International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Water Shortage: Rainwater Harvesting System Design in Busay Barangay Hall, Cebu City

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Abstract— *Water scarcity is one of the most pressing issues facing sustainable development. With the increased demand, a new product of water resources such as rainwater is essential to ensure a minor future water crisis. Rainwater harvesting, also known as RWH, is the process of harvesting and stocking rainwater for latterly using rather than permitting it to runoff. RWH systems can address the problem of water scarcity while also reducing reliance on domestic water supply. Barangay Busay is one of the barangays that lacks water supply since it is an upland area. The purpose of this study is to design an RWH that will mitigate the water shortage problem in Busay Barangay Hall. The researchers used photo documentation and document analysis and interviewed the Barangay personnel to gather important data for this study. In addition, this study used design software (STAAD Pro vi.8) and drafting software applications.*

Results and findings showed a water shortage problem in Busay Barangay Hall, and their only source of non-potable water is through water truck delivery once a week. The only option to have another source of water to alleviate water shortage is through rainwater harvesting. 78 Barangay Hall employees use non-potable water for toilet flushing, water gardening, and dishwashing. However, in this study, the researcher only focuses on the Barangay Health Center Department, with a total of 13 people and a safety factor of 15%.

In designing the frame structure, the researchers used STAAD Pro v.i8 to come up with adequate and safe steel sections that sustain lateral loads and dead loads. The steel section for the column is HSSP6x0.5. The base of the water tank is L40x40x10, and the rest is L25x25x5. Furthermore, two-way water distribution using a pump with one horsepower and a gravitational system are used to control the flow of water supply in the Barangay Health Center's restroom.

Keywords— *Barangay Hall, RWHS, structural frame support, tax incentives, two-way water distribution system, water shortage.*

I. Introduction

Water has long been recognized as a necessary substance for all life, and people use it in various ways. It is also a component of the broader environment on which biodiversity depends. However, freshwater supplies are rapidly depleting. It might seem strange, but water is a scarce resource in most parts of the world despite its richness. With the increased demand, a new development of water resources such as rainwater for human consumption is essential to ensure a minor future water crisis [1].

Rainwater harvesting, also known as RWH, is the process of harvesting and stocking rainwater for latterly using rather than permitting it to runoff. RWH systems can address the problem of water scarcity while also reducing reliance on domestic water supply [2]. Rainwater is a pristine water source before it hits a building or the earth's surface, and rainwater exploitation is a practice as old as human culture [3].

In Gansu, a province of China, a rainwater harvesting demonstration project was accomplished with admiring results. Before 2000, the project produced more than 2 million water tanks, having a total capacity of more than 73 million m³, providing drinking water to nearly 2 million people and extra irrigation for more than 230,000 acres of land [4]. According to the findings, since 2001 there were 17 provinces have implemented rainwater harvesting (RWH) systems which ended up in the construction of more than 5.5 million tanks for supplemental irrigation and drinking water across China.

Germany is currently leading the way in pushing the widespread adoption of this technology for domestic usage. As a result of local government support (in the form of grants and subsidies) for residential RWH, about one-third of new buildings in Germany now have a rainwater collection system [5]. In addition, France established a regulatory framework to motivate the use of rainwater by way of the tax credit as well as Spain, which has also implemented a new building incentive and subsidy program [6], [7].

Compared to other countries, the Philippines' rainfall patterns are beneficial, allowing for seasonal or year-round use of this water resource virtually everywhere. The Philippines receives approximately 2,400 millimeters (mm) of precipitation per year, one of the highest in the world. But only six percent of this precipitation is harvested [8].

Most rainwater harvesting systems, specifically the rainwater tank, are placed on the above-ground rain barrel or below-ground concrete cisterns of huge size, depending in the water demand. The location will only be possible on areas with larger space. Meanwhile, the Barangay Hall of Busay Cebu City is situated at the lower slope/downslope and doesn't have enough space to put a rainwater tank. With this, the present study aims to add a calculation and analysis of frame structure as part of the proposed design of RWHS. The frame structure serves as a support for the elevated rainwater tank and is the best option to address the lack of space that hinders the potential of the RHW.

The never-ending problem of water shortage, lack of awareness of the possible solutions to mitigate this problem, and research gap on the design measure of RWHS sparked the researchers' interest in conducting this study. Lastly, the

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purpose of this study is to mitigate water shortage in Busay Barangay Hall by designing a Rainwater Harvesting System.

II. Instruments and Methods

2.1. Instruments

The researchers used photo documentation, document analysis, and interview with the Barangay personnel to gather data on the current situation in Barangay Busay regarding water supply, available resources, and intended use of non-potable water demand. Also, the researchers collected data from DOST-PAGASA for specific details/documents regarding the accumulated monthly rainfall for the past five years. Furthermore, in gathering the data about the roof plan, the researcher utilizes a tape measure, paper, and pencil since it is an as-built measurement.

2.2. Methods

The researchers gathered the preliminary data from reliable sources such as Microsoft Academic, Google Scholar, Research Gate, and government websites. The data collected was compared to produce accurate results, which served as the basis for deriving outcomes for the secondary data.

2.2.1. Site Inspection, Interview, Photo Documentation, and Document Analysis on the Current Water Supply Situation of the Barangay Hall serves as the primary data of this study. Moreover, secondary data examined in this part are the current water supply of the barangay hall and if there are available water supply resources such as springs, waterfalls, etc. This determines if only rainwater is the possible alternative water supply. Moreover, the researchers also conducted a site inspection for the location of the rainwater tank.

2.2.2. In getting the average toilet flush per person per day, the researchers gathered the following: The non-potable water demand profile of the barangay hall in terms of intended uses for the water, number of users, amount used liters per day and total volume of water consumed for a month. The moderate toilet flush is five per day and 1.6 gallons per flush [9]. In addition, the researcher will use a 15 % safety factor for the design population.

2.2.3. Acquiring the Building Plan and Monthly Rainfall for the past five years of the Study Area – After collecting the water demand profile, the researcher requested the accumulated monthly rainfall for the past five years from DOST-PAGASA. In addition, upon getting the roof plan of the barangay hall, the researcher conducted as-built measurements since there are no building plans gathered from any government agency like DEPW and DPWH.

2.2.4. Calculation and Design Layout – The acquired data was utilized in the design and calculation process. In calculating the capacity of the rainwater storage tank, the RWH Design Manual by the United Architects of the Philippines (UAP) served as a reference. This research used the average monthly rainfall for the past five years, surface runoff coefficient, and catchment area to get the monthly water harvesting potential. Then, the health care department's summation of water demand is multiplied by the number of days in a month. After calculating the rainwater storage tank, the researcher used STAAD PRO vi.8 for the calculation, and design capacity of the frame support structure's reaction and member stresses that will sustain the wind pressure, earthquake, and hydrostatic pressure.

III. Results, Design, and Discussion

TABLE 1. Available water sources within a 5km radius

Classification of Water Sources	Availability
1. Surface Water includes rivers, lakes, streams, ponds, seas, and oceans.	NO
2. Groundwater like springs, wells, infiltration galleries, or wells	NO
3. Rainwater	YES

Table 1 shows the different classifications of water sources based on the Rural Water Supply in the Philippines Volume 1 Design Manual Chapter 4 and their availability within a 5 km radius of Barangay Hall Busay. In the interview, the Barangay Treasurer said there were no available water resources near the Barangay Hall. The only option to have another water source to alleviate the water shortage is through rainwater harvesting.

TABLE 2. Intended uses of non-potable water

Intended Uses of Non-Potable Water in Busay Barangay Hall	1. Toilet Flushing
	2. Washing Dishes
	3. Water Gardening

Table 2 shows the most common usage of non-potable water. According to the Barangay Treasurer, the most typical intended uses of non-potable water are toilet flushing, washing dishes, and water gardening.

TABLE 3. Total number of barangay hall employees

Department	Number of Employees
Barangay Officials (Including the Secretary and Treasurer)	10
Barangay Tanod	20
Others (Staffs, Garbage Collector, Etc.)	35
Barangay Health Workers	13

Table 3 shows the different departments of the barangay hall and the number of employees in each department. According to the Barangay Treasurer, the total number of barangay hall employees is 78. This study only focused on the barangay health department since it is the only area considered in making the as-built roof plan. Hence, the researchers only considered 13 people in calculating the water demand.

Table 4 shows the monthly rainfall and the average monthly rainfall for the past five years. It revealed that it has the highest rainfall recorded in October, with an average of 240.63 mm. On the contrary, the lowest amount of rain collected is in March, with an average of 54.5 mm. Moreover, it is not the month with the highest or lowest rainfall data to consider in the design of water tank volume.

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TABLE 4. Monthly Rainfall Data for the Past 5 Years in millimeters (mm). (Recorded by Rainfall Observations made at Cebu PAG-ASA Complex Station)

Month	2017	2018	2019	2020	2021	AVE
January	289.8	239.5	134.1	50.6	209	**184.6**
February	40.9	142.6	44.3	206	156	**117.96**
March	90.9	69.4	14.9	7.1	90.2	**54.5**
April	224.9	74.9	23.1	0.3	52.6	**75.16**
May	78.7	98.9	14.2	36.6	120.6	**69.8**
June	202.8	115.8	87.8	103.5	231.4	**148.26**
July	190.1	148.1	225.3	280.4	130.3	**194.84**
August	204.4	44.2	76.7	401.9	139.1	**173.26**
September	358	195.7	100	155.3	124.1	**186.62**
October	176.94	223.6	304.7	298.9	199	**240.63**
November	122.4	78.8	60.3	79.7	146.2	**97.48**
December	130	184.7	222.6	262.5	218.5	**203.66**

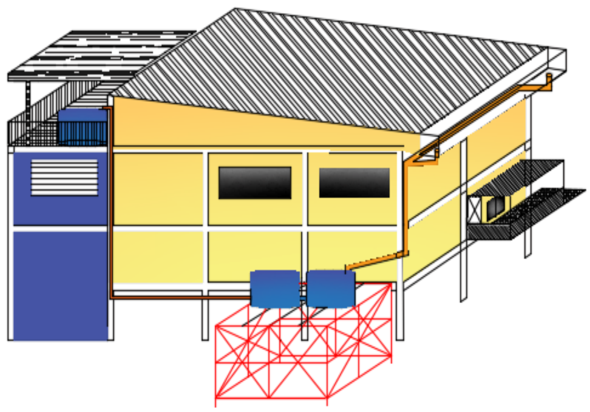

Fig. 1. Concept of the Proposed Rainwater Harvesting System Design

Figure 1 shows the rainwater harvesting system starts from the roof of the Barangay Hall, and it serves as the catchment area. However, roofs are generally exposed to a few contaminants, easily filtered and removed. The next step in the rainwater collecting process is to redirect rainfall from the roof into the conveyance system, which is the gutter. Afterward, from the gutter, the rain flows into the downspout. Currently, there is only one downspout in the Barangay Hall, but the researcher added one downspout in this design to avoid damage and easy flow of the rain. Adding one downspout is very important since the roof area is too large. Before entering the rainwater into the rainwater tank, the water flows through a robust pre-storage filter or first flush diverters. Its primary function is quickly filtering out the major contaminants that could flow from the roof, such as leaves, dirt, dust, etc. In addition, the proposed design of the rainwater harvesting system will not include a filtration system since the primary purpose of collecting rainwater is for flushing the toilet and other non-health use of water. Before entering the tank, the water is channeled into the water storage through a small screen after passing through the pre-storage filtration.

Figure 2 shows an isometric representation of a two-way water distribution system. This two-way distribution system used a pump with one horsepower and gravity distribution. The rainwater is stored in the main tank through the 4-inch PVC downspout; it is then pumped out or transferred to the other tank located above the target area to be supplied. The water is then distributed through a gravitational system from the secondary tank. If the secondary tank becomes empty, it will need to be refilled using the pump distribution method from the stored water in the main tank. Moreover, there is a globe valve installed that will regulate water flow. During the wet season, there are instances when it will rain consecutively, resulting in a filled main tank, and eventually, it will overflow to either the gutter or secondary tank. For this very reason, the proposed design of the rainwater harvesting system included an overflow pipe covered with a small screen to avoid contaminants.

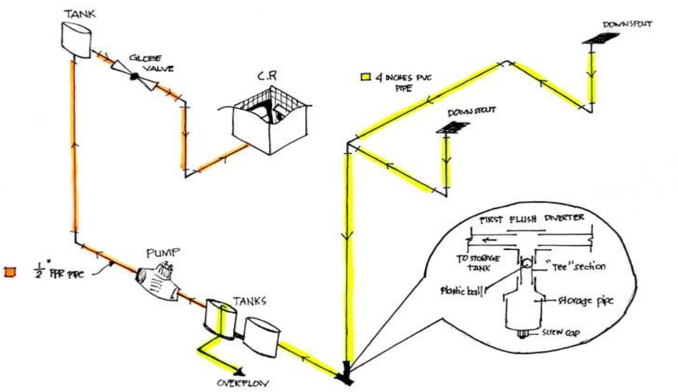

Fig. 2. Isometric View of Water Distribution Using Two-way System

IV. Conclusions, Recommendations

4.1. Conclusion

Findings proved a shortage of non-potable water in Barangay Hall of Busay Cebu City. Their source of water supply is through a mobile water truck that can supply up to 20 barrels or four cubic meters, good for one week. Within a five-kilometer radius from Busay Barangay Hall, there are no other non-potable water sources such as groundwater and surface water. The only option to have an alternative water source is through rainwater harvesting. 78 Barangay Hall employees use non-potable water for toilet flushing, water gardening, and dishwashing.

4.2. Recommendations

There is a need to have a promotion and education providing the cost-benefit scenario of rainwater harvesting comparing the social, economic, and environmental gains. Moreover, there is also a need to formulate government policies such as Tax incentives for energy conservation (water, electricity, etc.) in the individual household. Moreover, many existing RWH systems are entirely focused on the goal of water conservation, ignoring other potential benefits connected with RWH's multi-purpose nature, such as flood mitigation, enhancing from non-potable to potable used, and energy consumption. As a result, a better design of RWHS is required. For future researchers, build a sensor that will detect if the water level in the main tank is low or empty or not capable of refilling the secondary tank. With this, it can prevent the water pump from being damaged. Furthermore, to future researchers, it is recommended to continue this study by creating and designing of RC rainwater harvesting system.

ACKNOWLEDGMENT

The authors acknowledge the undying support from their family and friends. The authors would like to express their gratitude to the Busay Barangay Officials, especially to Hon. Maria Christia A. Famador willingly helped their full cooperation, which has made the research study achieve its smooth completion. Special thanks to the University of Cebu - Main Campus for supporting this research work financially.

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