater on the planet is in places with simple access for human consumption [5].

Water on the planet is unevenly distributed, with the largest volumes available in Asia and South America. Asia has the largest share of this resource in the world, totaling approximately 31.6% and reaching flows of 458,000 km<sup>3</sup> / year. The lowest potentials are found in Oceania, Australia and Tasmania [6].

### **2.4 Availability of water resources in Brazil**

Brazil is home to the largest river in length and volume: The Amazon River. This is located in the northern region of the country. In addition, over 90% of the national territory receives rainfall throughout the year and its geological, climatic and geographical conditions favor the formation and development of a wide river network, except in the semiarid region, where rivers are temporary.

Brazil has an estimated water availability of 35,732 m<sup>3</sup> / inhab / year, being considered a “water rich” country. Moreover, in relation to world water potential, Brazil accounts for 12% of the total amount of fresh water in the world [7].

Brazil's water availability is mostly distributed in watersheds. The main river basins in Brazil are the Amazon River, Tocantins-Araguaia, San Francisco, Northeast North Atlantic, Uruguay, East Atlantic, South and Southeast Atlantic, Paraná and Paraguay Rivers [8].

The largest hydrographic network in the world is the Amazon Basin, which covers a drainage area of about 6,112,000 km<sup>2</sup>, occupying about 42% of the surface of the Brazilian territory, extending beyond the border from Venezuela to Bolivia [8].

Although Brazil is rich in the availability of this water resource, these are unevenly available throughout the country.

In Brazil, it is verified that the most populous regions are precisely those with the lowest water availability, on the other hand where there is a lot of water, a low population index occurs. An example of this is the

Southeast Region of Brazil, which has a water potential of only 6% of the national total, but has 43% of the country's total inhabitants, while the Northern Region, which comprises the Amazon Basin, It has 69% of available water, accounting for only 8% of the Brazilian population [9].

### **2.5 Water scarcity issues**

Today the planet is already facing a water crisis as a result of the disorderly growth of pollution that often expands without adequate infrastructure causing pollution of water resources, of industrial growth that eventually lead to an increase in demand for clean water.

Water distribution in the world varies significantly over time and space, making many regions vulnerable to frequent water shortages. In 2005, approximately 8% of the planet's total population was vulnerable to water shortages and, according to estimates made at the time, about 25% more were heading in the same direction. The reduction in water availability due to the constant contamination of water resources and the increase in consumption in the industrial, agricultural and municipal sectors is quite visible when comparing data from 1950, where world reserves were 16.8 thousand m<sup>3</sup> / inhab. whereas in 2005 this value was reduced to 7,300 m<sup>3</sup> / inhabitant, and may be further reduced to about 4,800 m<sup>3</sup> / inhabitant. by the year 2030. From 1950 to 2000 the number of inhabitants in the world tripled, per capita consumption doubled and the total volume of water withdrawn from available reserves increased approximately nine times [10].

The differences between developed and developing countries are shocking and show that the global water resources crisis is directly linked to social inequalities.

Importantly, there is an unequal distribution of water resources in the world. According to data from the Ministry of the Environment, Brazil owns about 13.7% of all surface water, of which 70% is located in the Amazon region and only 30% is distributed to the rest of the country [11].

### **2.6 Utilization of rainwater**

The use of rainwater is inserted in the context of sustainability, since it proposes the use of natural resources in a balanced way and without harming the future generations. Being conceptualized as all the water resulting from atmospheric precipitation collected on roofs, roofs, where there is no circulation of people, vehicles or animals [12].

One way to prevent the sharp decline in drinking water availability is to reuse or use rainwater. Unfortunately, many people even consider joining some of these alternatives, but do not know how this can be done and whether this habit can harm their health. Rainwater, for example, has great potential for reuse, but is wasted by many.

It is very important to note that the saving of drinking water through the use of rainwater reduces the waste of clean, pure water in activities such as car washing, watering plants and lawns, flushing toilets, cleaning sidewalks, streets and patios, water mirrors and some industrial applications [12].

## **3. Materials and Methods**

### **3.1 Determination of the study area**

The place of study of this work was the Manaus Metropolitan Faculty Manacapuru unit - AM - FAMETRO, located at Travessa Cristiane Azevedo, 2295 - Terra Preta, Manacapuru - AM.

The building has a floor, having a total built area of 700 m<sup>2</sup>, where are distributed classrooms, laboratories, library, cafeteria and bathrooms, found that FAMETRO does not currently exist - and has never been used - any kind of system rainwater use in the building.

### 3.2 Materials

#### 3.2.1 Rainfall Data

The historical series of eleven-year daily precipitations from 04/2008/12/2018 / were analyzed, using the monthly average of precipitation, in millimeters, obtained for the city Manacapuru - AM, which will be made available by the National Institute of Weather - INMET.

## 4. Methods

### 4.1 Study Area

The catchment area was accomplished by the simple collection, through gutters, of the rainwater flowing into the slab of the study area of the Manaus Metropolitan Faculty of Manacapuru - FAMETRO. From the collection data, the rainwater reservoir was dimensioned in accordance with the survey of rainfall data from the city of Manacapuru - AM, considering the coverage areas of the horizontal plane surface building following the guidelines. NBR 10844/89 [13], for the calculation of the contribution area was 700 m<sup>2</sup> according to Figure 1, extracted through the Google Earth program (2019).



Figure 1: FAMETRO Study Area

Source: Google Earth Program Mosaic, 2019.

#### 4.1.2 Runoff coefficient

The amount of rain that can be used is not the same as the precipitation due to the losses to the roof material,

but also infiltration and evaporation.

According to the INTRANET Rainwater Primer [14] prepared by FEAM - Minas Gerais State Environmental Foundation, the initial volume of water discharged depends on the size of the catchment area, and usually 1 to 2 mm of rainfall is adopted. for each square meter.

Runoff coefficient (C), also called surface runoff coefficient always varies according to the building material (slab), according to Table 1. However, the value to be adopted in this study was with coefficient C = 0.9 [15].

Table 1: Runoff Coefficient

MATERIAL	RUNOFF COEFFICIENT
Ceramic tiles	0.8 to 0.9
Enameled tiles	0.9 to 0.95
Corrugated Metal Tiles	0.8 to 0.9
Asbestos cement	0.8 to 0.9
Plastic	0.9 to 0.95

Source: Adapted from [15].

**4.1.3 Rainwater Volume in the Fametro**

The calculation of the volume of rainwater in Fametro that can be used was performed by equation 1, according to [15].

$V = P \times A \times C \times \text{Capture factor}$  Equation 1.

Being:

V = monthly volume of rainwater used;

P = monthly average precipitation (mm);

C = Runoff coefficient = 0.9;

η uptake factor = water intake system efficiency 0.8; and

A = projecting roof area (m<sup>2</sup>).

**4.1.4 Flow in the rail design**

To perform the chute flow calculations was following the guidelines of ABNT NBR 10844/89 [13] which is given by equation 2:

$Q = I \times A / 60$

Being:

Q = Peak flow (liters / min)

I = Rain intensity (mm / h)

A = Contribution area (m<sup>2</sup>)

**4.1.5 Reservoir Sizing**

To calculate the reservoir sizing was followed the guidelines of ABNT NBR 15527/2007 [12]. Therefore, we adopted three methodologies for comparison, the Rippl method, the English practical method and the practical method of Professor Azevedo Neto.

**4.1.6 Ripp Method**

The Rippl Method was used for monthly demand and historical series of monthly rainfall, this method aims to ensure constant water supply in both rainy and dry periods. As a basis for this method, table 2 was used.

Table 2: Rippl Method

RIPPL METHOD							
1	2	3	4	5	6	7	8
Month	Average Monthly Rain (mm)	Monthly Demand (m3)	Capture Area (m3)	Monthly Rainfall (m3)	Difference between demand and rainfall (m3)	Column 6 difference from positive values (m3)	OBS

Source: Adapted from [15].

Equations 3, 4 and 5 will be used.

$S(t) = D(t) - Q(t)$ ; Equation 3

$Q(t) = C \times \text{rainfall}(t) \times \text{catchment area}$ ; Equation 4

$V = \sum S(t)$ , only for values  $S(t) > 0$ ; Equation 5

Where:  $\sum D(t) < \sum Q(t)$

Where:

$S(t)$  = volume of water in the reservoir at time  $t$ ;

$Q(t)$  = usable rainfall volume at time  $t$ ;

$D(t)$  = demand or consumption at time  $t$ ;

$V$  = reservoir volume in cubic meters; and

$C$  = surface runoff coefficient.

**4.1.7 English Practical Method**

For the design of the rainwater reservoir by the English Practical method, according to NBR 15527 [12], Equation 6 was used.

$V = 0.05 \times P \times A$  Equation 6

Where:

$P$  = Average annual rainfall, in millimeters;

$A$  = Collection area, in square meters;

$V$  = Volume of usable water and volume of water of the tank in liters.



**4.1.8 Practical Method of Professor Azevedo Neto**

For the method of Prof. Azevedo Neto from the rainwater reservoir, Equation 7 was used.

$$V = [(P / 2) / 12] \times A \times T \text{ Equation 7}$$

Where:

P = average annual precipitation in millimeters;

T = number of months of little rain or drought;

A = collection area, in square meters;

V = usable water volume and the reservoir water volume in liters.

**5. Diagnosis of rainwater use at Manaus Metropolitan College - Fametro**

To estimate the demand for non-potable water at FAMETRO, the use of the system by 350 students, 6 staff and 9 teachers according to the Faculty Secretariat - FAMETRO, with 1.5 uses per capita per day of discharge into the basin was considered, for the consumption of 20 working days.

Table 3: Parameters for estimating water demand for the study site.

INTERN USE	UNITS	PARAMETERS	
Discharge in the basin	Descar / person / day	Lower	Upper
		4	6
Discharge Volume	Liters / discharge	6,8	18

Source: Adapted from [15].

**5.1 Diagnosis of non-potable water use**

The calculation was performed through the consumption of non-drinking water following the methodology of [15] by equation 8.

$$(0.03 \times \text{built area}) + (0.07 \text{ employee No.}) + (0.8 \text{ No. Basins}) + 50$$

**5.2 Average volume spent on toilets**

The most economical sanitary basin in Brazil is 6 L / flush, but as we can have leakage of around 30%, therefore the rate of 9.0 L / flush will be used. As TOMAZ [15]. The average monthly volume spent on toilets was estimated by equation 9:

$$VMM = (\text{Employees}) \times (9 \text{ L / discharge / day}) \times (5 \text{ times / day}) \times 20 \text{ days} / 1000$$

**6. Results and Discussion**

**6.1 Rainfall data and rainfall in the Fametro.**

In Table 4 we can see that the year of 2013 had the highest rainfall intensity with 2,454.60 mm, so the month of October to May was the most precipitation.

Table 4: Average monthly rainfall from 2008 to 2017 - Manacapuru-AM.

Average monthly rainfall from 2008 to 2017 from Manacapuru-AM													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Sum
2008				448,4	292,4	135,8	0	56,4	64,6	192,4	262,8	166,2	1619
2009	24,6	14,4	16	0,8	0,8	0,2	0	0,6	89	81,2	38	152,8	418,4
2010	13,6	2	1,4	1,8	1	0,2	0	3,8	92,2	84,8	212	224,4	637,2
2011	236,4	247,8	327,4	412,4	186,2	129,8	47	48,2	35,4	0	130	308,6	2136,2
2012	546,8	211,6	280,6	370	114,2	47,8	94,6	30,8	55,8	37	180,6	269,2	2239
2013	266,4	264,6	319,6	199	194,4	44	193,2	82,6	42,4	233	424,8	190,6	2454,6
2014	319,8	193,4	570,8	298,6	342,6	133	0	71,8	52,4	71,8	196,4	47,2	2297,8
2015	471,2	128	482	211	230,6	115,8	124	33,8	46,6	37	146	178,8	2204,8
2016	162,2	224	273,8	268,2	189,4	84	52,6	83,6	96,2	139	210,8	521,4	2305,2
2017	353,4	433,4	301	226,8	0	0	31,4	68,4	141,8	145	201	337,8	2240

Source: Adapted from INMET, 2018

We can observe an irregular distribution of rain in the city Manacapuru-AM, with rainfall rates greater than 200 mm from November to April. So, then the driest months in turn are from June to October.

The rainwater volume calculation of the Fametro catchment area is 700 m<sup>2</sup>, with the monthly rainfall of November 2013 of 424.80 mm, using in Equation 1 the volume of rainwater that can be harnessed is 214.099 liters. The gutter design flow then results in 4,956 L / m

### 6.2 Diagnosis of non-potable water use at Manaus Metropolitan College - Fametro.

Non-potable water consumption at Manaus Metropolitan College Manacapuru - Fametro unit was calculated by Equation 8, with a per capita demand per day of 99.75 liters / day or 0.0997 m<sup>3</sup> / day.

### 6.3 Average volume spent in toilets

With the total of 365 people who flush toilets at Fametro Manacapuru - AM unit was calculated by Equation 9, thus water consumption in the toilets for 20 school days of the month is 328.5 m<sup>3</sup> / month.

### 6.4 Reservoir Sizing by the Rippl Method

The reservoir sizing by the Rippl method is shown in Table 5, the maximum reservoir volume was defined by analyzing the behavior of column 7, with the peak value (highest value) being 2395m<sup>3</sup>. So, when the values in column 6 are positive, the reservoir water level is falling and this is happening throughout 2013. Thus, the reservoir volume of 3000m<sup>3</sup>, corresponding to a supply of 69 days of supply, was adopted. dry (3 months). It stands out the Rippl method provides high values for the reservoirs.

Table 5: Reservoir Sizing by the Rippl Method

Runoff coefficient (CR) =		0,9					
Months	Average Monthly Rain	Monthly Demand	Catchment area	Monthly Rainfall	Difference between demand volume and rainfall volume	Cumulative difference from column 6 of positive values	Reservoir situation
	(mm)	(m <sup>3</sup> )	(m <sup>3</sup> )	(m <sup>3</sup> )	(m <sup>3</sup> )	(m <sup>3</sup> )	
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
January	266,4	328,5	700	168	160,5	160,5	D
February	254,6	328,5	700	167	161,5	322	D
March	319,6	328,5	700	201	127,5	449,5	D
April	199	328,5	700	125	203,5	653	D
May	194,4	328,5	700	122	206,5	859,5	D
June	44	328,5	700	28	300,5	1160	D
July	193,2	328,5	700	122	206,5	1366,5	D
August	82,6	328,5	700	52	276,5	1643	D
September	42,4	328,5	700	27	301,5	1944,5	D
October	233	328,5	700	147	181,5	2126	D
November	424,8	328,5	700	268	60,5	2186,5	D
December	190,6	328,5	700	120	208,5	2395	D
Total	2444,6	3942		1547	<b>Volume =</b>	<b>2395</b>	

**6.5 Practical Method English**

By the English Practical Method, the reservoir water volume is 14,868 liters or 14.86m3. It is noted that the English Practical Method provides Average Volume values.

**6.6 Reservoir Sizing by Professor Azevedo Neto's Practical Method**

By the Azevedo Neto Method, the reservoir water volume is 37,170 liters or 37,17m3. It is shown the great importance of the variable (T) that represents the number of months with little rain in the city of Manacapuru -AM, which in the present study is 3 months, so randomly adopted values may result in reservoirs larger than ideal size.

**7. Final Considerations**

The implementation of rainwater harvesting systems is an incentive for the population. Today this system is a matter of great importance for water resources management. With these systems of water use in public or private universities and colleges, in addition to reducing environmental impacts, is of great importance in environmental education and sustainability. Therefore, this work was important to contribute to this discussion. It should be noted that rainwater systems may have a positive impact not only at the University

and College, but also for the municipality of Manacapuru - AM.

The reservoir sizing for the use of rainwater at the Manacapuru Metropolitan Faculty of Manacapuru - UEA, by the methods provided by the NBR 15527/2007 guidelines were satisfactory. With ten-year rainfall data from 04/2008 to 12/2017, in the municipality of Manacapuru, the volume found for the reservoir to meet the analyzed rainwater demand was 37,170 m<sup>3</sup>, with a supply that will be approximately 80 % of non-potable water consumption at Manaus Metropolitan College Manacapuru unit.

Thus, given all the information presented, it is correct to reaffirm that this system of water use is very important, as it is possible to reduce the use of drinking water as well as the expenses, not to mention the reduction of floods, flooding, future rationing. water, and still help the environment with that.

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