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RESEARCH TITLE OPEN ACCESS

Design of Underground Rainwater Harvesting System for the Community in Sitio Centro of Barangay Nabuclod

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Abstract:

This study includes a thorough evaluation of the design of an underground rainwater harvesting system that is specially designed to the particular needs and environmental conditions of Sitio Centro in Barangay Nabuclod. This project, which draws on academic competencies in civil engineering, seeks to tackle water scarcity and enhance community sustainability. The design process prioritizes rainwater harvesting and storage tanks by conducting a thorough examination of the community's water needs, rainfall patterns, and geological features.

The proposed approach makes use of the underground storage tanks to increase land use efficiency while minimizing visual effect and vulnerability to outside factors. Furthermore, the system includes filtration and purification systems to ensure that gathered water fulfills quality criteria for a variety of home and agricultural applications.

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The project incorporates social and economic factors, with a focus on community participation, capacity-building initiative, and the use of cost-effective construction method.

Beyond the immediate benefits of increasing water resilience and self-sufficiency, the development of this underground rainwater harvesting system has far-reaching impacts. It acts as a model for sustainable water management strategies that can be applied to rural communities around the world facing similar water-related difficulties.

In conclusion, this abstract describes a comprehensive method to managing water scarcity and promoting environmental sustainability through the design and installation of an underground rainwater harvesting system in Sitio Centro. This project, which combines academic expertise, community interaction, and new design concepts, provides a possible answer to rural communities' critical water concerns.

Keywords — Rainwater Harvesting, Staad

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1. THE PROBLEM AND REVIEW OF RELATED LITERARURE

1.1 INTRODUCTION

Water is fundamental for sustaining life and facilitating the production of food. Every year, approximately two to three billion people face challenges due to water scarcity for at least one month. According to UNESCO (2023), projections indicate that the number of people in urban and rural areas experiencing water scarcity is expected to double from 930 million in 2016 to 1.7 - 2.4 billion people in 2050.

Water scarcity is a significant concern affecting diverse sections of the world-wide society (UN-Water, 2019). Whether a far-off rural village or a metropolitan district, the issue develops as the gap between the rate of water accessibility and demand continues to expand due to an increase in the populace, variations in climate, and bad practices in water administration among different factors that add to it. This research concerns factors surrounding the problem, with a focus on empirical reviews and policy analyses, with the ultimate goal to give reasonable routes through different case-study analyses of interventions towards realizing global water security and resilience.

In order to meet the demands of the locals for a sufficient and safe water system, various locations facing water crisis require assistance in improving the water supplies. Strategies like the use of ground water storage and rainwater harvesting are two of the most effective ways when combined with creative thinking, appropriate training, and long-term support is necessary to guarantee the system's proper implementation and upkeep. Rainwater harvesting systems range from simple rain barrels to more elaborate structures with pumps, tanks, and purification

systems (Ogale 2014). Rainwater harvesting is the simple process or technology used to conserve rainwater by collecting, storing, conveying and purifying rainwater that runs off from rooftops, parks, roads, open grounds, etc. for later use (Malikin 2022).

The non-potable water can be utilized for irrigating landscapes, flushing toilets, washing vehicles, or cleaning clothes, and it can also undergo purification for human consumption according to Ogale,(2014) With water scarcity a pressing problem for many densely populated regions, rainwater harvesting systems can supply households and businesses with water for use in dry seasons and lessen the demand on municipal systems.

The rainwater harvesting system offers numerous advantages, including cost-effectiveness, reduced water bills, diminished water demand, simple technology, erosion control, and mitigation of various pollutants like fertilizers, pesticides, and metals from surface water. It also provides clean water for landscaping without chemical or mineral contaminants. However, drawbacks such as unpredictable rainfall, lack of suitable storage infrastructure, maintenance needs, and necessary technical expertise for installation exist. Additionally, reliance on rainfall availability and storage capacity limitations are significant concerns according to BYJU'S Biology.

Sitio Centro, one of the rural areas in a mountainous region, faces water scarcity issues. The community has a total of 352 people and 71 households in the year of 2023, each having approximately 5 dependents. Furthermore, it is imperative to acknowledge that the entirety of the population residing in Sitio Centro comprises indigenous individuals. According to Officials of Sitio Centro said that they rely heavily on their water source from spring water and rivers at the base of the mountain. The project therefore seeks to provide sustainable water which will access non-potable water for domestic use, such as flushing toilets, bathing and washing clothes. Based on the census of Sitio Centro.

The study will provide a primary water source for individuals without a connection to the Prime Water Floridablanca service by utilizing rainwater gathering. This method effectively addresses household water usage needs by ensuring efficient water use in residences. It aims to optimize water consumption for domestic purposes.

1.2 REVIEW OF RELATED LITERATURE AND STUDIES

1.2.1 Bangladesh *(Sustainabillity of Rainwater Harvesting System in terms of Water Quality)*

Rainwater harvesting represents a time-honored and eco-friendly approach that can be readily employed for both drinking and non-drinking purposes in homes and businesses. Its implementation can alleviate the strain on treated water resources, fostering a more environmentally conscious lifestyle. This research paper ensures the reliability of this system by evaluating various water-quality factors of harvested rainwater against established acceptable thresholds. The analysis covers several parameters, including pH levels, fecal coliform, total coliform, total dissolved solids, turbidity, NH3–N, lead, BOD5, and others. The findings demonstrate that the overall water quality meets the standards set

in Bangladesh, indicating a satisfactory level. Furthermore, the rainwater harvesting system not only provides an ample supply but also facilitates energy conservation by reducing consumption. [1]

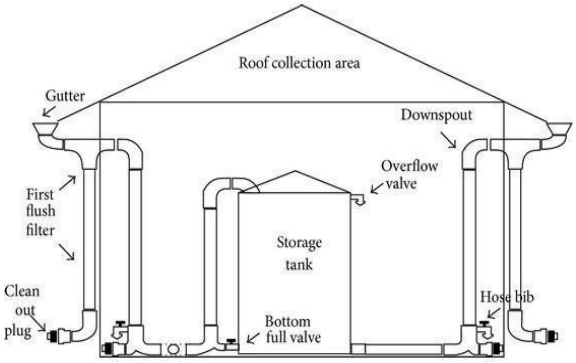


Figure 1.1 Schematic of a rainwater harvesting system by Sadia Rahman et al. (2014)

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

Water scarcity is a pressing challenge for sustainable development, prompting the need for alternative sources. Rainwater harvesting (RWH) is identified as a crucial solution to address this issue and reduce dependence on traditional water sources. In the upland Barangay Busay, lacking a consistent water supply, researchers propose designing an RWH system for the Busay Barangay Hall. Using photo documentation, document analysis, and interviews, the study highlights a water shortage issue, with the only non-potable water source being weekly truck deliveries. The proposed RWH system, designed using software like STAAD Pro vi.8, includes a steel frame structure and a water tank with specific dimensions. A pump and gravitational system ensure effective two-way water distribution, addressing the water supply needs of the Barangay Health Center's restroom.[4]

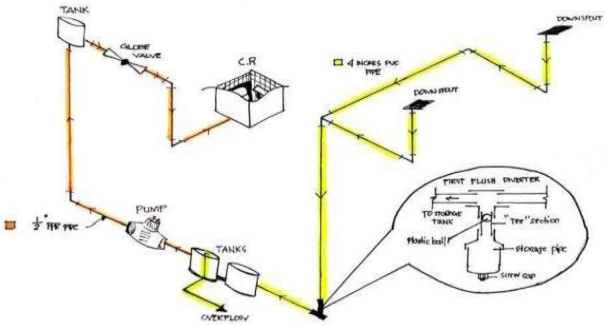


Figure 1.2 A Isometric View of Water Distribution Using Two-way System

1.3 BACKGROUND OF THE STUDY

Electricity access is essential for economic development, education, healthcare and quality of life. However, many remote and marginalized communities in the Philippines, like Sitio Madalumdun in San Pedro, Sasmuan, Pampanga still lack reliable electricity. The lack of electricity limits their modern economic activities.

The National Electrification Administration (NEA) has estimated that as of 2020, 2.3 million Filipino households, many situated in remote areas do not have access to power. Sitio Madalumdum is one of these areas and has 13 households. The area's coastline location and reliance on boat as their transportation may make it more difficult to provide electricity from the power grid [23].

By implementing a sustainable hydropower generator in Sitio Madalumdum, the community can achieve a reliable and environmentally friendly source of electricity. This has the potential to greatly raise people' standard of living, expand their economic options, and support the region's general sustainable growth.

1.4 STATEMENT OF THE PROBLEM

There is a water shortage in the community of Sitio Centro, forcing the people to hike for 30 to 45 minutes down the mountain to find water for their daily use. Based on the Barangay Official of Sitio Centro, their main source of water is spring water on river beds, which is soiled, contaminated, and that can cause diseases. Furthermore, the former spring water supply they once utilized ceased flowing five years ago. According to Barangay officials, the lack of water has resulted in the loss of many man hours that could have been used for economic activities such as farming and coal production, which are their primary sources of income. As stated by Prime Water, Floridablanca supplies 3,000 liters of water per month to Sitio Centro, which has unfortunately stopped due to financial constraints.
By providing sustainable water in this community, time will be saved for the locals to engage in other activities.

1.5 STUDY AREA

The environment of Floridablanca, a town in Pampanga, is primarily made up of grassyhills and mountains. The breathtaking Nabuclod Mountain Views provide an amazing view from Barangay Nabuclod as one of its biggest attractions. Floridablanca is a coastal district that covers 187.35 square kilometers, or 72.34 square miles, or 6.48% of the total area of Pampanga province. There are thirty-six (36) barangays in this municipality. As of the 2020 Census, Floridablanca has 135,542 residents, which accounts for 5.56% of Pampanga's total population.

1.6 OBJECTIVES OF THE STUDY

1.6.1 General Objective

The study aims to design a sustainable water supply system on Sitio Centro of Barangay Nabuclod, Floridablanca, Pampanga with emphasis on the design of Rainwater Harvesting Using Underground water Storage tank and roof downspout as a catchment type.

1.6.2 Specific objectives

- To analyze and appraise the requirements of residents in light of the proposed design for rainwater harvesting supply, leveraging existing data from provincial agencies.
- To create the system in compliance with NSCP 2015 standards.
- To provide a cost analysis of the materials used regarding the Rainwater harvesting design based on price and availability in the present market.

1.7 SIGNIFICANCE OF THE STUDY

The aim of this study is to help residents in the Sitio Centro of Barangay Nabuclod who currently have limited access to water by providing them with an alternative water source

through the installation of a rainwater harvesting system. The aim of this study will benefit the following groups:

Community

The study's emphasis on designing underground rainwater harvesting systems for Sitio Centro results in tangible benefits that went beyond immediate water supply improvements. It has the capacity to improve the community's quality of life, promote sustainable development, and strengthen social cohesion, all of which contribute to the citizens' long-term well-being and resilience.

Environment

This research also promotes water conservation and resilience in the face of droughts or disruptions to the primary water supply. Furthermore, the study helps to promote sustainable development by offering a practical solution that improves the community's quality of life while minimizing environmental effects. Rainwater harvesting aids in the management of stormwater runoff, thereby avoiding erosion, flooding, and poor spring water quality.

Future Researchers

This study offers a solid foundation and reference point for future research and development in water management systems. It provides insight into the feasibility, effectiveness, and potential challenges of establishing rainwater harvesting systems in comparable scenarios, which will guide future research endeavors.

1.8 SCOPE AND LIMITATIONS

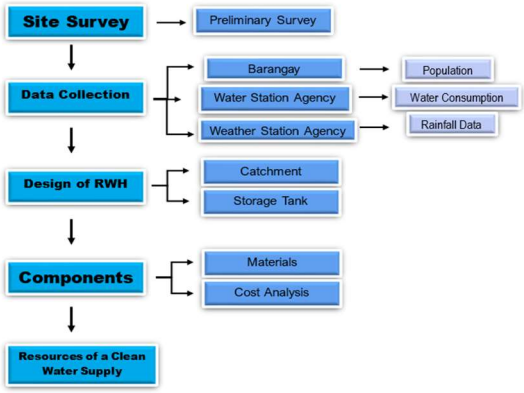
SCOPE

The researchers specifically focus on the design of underground storage tank using STAAD pro V8i SS6 and design of water catchment through roof downspouts to efficiently collect the rainwater. To ensure the delivery of clean water, the collected rainwater will undergo filtration before being stored in the designated water tank.The study will use the recommended basic water requirement of 54L/person/day according to B.S. Oplas Jr. (2015) as a guide, excluding drinking water, for which the standard allocation of 23L/person/day will be utilized for analysis. The final output of the filtered water will be accessible at a single station within the Sitio Centro.

LIMITATIONS

The study will be restricted to the water distribution within every household. Survey questions will also be excluded because all of the necessary data has already been provided by the Barangay of Sitio Centro, Nabuclod, Floridablanca, Pampanga as well as every associated agency. The study will not employ a pH meter since the objective is to concentrate only on filtering techniques to counteract acid rain, avoiding broader pH measurement features. The PAGASA states that the precipitation data they gathered was the only station that exists closest to the study's location. The researchers did not take into consideration the soil analysis tests since the results require expertise for good understanding, and soil qualities change seasonally, affecting analysis accuracy.

1.9 CONCEPTUAL FRAMEWORK



Definition of Terms

Catchment- used to collect and store the captured rainwater.

Downspout -a permeable apparatus designed to extract contaminants or particulate matter from a fluid or gas as it flows through

Filter – A permeable apparatus designed to extract contaminants or particulate matter from a fluid or gas as it flows through.

pH Meter - electric device used to measure hydrogen-ion activity (acidity or alkalinity) in solution.

Rainwater Harvesting (RWH) - is the collection and storage of rain, rather than allowing it to run off. Rainwater is collected from a roof-like surface and redirected to a tank, cistern, deep pit (well, shaft, or borehole), aquifer, or a reservoir with percolation, so that it seeps down and restores the ground water.

Scarcity -is the state of being scarce or in short supply; it is also referred to as a shortage.

Sustainable- is a way that meets current, ecological, social, and economic needs without compromising the ability to meet those needs in the future

Underground - relating to, or being something located beneath a surface and especially underground.

2. METHOLOLOGY

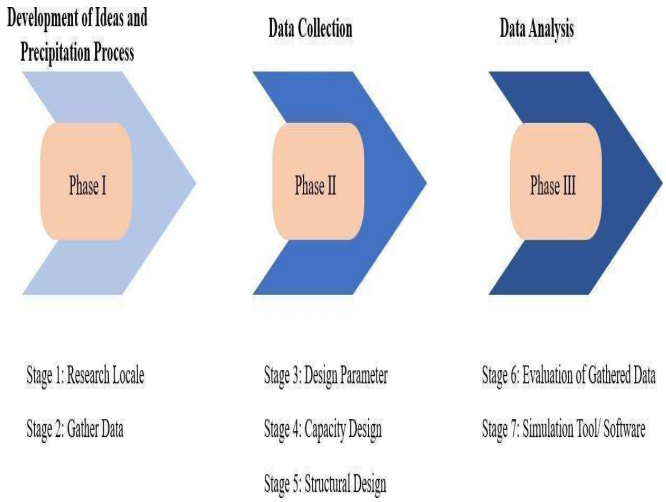
2.1 RESEARCH DESIGN

A framework of the research process is provided in this section to help researchers achieve their primary study goals. The study's procedural components and data collection methods are described in length by the researchers. The components of the rainwater harvesting system include a storage tank, filters, and a catchment. The key components of the suggested
water supply system is outlined below.

2.2 RESEARCH LOCALE

The researchers considered the geography of the study location while selecting where to locate the rainwater harvesting system. The researchers chose to design it for the open space behind the barangay hall due to its size constraints. Furthermore, the proposed system would be located in the center of Sitio Centro, at the highest point, to ensure easy access.

The Shuttle Radar Topography Mission (SRTM) is a cooperative international initiative led by the National Geospatial-Intelligence Agency and NASA. Its purpose is to construct the most comprehensive high-resolution digital map of Earth's topography, spanning 25 areas. As a result, all of the data used in Google Earth comes from NASA's satellites.



2.4 PHASE 1: Development of Ideas and Precipitation Process

Stage 1: Gathered data and information from the literature review

- The researchers gathered data and review related studies and related literature. This includes:
    1. Data Requested from Local Government Units (LGUs) and Private Companies
    2. Data Obtained based on Actual Observation of the Location
    3. Data Gathered from Review of Related Literature

2.5 PHASE 2: Data Collection

Using cement to smooth the interior allows for more efficient flow of water, and its resistance to rust and decay makes it perfect for a long-lasting pipeline system. By carefully selecting these materials, the researchers not only ensure the performance of their rainwater harvesting infrastructure, but also promote a long-lasting solution with little environmental impact. The researchers carefully selected materials for their rainwater harvesting tanks to ensure durability and structural integrity. The use of steel bars of 25mm x 6 meters, 16mm x 6 meters, and 10mm x 6 meters provides reinforcement, increasing the tanks' ability to endure diverse environmental conditions. The concrete slab further contributes to the tanks' stability, forming a solid foundation that can endure the weight and demands of a rainwater storage tank. Portland Cement serves as the bonding agent, binding the components together, and waterproofing materials are applied to protect the tanks from the potential degradation caused by moisture, ensuring a long-lasting and resilient solution to capture and store rainwater. The pipeline component, the researchers opted for a PVC pipeline with a 1000 series. PVC, recognized for its durability and corrosion resistance, is an excellent choice for conveying.

Below are some key calculations and formulas that may be relevant:
V = L x W x H
W - width
H - height
L - length

Case 1: When the tank is full and the surrounding soil is waterlogged:
$P = \gamma w\ H - C\ \gamma soil\ H$
Case 2: When the tank is empty and the surrounding soil is dry:
$P = C\gamma\ H + \gamma w\ H$

Where:
P = Pressure (kPa)
Ɣw = Gamma Water (9.81kN)
H = Height (m) = 3.6m
C = Cohesion (unit less) ; $C = 1 - \sin\theta\ 1 + \sin\theta$
Ɣs= Gamma Soil (kN/m^3)= 17 kN/m3
θ = 30º

A. Catchment Area

The researcher designed the catchment area using Sketchup app software. Since the proposed location was in a hilly area, the catchment area's proposed design has varying heights. The catchment zone covers an area of 1,500 square meters. Below is an illustration of the facade view of the suggested catchment area, where each segment is designed with varying elevations to suit the topography of the site.

B. Filtration System

Rainwater collected from the roof is usually combined with a variety of objects, including leaves, bird droppings, dust, and so on. Such contaminants must be eliminated before the water can be stored. Vortex Fine Filter will separate these substances and ensure that the water system can provide clean water to residents. The stainless steel mesh filter insert, with a fine mesh size of only 0.28 mm, effectively strains rainwater that flows in from the side before entering the tank. This procedure guarantees that leaves, moss, and other tiny particles carried by the water are efficiently cleaned and routed away through the filter cloth, eliminating clogging and assuring its durability. The filter insert's sturdy structure, which is entirely constructed of high-quality stainless steel, ensures its long-term effectiveness.

Calculating the geometric dimensions of a hydro powered generator within the context waterwheel concept involves assessing various factors such as the size of the waterwheel, the flow rate of water, the head (height) of water available, and the desired power output.

C. Water Storage Tank

An underground water tank is a reservoir for residential or commercial buildings that are made up of a base slab, sidewalls, and a roof slab. This type of tank is commonly used for rainwater harvesting because it requires little maintenance and reduces evaporation inside the water tank.

The water storage tank was designed and analyzed using STAAD Pro V8i SS6. The total volume of the storage tank, as per the researchers' calculated water demand is 860 cubic meters . The proposed tank will be 24.6m (length) x 3.6m (height) x 12.55m (width) in size, with fixed supports in the 12.3m midspan. In calculating the hydrostatic pressure around the tank, two cases were used.

4. SUMMARY, CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

The study's conclusions and outcomes were obtained from its stated objectives.

The best outcomes for this study were obtained using collected data as the primary source of information, improvements, and calculations. The researchers concluded the following Conclusions Based on the Findings:

The researchers calculated that by the year 2032, the projected population would reach 378, with an estimated daily water demand of 8.69 m3, equivalent to 23L/day per person. The researchers determined the average precipitation between 2012 and 2022 and used this to calculate the projected volume of rainwater collection, resulting in 269.51 m3/month for a catchment area of 1500 m3. This suggests that the rainwater catchment area could potentially collect more rainfall than needed to supply the Sitio for those months that have a low percentage of rainfall. The calculated volume is sufficient to meet the demands of the Sitio Centro community for 7months and 24 days. Additionally, the designed storage tank has a

capacity exceeding the required volume of water.

After thoroughly analyzing the designed tank for the study, the researchers detected no errors, warnings, or notes. Following a thorough analysis, the researchers determined that the tank is both appropriate for its intended application and safe to use. These findings provide reassurance concerning the tank's reliability, ensuring its usefulness in achieving the study's objectives while posing no risks or concerns.

4.2 RECOMMENDATION

Due to their remote geographical position and economic disadvantage, they face restricted access to data, while conversely, other associated agencies also lack precise information regarding Sitio Centro.The precision of the computations relies entirely on the quality of the gathered data, the equations employed, and the methodologies applied. In order to attain more dependable outcomes, a careful analysis and accurate parameters have been employed.

The researchers' recommended to consider the following:

- For water demand, conduct supplementary information, such as survey questionnaires and interviews, to gain a comprehensive insight into the water demand of residents, instead of relying only on data furnished by agencies.
- For precipitation, it is highly recommended to collaborate with other agencies involved in PAGASA to ensure that the data and procedures used are precise information about rain data. It is recommended to use the nearest rain gauge station data to make the data more accurate.
- For water storage tank, it is recommended that soil analysis will be performed in designing the water storage tank. Using software or applications like STAAD pro V8iSS6 and ASDIP, are structural engineering software to improve the accuracy of the design.
- For used methods, researchers recommended to utilize surface runoff methods in their future studies, taking into account the characteristics of the study area. It's also important to analyze surface runoff thoroughly for a better understanding of the topic.

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