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Design for Harvesting and Treatment of Rainwater in Naval, Biliran

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ABSTRACT

The study takes advantage of rainwater, a naturally processed water. Developing a design for an affordable, less chemically oriented method that would help many people gain access to the water they need easily. The design used materials that were cheap and can be easily accessed on the local market. The process starts from a stage where large particles of contaminants were removed through straining. The next was iltering the water through a sequence of sponge, charcoal, coarse and fine sand. And lastly was chlorination, which treated the rainwater from the bacteria's which were previously not removed from the filter. The study came up with the design that were easily availed on the local markets of Naval, Biliran. The components were easy to install and were effective in harvesting rainwater. The treatment results were not what the researchers envisioned it to be, but still they were able to produce safe drinking water. Sure enough, it could be an alternative for other uses aside from drinking. The design was incomplete, especially on the part of the treatment device; thus, further studies are recommended for its improvement. Nevertheless, the study proved that simple customized rainwater harvester and treatment device is achievable with the materials that can easily be found on the local market.

Keywords: *rainwater harvesting, less chemical method, customized.*

1. INTRODUCTION

1.1. Background of the Study

For the existence of all living beings (humans, animals and plants), water is very crucial. Almost all human activities—domestic, agricultural and industrial, demand use of water although water is nature's most wonderful and abundant compound but only less than 1% of the world's water resources are available for ready use. Hence it is required to use it carefully and economically (Esguerra et al, 2011).

It is very essential that the body is always supplied with the proper amount of water. Many have already experienced water scarcity. Due to this, many water harvesting designs have already been developed, mostly through the recycling of wastewater. But this kind of treatment will cost a lot of money and a lot of chemical processes are involved (World Health Organization, 2004).

Stated that the application of appropriate rainwater harvesting technology is important for the utilization of rainwater as a water resource. Rainwater harvesting is simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are also readily available. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption of family members have full control of their own systems, which greatly reduces operation and maintenance problems (World Health Organization, 2011).

This study however looks on a view of water harvesting and treatment as a means to be available and affordable to the regular people with less financial capabilities. It discusses a design on harvesting and treatment of rainwater into a safe drinking water with less expenses. Rainwater harvesting is a technique used for collecting and storing of rainwater from rooftops using containers such as tanks, jars and pots (Abbott, 2012).

The study also stated that water collected from roofs of local houses usually is of acceptable quality for domestic purposes. For it could be collected using existing structures not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies. Although regional or other local factors can modify the local climatic conditions, rainwater can be a continuous source of water supply for both the rural and poor (Nillo et al, 2011). The design shows a structure that harvests the rain in residential buildings. Rainwater harvesting and treatment designs has already been implemented in a lot of places all around the globe, however most of them uses a large area for their sand filtration, the modification to minimize the area is one of the design's priority so the local people would be able to afford it while still maintaining the efficiency of the treatment (Madrid et al, 2011).

1.2. Objectives of the Study
The main objective of this study is to design a rainwater harvesting equipment, which is an alternative source of safe drinking water as well as other uses. Specifically, the study sought to answer the following objectives.
1. To provide a simple design of rainwater harvesting and treating equipment with less expenses and has a locally available and cheap material; and
2. To design treatment facilities and design for harvested rainwater to reduce it potable and safe other uses.

2. METHODOLOGY
This chapter shows the procedures and concepts the researcher followed to achieve the objectives of the study, which includes the idea where the design itself is based, it also shows the previous researches the researchers acquired to form the sequence on how to create and achieve the design into a reality.

2.1. Project Description
The project description consists of two parts, the rainwater harvesting design and the water treatment design of the water. After the creation of the project we can collect or gather the data of the filtered water if the drinking water standards will be achieved.

Rainwater Harvesting The rainwater harvesting design is composed of Roof Gutters, Strainer, First Flush Sand and Charcoal Filter, Chlorination Container and Storage Vessels for consumption.

Rainwater Treatment The study takes on three levels of treatment namely the sand, charcoal filters and chlorination process. In every level of treatment, the rainwater is being gradually treated to achieve the drinking water standards. The first is Water treatment using a Sand Filter which will remove most of the large particles and bacteria then the water will pass the Treatment through Wood Charcoal which will eliminate the odor and lastly the Water Disinfection by Adding Chlorine (contained in household bleach) which will finish the treatment on the remaining bacteria.

In determining the time to place the standard amount of chlorine, compute the velocity of the water when it passes the sand filter, in the design the velocity of water is 0.902 li/s, from the time the first flush is already administered, it only needs 11 minutes to fill a liter of container, at this time it can already be chlorinated. And during the time of chlorination, the valve before the chlorination container should be closed, and the valve towards the overflow opened. This way we can prevent another batch of rainwater from entering the chlorination container and disrupts the treatment. Regulations require a PWS to maintain a chlorine content of *0.02 mg/L* and should wait 24 hours for the chlorine to settle down and neutralize the microorganisms before consumption.

2.2. Research Locale
The study was conducted on rainwater harvested on the roof of one of the researchers' residential roof in Larrazabal, Naval, Biliran. And is treated on the assembled device.

2.3. Research Subject
The subject of the study is to verify if the project is feasible as well as if the materials and components are easily availed as well as if the rainwater harvested is potable and safe for drinking.

2.4. Data Gathering Procedure
The researchers traveled to Eastern Visayas State University and the Local Philippine Drinking Water Office in Tacloban City for the testing of the gathered sample for the data needed for the design completion.

3. PREPARATION AND DESIGN CONSTRUCTION
The construction of the design is the part where the researchers construct the design of the water harvesting and treatment.

3.1. Preparation of the Materials
Fine and Coarse Sand The sand is from the seashores of Brgy. Talahid Almeria, Biliran, known for the white sand dunes. One of white sand's characteristic is that it is partly made of crushed shells and porous sand particles which is very good for adsorption, a primary mechanism of particulate removal in a sand filter.

In preparation the coarse and fine sand is separated through a sieve with 1 mm mesh and 10 mm mesh, and classified them as fine, coarse and gravel. Wash it for 10 times, to remove the sea water saltiness and other particles that may compromise the cleanliness and sterilized them separately through boiling for 20 minutes, this way bacteria and other microorganisms will be reduced and if possible removed.

Figure1. Sand

Wood Charcoal Wood charcoal is a common and cheap commodity in the local market. In preparation crush the wood charcoal to at least a 2 cm surface area, and sterilized it in a 20 minute boiling with water.

Figure2. Wood Charcoal

Pipes, gutter, elbows, tees and ball valves. Cut the pipes to the designated lengths, and attach the elbows, valves and tees to the designated places as shown by the table below.

Table 1 Length and Quantity of Pipe to be cut

PIPE	Length	Quantity
½ inch diameter	2 inches	6 pcs.
do	10 inches	1 pc.
do	11 inches	2 pc.
do	1 inch	2 pcs.
do	3 inches	1 pc.
do	8 inches	1 pc.
do	3.5 inches	5 pcs.
1 ¼ diameter	28.5 inches	1 pc.

Table 2 Specifications of the Materials

Material	Size	Composition
strainer	At most 1 mm mesh	cloth
Pipe	½ inch inside dia.	plastic
Tee	½ inch inside dia.	plastic
elbow	½ inch inside dia.	plastic
Ball valve	½ inch inside dia.	plastic
container	3 by 14 inches	plastic
faucet	½ inch inside dia.	plastic
sand	Fine and coarse	white
plywood	56 by 28.5 inches	
wood	1.5 by 2 inches	
roofing	10 by 28.5 inches	plastic
Nylon string	¼ by 12 inches	plastic
Wood charcoal	At least 2 cm (surface area)	
sponge		Synthetic foam

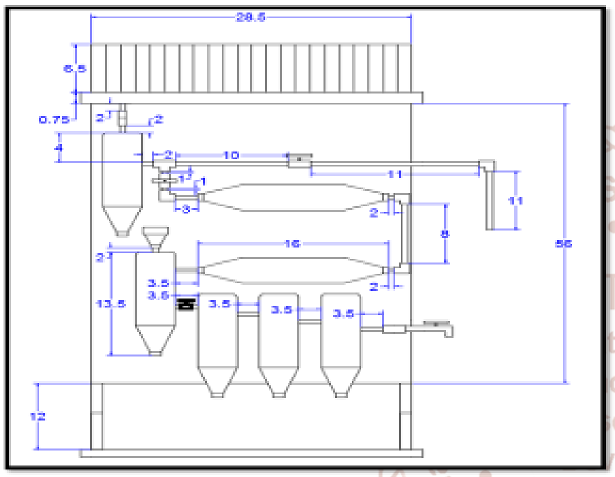
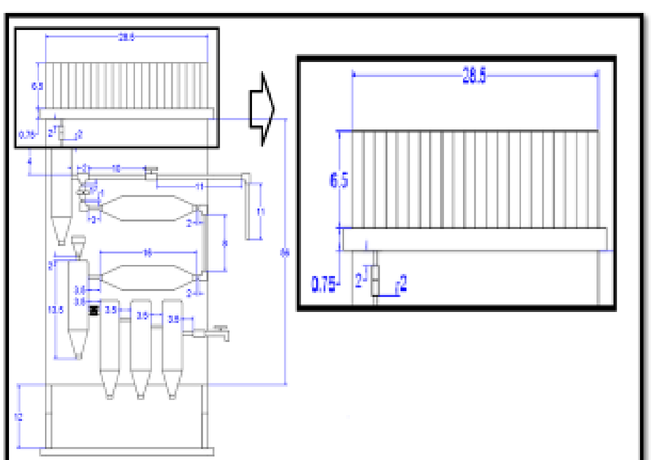


Figure3. Overall Skeletal Design (dimensions are in inches)

The above figure shows the exact over all measurements of the rainwater harvesting design.

3.2. Construction of the Parts

Roof and Gutter The roof is made up of plastic. The gutters are created so that there is only one downspout thereby making the collected rain flow straight to the first part of filtering which is the first strainer. And it should be inclined as to suit the down flow of the water and prevent stagnation. This method makes use of all the collected rainwater.



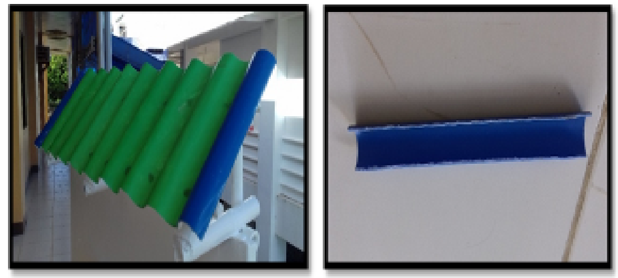


Figure4. Roof and Gutter

Strainer The pipe connecting the strainer to the first container is 1/2 inch plastic, has two elbows, three 2 inched pipes and is glued directly at the bottom of an upside down plastic coke container which is the first container.

Figure5. Pipe connected to the First Container with Elbows and Strainer

First Container The first container which will serve as storage to create a constant pressure for the water to be sand filtered is still a plastic coke container. The container is placed upside down so that its opening will be at the bottom which will serve as the first flush, this means that the concentrated contaminated rainwater from the rooftop is prevented from entering the treatment system. It also is placed with a small pipe with that goes up and an inch above the gutter for the air not to occupy the container.

The first container is 13.5 inches long and 3.5 inches in diameter. It is bored with a 1/2 inch hole, 3 inches from the bottom and attached with a plastic pipe 1/2 inches in diameter which runs towards two more pipes for the over flow and the sand filter. The container has an overflow to avoid the water from returning to the gutters, it's a pipe with a tee and a ball valve. The tee connects a pipe which runs towards the sand filter, while the ball valve connects another pipe which is the overflow, its overflow should run to another container for other usage aside from drinking.

Figure6. First Container

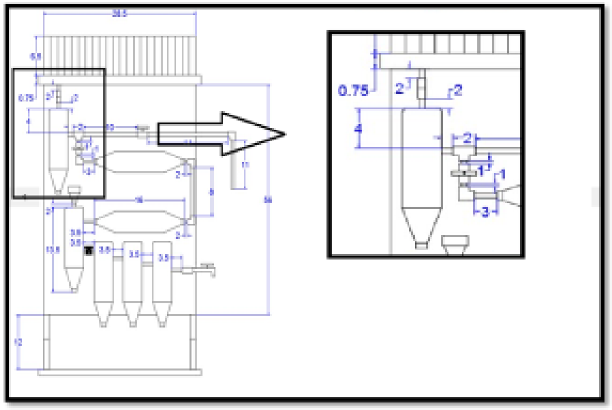
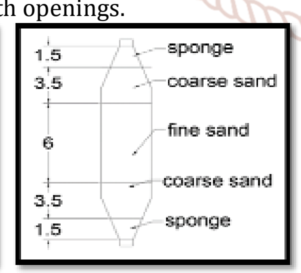


Figure7. Pipe with Elbows, Tee and Ball Valve and the First Container

Sand filter caps This caps serves as the entry point of the rainwater as it flows towards the sand and charcoal filters, a total of 4 customized caps, they are bored caps that is glued with cloth to serve as strainer, to prevent the sand or charcoal from getting out and flow with the treated water.

Figure8. Filter Cap with Strainer

The Pipe and the Second Container (Sand Filter) From the tee, a pipe is attached to the sand filter. The sand filter is made of plastic coke container which is cut 2 inches from its bottom and attached by another cut container but the container is cut 3 inches from the top. Its tips are filled with 1.5 inch thick sponge, next to the cottons are coarse sand and is 3.5 inches thick on both sides, then 6 inches fine sand at its middle. The container is capped with the strainer cap mentioned previously on both openings.



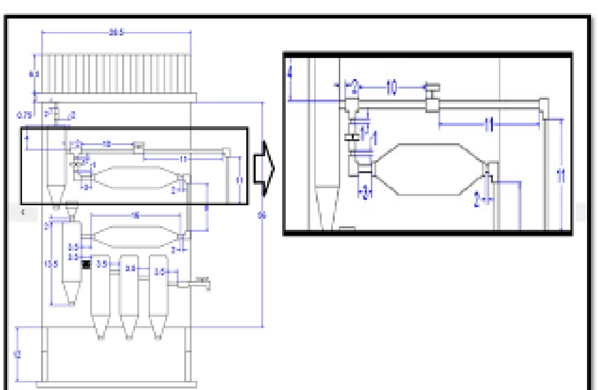
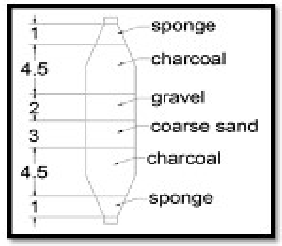


Figure9. Sand filter (*dimensions are in inches*)

Third Container (Wood Charcoal and Sand Filter) The third container is a combination of sponge, gravel, coarse sand and wood charcoal. The container is placed with sponges 1 inches at its ends, then placed with wood charcoal 4.5 inches in thickness next to the sponges as well as gravel 2 inches in thickness and a 3 inches thick coarse sand. The same as the sand filter, the openings of the charcoal filter is placed with the cap strainers.



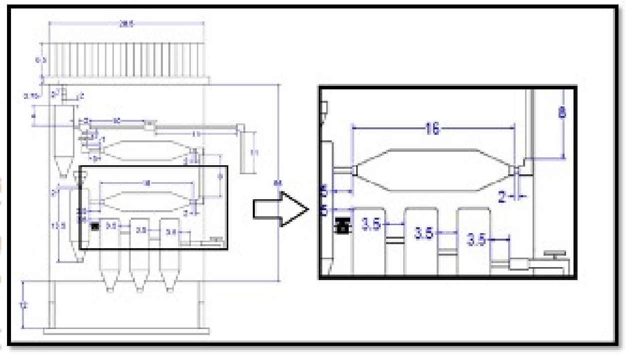


Figure10. Charcoal Filter

Chlorination Container The chlorination container is also an inverted plastic coke container, it is bored with ½ inch hole at its bottom for the funnel. The funnel is made up of a 0.5 liter mineral water container which is cut 3 inches from its top, same as the strainer cap its opening is glued with a pipe and cloth just like the strainer cap. The container is then bored with another hole ½ inch in diameter, this hole is for a pipe with a ball valve that will go to the storage containers.

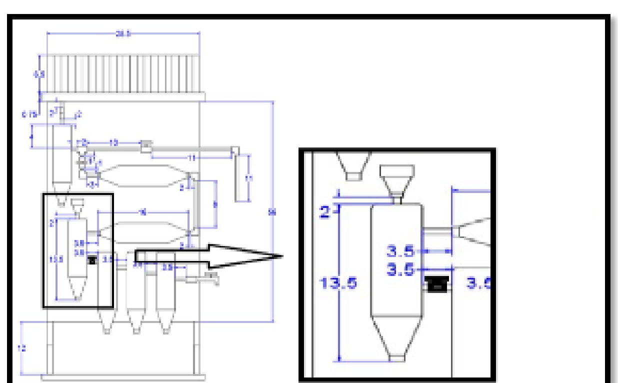


Figure11. Chlorination Container with Funnel (*Dimensions are in inches*)

Storage containers The first storage container is also inverted and is bored with a ½ in hole at its side 1 inch from the bottom, and on its opposite side another ½ inch hole 2 ½ inches from its bottom, which is then attached with a pipe towards another inverted container. Just like the first storage container it is bored on it's a ½ in hole 2 ½ inches from its bottom, while on the opposite side another ½ inch hole 4 inches from its bottom, which is again attached with another pipe towards the last storage container, which is also inverted and is bored with a ½ inch hole 4 inches from its bottom, and its opposite side another ½ inch hole 5 ½ inches from its bottom which is then attached with a pipe for the faucet attachment, for the drinking water.

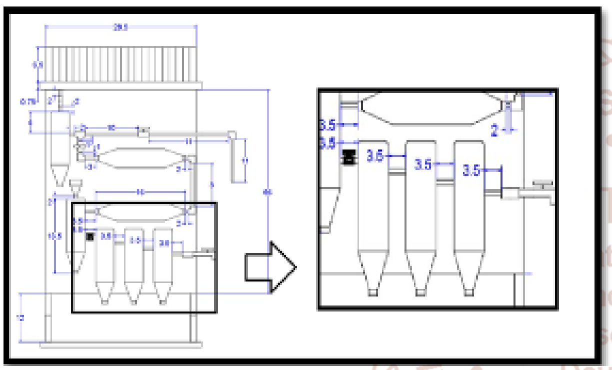


Figure12. Storage container from Chlorination Container with Faucet Attachment and Faucet (*dimensions are in inches*)

Frame and base. The frame is created to serve as the wall for the harvester and the treatment device. The plywood is cut 56 inches in height and 28.5 inches wide for the wall. The wood are cut as follows 2 pcs. 68 inches, 4 pcs. 10 inches (right angle cut at its ends), 2 pcs. 20 inches *and* 5 pcs. 30 inches wood. The 2 68 inches wood will serve as the height of the project, while the 3 30 inches wood will serve as the width, it will be placed equally horizontal on the back of the plywood. The 12 inches extra length of the 68 inches wood will serve as the base of the project. At its bottom will be the two remaining two 30 inches wood is placed parallel to the plywood's width while the 2 20 inches is placed perpendicular to the width of the plywood. Lastly, the 4 right angled cut 10 inches wood are placed as support parallel to the two 20 inches wood and two of each are placed at its opposites.

Figure14. Frame with Base (front and back)

4. QUALITY ASSESSMENT OF THE FILTERED WATER

This is the part where samples of the water that was filtered and chlorinated are brought to the laboratory for testing if it will be safe for drinking. Those results will be a great answer for the design made.

The rainwater sample is from the residential rooftop. The house is situated at a rural area, in Sitio Cogon, Brgy. Larrazabal, Naval, Biliran. A roof with galvanized iron sheets, with nearby trees. The roof has lasted for 15 years and rust is already visible.

4.1. Sample Testing

These results will determine if our design could be susceptible for potable water, if the standard parameters for drinking water are met, our design of Rainwater Harvesting and Treatment could help a lot of families with financial problems and water troubles in the vicinity of Naval. And if further studies will be conducted, it is possible for neighboring municipalities of Biliran to be able to gain access for this design.

A total of 3 different types of samples, namely:

1. 1st sample – Plain rooftop rainwater
2. 2nd sample – sand filtered only rainwater
3. 3rd sample –charcoal filtered only rainwater
4. 4th sample – sand and charcoal filtered rainwater
5. 5th sample – sand and charcoal filtered and chlorinated rainwater

Since Naval has no available equipment to test the previously said parameters, we decided to travel to Eastern Visayas State University (EVSU) Tacloban City for the actual testing.

Equipment used in Testing

A. Multi – Parameter
- For Total Dissolved Solids (TDS)
- Salinity
- pH

B. Drying Oven
- Total Dissolved Solids

C. Analytical Balance
- Total Suspended Solids (TSS) Mass

D. Filtration Set – up
- For TSS determination

E. Multiple Tube Fermentation Technique and Pour Plate Method
- Total and Fecal Coliform Count

Drinking Water Parameters

According to Philippine Standards for Drinking Water 1993 under the Provision of Chapter II, Section 9 of PD 856, otherwise known as the Code on Sanitation of the Philippines the following parameters are what we considered for the drinking:

1. E coli count = 0 or <1.1 MPN/100 mL
2. Total Dissolved Solids (TDS) = 500 mg / L
3. Total Hardness = 300 (as CaCo3) mg / L
4. Salinity = 0 mg / L
5. pH = 6.5 to 8.5 mg / L

4.2. Test Results

Table 5 Test Results

Parameters and Standards	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total Coliform count MPN/100 mL	<4.4 (failed)			<4.4(failed)	<1.1(passed)
Fecal Coliform Count MPN/100 mL	<4.4 (failed)			<4.4(failed)	<1.1(passed)
Total Suspended Solids (TSS) (mg/L)	0.0 (passed)	0.0(passed)	0.0(passed)	0.0(passed)	
Hardness (mg/L)	15 (passed)	24.8(passed)	34.4(passed)	30.2(passed)	
Salinity (mg/L)	0.0 (passed)	0.1(failed)	0.1(failed)	0.1(failed)	
pH (mg/L)	6.68(passed)	6.85(passed)	6.95(passed)	6.89(passed)	
Total Dissolved Solids (TDS) (mg/L)	3.3 (passed)	17.4(passed)	30.1(passed)	33.3(passed)	

Based on the previous table and the standard parameters of the Philippine National Standards for Drinking Water, with regards to Total Coliform and fecal coliform count, our sand and charcoal filter failed, but based on the table, our design never added the coliform counts, this only means that our sterilization on the sand and charcoal filter succeeded. Moreover the chlorine addition passed the given parameters. The table also showed that apart from the parameter of the filtered rainwater's salinity all the other parameters passed for drinking water. It is also observed that the rainwater before it was filtered (aside from total and fecal coliform count) the numbers were increasing, this only means that the sand and charcoal filter only adds the numbers of the said parameters. And that the sand and charcoal filter (although passed the standard numbers for drinking water) failed to improve the drinking possibility of rooftop harvested rainwater.

4.3. Environmental Impact

Availability of adequate and clean water for household uses is an enormous problem for rural households in developing countries (Mwendera, 2006). Rain Water Harvesting has the potential of meeting the water needs of these rural communities (Pacey and Cullis, 1986).

One reason the provision of safe drinking water is of paramount concern is that 75% of all diseases in developing countries arise from polluted drinking water (Third World Academy of Science (TWAS), 2002). Each day, 25,000 people die from use of contaminated water and several more suffer from water borne illnesses (Mason, 1996). About half of the people that live in developing countries do not have access to safe drinking water and 73% have no sanitation, some of their wastes eventually contaminate their drinking water supply leading to a high level of suffering. More than five million people die annually from water-borne diseases. Of these, about four million deaths (400 deaths per hour) are of children below age of 5 years. The lack of safe drinking water also stunts the growth of 60 million children per year (WHO, 1996; WHO-UNICEF, 2000). Rainwater harvesting is an important water source in many areas with significant rainfall but lacking any kind of conventional, centralized supply system. It is also a good option in areas where good quality fresh surface water or groundwater is lacking. The application of appropriate rainwater harvesting technology is important for the utilization of rainwater as a water resource (Esguerra et. al., 2011)

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The Rooftop Rainwater Harvesting and Treatment Design is still on its early improvement stages, the design is still flawed, particularly in the sand and charcoal filter since it failed to improve the drinking possibility of rainwater. But the design is feasible since compared to other drinking water treatment devices, it is affordable and the materials are readily available in the local market of Naval, Biliran. And based on the data gathered, the water that was treated is drinkable since the results' numbers are included on the standard parameters given by the Philippine Standards for Drinking Water.

The design provided safe drinking water and since it has an overflow it will also provide water for other uses such as water for bathing, washing etc., the design may have failed at some points but the objectives were achieved, the treated rainwater is drinkable, the water that will overflow will serve its other purposes and the materials are available and affordable.

5.2 Recommendations

The design is feasible and economical, since we made it as affordable as possible, but there are certain parts of the harvester that has loopholes, recommendations for future reference are stated below.

1. The pvc used has a small diameter, meaning it can't carry as many rainwater as compared to a pvc with large diameter. The containers used are plastic coke containers, the large containers are very expensive and has a very huge area, but in a long term use large containers are recommended.
2. Regarding the overflow pipe, it should not be in line with the filter pipe. Since the pressure needed to make the water flow escapes to the overflow and fails to let the water through.
3. The sand and charcoal filters, sterilization succeeded but failed to improve the drinking quality of water, recommendations needed is that the filters should be finer or in smaller sizes as possible. This way the bacteria and other parameters would be improved as well as the drinking water quality.
4. For stagnation prevention the filters should be inclined.
5. Adding another treatment device is not advisable, since the design has succeeded in treating the water.
6. The use of glue in between pipes, elbows and valves should be minimized since it never entirely solves the leaking of the water, Teflon and sealants are recommended.
7. It is also recommended that no right angle turns should be observed since according to a recent study behind water flowing on right angle turns, the water chemical structure changes as it passes through a 90 degree curve. This may affect the health of any person who drinks the water.

8. It is also recommended that the design is also applicable without being attached on residential roofs, aside from the roof which was used as a representation.
9. It is recommended that any tree branches overhanging the roof are trimmed to minimize the amount of leaves and bird droppings falling onto the roof. Rodents should not be able to get onto the roof as they may introduce pathogenic bacteria to the water.
10. Leaves and other debris should be cleaned off roofs and out of gutters at least once a month. The more you do to keep a roof clean, the better the water quality will be.
11. In this type of study, the place and climate should also be considered if rainwater collection should be possible, since many places are prone to heavy pollution, and climate the is devoid of rain. This factors could affect the drinking possibility of water. But in this study the municipality of Naval is not yet a developed area, the pollution is not as thick as modern cities so rainwater has still its primary characteristics.

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