Chapter 4 Technological Implementation for rainwater harvesting

Capítulo 4 Implementación tecnológica para la captación de agua de lluvia

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DOI: 10.35429/H.2022.8.42.55

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A. Marroquín, J. Alonso, Z. Chavero and L. Cruz (Coord) Engineering and Innovation. Handbooks-©ECORFAN-México, Querétaro, 2022.

Abstract

This project presents the collection and use of rainwater at the Higher Technological Institute of Huauchinango based on a physical model of water collection, with which water is collected and stored directly outdoors, providing real data on a daily. On the basis that rainwater can be used as an alternative to supply the water demand, in some of the daily activities. Primarily, the physical model of rainwater capture and collection is implemented, then it is stored in a water tank and from this data was collected in liters, during a period of time of 30 days, during this period of time different samples were taken, before and after passing through the filter, to determine some of its physical and chemical characteristics to define the use of water in the infrastructure of the Higher Technological Institute of Huauchinango.

Storm water, Sustainable, Ecological

Resumen

En este proyecto se expone la captación y uso de agua de lluvia en el Instituto Tecnológico Superior de Huauchinango a partir de un modelo físico de recolección de agua, con el cual se realiza la captación y el almacenamiento de la misma al estar directamente a la intemperie, proporcionando datos reales día a día. En base a que el agua de lluvia se puede emplear como una alternativa para abastecer la demanda de agua, en alguna de las actividades cotidianas. Primordialmente se pone en marcha el modelo físico de captación y recolección agua de lluvia, posteriormente se almacena en un tinaco y de este se tomaron los datos de volúmenes recolectados en litros, durante un periodo de tiempo de 30 días, durante este periodo de tiempo se tomaron distintas muestras, antes y después de su paso por el filtro, para determinar algunas de sus características físicas y químicas para definir el uso en las cabañas cotidianamente.

Aguas Pluviales, Sostenible, Ecológico

1. Introduction

It is made an investigation and distribution of rainwater, based on the fact that it can be used as an alternative to supply the water demand in some of the daily activities carried out at the Higher Technological Institute of Huauchinango. Particularly the presentation of a physical model of rainwater collection and filtering will provide the necessary data to determine the appropriate use in such facilities.

Based on the above, some problems that have arisen over time are presented. The main one is due to the growth of the urban population, and therefore to the increase in the demand for water consumption. These problems of water scarcity are rethinking the role of rainwater from being considered as a waste to being considered as a resource, capable of supplying several of the daily activities. This water resource can be depleted quickly, that said, it is intended to generate the implementation of a rainwater harvesting system to supply the required demand, making use of the water that we took as waste. This research work and for its development, different tests were elaborated to determine some physical and chemical characteristics of the collected water, and with these results to determine a good use of implementation for the utilization and optimization of captured water, following a series of phases within a methodology, a physical model is built which captures and filters the water improving its conditions for its use.

Objectives

General Objective

The construction of a physical model of rainwater harvesting in the Higher Technological Institute of Huauchinango.

Specific Objectives

- Investigation of materials to create a physical model.
- Research for correct model placement
- Build a physical model for rainwater harvesting.
- Analyze the quality of the collected water.

Justification

The objective is the construction of a physical model of rainwater harvesting, which has a filter that is made up of three different layers of granular materials, the collected water is intended to be used for the infrastructure of the Higher Technological Institute of Huauchinango.

After the model has been built, several samples of the collected water are obtained to carry out some analyzes of the physical and chemical characteristics such as apparent color, odor and taste, turbidity, pH, suspended solids, oxygen and conductivity. Once the results are analyzed, a comparison is made to make the best use of this water, thereby reducing the demand for this vital liquid.

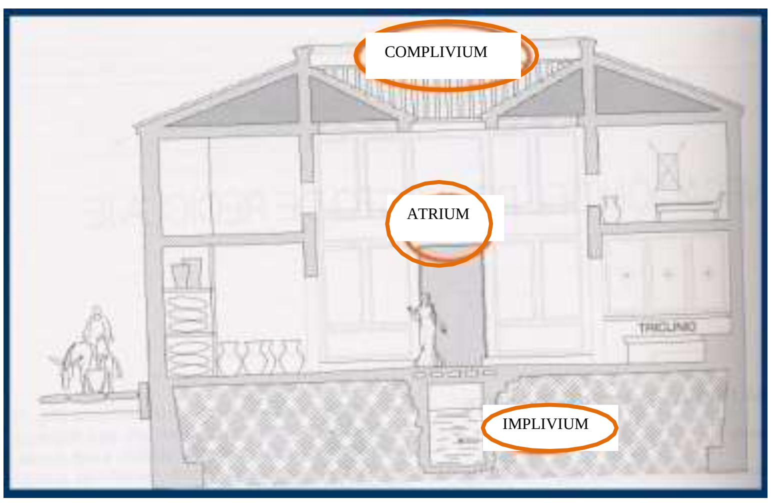
1.1 Chapter I Generalities

1.1.1 Historical background

The ancient civilizations grew demographically and some peoples occupied arid or semi-arid areas of the planet, the development of forms of rainwater harvesting began as an alternative for irrigation of crops and domestic consumption. Archaeologists found a sophisticated rainwater collection and storage system on the island of Crete, while working on the reconstruction of the Palace of Knossos (1700 BC). In Yemen, where rainfall is scarce, there are buildings (temples and prayer sites) that were built before 1,000 BC, which have patios and terraces used to capture and store rainwater. (Ballen S, et al; 2006).

Rainwater harvesting systems were considered when designing and building dwelling-houses, complementing them with the construction of cisterns for storing water for domestic use and thus satisfying the needs of man. During the Roman Republic (3rd and 4th centuries B.C.) the city of Rome was mostly occupied by single-family homes called "la Domus" (figure 1) that had a main open-air space ("atrium") and in it were installed a central pond to collect rainwater called "impluvium", rainwater entered through a hole in the roof called "compluvium". (Gallardo and Cornejo, 2008).

Figure 1.1 "La Domus" and its components of the rainwater harvesting system



Reference Source: (Gallardo and Cornejo, 2008)

In the pre-Hispanic Mexico there is evidence of these systems, such as in the archaeological zone of Xochicalco, Morelos, 650 to 900 AD, where there was no source of water supply, so efficient use of water was practiced. The central square and yard were designed to channel rainwater into cisterns, which stored the water for seven months. Figure 1.2 (Garrido 2006).

Figure 1.2 Left, Xochicalco Archaeological Zone. Right, Cistern built with stone for storage of rainwater

Reference Source: (Garrido, 2006)

As time passes and the accelerated increase of man advances, some problems began to appear, such as the great demand for water for daily consumption, evidencing a great decrease in the vital liquid, generating the change of some civilizations to other areas to supply this need.

With these arising needs, rainwater harvesting systems began to be presented in ancient times and there is no precise data on their origin, although authors agree on theories that these systems were generated from the first civilizations of the Middle East. (Rodríguez Negrete, and others, 2005).

1.1.2 Sustainability in the world

England and the United States were pioneers in the creation of associations and laws in defense of nature, an example followed later by France, Germany and Spain. The United States is where the idea of preserving large spaces in their original state, such as landscapes and “sanctuaries” for animal and plant life, leaving out the human presence, arises. In 1864 the government ceded, for this purpose, the Yosemite Valley and the Mariposa Grove, in California; and in 1872, the first national park in the country and the world, Yellowstone, was created.

Since then, some practices such as the use of renewable materials and/or the design of solar energy harvesting date back thousands of years. The contemporary green building movement grew out of the need for more energy efficient and environmentally friendly building practices. The oil price increases of the 1970s prompted significant research and activity to improve energy efficiency and seek renewable energy sources. This, combined with the green movement of the 1960s and 1970s, led to the first experiments with contemporary green building.

The U.S. Green Building Council (USGBC) promotes sustainability in the way buildings are designed, constructed, and operated. The USGBC is best known for the development of the rating system called LEED (Ledearship in Energy and Environmental Design), which promotes environmentally responsible materials, sustainable architecture techniques and public policies in the building industry (Greenbuilding, EPA, 2010).

1.1.3 Sustainability process in Mexico

Since 1988, Mexico has had the General Law of Ecological Balance and Environmental Protection, in which sustainable development is conceived as: "The process that can be evaluated through indicators of an environmental, political and social nature that tends to improve the quality of life and the productivity of people, which is based on appropriate measures to preserve the ecological balance, protect the environment and take advantage of natural resources, so that the satisfaction of the needs of future generations is not compromised.”

Policy initiatives related to energy saving in buildings began only in the mid-1990s, when the National Commission for Energy Saving (Conae) promoted the formulation and application of mandatory standards on energy efficiency. energy for lighting and the envelope of non-residential buildings. The National Commission for Energy Saving (Conae) recently began working on the implementation of a solar water heater program; Such an initiative, together with the establishment of sustainability guidelines for public sector acquisitions, leases and services, will undoubtedly contribute to the promotion of more efficient construction.

1.2 Chapter II Rainwater harvesting

Implementing rainwater harvesting has been given different methods and systems, such as the trench method, this method allows rainwater to be retained and filtered regardless of its runoff surface. Several studies have been carried out on the retention trenches that have generated optimization in their use and an excellent process depending on the site to use this method, and for which they have generated questions to be resolved about these models, generally reaching all these devices. To the same question "what would be the time that both retention and infiltration trenches would be useful", this is the aspect with the greatest impact that can be resolved with this type of system to rehabilitate rainwater. (Proton and Chocat, 2007).

Different studies have been carried out which evaluate the hydraulic behavior of the retention and infiltration trenches, one of these was carried out by (Proton and Chocat, 2007) from an experimental setup which consists of generating a single conduit for rainwater, dividing filtration in various hatches or filter modules and delivering to a single conduit, which is the output of the model. Parallel to this (Proton and Chocat, 2007) they study and test modeling in order to generate projected results of the number of years of rainfall. To carry out this research work, a supply of real runoff water was taken, captured on a highway or urban road stored in a tank to optimize its use in these tests. The water obtained was recirculated in the model to produce representative volumes of periods projected to years of rainfall.

1.2.1 Catchment Area

Places where they are used to collect water can be roofs, patios, esplanades, paved roads, garages and any non-permeable surface where rainwater runs off and it is feasible to collect it. As a rule, in all the systems they use the catchment on the roofs, which must have an adequate slope and surface, which facilitate the runoff of rainwater towards the collection and storage system. As a rule, in all the systems they use the catchment on the roofs, which must have an adequate slope and surface, which facilitate the runoff of rainwater towards the collection and storage system. The quantity and quality of the collected liquid varies depending on the treatment technologies and the annual precipitation of the area and the collection area. This amount can be affected by roofing materials, splashing outside the catchment area, leaks, evaporation, and absorption.

1.2.2 Driving system

It is a set of gutters or pipes of different materials and shapes that conduct rainwater from the catchment area to the storage system, through drops with PVC pipe for current buildings for buildings already built. Gutters are installed on the lower edges of the roof, where rainwater tends to collect before falling to the ground; the material must be light, resistant, easy to join together, must match the finishes of the facilities (urban areas), and must not contaminate with organic or inorganic compounds; Therefore, it is recommended to place meshes that stop garbage, solids and leaves, to avoid obstruction of the flow in the conduction pipe; likewise, carry out cleaning tasks on the roofs at the beginning of the rainy season.

1.2.3 Storage and retention

The rainwater storage tank allows access to water close to the point of use, at the time and in the quantity required. It can be built above or below ground level (cisterns) and be made of materials such as plastic (which does not transmit odors or flavors to the water), cement, partition or block. One of the biggest challenges in installing this system is to lower the cost of materials and construction. In the Blue Schools (IRHA 2018) and Mazateca (Isla Urbana 2018) projects, geomembrane tanks with low labor cost metal supports were installed.

Advantage:

Can be used in community and family systems
Long life time
Low maintenance cost

Disadvantages:

Must have sufficient water supply from surface or catchment roof
Relatively high cost
Possibility of reproduction of disease transmission vectors (mosquitoes, flies, etc.)
Possible contamination to lack of maintenance.

The storage tank allows the collection of water during the rainy periods, making the water resource available near the houses, especially in periods of drought. They can be built above or below ground level (cisterns). The tank can be made of materials such as plastic (which does not transmit odors or flavors to the water), cement, partition, block or geomembrane. PAHO (2004) recommends using masonry for volumes less than 100 and 500 liters in rural areas. The interior of the tank must be insulated to keep out insects and sunlight, which leads to algae growth inside the tank. Some tank models may have buttresses.

1.3 Chapter III Design Considerations

To determine the size of the tank, the number of users, consumption habits and the collection capacity of the collecting surface must be considered. Ideally, the tank should have the capacity to supply water throughout the dry season plus an additional 5% volume, which is the minimum level that should always be in the tank to avoid damage due to decreased humidity within it. Details and formulas for calculating the volume of the storage tank are provided by PAHO (2004), who indicates that the size of the tank will depend on the supply and demand in each of the months of the year, so a volume must be counted that store water during periods of abundance to ensure water during periods of drought, without losing sight of the economic factor. According to PAHO (2004) “there is a direct relationship between the investment required to implement the rainwater system, and the catchment area and storage volume, often resulting in a restriction for most of the stakeholders.

The storage tank must have the following elements: an easily accessible door for cleaning, a turbulence reducer, an overflow, a household intake 10 cm above the bottom of the tank (which does not obstruct the passage) and a drain valve at the bottom of the tank (Gutierrez and Bulnes 2016). PAHO (2004) recommends that storage tanks be no more than 2 meters high to minimize overpressure. In some cases, the surface of the tank can be used to capture rainwater directly, as long as the filtering process of the water before it enters the tank is guaranteed. In the event that the tank is of the cistern type, a pumping system should be considered to extract the water, either mechanized or by human force, as well as the placement of a manifold at the end of the extraction tube. In addition, it is recommended to place a measuring ruler (García and Hernández 2017) with a level scale on the outside of the tank to be able to calculate the amount of water in the tank during monitoring or water purification work.

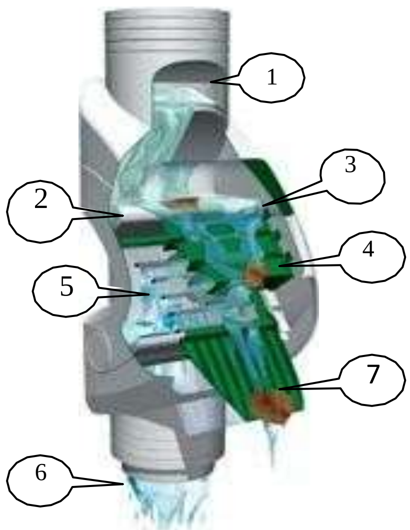
1.3.1 Operation and maintenance

It is important to keep the tank door closed. The inside of the tank should be cleaned every two years, at the end of the dry season, emptying it completely, cleaning the walls and the bottom with a soft broom and a mixture of water and chlorine (proportion 20/1), let it rest for half hour and then rinse, removing all the water inside. At the end, the tank must be filled by at least 5% (García and Hernández 2017). Next, it is recommended to check the quality of the water and that there are no leaks in the tank. If the latter occurs, a mixture of cement and water (with the previously prepared surface) should be applied to the outside.

1.3.2 Rainwater treatment

- The elements to guarantee the quality of the water captured in the treatment, can be the filters that are the most used today.
- The use of filters prevents the passage of solid waste dragged by precipitation into the tank, preventing its sedimentation or fermentation and bad smell of the water. The filter drain is directly connected to the cistern or storage tank.
- There are a large number of manufacturers of self-cleaning external filters for rainwater collected on the roofs of buildings. The capacity and dimensions of the filters depend on the catchment area.
- The first filter can be a grid placed in the pipe or gutters that carries the collected water and that serve to retain mainly the leaves of the trees or other large solids, as shown in the following.

Figure 3.1 3P Rainus filter, filter parts and their operation



Reference source :(image taken from www.3ptechnik.com.mx)

1. Connection to storm water downspout
2. Perimeter filter
3. Passage of filtered water
4. Fall and drag of removed solids
5. Perimeter collection
6. Lateral collector towards cistern
7. Collection of removed solids

The quality of the water collected is achieved by means of special devices, especially when the water is to be consumed directly, that is, it is to be drinkable in the first few millimeters of rain, a first runoff diversion trap can be used to drag polluting solids that have been deposited on the roofs. The implementation of traps for the first runoff allows the removal of the highest density particles. The trap for diversion of the first runoff of water also avoids the contamination of the water in the tank with the first precipitations, which are the most polluted. The water diversion device can be installed on each downspout supplying water to the cistern, or larger units that can handle multiple inlet pipes.

1.4 Chapter IV Technological implementation for rainwater harvesting

Scope

- Show the advantages of carrying out an implementation of rainwater harvesting generation systems as a viable solution for the sustainability of the infrastructure of the Higher Technological Institute of Huauchinango.
- Take advantage of the implementation of gutters to collect water and thus reduce the consumption of drinking water and take advantage of rainwater.
-

Limitation

– Lack of user participation.
– High cost to create sustainability.

1.4.1 Methodology

Current situation

The infrastructure of the Higher Institute of Huauchinango is in optimal conditions and its current water supply is not so critical, it is only a matter of focus since presenting our position with nature, it is convenient to work for it, take care of it, and reuse it. Working with rainwater harvesting is the solution to minimize the use of water supplied by the municipality, giving a plus to our ecology, making these benefits known and taking care of our environment by taking advantage of a vital liquid that is wasted to reuse it for purposes ecological.

Precipitation

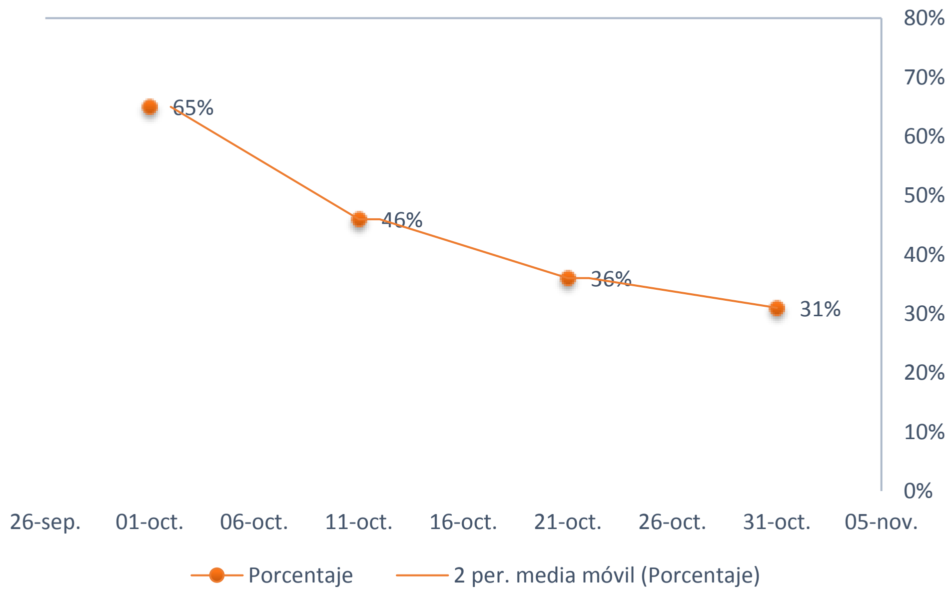
A wet day is a day with less than 1 millimeter of liquid or liquid-equivalent precipitation. The chance of wet days in Huauchinango, Puebla varies very significantly throughout the year.

The wetter season lasts 4.5 months, from May 28 to October 13, with a greater than 43% chance of a given day being a wet day. The maximum chance of a wet day is 77% on July 3.

The drier season lasts 7.5 months, from October 13 to May 28. The smallest chance of a wet day is 9% on January 13.

Among the wet days, we distinguish between those with only rain, only snow, or a combination of the two. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a maximum probability of 77% on July 3 (Ovacen, 2018).

Graph 4.1 Chance of Precipitation in October



Reference: (Own Elaboration, 2021)

1.4.2 Correct placement of the model for rainwater harvesting

Materials

Anthracite

For the main and first layer, this material is an excellent filtration medium, mainly for the elimination of chlorine and organic compounds present in the water that is captured.

Sand

As a second layer of the filter we find sand, with a lower density than gravel. Thanks to its round-shaped grain symmetry, it ensures porosity, letting the water flow easily, but retaining some suspended particles that continue to appear in the rainwater.

Gravel

As a third segment, this one below is used in the filters due to its density, the heaviest of these materials already installed previously, it has great characteristics which make it a very good material for filtration, which does not impart any characteristic to the water collected, passage of the water through the gravel will stop at these contaminants.

Geotextile NT1600

Finally, we have this material which, due to its fine conformation structure, its main quality is found in its faces, one of these is waterproof and the other is permeable, therefore, it is an excellent retainer of contaminants that water can bring. and fine particles, mentioning its properties above as a filter material, it is chosen to use between layers, this being one more layer of filter material in the rainwater harvesting model.

False bottom

It is like a type of storage tank where some suspended solids that may occur can settle, since the outlet of the collected water is located at a height of 0.10 m from the bottom, so the last contaminants end up here and let the water come out fully filtered for use.

1.5 Implementation prototype

Finally, we find the physical prototype to verify the operation since this is how the collected water samples were taken to see the difference and verify its usefulness of the collected rainwater. This physical prototype is made with glass walls to appreciate its operation almost in its entirety.

Figure 5.1 Physical Prototype

Reference Source :(Own Elaboration, 2021)

With the taking of samples for the study of the quality of the water to establish its use, we were able to realize that a notable difference can be seen with the naked eye with the use of this filter.

1.6 Results

1.6.1 Comparative physical and chemical properties

By taking into account the type of water to be collected, a comparison between rainwater is generated, measurements of these physical and chemical characteristics are made through an analysis of samples taken, before entering the model and at the exit of the model., the characteristics measured are the following: Determination of pH, Turbidity, Apparent Color, Suspended Solids, Odor and Taste, Oxygen and Conductivity.

In accordance with resolution 2115 of 2007, a comparison of its physical properties is made with a sample captured before and after the filter, obtaining the following results.

Figure 6.1 water Sample before passing through the Prototype (Filter)

Reference Source: (Own Elaboration, 2021)

Figure 6.2 water Sample after passing through the Prototype (Filter)

Reference Source: (Own Elaboration, 2021)

Table 6.1 Physical Properties

Physical Characteristics	Drinking water Maximum value Acceptable	Rainwater collected before filter	Rainwater collected after filter
apparent Color	15	12	10
Odor and taste	Acceptable	Acceptable	Acceptable
Turbidity	2	7,47	7,81
pH	6.5 a 9.0	5,33	5,57
Suspended Solids	100	116	111
Oxygen	3 ml/lt.	2,7	2,7
conductivity	250	217	208

Reference Source: (Own Elaboration, 2021)

Based on these results obtained, we can use this water for flushing toilets and general services such as cleaning the facilities without presenting any inconvenience.

1.6.2 Catchment area

The collection of rainwater is carried out through the roofs, taking advantage of its large collection area. In this case, the drop that the tin roofs have with the slope and gutters that it contains are good for capturing this liquid.

In this regard, the material of these sheets is selected due to its conditions of easy handling, cost and good handling when building this cover, another great feature that this polyethylene provides is that it maintains the characteristics of water without altering its conditions. initials, it offers us a great impermeability which provides a collection without losses at the time of precipitation that occurs in the area.

Table 6.2 Collection data by model in liters and duration in minutes

Day	duration minutes (m)	intake in liters (lt)
1		
2	180	182
3	90	88
4		
5		
6		
7		
8	95	99
9	42	54,5
10		
11		
12	50	82
13	45	66,2
14		
15		
16	50	111,5
17	40	92
18		
19		
20		
21	53	100,8
22		
23	65	80
24	21	86
25		
26		
27		
28	14	59
29		
30		
	Total	1101

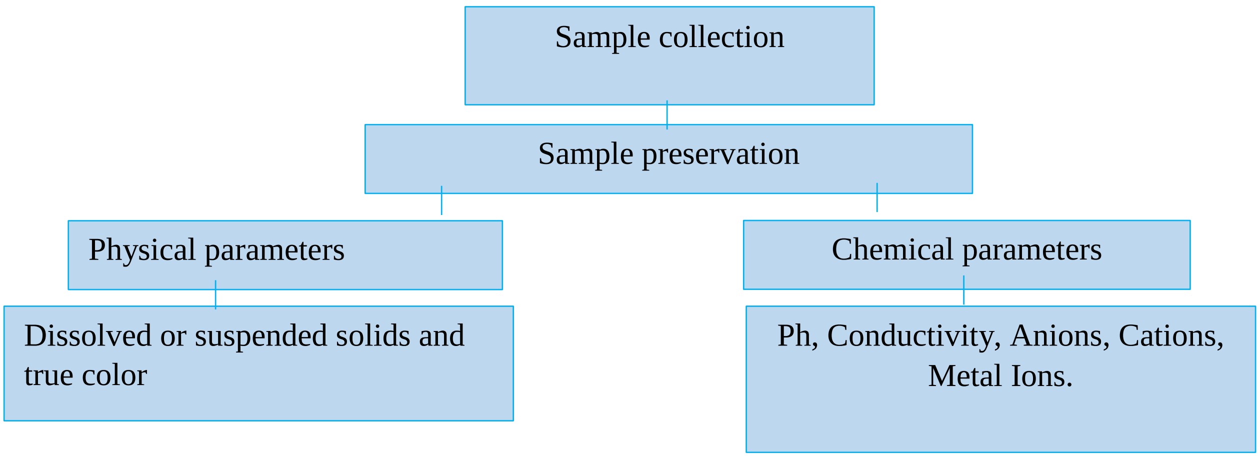
Reference Source: (Own Elaboration, 2021)

Volume captured during the month in m3.

Based on the data collected above, an equation will be used to see the volume captured in liters during the month.

$\mathbf{V}$= 1101 Lt * $\frac{1m3}{1000\,Lt}$ = 1.10 M3

Figure 6.3 Comparative physical and chemical properties



Reference Source: (Own Elaboration, 2021)

The rainwater captured according to its characteristics will be used for the discharge of toilets and general services such as cleaning in the facilities, it is assumed that, of the total design volume, only a percentage of 65% of this will be used for the aforementioned uses.

Daily demand used for flushing toilets and general services.

D= 0.45 m^3/day * 0.65 = 0.2925 m^3/day

Monthly demand used for flushing toilets and general services.

D= 0.2925 m^3/day * 30 = 8.775 m^3/day

The month of 30 days is determined, according to this it is calculated that the monthly water demand for this type of use is 8,775 m3.

Financing

Without Financing

Gratitude

To the Higher Technological Institute of Huauchinango and the Industrial Engineering Division for the facilitations provided for the preparation of the presented chapter.

Conclusion

According to the situation presented, it can be shown that the use and exploitation of rainwater is becoming a great alternative that is not common, which allows reducing the impact caused by conventional supply sources.

So with this we can say that the rainwater collection and filtering model created provides a sustainable solution, it is also providing water of an acceptable quality according to resolution 2115 of 2007 to be used in daily activities such as the discharge of toilets and general services such as the cleanliness of the facilities, except for use for human consumption that could affect health.

The benefits that will be reflected when implementing it:

- Sustainability
- Environmental benefit
- Economic savings

Based on atmospheric data from the region, it is a project that fits perfectly since the area is humid-rainy, this puts our plan into operation most of the year, but in terms of collection, the total volume demanded for the determined use, this is due to the fact that the collection area is small in consideration to supply the required need, however, a significant saving potential is obtained of a percentage of 65% of the 8,775 m3 consumed in a month in these activities such as it is in W.C. and cleanliness of the facilities.

From the point of view, this type of alternative resources such as rainwater harvesting is one of the best projects that are currently being managed, due to various factors such as excessive consumption of drinking water, waste, increased payment fees, this It will generate more of the scarcity that already exists, opening the way to rationing at home regardless of how many inhabitants there are in it, and with this collection method, not only does it not affect your economy, you learn to take advantage of the environment without polluting and specifically satisfy your daily needs.

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