Reduction of Contamination from Water Using Rainwater Filtration System in NCR, Philippines

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Abstract

Water shortage and the rising cost of water services have been a problem of communities around the world for centuries. In 2019, the World Health Organization (WHO) had reported that around one out of ten, approximately eleven million people in the Philippines do not have access to improved water sources. Climate change is one of the main contributing factors to this problem. UNICEF stated that climate change disrupts weather patterns, leading to extreme weather events, unpredictable water availability, exacerbating water scarcity, and contaminating water supplies. Such impacts can drastically affect the quantity and quality of water needed to survive. Considering the occurrence of such abnormal phenomena, the aim of the study was to assess the quality of water sources in Metro Manila (NCR) and create an effective water filtration system that can be used to help reduce the contamination of water that Filipino households can utilize. The researchers gathered and analyzed data through comparative analysis, together with the support of similar studies, to help determine the optimal amount of components that will be used for the filter and establish if the filter is indeed effective in reducing contamination. The obtained results from the tests conducted for the seven water quality parameters tests between the Filtered Rainwater and Unfiltered Rainwater found that there was a reduction in the contaminants after the filtration of the rainwater using the filter prototype.

Keywords
Rainwater, Water Quality, Rainwater Filtration System, Water Scarcity, Physico-chemical parameters

1. Introduction
The prevalence of water scarcity is a problem that is affecting different areas of the world, most especially those residing in rural areas and those who belong in the poorest sectors of the society. This situation is evident in several countries of the world, including the Philippines. Lee et al. (2019) mentioned that the country is ranked 33rd out of the 48 countries in the Asian Development Bank (ADB) when it comes to water security. With this impediment, people are left with no choice but to rely on unsafe and untreated water sources for their alternative water supply just so they could suffice their water needs. However, utilizing such water sources poses serious threats in terms of health of the people. Some of the potential risks include infections such as diarrhea, cholera, hepatitis, and typhoid.
The rapid increase in global population also increases water consumption, thus further depleting water sources than it normally should. Kummu et al. (2016) stated that “rapidly increasing populations and increases in total water consumption resulted in a nearly 16-fold overall increase in the population under water scarcity within the 20th century”. Because of this, safe alternative sources of water are starting to be explored by different sectors and organizations as an attempt to alleviate and mitigate the effects of water scarcity. Among the different alternatives available is the use of rainwater harvesting system, which Sendanayake (2016) noted to be a feasible supplementary source of water especially to countries which have abundant rainfall.

1.1 Objectives
Considering the crucial role of water in different aspects of human life, other alternative sources of water must be furthermore explored to help address the impending problem of water scarcity in different areas of the world, including the Philippines. The aim of the study is to focus on coming up with an effective purification system that can be used to reduce contaminants in rainwater and make this a viable alternative source of water for households in Metro Manila. The findings of this study will contribute significantly not just to communities in, but to different local communities across the world as well that experience water scarcity as one of its main problems. Rainwater harvesting or the collection of rainwater in a proper way can be a permanent solution to the problem of the water crisis in various parts of the world. Having a further study of this subject matter is essential for the improvement of the project, so that appropriate steps will be taken.

General Objective: The overall objective of this study is to design a product that would enable people to treat, and filter harvested rainwater and use this as their sustainable source of water for household usage.

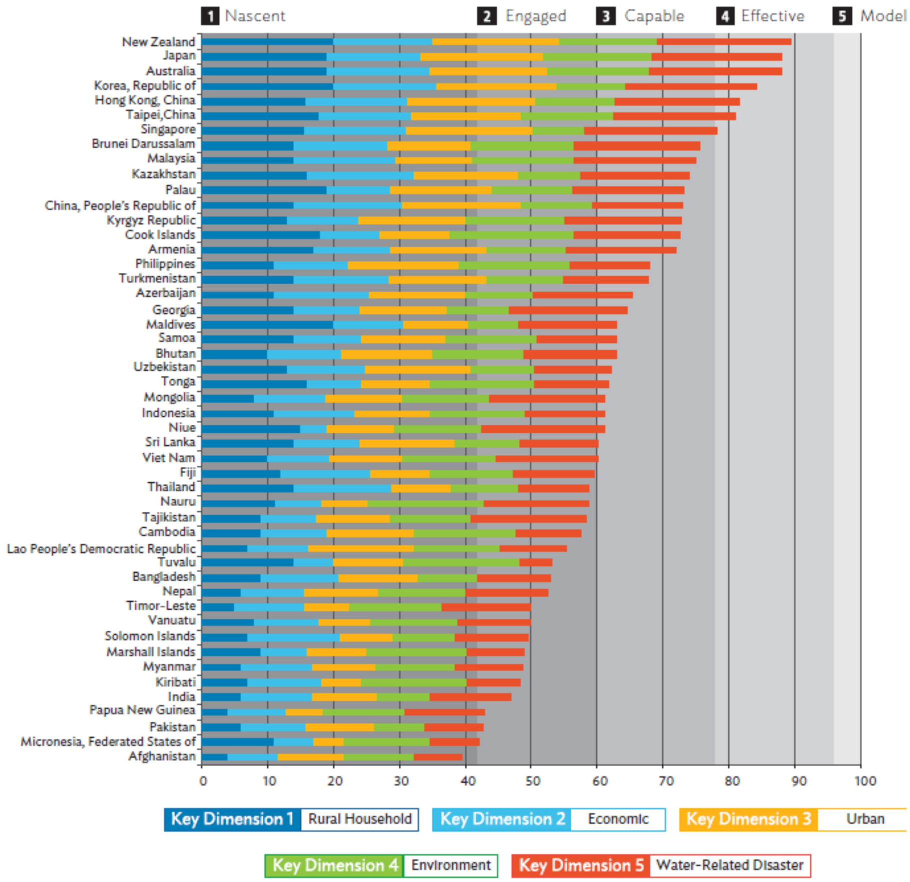
Specific Objective:
- to integrate coconut shell activated carbon into the purification system
- to be able to reduce contaminants from water using the purification system
- to determine if the filtered rainwater complies with the water quality standards of the Philippines
- to determine if the water quality of rainwater significantly improved after going through the water filter

2. Literature Review
2.1 Global Water Crisis
Water scarcity may be a problem that is more evident to developing countries, but it is considered to be an issue that the whole world is currently facing. A study by Mekonnen and Hoekstra (2016) found out that there are about 4 billion people who experience severe water scarcity during at least one month of the year (as cited in Sun et.al, 2021). That is approximately two-thirds of the global population experiencing this problem in water scarcity. Additionally, it is estimated that around 50 to 70 percent of the world's natural wetland area has been lost over the last 100 years (United Nations, 2019). National Geographic also stated that 3.3 million people around the world are dying as a result of dirty water and lack of a toilet and proper hygiene, having most of them as children under five years old (Manila Times, 2020).

The rapid growth of the global population is resulting in a continuous increase in water demand as well, putting the limited global water reserves in a bind. While the human population has doubled in the last 50 years, there has also been a corresponding growth in industrialization and economic development, which increases water usage, water ecosystems transformation, and huge loss of biodiversity (Guarino, 2016). The lack of access to reliable and usable water resources is a major issue not only because the global water demand cannot be accommodated, but also because it leaves the people with no choice but to settle for unsafe water resource alternatives. Most of these alternative sources pose several threats regarding the health and safety of the people who will be making use of it. Around 827,000 people from low and middle-income countries die each year as a result of inadequate water, sanitation, and hygiene, with around 432,000 of those deaths to be caused by poor sanitation (World Health Organization, 2019). It is forecasted that half of the world's population will already be living in water-stressed areas by 2025, and around 700 million people are expected to be displaced from their homes or communities by the year 2030 due to intense water scarcity.

2.2 Philippine Water Crisis
The Philippines, despite being a tropical country abundant in water resources, is still no exception to the global crisis brought about by water scarcity. As an archipelagic country surrounded by hundreds of bodies of water, only 36% or 148 of the country's river systems can be used as sources of water supply, while only 42% of the groundwater is free from contamination. Doctor Gundo Weiler, a WHO Representative in the Philippines, said, "Water is an extremely important resource that we cannot live without. But there are Filipinos who are still being left behind in terms of access to improved water sources." Despite the access of some portion of the population to improved water, people still rely on purchasing their water from commercial sources, thus accounting for a high percentage of average Filipino's monthly wage. This shows that even Filipinos are affected in an economical perspective regarding reliable and sustainable sources of water and sanitation. A study on the demands and shortages in the Philippines was conducted by the Japan International Cooperation Agency, identifying nine major areas in the country that are

considered to be "water-critical areas." These areas include Metro Manila, Metro Cebu, Davao, Baguio, Angeles, Bacolod, Iloilo, Cagayan de Oro, and Zamboanga (figure1).



Source: Asian Development Bank.

Figure 1. National water security score among ADB members

The water security scores of different Asian Development Bank members as reflected in five (5) key dimensions are shown in Figure 1. The five key dimensions identified are Rural Household, Economic, Urban, Environment, and Water-Related Disasters, all of which are scored using a scale of 1-20. It can be seen from the figure that the Philippines ranked 16th overall among 49 countries in terms of the overall national water security score. This score indicates that the overall water security in the country is good. However, when looking at the key dimensions that consist of the overall score, it can be observed that the water security in rural areas is still low, and that the great disparity between water security among rural and urban areas is still present in the year 2020. The issue of poverty in the nation furthermore aggravates the situation regarding water safety and accessibility. The disparities of socio-economic status in the Philippines are evident when comparing how the urban areas are provided better access to power, food, and water (Cayonte et al. 2019).

Water crisis is certainly not a new problem in the Philippines, and it worsens as a consequence of climate change. The cities of the Philippines have been designated as some of the worst for water security in Asia. As a result of climate change and global warming, the mean temperature of the Philippines is expected to rise by 1.8°C to 2.2°C in 2050 (PAGASA, n.d.). The increase in temperature during the dry season and extreme rainfall during the wet season, this will undoubtedly affect water supply and quality. Tolentino (2020) mentioned that with the Philippines continuing to experience high weather temperature, water rationing was being announced for some parts of Metro Manila; thus, limiting the supply of water to households. According to the Global Climate Risk Index (Germanwatch, 2020), the Philippines continuously rank among one of the most affected countries both in the longterm index and in the index for the respective year. In addition to this, our population is expected to increase by approximately 30% in 2050 as reported by the United Nations in their World Population Prospects (2019) which will further deplete our freshwater resources.

Due to the uncertain occurrence of the El Niño phenomenon and the continuing high weather temperatures, the water crisis affects more and more households throughout the year. Approximately 14 million residents that live in Manila, Rizal, and Cavite are heavily reliant on Umiray-Angat-Ipo river systems as their main source for clean and safe water (Metropolitan Waterworks and Sewerage System, 2021). Last March 2019, around 52 barangays had no water, and over six million customers were affected by the El Niño which is also drying up dams and other water sources. This crisis affected more than 10,000 households as the water level in La Mesa Dam reached the critical point. There are three main sources of water supply in Metro Manila: Angat, Ipo, and La Mesa dams. In an interview with Vicente Manalo, an administrator in PAGASA, it would be alarming if the water level of Angat is below normal because the main source of La Mesa dam is Angat dam. With the increase in population, water suppliers do not have enough sources to cover the growing demand. This water crisis highlights the uncertainty of our water supply even in the National's capital (WHO, 2019).

2.3 Harmful Effects and Other Risks

The issue of water scarcity in the country is resulting in a lack of reliable water supply that can be used by the people, opening opportunities for them to resort to unsafe and untreated water sources to suffice their needs for water. According to the World Health Organization (2020), there are around 50.3 million Filipinos who do not have access to safely managed sanitation services. Moreover, there are an estimated 6 million Filipinos who still practice open defecation. Aside from these practices, another option that people do is storing more water in large drums or containers when it is still present or available. This practice allows them to prepare in case there is an unexpected water supply cutoff or water shortage in their area. However, this scenario is prone to mishandling and will open more possibilities for mosquitoes to breed in these containers or storages, thus increasing the potential harm from mosquito-borne diseases such as dengue.

Such unsafe habits and practices can pose serious problems with the availability of usable water resources in the country due to the harmful and potentially contaminated water resource alternatives that people resort to. In Metro Manila, only 15% of households are connected to sewerage systems, with only half of which receiving sewage treatment (Jalilov, 2017). Abeyasinghe (2020) stated that untreated water waste from poor sanitation can bring several negative effects both on the environment and human beings. Among the negative impacts to humans include diseases that cause poor health and nutrition, loss of income, decreased productivity, and missed opportunities.

The need for accessible clean and usable water is even more significant than ever due to the surge of COVID-19 outbreaks that has hit the Philippines since January of 2020. Proper sanitation has been the go-to solution for most Filipinos in attempting to prevent risks of further transmission of the disease. Hand hygiene is a widely accepted principle in the prevention of disease transmission because it has a 24% to 31% likelihood of decreasing the spread of transmissible disease (Rundle et al., 2020). Additionally, the IBON Foundation (2020) stated in their article that the World Health Organization has emphasized the importance of frequent and proper hand hygiene as one of the most important preventive measures against COVID-19 infection. However, this practice may not be widely implementable in the country due to the great disparity of reliable water sources among the different regions. The World Health Organization (2020) has stated that based on 2019 data, lack of handwashing facilities, water, and soap has resulted in over 7 million Filipinos who are still unable to wash their hands. Among them are mostly from those who live in the rural areas and those who belong among the poorest Filipino households.

2.4 Tropical Cyclones

There are more Tropical Cyclones (TC) that enter the Philippine Area of Responsibility (PAR) than anywhere else averaging 20 tropical cyclones per year with an annual rainfall ranging between 959.9 millimeters to 4,464.9 millimeters that varies from one region to another. According to the data provided by PAGASA (n.d.) that averages over a 30-year period, Hinatuan station in Surigao del Sur receives the highest amount of rain with an annual rainfall of 4,464.9 millimeters while General Santos City station in South Cotabato receives the least amount of rain with an annual rainfall of 959.9 millimeters. The annual rainfall of the weather stations located in the National Capital Region ranges between 1,767.8 millimeters to 2,103.6 millimeters.

Engineer Bonifacio B. Magtibay, a WHO Environmental and Occupational Health Technical Officer, recommended individuals to contribute in their own ways to converse water and avoid further water scarcity by recycling water and different strategies such as rainwater collection systems. The Rainwater Harvesting (RWH) system is considered as a viable supplementary source of water especially in countries with abundant rainfall like the Philippines (Sendanayake, 2016).

2.5 Combating Water Shortages Using Rainwater Harvesting Systems

In the Philippines, a study was conducted by the engineering students of De La Salle University. Ignacio et al. (2019) designed and manufactured a model for an Integrated Water System (IWS), which is composed of a Rainwater Harvesting System (RWHS), Water Treatment System (WTS), and Eco-Toilet System (ETS). Their system was inspired by similar papers that have designed and installed RWHS and IWS. The RWHS and WTS use rainwater which can be used for domestic purposes. In their model, the ETS can be used for agricultural purposes, promoting food security. This study was also done in support of UN'S SDG 6' Clean Water and Sanitation, "Ensure Availability and Sustainability Management of Water and Sanitation for All".

This model was installed in Mulanay, Quezon Province, Philippines, one of the identified 331 waterless municipalities in the country. The researchers discovered from the database of Mulanay that more than 80% of the local inhabitants have a limited water supply and nearly 50% lack access to at least basic sanitation. They also took in consideration the behavioral intention and perception of the users of the IWS, extending the study by conducting a survey using The Combined Technology Acceptance Model and Theory of Planned Behavior (C-TAM-TPB) to measure the social acceptance of the installed technology.

2.6 Components of the Filter

Considering the current situation of the researchers, mainly limited mobility due to the pandemic, budget constraints, limited communication, and limited knowledge of the procurement of necessary materials to make a prototype that is comparable to those in the market, the researchers opted to make a filtration system that is simple yet effective in filtering rainwater that is comparable to tap water. The components considered are chosen due its abundant availability, which makes the filter easier to produce, its support to SDG 12 "Responsible Consumption and Production for using natural materials, and the components' performance in related studies. The table 1 summarizes both variable's units of measurement and instrument/s to be used.

Table 1. Filter materials and instrument used for measurement

Factors	Unit of Measurement	Instrument Used for Measurement
Independent Factors		
Filter Materials		
1. Activated Coconut Carbon	g	Weighing Scale
2. Gravel	g	Weighing Scale
3. Sand	g	Weighing Scale
4. Filter Wool	cm	Measurement Tape/Ruler
Dependent Factors		
Water Quality Parameters		
1. pH level	units	Litmus Paper pH strips, Electrometric Method
2. Chloride	mg/L	Argentometric
3. Phosphate	mg/L	Stannous Chloride
4. Chemical Oxygen Demand (COD)	mg/L	Closed Reflux
5. Total Suspended Solids (TSS)	mg/L	Gravimetric
6. Nitrate (NO_3)	mg/L	Nitrate Electrode Method
7. Fecal Coliform	MPN/100mL	Multiple Tube Fermentation

Filter materials refer to the different biofiltration components that the proponents utilized in the filtration system that was used in this study. The researchers adopted the usual components of a biofiltration system together with the integration of activated coconut carbon as an alternative to the usual activated carbon components that has been utilized in previous studies. The main filter materials that were tested in this study are activated coconut carbon, sand, gravel, and filter wool.

The water quality parameters refer to the different chemical parameters, specifically physicochemical parameters, that were assessed in determining the quality of collected water samples. These parameters include the pH level, Chloride, Phosphate, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Nitrate (NO3-N), and Fecal Coliform of the water samples. Each parameter will be evaluated based on their corresponding standard values for water quality parameters. This will dictate the quality level of the water and will determine if it is safe for household use, human consumption, and other possible uses.

3. Methods

The research design that was utilized for this study focuses on the reduction of water contamination analysis using the newly designed rainwater filtration system by the researchers. Comparative analysis was conducted between the water quality parameters of the filtered rainwater as compared to the unfiltered rainwater. The analysis was conducted by gathering data samples of rainwater from Metro Manila and placing it into the activated coconut carbon filtration system to test the properties and the performance of the filter.

The main target of the study was to provide an alternative source of water for residents in Metro Manila, therefore it is necessary to collect rainwater samples from the vicinity to obtain more accurate results. Rainwater samples for the study were obtained from one household among the proponents, who is currently residing in Metro Manila, specifically in the city of Las Piñas. Afterwards, the collected water samples were brought to a testing laboratory within the subject site to get its parameters tested within the holding time upon its collection. The laboratory is located at Mach Union Building, Alabang Zapote Road, Las Piñas City, Philippines. The quality of filtered rainwater obtained will be compared with the quality of unfiltered water to assess its potential as an alternative or an emergency water source for households.

All water has some form of bacteria. However, the presence of bacteria does not mean the water is unsafe to use; since, only disease-causing bacteria known as pathogens lead to disease (North Dakota State University, 2019). Hence, a thorough process of water quality testing is a must for any potential liquid source to find out its specification. In line with this, the dependent variables of the study are the data that will be coming from the water quality results of the filtered rainwater and unfiltered rainwater. The volume (size) of the samples to be collected and the identified water parameters to be tested will depend on the following:

1. The DENR Water Quality Standards
2. Requirements of the Water Testing Laboratory
3. Availability of Water Parameters that can be tested from the Water Testing Facility
4. The Cost to Test Each Water Parameters for Each Sample

To have ideal and reliable results, a total number of 15 trials of water tests were conducted, which were done through the months of June - September of the year 2021. Evidently, it would have been ideal to take numerous repeated samples in a specific community or model, obtaining excellent statistical data, but given the restricted protocols brought by the COVID-19 situation, the proponents based the number of samples to be obtained from the gathered data from existing journals. The model used in this study is presented below in Figure 2.

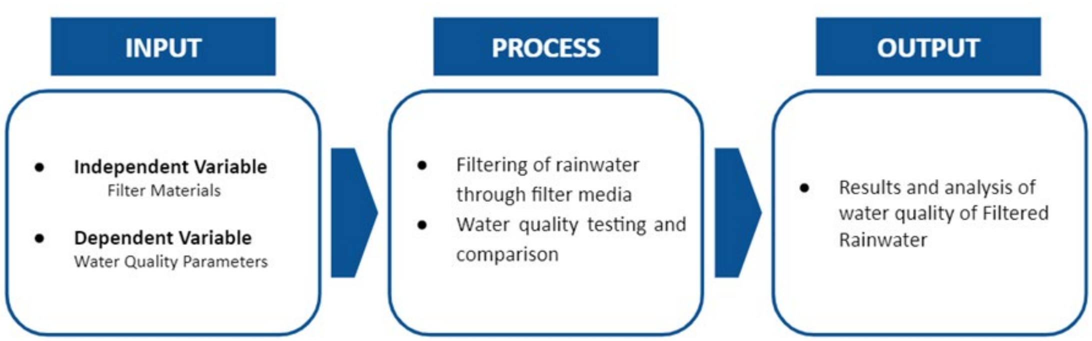


Figure 2: Conceptual framework

The parameters used to assess water quality are pH level, Chloride, Phosphate, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Nitrate (NO3-N), and Fecal Coliform of the water samples. Each parameter will be assessed based on their corresponding standard values for water quality parameters. The Water Quality Guidelines (WQG) and General Effluent Standards (GES) of 2016 by the Department of Environment and Natural Resources (DENR) was used to determine the quality of water samples. The DENR has stated that this guideline will be applicable to all water bodies in the country, with different classifications provided depending on the water's intended beneficial use. The guidelines mentioned that water intended for sources of potable and domestic use should adapt to the DENR Class A WQG except for the Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) parameters, hence the Class A WQG was the basis of the standard values of the water parameters that was used for assessment of the quality of the water samples.

4. Data Collection

The proponents were able to collect 15 samples of rainwater during the duration of the months of June – September of the year 2021. The Sample of harvested rainwater was collected based on the details of location, date, and time. Hence, the test for each water parameter besides the pH level was conducted within 24 HRS upon the collection of rainwater to avoid any changes in the sample physically and chemically. Each sample was directly transported to the Water Testing Laboratory having the precautions of the prescribed sample volume, container type, and preservation details. The pH level parameter is required to be tested within 15 minutes; thus, the proponents personally conducted a litmus paper test on the rainwater samples. To be assured of the data conducted for the pH level, the Water Testing Laboratory still conducted a comprehensive test to compare to the data that was collected directly by the proponents. As the pH level data were on par with each other, the proponents decided to use the collected results from the laboratory to ensure the accuracy of the water analysis.

5. Results and Discussion

The Rainwater Filtration System with the activated coconut carbon was effectively conceptualized and actualized as a prototype to filter rainwater samples obtained from the subject site. In line with this, the optimal mixed-ratio, and the components inside the system, particularly the gravel, sand, and the newly integrated ingredient, activated coconut carbon, as discussed in the previous section, were successfully derived and applied to the biofilter (figure 3).

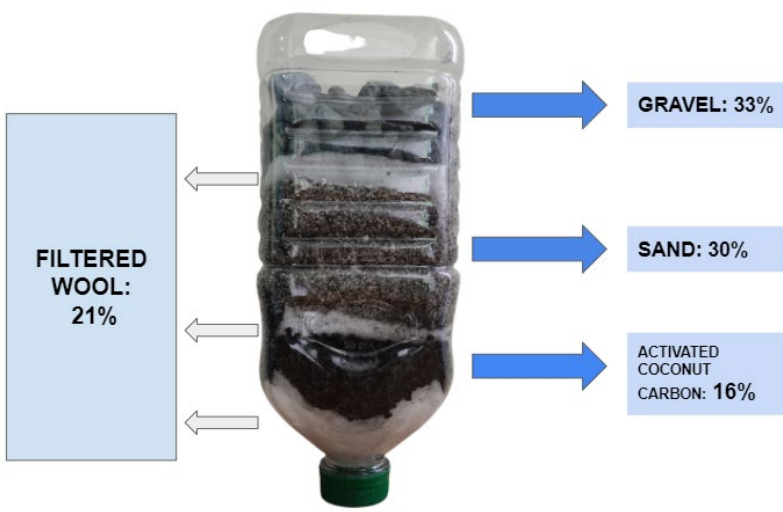


Figure 3. The optimal mixed ratio of the filter components

5.1 Numerical Results

Table 2. Summary of the means for filtered rainwater vs. Unfiltered rainwater

Parameters	Units	DENR Class A Standards	Unfiltered Rainwater	Filtered Rainwater	Reduction of Contamination Percentage
Chloride	mg/L	250	258	248	3.88%
Chemical Oxygen Demand (COD)	mg/L	60	71	58	18.31%
Phosphate	mg/L	0.5	0.58	0.48	17.24%
Nitrate as N	mg/L	7	9.9	6.9	30.30%
pH	units	6.5 - 8.5	8.38	7.18	14.32%
TSS	mg/L	50	51.78	47	9.23%
Fecal Coliform	MPN/100mL	< 1.1	126.75	1.80	98.58%

Shown in this table 2 are the means for each parameter under the Unfiltered Rainwater group and Filtered Rainwater group alongside with its percentage of reduction in contamination. It can be seen that all of the parameters had reduced amounts after filtering the rainwater through the filtration system. The results obtained by the proponents have agreed with other similar studies done previously by other researchers. The use of activated carbon to remove harmful impurities, whether in the treatment of water or air, is essential (Alves et al. 2021).

5.2 Discussion

Chloride

It is better for the Chloride Parameter if the amount of the substance found in the water is less than or equal to 250. Thus, the table shows that the means of the data of Filtered Rainwater is within the standards dictated by Class A for Chloride. As for the Unfiltered Rainwater, it is shown here that it does not comply with the standards for Class A. The analysis to find the decrease of the Chloride Parameter from the Filtered Rainwater compared to the Unfiltered Rainwater resulted in a 3.88% reduction of contamination. The depletion of the Chloride Parameter in the Filtered Rainwater made the sample comply with Class A Standards.

Chemical Oxygen Demand (COD)

Based on the DENR Water Quality Standards, it is better if the number of COD found in the water is less than or equal to 60. Furthermore, the table shows that the means of the data of Filtered Rainwater lies under the standards dictated by Class A; thus, it shows compliance. As for the Unfiltered Rainwater, it is shown here that it does not comply with the standards for Class A. The Chemical Oxygen Demand (COD) Parameter Test conducted for the Filtered Rainwater as compared to the Unfiltered Rainwater resulted in an 18.31% reduction of contamination. The percentage for the COD Test is significant as the collected rainwater after the filtration process shows improvement; hence, the study figured that it is now in compliance with Class A Standard.

Phosphate

The chart shows that the means of the data of Filtered Rainwater is within the range of the standards dictated by Class A for phosphate. However, as for the Unfiltered Rainwater, it is shown here that it does not comply with the standards for Class A. The table also displays the reduction of contamination percentage of the Phosphate Parameter Test conducted for the Filtered Rainwater as compared to the Unfiltered Rainwater. In the study, it was computed that the level of Phosphate from the Unfiltered Rainwater decreased by 17.24% using the Water Filter prototype.

Nitrate as N

For Nitrate, it is better if the amount of the substance found in the water is less than or equal to 7. With this, the table shows that the means of the data of Filtered Rainwater is within the standards dictated by Class A. As for the Unfiltered Rainwater, it is shown here that it does not comply with the standards for Class A. Moreover, it can be observed from the table that the Nitrate Parameter Test conducted for the Filtered Rainwater as compared to the Unfiltered Rainwater resulted in a 30.30% reduction of contamination.

Acidity & Basicity (pH)
For the pH level, it is acceptable if the level in the water is within the neutral case having a 6.5-8.5 result. Thus, the table shows that the means of the data of Filtered Rainwater and Unfiltered Rainwater are within the standards dictated by Class A. In line with this, the analysis to find the decrease of the Acidity and Basicity (pH) Parameter from the Filtered Rainwater as compared to the Unfiltered Rainwater resulted in a 14.32% reduction of contamination.

Total Suspended Solids (TSS)
The table shows that the means of the data of Filtered Rainwater is within the standards dictated by Class A. In this case, it is better if the amount of the TSS substance found in the water is less than or equal to 50. With this, the means of the Filtered Rainwater comply with the criteria; however, the Unfiltered Rainwater does not comply with the standards for Class A. In the study, it was computed that the level of Phosphate from the Unfiltered Rainwater decreased by 9.23% using the Water Filter prototype.

Fecal Coliform
For the Fecal Coliform, it is deemed acceptable if the data result is lower than 1.1. Thus, the table shows that the means of the data obtained for the Filtered Rainwater is close to the acceptable range. However, as for the Unfiltered Rainwater, it is shown here that it does not comply with the standards for Class A. The Fecal Coliform Parameter Test conducted for the Filtered Rainwater as compared to the Unfiltered Rainwater resulted in a 98.58% reduction of contamination. The percentage for the COD Test shows significant improvement; hence, the study figured that the Filtered Rainwater is now in compliance with Class A Standard.

Conclusion
Overall, It can be observed that the fecal coliform had the most significant reduction among the parameters, having the amount of 126.75 MPN/100 mL being reduced to 1.80 MPN/100 mL with a total of 98.58% reduction of contamination. The huge decrease in the amount of fecal coliform can be attributed to the use of activated carbon as one of the main components in the filtration system. Similar results have been observed by Nguema et al. (2020), who has stated in their study that activated carbon based on coconut shells is effective in fixing bacteria in the treatment of well-contaminated waters. The result of their study showed that 92.4% of fecal coliforms were fixed, together with other bacteria, due to the activated carbon being used in the water treatment process.

5.3 Proposed Improvements

Considering the findings above, the following recommendations are forwarded:

1. The study enabled the researchers to come up with innovative ideas that could help enhance the Philippines and even the world’s water quality and water sanitation practices. Thus, the research paper could be utilized as a reference by present and future researchers studying the Water Filtration process and Rainwater potentials to address more concerns in addition to the objectives presented.
2. The prototype's components were proven to be effective; thus, they could be further analyzed and referred to for additional research of its benefits and usage.
3. The actualized prototype could also be applied to each Filipino household to have a sustainable clean water supply. In addition, it can also be implemented in a large-scale setup to elevate concerns that could be addressed.
4. The initiative of creating a rainwater harvesting system could be intensified with the addition of considering the measurements of the rooftop gutter, drainage piping system, and the application of the components of the tested prototype for a wide-scale and complete design structure of the filtration system.
5. A pilot study is also recommended for enhanced and comprehensive community involvement. The ideals of the project could help the country more if the local government and NGO units are willing to study the results of the research and are willing to participate in its implementation.

6. Conclusion

Water scarcity involves water stress, shortage or deficits, and water crisis resulting from the consolidation of factors, including the increase in population, urbanization, and climate change. Further, the Philippines, just like the tropical nations and countries with a large body of water source, are expected to have enough water to meet household, industrial, agricultural, and environmental needs; however, resulting to not being optimized due to the lack of sustainable means to provide it in an accessible manner to all its people. As the research led to an analysis that there is truly a grave problem for a need for reliable and usable water resources, the proponents initialized the application of an efficient rainwater harvesting and filtration system for the Filipino households.

The study found that collecting rainwater can be considered a sustainable source of household water that can adverse the effects of water scarcity in the Philippines and address the volume of wastewater or stormwater runoff during the rainy season. Moreover, the study also showed the effectiveness of coconut shells as an alternative material for producing activated carbon in a rainwater filtration system, its effectiveness to reduce or eliminate contaminants in rainwater, and its viability when adopted in the Philippines. The collection of rainwater could help as well in the economical aspect of the nation to reduce costs for managing water collected by the Ipo, La Mesa, and Angat Dam and will help the LGUs to prioritize water sanitation is considered to be a top essential to elevate the quality of health.

In line with this, the proponents successfully actualized a small-scale prototype of a Rainwater Filtration System with the activated coconut carbon as an innovative integrated component to filter rainwater samples obtained from the subject site. The formulated Filter prototype is an idea by the researchers to mitigate the effects of water scarcity that could help Filipino households access a water source that could be used for industrial purposes. In addition, the optimal mixed-ratio and the type of components inside the system, particularly the gravel, sand, and the activated coconut carbon with a percentage ratio of +-33%: +-30%: +-16% were also figured and applied to the biofilter. The Filter prototype was used to filter fifteen (15) rainwater samples that were analyzed through the seven (7) water parameters to find if the results are on par with the Global Water Quality Standards and if there is truly a reduction of contamination of the filtered rainwater as compared to the unfiltered rainwater.

6.1 Summary of Water Analysis

The researchers analyzed unfiltered and filtered rainwater by gathering necessary data through samples of rainwater from Las Piñas, Metro Manila. Rainwater was collected during heavy rainy days and filtered through the activated coconut carbon filtration system to test the characteristics and performance. The filtered rainwater then, along with other sources of water and unfiltered rainwater, is then sent to the water testing laboratory to determine the water quality from these sources.

In the analysis of the seven (7) water quality parameters between the Filtered Rainwater and Unfiltered Rainwater, it was found that there was a reduction in the contaminants after the filtration of the rainwater, particularly in the TSS parameter and the Fecal Coliform parameter.

The two groups are then compared to the Class A standards for freshwater and assessed if they comply with the standards. It was found from the means of the Filtered Rainwater that it complies with the Class A standards for all water quality parameters. However, from the means of the Unfiltered Rainwater, it was found that all the parameters, except for the pH level, do not comply with the standards set for each water quality parameter.

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