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Proposed Rainwater Harvesting System with Filtration: An Alternative Source of Potable Water

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Abstract --- *Rainwater is considered as the cleanest source of water in the world, however, its utilization in the Philippines was only limited to non-potable purposes. Previous studies claimed that rainwater can be a viable source of potable water if treated accordingly and can serve as an aid to the centralized water distributor in the community, thus, with the impending problems concerning water scarcity, there is a need to develop rainwater harvesting system that can produce potable water. This study was conducted to propose a design of rainwater harvesting system filtration for an alternative potable water source and to assess the physicochemical properties of the harvested rainwater before and after filtration. This study utilized a descriptive-developmental research design using researchers-made questionnaire subjected to validation by six (6) experts as a measurement for the evaluation of the acceptability level of the design with civil engineers and mechanical engineers as expert participants. Also, a physicochemical analysis was conducted based on the Philippine National Standards for Drinking Water 2017, Annex B-1 Mandatory Drinking-Water Quality Parameters. The result showed that the filtered rainwater complied with the required standards stipulated in the Philippine National Standards for Drinking Water (PNSDW 2017). This implies that rainwater is a viable source of drinking-quality water using a system with the purpose of capturing, storing, and treating rainwater. Also, the expert participants evaluated the proposed design as acceptable in terms of its functionality, durability, and usability. Hence, it is recommended that the proposed design may be considered for utilization as an alternative source for potable water.*

Keywords --- *rainwater harvesting system, filtration, drinking water, water quality, physicochemical analysis, total dissolved solids, pH level*

I. INTRODUCTION

1.1 Background

Water is one of the basic needs for human health. Getting enough water can prevent dehydration which leads to constipation, kidney stones, and cholera [1]. However, in the Philippines, there are more than 3 million people who still use water that is not safe for human consumption [2]. This can be observed every after an onslaught of a typhoon. As reported, one of the challenges faced by the victims of Typhon Haiyan is the lack of access to clean drinking water. People, due to scarcity, end up spending money which puts a strain on a family who is then unable to afford much food [3]. And for the Philippines, rain can also be a curse that fuels the water crisis. Reports say that it is not during summer that Filipinos fully experience the water crisis in the country. But it is when the rain pours that people experience it the most [4].

Rainwater harvesting (RWH) is a method of collecting and storing rainwater that can be used for indoor and outdoor domestic use such as toilet flushing and laundry. It is a scientific and ancient alternative source of fresh water that has several economic, environmental, and social sustainability benefits [5]. Rainwater harvesting is also an efficient storm-water control system for flood-prone regions as it lessens the amount of run-off [6]. Furthermore, it is an important method of addressing the shortage of regional and global water resources [7] [8].

Rainwater harvesting (RWH) is considered in the Netherlands as a significant measure to increase the production of drinking water [9]. However, the application of rainwater has been limited to non-potable applications such as toilet flushing and irrigation [10]. Nonetheless, it was reported that a potable water of 39% to 43% was achievable by using rainwater harvesting (RWH) in Brazil [11]. Some urban areas in Australia also often use rainwater harvesting systems to aid the country's centralized water supply system in distributing potable water [12].

In the Philippines, RWH was utilized as an alternative supply of water for different areas of agriculture. These include irrigation, livestock, and poultry, which emphasize their feasibility and viability for the community and the economy. The investments in establishing rainwater harvesting projects provided relief to areas that suffer from water scarcity, such as Baranggay Sapilang, Bacnotan, La Union. [13] In addition, with the frequent occurrence of

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cyclonic events in the country, the utilization of RWH can help mitigate flooding in the highly urbanized region of Metro Manila. This was based on the data gathered from five (5) rainfall stations located in Metro Manila, specifically: The Science Garden, Port Area, Polo, Nangka, and Napindan. [14]

Abundant rainfalls experienced by tropical countries like the Philippines is considered as a water resource that must be utilized for the development of water distribution, and the use of RWH is an aid that addresses the unbalanced rainfall distribution by collecting and storing rainfall and surface runoff. [15] Based on the data shown by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), an average of approximately 2,348 millimeters of rainfall has been recorded annually from 1901 to 2021. However, this varies geographically from 960 millimeters in southeast Mindanao to over 4,050 millimeters in central Luzon [16]. As shown in the retrieved data of PAG-ASA's Climatological Normal from 1991-2020, Surigao City experienced 192 rainy days and a record of 3,757.3 millimeters amount of rainfall annually [17]. Moreover, the greatest amount of rainfall per day is recorded to be 320.9 millimeters, as of 2021 [18]. Based on the reports, rainwater harvesting system could be a suitable solution to lessen the water crisis in Surigao City since it is constantly raining.

In light of the foregoing concepts, the researchers conducted a study on the proposed design of rainwater harvesting system (RWH) with filtration as an alternative supply of potable water. In this study, the researchers documented the technical specifications of the design, evaluated its acceptability level in terms of its functionality, durability and usability, and conducted a physical-chemical tests based on the parameters specified in the Philippine National Standards for Drinking Water 2017, particularly, in Annex B Table B-1 for Mandatory Drinking-Water Quality Parameters.

1.2 Statement of the Problem

This study aimed to answer the following questions:

1.What are the components of the water filter?
2.What are the technical specifications of the proposed design?
3.What is the physicochemical parameter of the rainwater before and after the filtration?
4.What is the acceptability level of the design of the rainwater harvesting system in terms of functionality, durability, and usability?
5.Is there a significant difference of the acceptability level of the proposed design as perceived by the experts in terms of their length of service/experience?

1.3 Literature Review

This study was anchored on the study entitled "Rainwater Harvesting as a Drinking Water Option for Mexico City" by Gispert et al [19] to construct a better and more economical rainwater harvesting system. Water is essential for human survival. Since the pre-historic era, the primary criteria for choosing an area of settlement are the availability of water source. The natural protection and soil quality are considered as secondary. However, as small area of settlements developed into cities, the sources of fresh water within the boundaries became insufficient for the needs of the rapidly growing population [20].

Rainwater is considered as the cleanest water sources in the world. Its quality exceeds the surface water and is comparable to the quality of a ground water. Rainwater is also safe for non-potable utilization because it does not come in contact with salts and minerals that can be harmful for humans. Factors such as geographical location, activity in the area and quality of storage tanks usually affects the quality of rainwater however, with minimal treatment, it can be used as a potable water and for other domestic use [21]. With the frequent occurrence of typhoons in the Philippines, a significant amount of rainwater that fuels the water crisis has been recorded. Utilizing the rainwater as a supplementary source could minimize the water demand being drawn out from main sources as well as the surface runoff that causes floods [14].

Rainwater, as a natural source of freshwater, is abundant in the Philippines. An average annual rainfall of 2,400 mm that varies over time has been recorded and become excessive during rainy season, resulting to flooding. Despite the abundance, utilization of rainwater in the country is not optimized [22]. As we enter the 21st century, the water crisis that the world is experiencing is getting worst and is putting strain to the environmental sustainability of all nations, especially the Third World Countries like the Philippines [23].

As indicated in the Senate Bill No. 36, Section 1 introduced by Senator Francis Pangilinan, in order to reduce flooding, the people must put an effort in minimizing the increase in rainwater runoff. By meeting the purpose of the Act, the increase in nonpoint source pollutions caused by rainwater runoff will also be minimize. Section 3 also states that "all landowners or developers of proposed commercial, industrial, and residential or any residential multi-dwelling units of more than 1,000 square meter land area must submit a Rainwater Management Plan (RMP) as part of the site development application and approval process" [24].

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Rainwater Harvesting

For countries with abundant rainfall like the Philippines, rainwater is considered as a water resource development. However, due to its seasonal occurrence, it is not fully used [15]. With the increase in the amount of run off and demand of potable water caused by rapid urbanization, flooding and scarcity of potable water supply has become a problem for the country [14]. One particular approach to address the unbalanced rainfall distribution is the utilization of Rainwater Harvesting (RWH) System which involves collecting and storing direct rainfall and surface runoff for future use [25].

Rainwater Harvesting involves collecting and storing captured rainwater as a principal or supplementary water source. It is possible to use it for potable and non-potable applications [26]. Examples of its utilization exists in the industrial and agricultural fields. Its concept varies from small to basic, depending on its intended purpose. It is also used to reduce pressure on centralized water supply and distribution systems [27]. Rainwater harvesting is an ancient practice developed back in 2000 BC in India, China, and Mesopotamia. Many cultures have used this technology for agricultural purposes [28]. The Philippines have been using rainwater for rice terraces for thousands of years [29] and in ancient Rome, designs of houses include rooftops to catch rain and store it for general household use [30].

In some countries, rainwater harvesting provides solutions that help reduce the ecological footprint caused by urbanization and industrialization. With the increasing number of populations, this is beneficial to a developing country like the Philippines. In fact, this approach was already used in the islands of Malangabang, Ilo-ilo to address the threat of climate change to the source of water used by locals for domestic use. A present study discusses the avenues that rainwater harvesting system may provide to areas such as the Island of Malangabang, where water is scarce [30].

One of the advantages of rainwater harvesting systems is its cost efficiency. It is a low-cost technique that only require expertise in specified areas. However, it is important to note that rainwater is not always sustainable given the fluctuating weather conditions. For arid and semi-arid places, rainwater harvesting system is used as an alternative water source when other sources are scarce but is not deemed to be reliable. Nonetheless, it is still a valuable supplement during drought and monsoon climate [31].

Moreover, in consideration to the situation of the people often affected by water scarcity, rainwater harvesting is an efficient and economical solution that lifts the burden caused by the crisis. It also promotes green industrialization as it reduces the demands of processed water supply especially in countries, such as Dhaka, Bangladesh, that relies on groundwater and surface water as their main source of water. And due to the increase of population, there is also an increase of pollution in the surface water. This limits its applicability, regardless of the treatment process, and puts a strain in the existing water crisis. Thus, the aforementioned study implies the importance of rainwater harvesting systems to countries like Dhaka, Bangladesh [32].

Rainwater Harvesting System with Filtration

EXISTING DESIGN

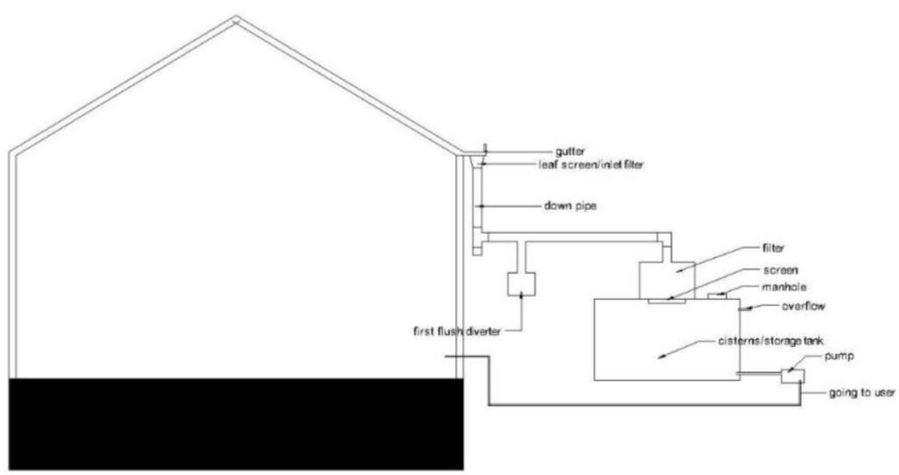

Figure 1. Rainwater Harvesting System with Filtration

Rainwater Harvesting System is a simple system that collects rainwater and storing it in a tank. As observed in some practices in the past, people collect rainwater using barrels or pale for household use. However, to ensure its supplementary purpose, a rainwater harvesting system must be designed, and constructed properly. The most

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commonly use design of rainwater harvesting system is the Rooftop rainwater harvesting system. Figure 1 shows the basic components of rooftop rainwater harvesting system that is typically used [33].

- Catchment Surface (Roof) – This is an important component of the system. The quality and quantity of rainwater that can be captured from a catchment surface depends on its size, texture, and material. The recommended roof material is an unpainted corrugated galvanized iron sheets because it does not corrode easily and it does not contain coloring chemicals that is very harmful to human health. Also, corrugated galvanized iron has a runoff index of 85%, which means that less water is loss during runoff [34].
- Gutters and downpipes – These are horizontal and vertical rain water channel where water from the roof flows, going down to the tank [34]. Gutters should be supported to prevent sagging and falling off when loaded with water. The way it is fixed is dependent on the construction of the house. Commonly used materials are iron or timber brackets that are fixed into the walls [35].
- Screens - The type of screen that can be used is determined by the debris that accumulates in the catchment surface and the intended purpose of the harvested water [36].
- First-flush diverters– First flush ensures the flushing out of the first harvested rain that carries pollutants from the air and catchment surface [37].
- Filters – This component is used to eliminate suspended pollutants form the collected rainwater. It is composed of filtering media such as fiber, coarse sand and gravel layers, depending on the intended purpose of the harvested purpose [35].
- Cisterns – Cisterns, also known as the storage tanks, stores the harvested rainwater. It can be constructed using fiberglass, polypropylene, concrete, or metal. However, it is said that to ensure optimum quality, storage tanks should be made of non-reactive materials such as glass [36].
- Delivery System – This system includes pumps and pipes connected to the faucets. Pumps are used to achieve the desired water pressure and will require a one-way check valve to prevent backflow and loss of pressure [36].

Rainwater Harvesting System as an Alternative Supply of Potable Water

One of the affected infrastructures during the onslaught of Super Typhoon Odette is the water supply. It caused damage in the pipeline conveying water from dam to a water treatment facility that supplies potable water. In Butuan City, the Butuan City Water District (BCWD) operated through three pump stations to augment the water supply throughout its service area [38]. The local government of Surigao del Norte was then in urgent need of assistance to aid the scarcity of clean water. This problem was also experienced by locals living in Dinagat Islands, Siargao Island, and other areas in the Caraga region affected by Super Typhoon Odette [39].

While proven to be an efficient supplementary to the water crisis being experienced globally, rainwater is still not deemed for human ingestion. There are threats to human health that may be different depending on the location, rain frequencies and the process of collection [40]. Contamination of the harvested rainwater with disease causing microorganisms, such as bacteria, viruses, and protozoa, poses a biggest risk to human health. In addition, the leaching from roof materials, like lead, and copper, may also occur when harvesting. Nonetheless, if proper attention is given and with the suitable water treatment, utilization of harvested rainwater may be maximized and be of used to aid the scarcity of freshwater sources [41].

In a present study covering Metro Manila (NCR), Philippines, a filtered harvested rainwater was tested and evaluated in terms of the following parameters: pH level, Chloride, Phosphate, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Nitrate (NO3-N), and Fecal Coliform of the water samples. These parameters were selected in accordance to the DENR Water Quality Standards, requirements of the testing laboratory, availability of water parameters and the cost. According to the results, it was found that the Filtered Rainwater complies with the Class A standards for all water quality parameters [42]. This contradicts to the aforementioned claims stressing that the utilization of rainwater was limited to non-potable uses and is labeled as unsuitable for human ingestion.

Drinking Water Standards

Together with the importance of safe and readily available source of water for domestic use and recreational purposes, the accessibility to clean drinking water holds great importance for public health. [43] The World Health Organization put emphases to this in their longest-standing normative publications, the Guidelines for Drinking-water Quality, that assists the water and health regulators, and policy makers in the development of national standards for drinking water. [44] With this, an Administrative Order subjected to the prescription of the standards and procedure on drinking-water quality was issued based on the 1958 World Health Organization Standard for Drinking Water and

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the 1962 United States Public Health Service Standards and called as the Philippine National Standards for Drinking Water 2017 [45]. The PSNDW of 2017 applies to all drinking water-service providers and those who are involved in determining the safety of public's drinking-water. [45] Based on the PSNDW of 2017 Annex B-1, the Mandatory Drinking-Water Quality Parameters are presented in Table 1.

Table 1. Annex B-1, the Mandatory Drinking-Water Quality Parameters

No.	Parameter
1	Arsenic (As)
2	Cadmium (Cd)
3	Lead (Pb)
4	Nitrate (NO_3)
5	Color (Apparent)
6	Turbidity
7	pH
8	Total Dissolved Solids
9	Disinfectant Residual

II. METHODS AND MATERIALS

This study used the descriptive-developmental research design and was conducted at was conducted at Surigao City, Surigao del Norte, Philippines. Accordingly, descriptive research design is a method that examines the current state of the topic and systematically describe that relationship of each event experienced and developmental research design refers to the prototyping process that is used in presenting an overview of ideas, design experimentations and determine problems in the process [46]. Hence, it is deemed appropriate to use this research design since this study aimed to develop rainwater harvesting system design, conduct physicochemical tests to assess the harvested and filtered rainwater, and evaluate the acceptability level of the proposed design in terms of its functionality, durability, and usability.

The acceptability level of the design of the rainwater harvesting system with filtration was evaluated by eight (8) civil engineers and two (2) mechanical engineers with expertise in the field. The participants were selected using purposive and convenience sampling based on their expertise, knowledge, and availability. This study utilized a researchers-made five-point Likert checklist to evaluate the acceptability level of the proposed design of the rainwater harvesting system with filtration. The acceptability level as perceived by professionals was determined in terms of its functionality, durability, and usability.

To ensure the accuracy of the instrument, the researchers-made evaluation checklist for the proposed design of the rainwater harvesting system was rated by six (6) experts for content validity. The validity test resulted to a content validity index (CVI) of 1.00 which is higher than the acceptable CVI value of 0.83 for at least six expert validators [47]. Content validity is vital in constructing a measurement tool, such as a questionnaire, for research for it provides essential evidence to support the validity of the tool [47].

The researchers gathered related ideas through research that was used in creating the design of the rainwater harvesting system and water filtration. The researchers also conducted research on suitable water filter components and determined the components utilized for the prototype. Following the determination of the components, the prototype was built. A pre-filtration test was then conducted to identify the physicochemical quality of the untreated rainwater. The results were then analyzed, and a stimulation then followed. After the stimulation, physicochemical post-filtration tests were conducted. The evaluation began after the prototype was finished, and the result obtained was satisfactory. The acceptability level of the design was evaluated by experts and validated by a statistician.

This study determined the quantitative information for analysis. For Project Development Tools, AutoCAD Software was used for designing and annotating 2D geometry and 3D models with solids, and surfaces, and mesh objects. It is equipped with automation, collaboration, and machine learning features that helps maximize productivity. This software was used in designing the rainwater harvesting system. Also, the researchers conducted a

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physicochemical analysis for the pre-filtration and post-filtration process to determine the quality of the rainwater in terms of the mandated physicochemical parameters. This was used to determine the acceptability level of the water filter. To analyze the quantitative data, Mean and Standard Deviation were used to give description and interpretation of the acceptability level of the design of the rainwater harvesting system in terms of functionality, durability, and usability. Mann Whitney U-Test, a non-parametric test, was used to determine if significant difference exists in the acceptability level of the design of the rainwater harvesting system in terms of functionality, durability, and usability when the expert participants are grouped based on their length of service/service. The normality of the data was first checked and analyzed using Shapiro-Wilk Test. The data were found to be not normally distributed which led the researcher to use this non-parametric test.

III. RESULTS AND DISCUSSION

Components of Water Filter

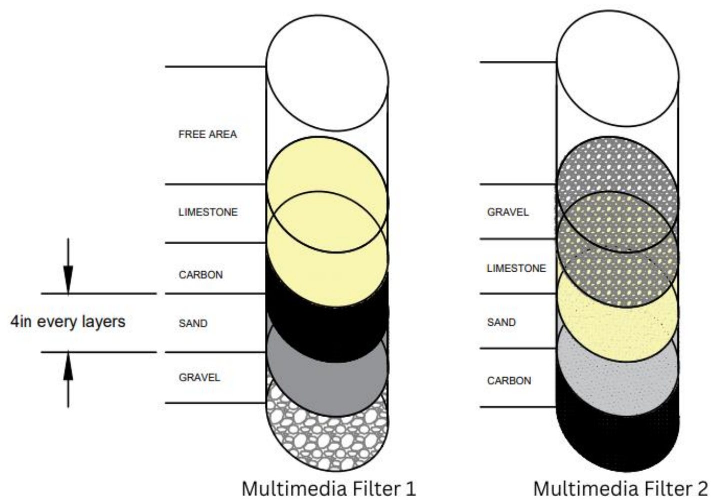

Figure 2. Components of Multimedia Filter

Gravel

The gravel's role is to absorb impurities and traps heavy metals and its porosity can be used as a gap for water to flow through [48]. In the design of the water filter, a 1 ½ size gravel was used with a 4-inch-thick layer. As shown in the figure, the gravel was placed at the bottom of first multimedia filter and at the top of the second multimedia filter. Because of its density, it served as the bedding the other media. Before it was used, it was washed thoroughly using chlorinated water and distilled water, separately.

Silica Sand

Silica sand absorbs filters small particles that causes impurities and eliminate physical properties such as odor and turbidity. [48] This filter media was placed above the gravel and is 4-inch thick. Like the gravel, the sand used was washed using a chlorinated water and distilled water.

Wood Charcoal

Wood charcoal is a good biofilter medium because it can easily withstand most of the toxic conditions likely to be developed in the biofilter and is effective in reducing odor, taste and turbidity. [49] The wood charcoal was used as an alternative of activated carbon because it is cost efficient and is available in the community. Before it was placed in the filter, it undergone a series of flushing to remove the fine particles that decolorizes the water.

Limestone

Limestone is a medium used to raise the pH and adjust the hardness of the water [50] A mixture of fine and coarse limestone was used in the design.

Silk Screen

Silk Screen served as a medium that retains sand, charcoal, and limestone. respectively. This medium was used to separate each layer and to blocking the entries of impurities to the next layer of filter medium.

Technical Specifications of the Proposed Design

Components of the Rainwater Harvesting System Design

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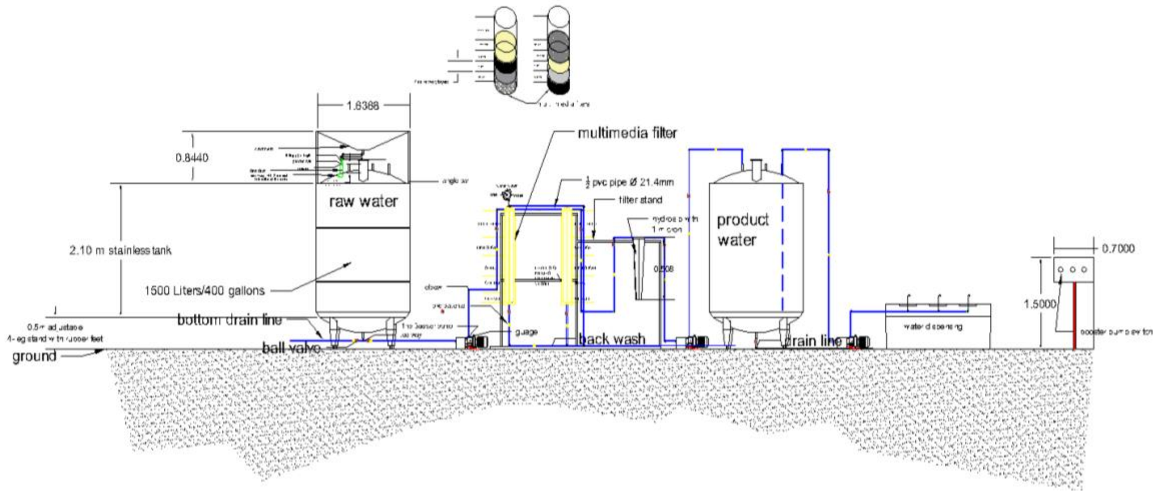

Figure 3. Rainwater Harvesting System with Filtration

Catchment Saucer

As shown in Figure 3, the architectural plan of the rainwater harvesting system has a catchment saucer to capture rainwater instead of using the roof. This can minimize the contact of harmful contaminants that are trapped in the roof gutters. The material that should be used is a Galvanized Iron (G.I) Sheet with a runoff coefficient of >0.90 [51]. The effective area of the catchment saucer as stated in the design is:

$$EA = b^2 + 2bd$$
$$EA = (1.65)^2 + 2(1.65)(0.7909)$$
$$EA = 5.3325\ m^3$$

Multimedia Filter

The multimedia filter incorporated in the design undergone a stimulation to test its porosity utilizing gravitational force. This is to ensure that the water can easily penetrate each filter medium. As discussed above, the components of the multimedia filters are gravel, silica sand, wood charcoal, limestone, and silk screen. Gravel and silica sand is a medium that absorbs impurities, traps heavy metals and improve physical properties [48]. The utilization of wood charcoal served as a cost-efficient alternative of an activated carbon and is an essential medium for reducing odor, taste, and turbidity [49]. To stabilize the pH level of the rainwater, a coarse and fine limestone were used [50].

Delivery System

Delivery Systems include pumps and pipes that connects each member of the systems. A 1hp can be used to achieve the desired water pressure and requires a one-way check valve to prevent backflow and loss of pressure [36]. As suggested by the experts, utilization of 1hp is suitable as it will be utilized in the backwashing process.

Cisterns or Tanks

Computation of the Volume of Storage Tank

The volume of the storage tank was calculated based on the annual available water and the monthly water use [26]. The rainfall data from the PAGASA Climatological Data as of 2020, shown in Figure 4, was used in obtaining the aforementioned values.

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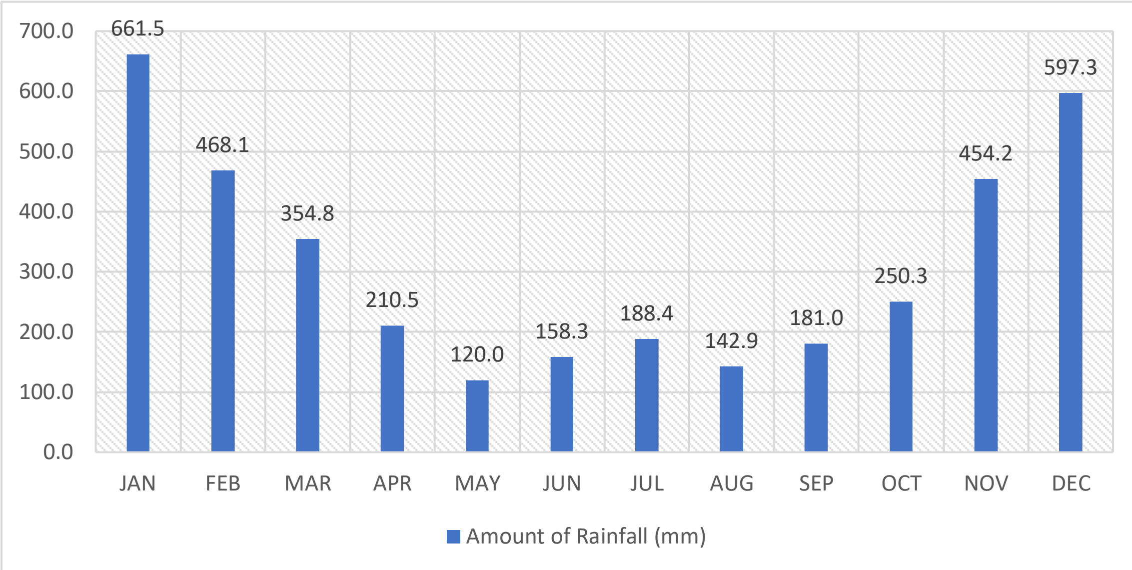

Figure 4. Rainfall data from the PAGASA Climatological Data as of 2020 in Surigao City

Based on the graph, the highest amount of rainfall as of 2020 is in the month of January, and the lowest amount of rainfall is in the month of May. The data shown in the figure was the dependent variable used in calculating the annual average rainfall. Utilizing the average amount of rainfall from January to December, the calculated annual average amount of rainfall was obtained.

Annual Average Rainfall = 661.5 + 468.1 + 354.8 + 210.5 + 120.0 + 158.3 + 188.4 142.9 + 181.0 + 250.3 + 454.2 +597.3

Annual Average Rainfall = 3757.3 millimeter (mm)

Therefore, with an annual average rainfall of 3757.3 mm and a saucer catchment area of 5.3325 m^3, the annual available water was calculated by multiplying the specified values to the runoff coefficient of a Galvanized Iron (G.I) sheet. The runoff coefficient of a G.I. sheet is >0.9 [51].

Annual Available Water= Saucer Catchment Area x Average Annual Rainfall x Runoff Coefficient

Annual Available Water = 5.3325 m^3 x 3757.3 mm x 0.90

Annual Available Water = 18.032 cubic meter (m^3)

The monthly water use can now be determined by dividing the annual available water to 12 months.

Monthly Water Use = Annual Available Water/12

Monthly Water Use = 18.032/12

Monthly Water Use = 1.502 m^3

Table 2 shows the spreadsheet calculations for determining the storage requirement. The cumulative rainfall harvested (inflow) and the cumulative water use (outflow) was taken into consideration in calculating the capacity of the storage tank which was obtained by subtracting the inflow to the outflow. Based on the table presented, the greatest excess occurred on March with a storage requirement of 2.62 m^3 and the lowest excess was on the month of October (-1.67 m^3). Therefore, the volume of the storage tank required is approximately 2.62 m^3 (approximately 3m^3) in order to store the water over and above consumption [26].

Table 2. Determining the Storage Requirement

Month	Average Monthly Rainfall (mm)	Rainfall Harvested (m^3)	Cumulative Rainfall Harvested (m^3) *Inflow*	Assumed Monthly Water Use (m^3)	Cumulative Water Use (m^3) *Outflow*	Volume Storage of Tank (m^3)
JAN	661.5	3.17	3.17	1.5	1.5	1.67
FEB	468.1	2.25	5.42	1.5	3	2.42
MAR	354.8	1.70	7.12	1.5	4.5	**2.62**
APR	210.5	1.01	8.13	1.5	6	2.13
MAY	120.0	0.58	8.71	1.5	7.5	1.21

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JUN	158.3	0.76	9.47	1.5	9	0.47
JUL	188.4	0.90	10.37	1.5	10.5	-0.13
AUG	142.9	0.69	11.06	1.5	12	-0.94
SEP	181.0	0.87	11.93	1.5	13.5	-1.57
OCT	250.3	1.20	13.13	1.5	15	-1.87
NOV	454.2	2.18	15.31	1.5	16.5	-1.19
DEC	597.3	2.87	18.18	1.5	18	0.18

The Physicochemical Quality of the Rainwater Before and After Filtration

In classifying the quality of drinking-water parameters, mandatory parameters are the core parameters that shall be required in determining the quality of the water. [45]. This study utilized the Annex B Table B-1, the Mandatory Drinking-Water Quality Parameters of the Philippine National Standards for Drinking Water 2017. The samples were examined by the Environmental-Health Laboratory Services Cooperative, a Department of Health (DOH) – Accredited Laboratory in the Philippines and adhered to the laboratory's standard sampling requirements. The methods of analysis conducted by the laboratory in determining the physicochemical parameters of the submitted samples are presented in Table 3.

Table 3. Physicochemical Test Method of Analysis

Parameters	Method of Analysis
Color	2120 Visual Comparison - Chloroplatinate
Turbidity	2130 Nephelometric
Residual Chlorine	4500-Cl DPD Ferrous Titrimetric
pH @ 25.0 °C	4500-H+ Electrometric
Lead	3113 Electrothermal Atomic Absorption Spec
Cadmium	3113 Electrothermal Atomic Absorption Spec
Arsenic	3113 Electrothermal Atomic Absorption Spec
Nitrate*	4500-NO3- Electrode Method
Total Dissolved Solids	2540 Gravimetric

Each physicochemical parameter specified in PSNDW 2017 Annex B-1 was evaluated based on their corresponding standard values for water quality parameters [42]. The indicated methods of analysis were applied in determining the quality level of the submitted rainwater samples. One of these methods is the 2540 Gravimetric method which evaporated the filtrate and was further subjected to a temperature of 180°C to determine the total dissolved solids present in the water sample [52].

Table 4 presents the physicochemical test results of the rainwater harvested before filtration in terms of its Color and Turbidity for its physical parameters, and its Residual Chlorine/Disinfectant, pH level, Lead, Cadmium, Arsenic, Nitrate, and Total Dissolved Solids (TDS) for its chemical parameters. Based on the result presented, the rainwater harvested failed to meet the standards set by the Department of Health in terms of the water's color, turbidity, pH, and Total Dissolved Solids (TDS). This shows that the rainwater harvested before filtration is not safe for drinking purposes [45].

Table 4. Physicochemical Test Results of Rainwater Before Filtration

Parameters	Unit	Results	PNSDW Standards	Remarks
Physical				
Color	CU	11	10	FAILED
Turbidity	NTU	8	5	FAILED
Chemical				
Residual Chlorine	Mg/L	0	0.3-1.5**	-
pH @ 25.0 °C	-	5.0	6.5-8.5	FAILED
Lead	mg/L	0.00008	0.01	PASSED

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Cadmium	mg/L	ND(MDL=0.0003)	0.003	PASSED
Arsenic	mg/L	ND(MDL=0.0006)	0.01	PASSED
Nitrate*	mg/L	0.95	50	PASSED
Total Dissolved Solids	mg/L	17	less than 10	FAILED
Note: *ND – Not Detected* *MDL – Method Detection Limit* **Not accredited by the Philippine Accreditation Bureau* *** Limit applies only to sample description presented above.*				

The results of the physicochemical tests of the rainwater after filtration is shown in Table 5. As observed in the presented results, all physicochemical parameter standards specified were complied. Compared to the results presented in Table 4, the amount for Color, Turbidity, Lead, Nitrate, and Total Dissolved Solids reduced after the intervention of the filtration system. The reduction of the amount of Lead, Nitrate, and Total Dissolved Solids can be attributed to the application of gravel and silica sand that traps heavy metals and impurities. [48] The use of wood charcoal is an essential filter medium in reducing the number of contaminants in the water [49]. The results obtained may also satisfy the potential use of wood charcoal as an alternative of activated carbon.

Table 5. Physicochemical Test Results of Rainwater After Filtration

PARAMETERS	SAMPLE 1		SAMPLE 2	
Physical				
Color	5	PASSED	3	PASSED
Turbidity	2	PASSED	1	PASSED
Chemical				
Residual Chlorine	0	PASSED	0	PASSED
pH @ 25.0 °C	7.0	PASSED	7.0	PASSED
Lead	0.00003	PASSED	0.00001	PASSED
Cadmium	ND(MDL=0.0003)	PASSED	ND(MDL=0.0003)	PASSED
Arsenic	ND(MDL=0.0006)	PASSED	ND(MDL=0.0006)	PASSED
Nitrate*	0.45	PASSED	0.15	PASSED
Total Dissolved Solids	3	PASSED	2	PASSED

The foregoing results only applied to a less controlled environment and is only limited to the samples submitted to the samples submitted to the laboratory. Thus, further research is needed to understand the degree to which these results, obtained in a span of two (2) months, apply in a carefully monitored conduct.

Acceptability Level of the Design of the Rainwater Harvesting System

Table 6. Acceptability Level of the Design of Rainwater Harvesting System in terms of Functionality

Indicators	Mean	SD	Verbal Interpretation	Qualitative Description
1. The rain saucer catchment effectively reduces the contamination of the harvested rainwater.	4.40	0.80	Strongly Agree	Highly Acceptable
2. The size of the catchment area can capture significant amounts of rainfall, even in areas of low rainfall availability.	3.70	1.10	Agree	Acceptable
3. Each component of the water filter is suitable for its intended purpose.	4.40	0.66	Strongly Agree	Highly Acceptable
4. The piping layout is appropriate to the proposed design.	3.39	1.11	Moderately Agree	Moderately Acceptable
Average	3.97	0.92	Agree	Acceptable

Legend:

4.20-5.00	Strongly Agree	Highly Acceptable

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3.40-4.19	Agree	Acceptable
2.60-3.39	Moderately Agree	Moderately Acceptable
1.80-2.59	Slightly Agree	Less Acceptable
1.00-1.79	Disagree	Not Acceptable

Table 6 shows the acceptability level of the design of the rainwater harvesting system in terms of durability. The data presented above shows that the acceptability level of the design of the rainwater harvesting system in terms of functionality. The indicators *the rain saucer catchment effectively reduces the contamination of the harvested rainwater* and *Each component of the water filter is suitable for its intended purpose* got the highest mean which can be qualitatively described as *Highly Acceptable*. It is expressed that the experts agreed to the utilization of rain saucer catchment contributes to the effective reduction of contamination in the harvested rainwater and the components of the multimedia filter is deemed suitable for its intended purpose.

Meanwhile, the indicator *The piping layout is appropriate to the proposed design* got the lowest mean which can be qualitatively described as *Moderately Acceptable*. This result implies that the experts moderately agreed that the piping layout is appropriate to the proposed design. As to the acceptability level of the design in terms of functionality, experts agreed that the proposed design is acceptable. This implies that the designed rainwater harvesting system with filtration has the capability to provide functions that meets the requirements of the intended purpose [51].

Table 7. Acceptability Level of the Design of Rainwater Harvesting System in Terms of Durability

Indicators	Mean	SD	Verbal Interpretation	Qualitative Description
1. The design of the rainwater harvesting system is stable and ensures safe installation in the community.	4.50	0.50	Strongly Agree	Highly Acceptable
2. The materials used in the design is reliable to withstand the pressure of the harvested rainwater.	4.40	0.66	Strongly Agree	Highly Acceptable
3. The design has a great lifespan and can prevent significant deterioration for a period of time.	4.00	0.77	Agree	Acceptable
4. The structural design of the rainwater harvesting system follows the standard required loads.	4.20	0.60	Strongly Agree	Highly Acceptable
Average	4.28	0.63	Strongly Agree	Highly Acceptable

Legend:

4.20-5.00	Strongly Agree	Highly Acceptable
3.40-4.19	Agree	Acceptable
2.60-3.39	Moderately Agree	Moderately Acceptable
1.80-2.59	Slightly Agree	Less Acceptable
1.00-1.79	Disagree	Not Acceptable

The results of the evaluation of the acceptability level of the design in terms of durability is shown in Table 7. As presented, the indicator *The design of the rainwater harvesting system is stable and ensures safe installation in the community* got the highest mean which can be qualitatively described as *Highly Acceptable.* This tells that the participants strongly agree that the proposed design can be safely installed in the community. While the indicator *The design has a great lifespan and can prevent significant deterioration for a period of time* got the lowest mean and can be qualitatively described as *Acceptable*. This interprets that the participants agreed that the design can withstand deterioration for a certain period of time, but still needs further improvement. Nonetheless, the result shows that the design is durable and is safe for community and household installation. Based on this report, it can be said that the design is reliable and can perform to its intended purpose at a specific amount of time without the fear of immediate deterioration since the durability of the system also refers to its reliability [53].

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Table 8. Acceptability Level of the Design of Rainwater Harvesting System in Terms of Usability

Indicators	Mean	SD	Verbal Description	Qualitative Description
1. The filter media installed in the design is efficient in supplying potable water to the community.	4.10	0.83	Agree	Acceptable
2. The design of the rainwater harvesting system is cost-efficient and can be installed and utilized by homeowners.	4.00	1.34	Agree	Acceptable
3. The materials used improves the efficiency of the rainwater harvesting system as an alternative source of potable water.	4.20	1.17	Strongly Agree	Highly Acceptable
4. The design can aid the community's centralized water supply system and can serve as an alternative supply of potable water.	4.30	1.10	Strongly Agree	Highly Acceptable
5. The design is easy to use and can be maintained easily.	4.10	0.83	Agree	Acceptable
6. The filter media can be cleaned easily.	3.90	1.14	Agree	Acceptable
Average	4.10	1.07	Agree	Acceptable

Legend

4.20-5.00	Strongly Agree	Highly Acceptable
3.40-4.19	Agree	Acceptable
2.60-3.39	Moderately Agree	Moderately Acceptable
1.80-2.59	Slightly Agree	Less Acceptable
1.00-1.79	Disagree	Not Acceptable

Concerning the acceptability level of the design in terms of usability, it can be seen in Table 8 that the indicator *The design can aid the community's centralized water supply system and can serve as an alternative supply of potable water* got the highest mean and can be qualitatively described as *Acceptable*. The result shows that the participants agreed that the design can be an efficient aid to the community's centralized water supply system as an alternative supply of potable water. The indicator *The filter media can be cleaned easily* got the lowest mean which can be qualitatively described as *Acceptable.* As to the usability of the proposed design, the participants agreed that the design is cost-efficient, and the materials used are effective. This result can be attributed to the effectiveness of the design with which the system may perform its intended purpose and can be easily installed and used [54].

Significant difference of the acceptability level of the design of the rainwater harvesting system based on the length of service/experience.

For the significant difference of the acceptability level of the design of the rainwater harvesting system, the evaluators are classified into two groups. The first group refers to the expert evaluators that is practicing their field of expertise for 1 to 4 years. While the second group refers to those who are practicing their field of expertise for 5 to 8 years.

Table 9. *Significant difference of the acceptability level of the design of the rainwater harvesting system based on length of service/experience*

Dimensions	Z-value	p-value	Decision	Interpretation
Functionality	-1.103	0.270	Do not reject null hypothesis	Not Significant
Durability	-0.538	0.591	Do not reject null hypothesis	Not Significant
Usability	-0.753	0.451	Do not reject null hypothesis	Not Significant

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As shown in Table 9, the p-values are greater than 0.05 significance level. Thus, the null hypothesis was not rejected which implies that there is no significant difference in the acceptability level of the design of the rainwater harvesting system when the expert participants are grouped based on length of service/experience. This result means that the evaluation of the expert participants, regardless of their length of experience in their field of expertise as engineers, is statistically similar. This is in line with the claim that contextual knowledge and experience can be used as a support during statistical investigations [55]. With this, it can be safely said that the experts agreed that proposed design, based on what they have seen on the technicalities of the design and the feasibility of its intended purpose, is acceptable. This may imply that the utilization of rain saucer catchment as well as the design of the multimedia filter, is an effective intervention to effectively reduce the contamination of the rainwater. However, some aspect, specifically the *piping layout*, might need an improving which prompted the evaluators to rate the indicator as moderately acceptable.

IV. CONCLUSION AND RECOMMENDATION

Based on the results, it is concluded that the required capacity of the tank is at least 3 cubic meter to store the water over and above consumption. Wood charcoal can be an efficient alternative for activated carbon. The physicochemical properties of the harvested rainwater after filtration complied to the standards stipulated in the Philippine National Standards for Drinking Water 2017. Thus, the filtered rainwater is safe for human consumption after thorough filtration. Moreover, it must be noted also that the design of the rainwater harvesting system with filtration as an alternative supply for potable water is acceptable in terms of its functionality, durability, and usability. The evaluation of the expert participants, regardless of their length of service/experience, is statistically similar. Hence, the experts agreed that proposed design, based on what they have seen on the technicalities of the design and the feasibility of its intended purpose, is acceptable.

Therefore, the researchers have recommended that the sampling of rainwater and the installation of the rainwater harvesting system must be at Surigao City, Surigao Del Norte, Philippines. It is not guaranteed that the physicochemical properties of the rainwater are the same with other areas in Surigao Del Norte. Also, the conduct of the study was only limited to three (3) months. With the impending summer that lessens the amount of precipitation, there were difficulties encountered in gathering the samples for the water analysis. Due to this, the experiment was conducted with one (1) replication only. With this, the future researchers may conduct further study on rainwater harvesting during rainy season.

To have a more sustainable living, the community is highly recommended to invests in rainwater harvestings systems installation in their household. This is to avoid reoccurrence of grave water scarcity that was experienced by the victims of Typhoon Odette. Utilization of rainwater harvesting systems also lessens the surface runoff that causes landslides, and floods. Thus, it is recommended that the proposed design may be considered for utilization. Furthermore, it is recommended that future researchers conduct a comparative study that will determine the cost effectiveness of the design as compared to the total installation and maintenance cost of the existing rainwater harvesting system design. Before the utilization of the proposed design, the researchers recommend conducting further study to improve the design, making it suitable for the condition of the community. Also, given the duration of the conduct the study, the lifespan of the design filtration system was not determined. Thus, it is highly recommended to conduct scientific investigation on how long it will take for the filter to maintain its effectiveness.

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