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Original Research Article

Rainwater Processing System into Ready-to-Drink Water PIR Sensor (Hc-Sr501) and Arduino Uno

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Abstract

Lack of drinking water is a condition where the availability of clean water is insufficient to meet basic human needs. This study aims to build a rainwater treatment system based on the Passive Infrared (PIR) HC-SR501 sensor and the Arduino Uno device. The method used is the applied experimental method. The results of the study showed that the content of rainwater seen from the physical, chemical and biological properties after the filtration process was as follows: temperature 27.4 ° C, total dissolved solids (TDS) 163 mg/l, turbidity 1.31 NTU, color 0 TCU -> 0 TCU, odorless, pH 8.1, nitrate (as NO_3) 0.7 mg/l, nitrate (as NO2) 0.12 mg/l, Chromium Valence 6 (Cr6+) 0 mg/l, Iron (Fe) 0.61 mg/l, Manganese (Mn) 0.03 mg/l, Chlorine Residue 0 mg/l, Arsenic (As) not detected, Cadmium (Cd) 0.060 mg/l, Lead (Pb) 0.06 mg/l, Fluoride (F) 0 mg/l, Aluminum 0.05 mg/l, Total Coliform 4 CFU/100ml, E.coli 0 CFU/100ml. This data shows that rainwater has changed from not drinkable to drinkable although there are some shortcomings that require modification, namely in the Ultraviolet lamp. The modified filtration treatment design can optimize the physical, chemical, and biological properties of the air.

Keywords: Rainwater processing; PIR-sensor (HC-SR501); Arduino Uno; ready-to-drink water.

1. Introduction

Rainwater is the result of a natural process that occurs as water droplets from the atmosphere that fall to the earth's surface due to condensation of water vapor in the atmosphere. This process then forms rain clouds (Winarno et al., 2023). Rainwater is also a natural water source (Zuliarti and Saptomo, 2021) which is essential for life on Earth. Rainwater content can vary depending on several factors including geographic location, air pollution (Nitasari et al., 2023), and the atmospheric conditions where the rain forms. Rainwater is pure water that occurs from the evaporation of sea water or the earth's surface which undergoes a condensation process in the atmosphere and finally falls back to the earth in the form of rain (Joleha et al., 2019). The content of rainwater depends on the environmental conditions where the rain occurs and falls, the water can be contaminated with various soluble or dissolved substances.

Some contaminants that may be present in rainwater include (Supriatin et al., 2017): Gases and Particles: Rainwater can contain various gases such as nitrogen dioxide (NO2), sulfur dioxide (SO2), oxygen (O2), carbon dioxide (CO2), and several other types of gases that can dissolve in rainwater during fall process. Solid particles such as dust, soil and air pollutants can also be dissolved in rainwater. Air Pollution: Air pollution such as motor vehicle exhaust, industrial emissions, and other air pollutants can be carried by the wind and dissolved in rainwater when it falls to the earth's surface. Bacteria and Microorganisms: Rainwater can also contain bacteria and other microorganisms, especially if it comes into contact with contaminated surfaces such as building roofs or contaminated soil. Environmental

Pollution: Chemical substances such as pesticides, herbicides, heavy metals and other chemicals in the environment can also be dissolved in rainwater.

The impacts of contamination in rainwater on human health include: Long-term exposure to rainwater containing heavy metals and organic pollutants (Kenny et al., 2023) can cause serious health problems such as nerve disorders, organ damage, and cancer. Biological contaminants in rainwater can cause infectious diseases if the water is used for drinking or sanitation purposes without adequate treatment. The level of rainwater contamination can vary in various places and is influenced by various things (Mardizal et al., 2024), including industrialization, agricultural activities, vehicle traffic, and local environmental policies. Monitoring and managing stormwater quality is important to protect human health, the environment and sustainable water resources.

Often, rainwater that falls only becomes surface runoff, or surface runoff, and is not used (Asnaning et al., 2018). Experiments to process rainwater for drinking water are an effort to utilize rainwater for daily needs (Budiman et al., 2023) as a very possible alternative. The use of rainwater for alternative drinking water (Nurdin et al., 2019) needs needs to be (Nurdin et al., 2019) considered carefully because rainwater can be contaminated with various dissolved or dissolved substances, especially if it is exposed to air pollution, surface pollution, or other contamination when it falls to the earth's surface. Even though rainwater is basically clean (Wijaya, 2021), it does not yet meet the level of clarity suitable for drinking water (Dara Lufira et al., 2021) and there is a risk of contamination by dangerous substances (Nopan Bagas et al., 2024) which can be dangerous to health if consumed without proper processing.

Some considerations when using rainwater for drinking water includes as follows. Filtering: Before being used for drinking water, rainwater must be filtered to remove solid particles such as dust, leaves and other impurities that may be dissolved in it. Treatment: Rainwater must be treated properly so that dangerous contaminants can be removed. Storage: To prevent contamination during storage, storage should be carried out using clean and closed containers. It is important to keep storage containers clean so that no bacteria or algae grow in them. Quality Testing: Before being used for human consumption, rainwater must be quality tested by an accredited laboratory to ensure its suitability for drinking.

In some cases, rainwater can be used as an alternative source of drinking water (Kapita et al., 2022) if it has gone through appropriate processing and has been tested to meet applicable drinking water quality standards. However, it is important to understand the risks and ensure that rainwater is properly treated and tested before being used for human consumption (Adelia et al., 2022). In areas prone to drought, rainwater harvesting is a very important solution to ensure the sustainability of water supplies, especially for clean water and drinking water needs. This rainwater harvesting system can greatly help overcome the problem of water scarcity during dry seasons, where water supplies from conventional sources, such as rivers or reservoirs, can be very limited. In drought-prone areas, utilizing rainwater collected during the rainy season can reduce dependence on other limited water sources. However, to ensure that harvested rainwater meets safe drinking water quality standards, a proper treatment system is needed. Several studies have been carried out on processing rainwater for clean water needs. However, when there is a drought, the need for drinking water also becomes a problem. So, to meet drinking water needs in areas prone to drought, it is very important to carry out further research to utilize rainwater that is stored during the rainy season and will be harvested during the dry season.

Therefore, it is necessary to carry out research on the use of rainwater for alternative drinking water by using an automatic filtration device and which can be consumed directly without having to be cooked first. The aim of this research is to create a rainwater treatment system for drinking water based on a PIR type sensor (HC-SR501) and an Arduino Uno device. This type of sensor (HC-SR501) is used to detect human movement based on infrared radiation emitted by the human body. The HC-SR501 PIR sensor has two main settings that can be adjusted, namely sensitivity and delay Time. Sensitivity to adjust the sensor detection distance so that the sensitivity can be adjusted using the potentiometer available on the sensor. Delay Time to adjust how long the sensor will continue to send an output signal (HIGH) after detecting movement. This delay time can also be set using a potentiometer. This sensor is placed under the drinking water output which functions to detect the movement of the hand of a person holding a glass to take drinking water, then the device will automatically work and the water will flow until the glass is pulled from its place then the device will stop working.

2. Methods

This research is experimental and applied by creating a rainwater treatment system for ready-to-drink water. The samples tested were rainwater before filtration and rainwater after filtration which was tested at the Regional Health Laboratory of the Health Service.

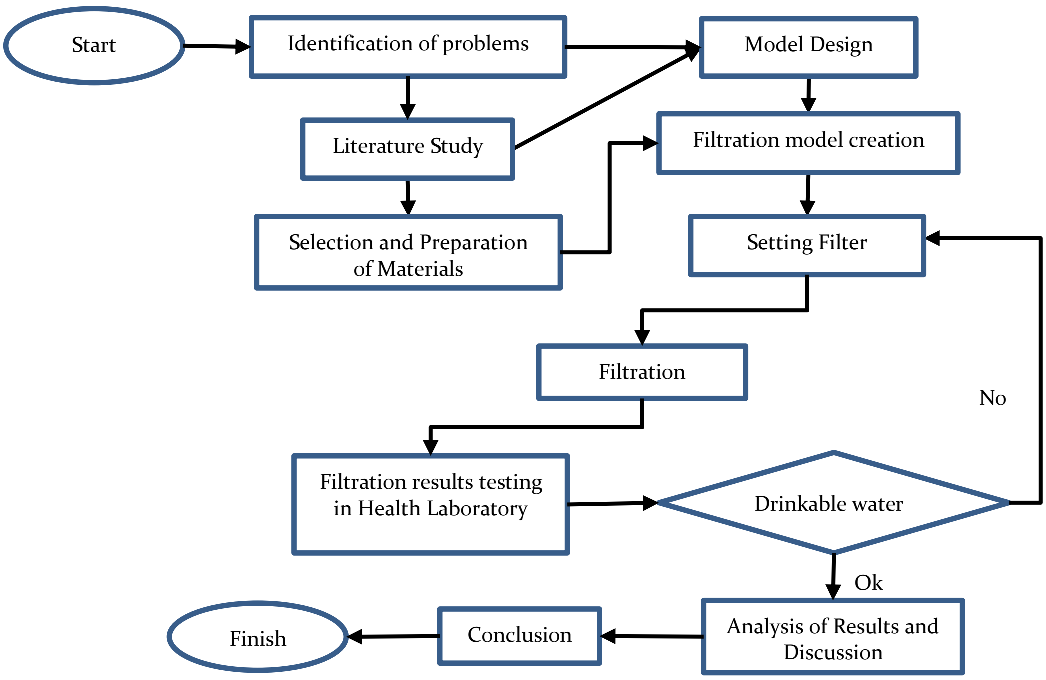

Figure 1. Research Flow

The steps in the research are as Table 1 follows:

Table 1 Table of research steps

No	Job description
1	Problem identification: identify problems in drought-prone areas in Bojonegoro Regency. The problems that often occur are regarding the need for clean water and drinking water. So, the solution that can be applied in drought-prone areas is to utilize rainwater with a rainwater harvesting system that can be used for clean water and drinking water needs.
2	Literature study: after identifying the problems, then conduct a literature study related to rainwater as clean water and drinking water from several similar studies that have been conducted.
3	Model design: create a proper and simple filtration tool design.
4	Selection of tools and materials: after making a design, the next step is to choose the type of tools and materials that will be used in making the filtration tool.
5	Creating a filtration model: creating a filtration tool or model according to the design diagram that has been created.
6	Installing a filter tube: assembling the filter by installing an FRP tube by filling the materials in the FRP tube and installing a pipe installation according to the needs and assembled with a

No	Job description
	housing and membrane filter cartridge and combining it with an ultraviolet lamp and installing a pump and control device to turn the system on and off.
7	Testing the filtration tool; after the filtration tool/model is complete, the next step is to experiment with the tool and test the filtration results.
8	Testing the filtered water in a health laboratory: testing the filtration results in the form of rainwater that has been processed using a filtration tool in a health laboratory.
9	The results of testing water are suitable or unsuitable for consumption: the results of water testing from the health laboratory are then analyzed according to the provisions of drinking water and clean water quality standards.
10	If not yet drinkable: if the test results show that the results are not yet drinkable, the membrane filter replacement process is repeated by replacing the membrane filter with a softer size to obtain optimal filtration results in accordance with drinking water quality standard regulations
11	If drinkable: if the test results show that the water is drinkable, the analysis of the research results as a whole is continued and the research results are concluded until the research process has been finished.

3. Result and Discussion

3.1 Making a Ready-to-Drink Water Treatment System

Creating a drinking water treatment system involves various stages, from planning and design to construction and testing. Begins with identifying Needs: determining the required tool capacity based on the amount of use and daily needs. Determining Water Source: identifying the source of water to be treated (eg well water, river water, rainwater). Selecting a Treatment Method: Determining the appropriate water treatment method (filtration, disinfection, etc.). An image of the system design can be seen in Figure 2 below.

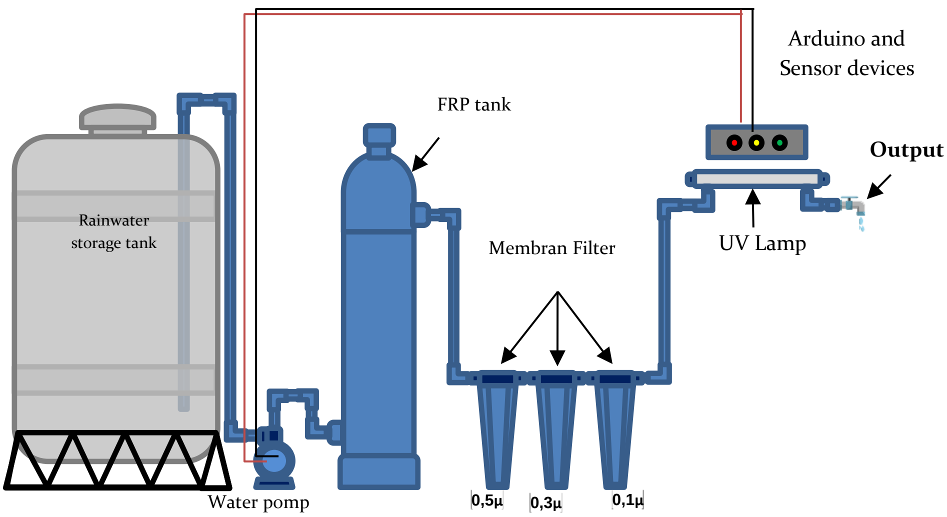

Figure 2. Design of rainwater treatment plants for drinking water

From the application of the design above, this research was carried out by assembling all the required components and making it into a practical system for processing drinking water from rainwater as in Figure 2 above. There are several components in making this filtration tool, including the main components which include: a filter that functions to remove large and small particles, Activated carbon is used to remove organic substances and odors, ultrafiltration or reverse osmosis membrane that functions to remove small contaminants such as bacteria and viruses, ultraviolet or chlorine disinfection that functions to kill any remaining pathogens, storage tank that functions to store treated water and a pump that functions to circulate water through the system. The materials and tools needed to make this tool include: PVC pipe that functions to circulate water between components, water tank for initial and final storage, ceramic or silica sand filter for initial filtration, activated carbon that functions to remove odors and chemicals, ultraviolet unit for final disinfection, water pump for water circulation and fittings and valves that functions to connect pipes and control water flow.

3.2 Water Quality Testing

According to the Republic of Indonesia Minister of Health Regulation no. 2 of 2023 regulates the implementation of PP no. 66 of 2012 relating to environmental health, water quality testing as a guarantee that the water tested has met standards that are suitable for consumption and use. This testing involves measuring various physical, chemical, and microbiological parameters.

Table 2 Rainwater Test Results Before Processing

No.	Parameter	Unit	Maximum levels allowed *)	Results	Information	Result of Analysis
	I. Physics					
1	Temperature	°C	Air temperature ± 3 °C	27.2		Not meet
2	Number of Dissolved Solids (TDS)	mg/ltr	<300	1115		Meet
3	Turbidity	NTU Scale	<3	2.47	NTU: Nephelo Turbidity Unit	Meet
4	Colour	TCU	10	0	TCU: True Colour Unit	Meet
5	Smell	-	odorless	odorless		Meet
	II. Chemistry					
6	pH	#	6.5 - 8.5	7.6	pH Minimum 5.5	Meet
7	Nitrat (As NO_3)	mg/ltr	20	1.5		Meet
8	Nitrit (As NO_2)	mg/ltr	3	0.03		Meet
9	Valence Chromium (Cr^{6+})*	mg/ltr	0.01	0		Meet
10	Iron (Fe)	mg/ltr	0.2	0.02		Meet
11	Mangan (Mn)	mg/ltr	0.1	0.02		Meet
12	Residual chlorine	mg/ltr	0.2-0.5 with a contact time of 30 minutes	0		Meet
13	Arsen (As)	mg/ltr	0.01	-		Meet
14	Kadmium (Cd)	mg/ltr	0.003	0.031		Not meet
15	Lead (Pb)	mg/ltr	0.01	0.01		Meet
16	Fluoride (F)	mg/ltr	1.5	0		Meet
17	Aluminium (Al)	mg/ltr	0.2	0.04		Meet

Source: (Test Results at the Tuban Regional Health Laboratory, 2024)

*) PERMENKES RI No. 2 of 2023
Concerning Implementing Regulations of PP Number 66 of 2012 about Environmental Health

From the table above it can be seen that all test parameters (Kementerian Kesehatan, 2023) show safe results in accordance with the Minister of Health Regulation Number 2 of 2023. So, it can be said that rainwater is safe for clean water needs in accordance with applicable regulations. The table 3 below is the results of microbiological tests on rainwater before processing.

Table 3 Results of microbiological testing of rainwater before processing

Parameter	Unit	Method	Level Allowed	Results	Result of Analysis
Total Coliform (Total Coliform Bacteria)	CFU/100ml	Membrane Filter	0	36	Not meet
E. Coli (Escherichia coli)	CFU/100ml	Membrane Filter	0	6	Not meet

Source: (Test Results at the Tuban Regional Health Laboratory, 2024)

Table 3 above shows that rainwater before being processed using a filtration device showed a value of 36 CFU for coliform bacteria and 6 CFU for e-coli bacteria and exceeds the maximum allowable levels (Menteri Kesehatan Republik Indonesia, 2017). It can be interpreted that the water is not suitable for consumption.

Table 4 Results of Microbiological Testing of Rainwater After Processing

No.	Parameter	Unit	Maximum levels allowed *)	Results	Information	Result of Analysis
	I. Physics					
1	Temperature	°C	Air temperature ± 3 °C	27.4		Not meet
2	Number of Dissolved Solids (TDS)	mg/l	<300	163		Meet
3	Turbidity	Skala NTU	<3	1.31	NTU: Nephelo Turbidity Unit	Meet
4	Colour	TCU	10	0	TCU: True Colour Unit	Meet
5	Smell	-	odorless	Not Smell		Meet
	II. Chemistry					
C6	pH	#	6.5 - 8.5	8.1	pH Minimum 5,5	Meet
7	Nitrat (As NO_3)	mg/ltr	20	0.7		Meet
8	Nitrit (As NO_2)	mg/ltr	3	0.12		Meet
9	Valence Chromium (Cr^{6+})*	mg/ltr	0.01	0		Meet
10	Iron (Fe)	mg/ltr	0.2	0.61		Not Meet
11	Mangan (Mn)	mg/ltr	0.1	0.03		Meet
12	Residual chlorine	mg/ltr	0.2-0.5 with a contact time of 30 minutes	0		Meet

13	Arsen (As)	mg/ltr	0.01	-	Meet
14	Kadmium (Cd)	mg/ltr	0.003	0.060	Not meet
15	Lead (Pb)	mg/ltr	0.01	0.06	Not Meet
16	Fluoride (F)	mg/ltr	1.5	0	Meet
17	Aluminium (Al)	mg/ltr	0.2	0.05	Meet

Source: (Test Results at the Tuban Regional Health Laboratory, 2024)

*) PERMENKES RI No. 2 of 2023

Concerning Implementing Regulations of PP Number 66 of 2012 concerning Environmental Health

From the table 4 above it can be seen that all test parameters show safe results. It can be said that rainwater is safe for clean water needs in accordance with applicable regulations.

Table 5 Results of microbiological testing of rainwater after first processing

Parameter	Unit	Method	Level Allowed	Results	Result of Analysis
Total Coliform (Total Coliform Bacteria)	CFU/100ml	Membrane Filter	0	21	Not meet
E. Coli (Escherichia coli)	CFU/100ml	Membrane Filter	0	0	Meet

Source: (Test Results at the Tuban Regional Health Laboratory, 2024)

Table 6 Results of microbiological testing of rainwater after second processing

Parameter	Unit	Method	Level Allowed	Results	Result of Analysis
Total Coliform (Total Coliform Bacteria)	CFU/100ml	Membrane Filter	0	4	Not meet
E. Coli (Escherichia coli)	CFU/100ml	Membrane Filter	0	0	Meet

Source: (Test Results at the Tuban Regional Health Laboratory, 2024)

From table 5 and table 6 above, it can be seen that for clean water needs, from the results of laboratory tests with physical, chemical and biological characteristics, it is known that the rainwater tested is suitable for meeting clean water needs. Meanwhile, there are two different microbiological test results on rainwater samples after going through a filtering process with filter membranes measuring 0.5 microns, 0.3 microns and 0.1 microns. This test aims to assess the microbiological quality of rainwater after processing using this treatment system, focusing on the presence of coliform bacteria and Escherichia coli (E. coli), which are important indicators in assessing the microbiological safety of water for human consumption.

The rainwater filtration system using filter membranes with sizes of 0.5 microns, 0.3 microns and 0.1 microns showed excellent effectiveness in removing pathogenic bacteria such as E. coli, with results of 0 CFU in both tests. However, even though 0 CFU of E. coli was detected, coliform bacteria were still detected in quite significant numbers, namely 21 CFU in the first test and 4 CFU in the second test. The decrease in coliform numbers in the second test shows that using more smaller filters (0.3 microns and 0.1 microns) can improve water quality, although there is still a small amount of coliform contamination.

Even though there is a small amount of coliform contamination, the results of microbiological tests show that this filtered rainwater can be considered suitable for meeting clean water needs, especially if combined with other processing techniques such as disinfection (for example using chlorine or UV) to further reduce remaining bacteria. It is important to further reduce coliform contamination to near 0 CFU so that water quality meets more stringent drinking water standards.

Overall, healthy drinking water must meet physical, chemical and microbiological quality standards stipulated in Minister of Health Regulation Number 32 of 2017. Water quality checks include physical parameters (such as temperature, color, odor, turbidity), chemical (such as pH, levels of heavy metals, chlorine, TDS), as well as microbiology (including coliforms, E. coli, and other pathogens). Strict processing and monitoring is very important to ensure the water consumed is safe and does not harm health (Pontororing et al., 2019). These include water that must be clear or not cloudy, colorless, tasteless, neutral pH, and must not contain pathogenic bacteria such as Escherechia coli (Vaulina et al., 2021). The regulation clearly states that hardness is one of the requirements that must be met (Menteri Kesehatan Republik Indonesia, 2017).

4. Conclusions

The modified filtration treatment design showed significant improvements in the physical, chemical, and biological quality of rainwater. Although before the rainwater filtration met the clean water quality standards of the Ministry of Health of the Republic of Indonesia Number 2 of 2023, the final results were more optimal after going through the filtration and sterilization process. The water produced is safer and more suitable for consumption as drinking water. For better results, it is necessary to install a longer ultraviolet lamp to be more optimal in eliminating bacteria. Filtration System Circuit Diagram: Preparing Rainwater Samples, Rainwater Content Analysis. FRP tube filter system circuit and membrane filter with a softness size of 0.5 Microns, 0.3 Microns, 0.1 Microns. Ultraviolet (UV) Lamp, Output Channel Arduino Uno Circuit & PIR Sensor (HC-SR501). Water Quality data output display.

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