WATER FOR LIFE: Sustainable and innovative water solutions for vulnerable communities

Documento de trabajo

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In Colombia, approximately 30% (13.6 million people) of the total population lives in rural areas. Out of this 30%, the 39.7% do not have access to a water supply system, 60% do not have sanitary units or a sewer system and only 11% have access to drinking water.

To train engineering students with social commitment [1], teachers and students of two colleges of engineering have formed a group to conceive, design, implement and operate specific technical solutions in Colombian marginal communities [2].

In this order, teachers and students from the departments of Civil Engineering, Environmental Engineering, Industrial Engineering and Chemical Engineering of the University *Corporación Universitaria Minuto de Dios* (http://portal.uniminuto.edu) and the University *Universidad de los Andes* (www.uniandes.edu.co) have been a consolidated team since two years ago. This team has worked to design and to implement technology for vulnerable communities in Colombia with solutions that are technically innovative,

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economically, socially and ecologically sustainable and culturally appropriate[2]. Recently we have joined efforts with a group of engineering students from Nankai University (http://env.nankai.edu.cn/en/) in China, with whom we have been sharing technical information in order to improve the water filter technology and implement it in Colombia and China.

To consolidate this Community Innovation Projects – CIP, we have taken a specific line of work in the design and implementation of relevant technology to improve the water quality of marginal communities. The project's goal is not only to design technically and economically feasible solutions, but to allow the community to adopt and use it properly.

This team-project presents the proposal of the initial work teams, the proposal of the design and implementation of the filter through the accessible design and implementation technology and the alliance and coordination between universities and the communities. The team-project presents as well the results obtained up until now from the implementation of the technology in specific rural community in Colombia.

The project's long term goal is to improve the quality of life of rural communities through the improvement of the quality of water, in order to reduce deaths related to the consumption of non treated water.

References

[1] Aldana, E. Reyes, A. (2004). *Disolver problemas: Criterio para la formular proyectos sociales*.

[2] CDIO. http://cdio.org. Retrieve on February 15 (2008).

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1. Introduction

It is not uncommon for engineers around the world to neglect social issues and problems that must be solved so future generations can live in a more just society. This is the reason why a group of students and professors from the Universidad de los Andes and the Corporacion Universitaria Uniminuto have created CIP, Community Innovation Project inspired by the worldwide organization known as Engineers Without Borders.

Currently CIP is made up of industrial engineers, civil engineers and environmental engineers.

2. Problem

The problem of concern is the shortage of drinkable water in the area. The project's goal is to improve the quality of the water to improve the community's quality of life and reduce the probability of contracting diseases.

Currently the water comes from a source located on private property, where a recollection tank is located, from which water is distributed to the rest of the village. The water from this tank doesn't receive any type of treatment and, in its current state it is not apt for human consumption.

3. Objectives

CIP's main objective is to contribute to the development of society through the implementation and development of technology, especially in those communities that have been forgotten by the rest of society.

With this in mind, CIP plans to improve the quality of the community's everyday drinking water through sustainable solutions.

4. Characterization of the community

4.1. General information

The district is called Torres and is located to the north of the municipality of Guayabal de Siquima. Currently there are approximately 30 families distributed amongst various areas. Our main area of concern is high Torres, where the district's aqueduct operates, and where 17 families are located.

4.1.1. Geographic information

Guayabal de Siquima is located northwest of Bogota. It limits with Villeta to the north, with Anolaima to the south, with Alban to the east and with Bituima to the west.

Inside the district there are two main sources of water: the source where the aqueduct's water inlet is located and a small stream from which the inhabitants obtain the water they use to feed the livestock.

There are a total of three routes of access to this sector: one that comes from the Trinidad district, another from the Chimbe district and the last one from the Villeta district.

There is a single transportation service which is costly for the inhabitants[10]. The roads are in a good state even though they are not paved. However there is a high risk of landslides.

4.1.2. Economy

The only economic activity is agriculture, specifically sugar cane, corn and coffee. Most of the people own farms are approximately 2 to 5 fanegadas[11] in size. The people work in larger farms (10 to 30 5 fanegadas) which produce brown sugarloaf and coffee and whose owners live in the farm.

4.1.3. Society

[10] 6000 COP until the cabecera municipal

[11] Each fanegada is equivalent to 6800 square meters.

A large part of the population is made up of adults since most of the younger people have left searching for better opportunities. The average size of a family ranges from 4 to 6 people. Approximately 10% of the population can't read or write. There is a strong belief in La Virgen del Carmen as can be observed in the presence of flags with her image on them at the entrance of several houses.

4.1.4. Health

The life expectancy for women ranges between 70 and 80 years. The life expectancy for men is 70 years. The main causes of death are violence and advanced age. There are mosquitoes all year round which cause several diseases.

The nearest health center is located in Guayabal. In case that specialized treatment is required the person is remitted to Facatativa. In order to get to the health center, the inhabitants must take a bus.

The community's children have received shots. The mayor's office has health campaigns every 4 months, but most of the inhabitants of the community have never assisted.

4.1.5. Education

There is a primary school in the district, which has 20 students. There are also 3 high schools in the region: one in Guayabal, one in Chimbe and another in San Julian.

4.1.6. Utilities

Water is provided by the district's aqueduct. Electricity is provided by CODENSA[12] and by the Electrificadora de Cundinamarca, both of them characterized by high prices. There are no phone lines so the inhabitants must communicate by cell phone.

The aqueduct exists approximately 10 years ago. At first there was a small tank which was replaced with a larger one 3 years ago. This tank doesn't have any filtering system which has a noticeable impact on the quality of the water obtained from it.

Six months ago the aqueduct was legalized. During this process the community was accompanied by the municipal spokesperson. The community gathered the money required to pay the

[12] Utility Company which provides energy to Bogotá and Cundinamarca.

legalization costs: 420000 COP at the CAR[13] and 30000 COP at the Chamber of Commerce. The president of the aqueduct is Mr. Dionel Riaño.

Recently the water storage tank has been failing. There have also been distribution problems due to lack of pressure. Furthermore, the water source is located on private property which makes access difficult and increases the risk of contamination due to the presence of livestock on the farm. During the months of July and August there are shortages of water and food.

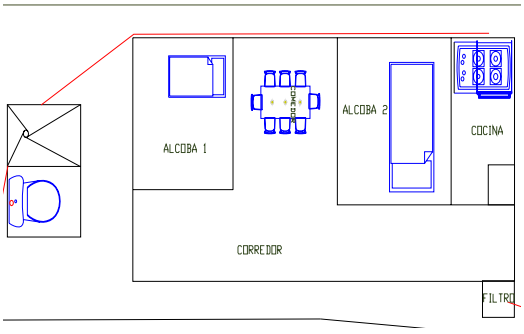
4.2. Characterization of the initial families

The families chosen for the project's initial phase were the following:

- Leonel's family.
- Adán's family.
- Jorge's family.
- Carlos's family.

4.2.1. Leonel's family

Leonel lives by himself and is visited every now and then by his family. His home is made of brick, it possesses sturdy columns and beams which add resistance to the house. The house is composed by 2 bedrooms, a dining room, kitchen and a bathroom. A diagram of the house is presented below:



The water filter was placed outside the house, near the entrance to the kitchen and beside the guadua fence.

[13] Corporación Autonoma Regional: Government entity responsible for the administration and protection of a state's natural resources.

4.2.2. Adán's family

Adan is a retired employee from the Secretaría de Obras Públicas de Bogotá. He has lived 7 years in the district. He moved here because he suffered a heart attack and his doctor recommended that he moves to warmer place.

His family visits him every 15 days and sometimes his wife and his children stay with him during the weekend but generally he lives by himself. He grows coffee and bananas and also raises chickens.

The main pipe (which comes directly from the water supply tank) is split in two. One of these is connected to the tank located at his house's entrance. In this tank the water coming from the water supply tank is mixed with rain water which is then used to wash clothes and coffee. Adan boils the drinking water but says he would like to get some bleach.

The bathroom is located behind his house in a separate structure. On top of this structure there is a tank which provides the water he uses in the bathroom and kitchen. Sewage is deposited in a septic tank located behind the bathroom.

The picture below shows the possible location for the water filter, beside the yellow window.

4.2.3. Jorge's family

The water from the aqueduct reaches a tank located approximately 50 meters from the house (downhill). This tank is open since and a pump is located on top of it in order for the water to reach the house. This tank is full of leaves, dead insects, larvae and other unidentified particles. The water reaches the house through a hose.

The bathroom is located behind the house in a separate structure. The tank located on the top of the bathroom and also has insects inside of it even though it is closed.

The filter will be installed next to the kitchen. The main difficulty is the possible lack of pressure due to the location of the tank and consequently the possible lack of a constant water supply to the filter.

4.2.4. Carlos's family

Carlos is currently living by himself since his wife is in Bogotá due to health problems. He lives in a very old house built from guadua, mud and other materials which are typically found in these homes.

Inside the house there are 2 large bedrooms and a kitchen with a gas stove and a firewood stove. The kitchen with the firewood stove is located beside the house while the kitchen with the gas stove is located in a separate building next to the bathroom. On top of the bathroom there is a 500L reserve tank.

The filter will be placed next to the green tank shown in the picture above.

4.3 Characterization of the families (second stage)

In this second part of the project, we finished the filter instalation for nine families missing. This section aims to show a small characterization of the families and the process of installinf the filters.

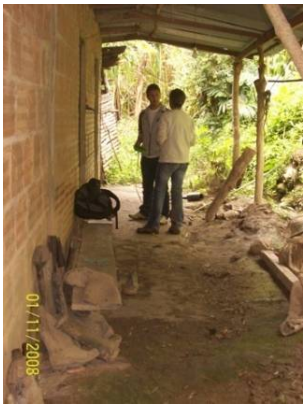
4.3.1 Casa 1

4.3.2 Casa 2

The house is the one with the most difficult access in the village, is located amidst trees and plants; The water comes from a tank located on top of a hill and is covered by trees, making the water down with fallen leaves or small animals.

The kitchen and bathroom are located on the side of the house and way back.

The photo below shows the possible location for the water filter, in front of the kitchen.

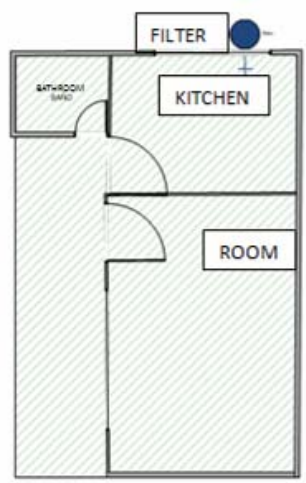


Another difficulty faced by the state house is the bathroom and kitchen, because in the kitchen the owner takes out the garbage burning, which can be another source of contamination.

4.3.3 Casa 3

This house belongs to the family of Gloria Arévalo, it counts with public services as electricity, water (aqueduct of the community) and gas. The family has 3 children who have school attendance.

With regard to the characteristics of the house:
- Do not have drainage channels for disposal or cleaning water.
- Have septic tank. Bathrooms are in good condition.
- The house has only 1 room for 6 people in the house.



The filter was located adjacent to the kitchen, so that we could make a direct wing committed to ensure the comfort cuisine in its use and therefore have a high utilization rate.

4.3.4 Casa 4

The house has to different type of kitchen, one is the traditional one and the other one is based on wood. As the owners want to change the location of the kitchen, the water filter is located behind the kitchen, so when the new kitchen is working they don't have to move again the filter, they have to relocating the pipeline.

The new location of the kitchen

4.3.5 Casa 5

4.3.6 Casa 6

Manuel is the current responsible for the house; he lives with his wife and his two Childs. The house counts with public services. Although, it has gas in the kitchen they prefer to cook on wood, because, it is cheaper.

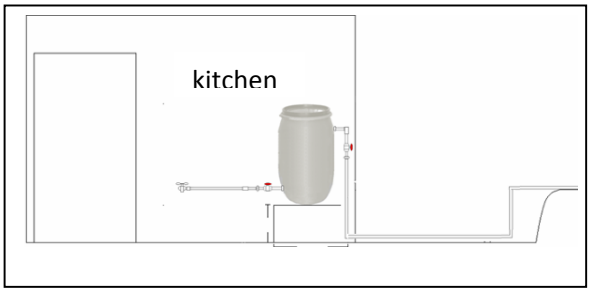
The house has 3 bedrooms, 1 bathroom. In general the house is in acceptable conditions. The family is dedicated to the raising of chickens, for that reason the house is surrounded by a mesh to prevent entry of animals into the common spaces.

The filter was ubiccated in the back of the house, near to the kitchen.

4.3.7 Casa 7

Jose Antonio lives with his wife and his son in an old house with 2 bedrooms, a kitchen and a small dining room. This house hasn't bathroom own, instead of it, they have a septic fosse near to the house. The house counts with public services, except for the telephone service.

Jose Antonio and his son are farmers and his wife Leyla is housewife. For this reason, the filter was located near to kitchen with the purpose of to have the water supply in this place, near to the kitchen, because she hasn't water in the kitchen.

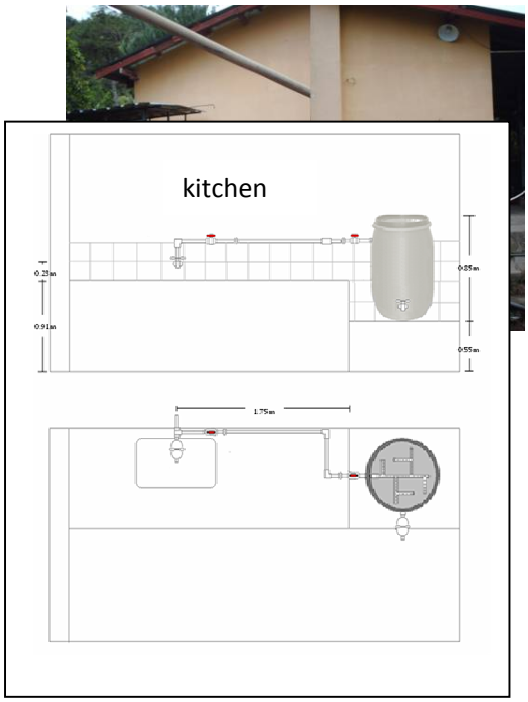


4.3.8 Casa 8

This house has the biggest problem with water quality, because this house consumes water of a different source and this present high turbidity.

Cesar Garay is the responsible for this family and he lives with his wife and his two children in a house in relative good condition, but with a water service very poor.

Filter was put in the kitchen close to the dishwasher and close to where they take out water for consume.



4.3.9 Casa 9

The owner of this house is Mr. Gilberto hi lives there with his wife a 5 years old girl. Mr. Gilberto has more sons but they don't live with him.

Number 9 house or Mr. Gilberto is the best of “Vereda Torres” because it has 2 good bathrooms, kitchen, bedrooms, dining and other thing.

It also has it is own water supply, wich comes from the ground of the farm, and he has a reservoir of about 8 to 10 $m^{3.}$

Into the form is located the reservoir and the water that supplies all the “Vereda Torres” the filter is located on a concrete plate over the private bathroom, wich supplies the kitchen all the time.

5. Slow sand filter

5.1. Description

The slow sand filter implemented in Torres is a simple system of crude water treatment. This water may come from sources of supply or rain water. The main purpose of the filter is to improve the quality of the water that is consumed by the families that live there. This process of the water quality improvement consists in the removal of the water pathogens that promote diarrheal diseases and health problems in general.

5.2. Filtering process

When the filter begins its operation, the water flow –that is controlled by a floater valve- goes through the filter bed, who consists in two sand layers of different specific diameter and one gravel layer that function as support material for the sand.

At the beginning, the filter will not be completely efficient, because the filter bed works with a superficial biological layer, who needs a maturation period to make a turbidity efficient removal.

This process will take from 2 to 3 weeks14. In the period of maturation, the organic matter in water flow will begin to be removed by the filter bed, causing that the sand pores become smaller and therefore more selective. As a result of that, an accumulation of organic matter will take place in the filter bed, which will be decomposed by the microorganisms that live there, acting like an indirect disinfection agent. After that, the water that has crossed the filter bed is caught and leaded by a drainage network, taking it out of the system to the exit line, ready for the consumption. The quality of the exit water can be described in terms of the removal percentage, which is more than 95% of microorganisms (total Coliforms and E. Coli), therefore for a total disinfection is possible to dose drops of chlorine to the treated water.

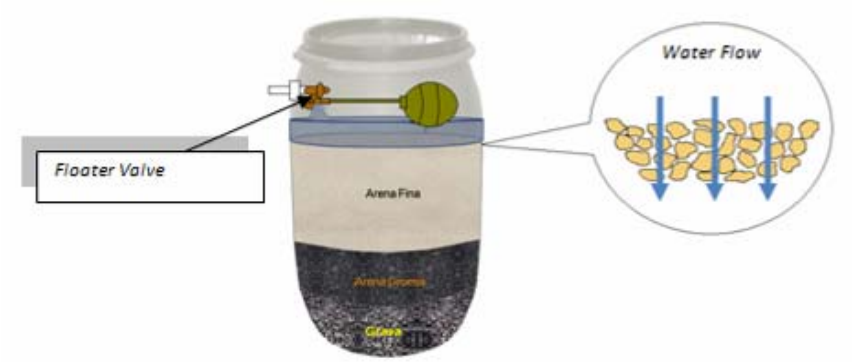
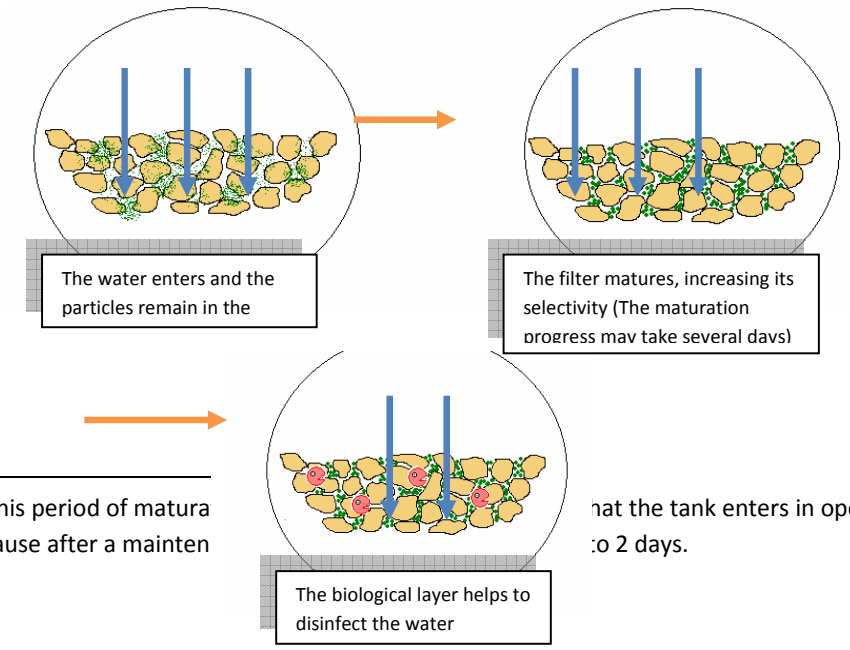


Figure 1. Filter General Scheme



[14] This period of matura ...hat the tank enters in operation the first time, because after a mainten ...o 2 days.

Figure 2. Filtration and maturation of the filter bed

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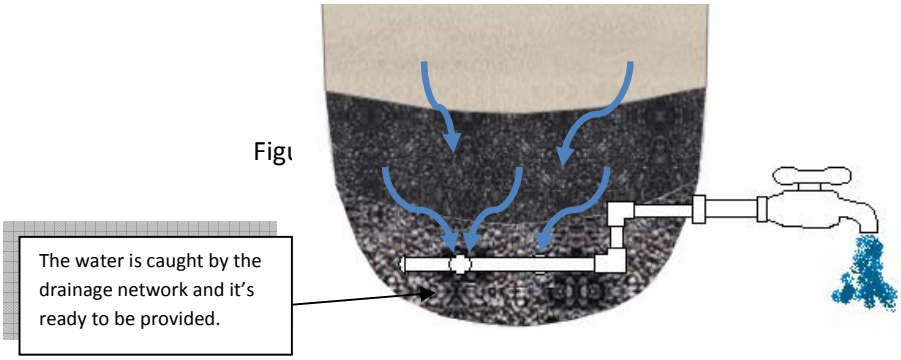


5.3. Design parameters

The filter bed is formed by a fine sand layer and a coarse sand layer, this sands have a specific size of 0,3 - 0,45 mm and 0.7 - 1,2 mm respectively, all this filter bed is supported by a gravel layer of 1 - 2cm of diameter (To see figure 4).

For an efficient removal of the microorganisms, it is necessary that these layers of material have a specific thickness. For the case of the fine sand the thickness of the layer is 40cm, for the case of the heavy sand the thickness of the layer is 15 cm and finally the layer of gravel has a thickness of 15 cm. This is the layers order in descendent sequence.

This material is disposed in a polythene barrel, with a capacity of 40 liters. According to the parameters of the filter bed, that were mentioned previously, the filter this in the capacity of produce approximately 70 liters of water per hour, which is necessary to satisfy the needs of a

family of 5 people. It is important to wash the material before of putting it on the barrel, in order to eliminate present impurities and microorganisms that can contaminate the filtrate process.

The drainage network this located in the gravel layer that maintains the system. This PVC drainage network is fish skeleton shaped (To see Figure 5); it's distributed in the base of the barrel with the purpose of catch all the treated water and transports it to the distribution or consumption point.

Finally the filter counts with a water entrance line, that allows to the water entrance to be connected with the source, and simultaneously it allows to disconnect the filter from the water supply with a valve, in case of transfer or repair (To see figure 6). In the same way the filter counts on a line of exit that allows the distribution of the water for consumption (To see figure 6).

Figure 4. Filter Bed Structure

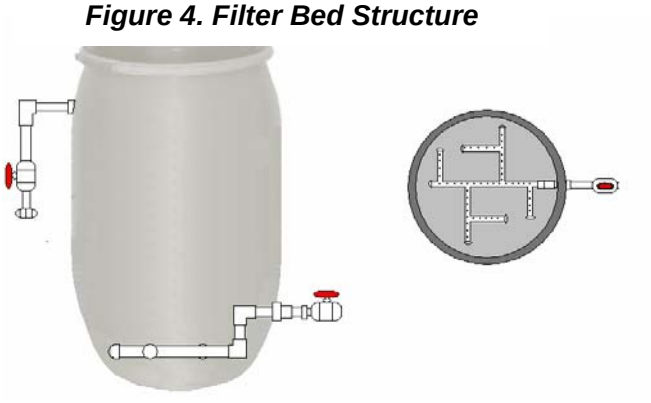


Figure 5. Drainage Network.

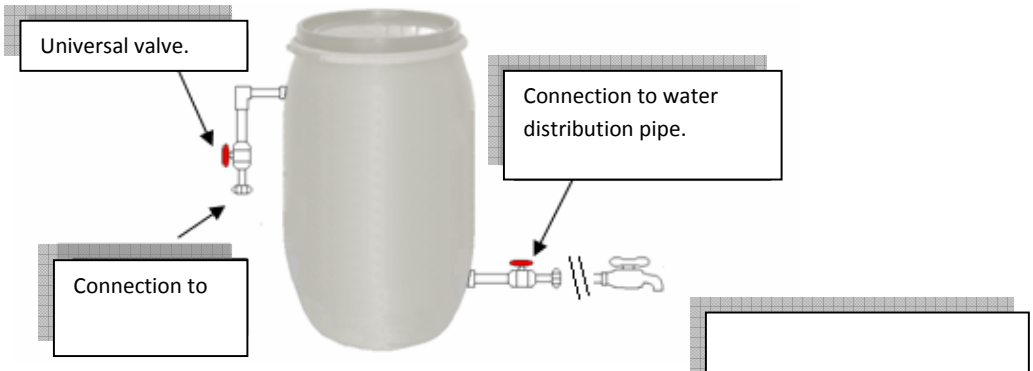


Figure 6. Filter Entrance and Exit Lines.

5.4. Maintenance

The maintenance of the sand filter is as simple as the technology is. It consists on remove a part of the Biological layer that has been formed during a period of 6 months, which is the average time of operation.

The removal should be realized in the following way:

The superior 5 cm of the fine sand layer has to be removed, and replaced with sand of the same characteristics. That's because after the average period of operation, the biological layer has grown too much and prevents the normal flow of the water.

After the replacement of the sand layer, is necessary to wait for the maturation of the filter, maturation that will be faster this time, only 1 to 2 days. In this period is recommendable not to use the water for human consumption.

5.4.1. Materials Cost

The next table shows the required materials, theirs unitary value and the total value[15]:

[15] Cost are in COP.

ITEM	CANTIDAD	VALOR UNITARIO	VALOR TOTAL
caneca plástica (40 galones)	1	$ 35.000,00	$ 35.000,00
tubo 1/2" PVC (agua potable)	1	$ 1.333,33	$ 1.333,33
Tees 1/2" PVC (agua potable)	6	$ 400,00	$ 2.400,00
tapones 1/2" PVC (agua potable)	7	$ 300,00	$ 2.100,00
flotador para tanques	1	$ 16.000,00	$ 16.000,00
codos 1/2" PVC (agua potable)	2	$ 400,00	$ 800,00
flanches 1/2"	2	$ 5.500,00	$ 11.000,00
llave cromada (grifo)	1	$ 5.000,00	$ 5.000,00
adaptador hembra 1/2"	1	$ 300,00	$ 300,00
adaptador macho 1/2"	1	$ 300,00	$ 300,00
soldadura PVC	1	$ 7.000,00	$ 7.000,00
limpiador (acetona)	1	$ 3.000,00	$ 3.000,00
arena fina tamiz (40-60)	3	$ 12.500,00	$ 37.500,00
arena gruesa tamiz (10-12)	1	$ 12.500,00	$ 12.500,00
grava (1/2"-1/4")	1	$ 12.500,00	$ 12.500,00
		TOTAL	$ 146.733,33

5.4.2. Filter Construction

The filter construction began on February 22 of 2008, after the purchase of the pertinent materials.

The construction procedure was the following one:

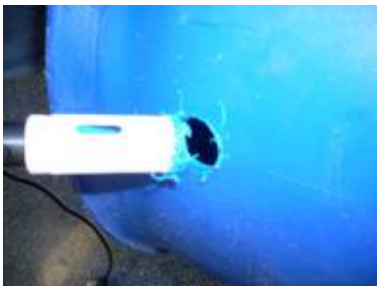
1. Construction of first the drainage system:

2. Determination of the exit key height, according to the height of an average bucket, doing simpler the water harvesting.

3. Hydraulic tests to determine the reason between the water produced by the filter and the water provided to the filter. If the reason has a very small value, the filter must be corrected.

4. Correction in the drainage system: Addition of tubes and holes to increase the pickup area.

5. Perforation of the water exit hole:



Measure and mark the heights that correspond to each part of the filter bed, and then fill the barrel with the different materials.

Height marks

Barrel with the filter bed

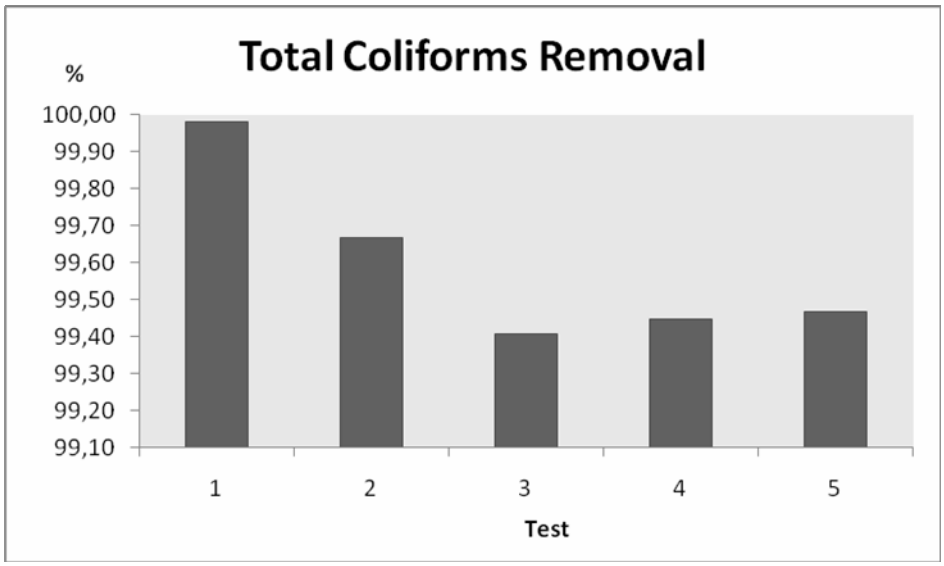
5.4.3. Tests applied to each filter

The tests performed to each filter were the following ones:

- Total Coliforms and E.Coli
- Turbidity
- Color
- pH
- Hardness

The filters showed improvements in Total Coliforms, E.Coli, Turbidity and Color. The parameters used as reference for the filter efficiency were Total Coliforms and E.Coli, because these are directly associated with microorganism activity, that may cause human health diseases.

The filter efficiency in Total Coliforms and E.Coli removal was over the 99% for all the tests on filters already matured. Some of the tests are shown in the next graphic:



Total Coliforms Removal