DESIGN AND FABRICATION OF AN AUTOMATED RAINWATER COLLECTION SYSTEM USING MICROCONTROLLER

A thesis
by

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DECLARATION

We hereby , declare that the work presented in this project is the outcome of the investigation and research work performed by us under the supervision of **Hasan Tareq Mahin** , Lecturer , Depertment of of Mechanical Engineering , Sonargaon University (SU) . We also declare that no part of this project and thereof has been or is being submitted else where for the award of any degree.

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ABSTRACT

The development of a society is significantly dependent on the availability of healthy water. But presently like all the other parts of the world, Bangladesh is facing increasing scarcity of water resources. In this situation, sustainable management of freshwater can be ensured by the utilization of alternative water sources. As Bangladesh is privileged by a huge quantity of rainwater annually throughout the country, rainwater collecting can be the most potential alternative water supply option for Bangladesh. In this approach, a system for collecting rainwater is developed. Here microcontroller is used for automatic controlling of the system to get suitable water in an easier way where two separate reservoirs are used for drinking water and general-purpose water. To execute this system more adequately and sustainably some recommendations have been also made as future steps.

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LIST OF ABBREVIATIONS

RWH	Rainwater Harvesting
SMPS	Switched Mode Power Supply
DC	Direct Current
AC	Alternating Current
RPM	Revolution per Minute
PWM	Pulse Width Modulation
GND	Ground
Amp	Ampere
I/O	Input /Output
DCV	Direction Control Valve
IOT	Internet of Things

Chapter 1

INTRODUCTION

1.1 Background

Water that covers about 70% of earth's surface is an essential substance for the nature and the ecosystem of the world. It has a number of unique chemical and physical properties that make it indispensable to life and, in fact, it makes up about 60% of adult body weight [1, 2]. Water is reported to be grouped into atmospheric, surface, and ground water where atmospheric water includes moisture contained in the cloud, which precipitates as snow and rain [3]. Rain water, on the other hand, is a form of precipitation in which liquid water falls to the earth's surface [3]. Rainwater and snowmelt are thought to be the primary sources of all drinking water in this world [4]. About 97.5% of all water on earth is salt water, leaving only 2.5% as fresh water, which can be found in various forms such as glaciers and permafrost and groundwater and surface as well as atmospheric water [5, 6]. So it is evident that fresh water, though renewable, is a limited resource. Reports revealed that 768 million people worldwide lack access to safe water, often called physical water scarcity [7], whereas 1.8 billion people are predicted to live in regions with absolute water scarcity by 2030 [8]. This has happened due to unplanned management of water resources, insufficient planning, and insufficient political will. Water scarcity is, therefore, thought to be a serious problem throughout the world, and mitigating this problem is one of the biggest challenges of the 21st century [9].

Figure 1.1: The long walk for water in Bangladesh [11]

In Bangladesh, only 58.5% of the population has access to safely managed water [10]. Bangladesh is still the country with the largest proportion of people exposed to arsenic contamination in the world. More than 1.8 million people in Bangladesh lack access to an improved water source and 36 million lack improved sanitation. In Bangladesh and around the world, millions are navigating the Covid-19 pandemic with the added challenge of living without access to safe water. Bangladesh is looking forward to recharging its aquifers with storm water, reclaimed water, desalinated water and potable water, in an effort to ward off the depletion of this precious resource.

The Bangladesh Water Development Board has finalized a draft national strategy for what it calls managed aquifer recharge and submitted it to higher authorities for approval. Bangladesh ranks sixth in the world for countries with the largest estimated annual groundwater extraction, according to the UN World Water Development Report 2022. By 2030, groundwater levels in the greater Dhaka area may drop by between 3 and 5.1 meters per year, approximately 70 per cent faster than the current rate according to a study by the Bangladesh Water Partnership and supported by the 2030 Water Resource Group [12].

Figure 1.2: Acute water crisis in Satkhira, Bangladesh [13]

Bangladesh has a humid, warm climate influenced by pre-monsoon, monsoon and post-monsoon circulations and frequently experiences heavy precipitation and tropical cyclones. Bangladesh is a very wet country, receiving on average about 2,200 millimeters (mm) of rainfall per year. Most regions receive at least 1,500 mm and others, such as in the northeastern border regions, receive as much as 5,000 mm of rainfall per year [13]. Rainwater harvesting is a simple and low-cost technique that can utilize these rainwater as a resource to solve water crisis.

Bangladesh heavily relies on groundwater for drinking water and irrigation. However, excessive extraction of groundwater has led to depletion of aquifers, causing water scarcity in many areas. The falling water table is a concerning issue that affects both rural and urban communities. Bangladesh is the widespread presence of arsenic in groundwater. Millions of people are exposed to high levels of arsenic through drinking water, leading to severe health problems, including cancer, skin lesions, and various other diseases.

Surface water sources, such as rivers and lakes, suffer from pollution due to industrial waste, agricultural runoff, and improper disposal of sewage and solid waste. This contamination poses risks to human health and ecosystems, affecting the availability of clean water for various uses. Lack of access to clean and safe water contributes to the prevalence of waterborne diseases, including diarrheal diseases, cholera, and typhoid. These diseases disproportionately affect vulnerable populations, particularly children, resulting in high mortality rates and health burdens.

Bangladesh is highly vulnerable to the adverse effects of climate change, such as increased frequency and intensity of floods, cyclones, and salinity intrusion. These climate-related events lead to the contamination of water sources, displacement of populations, and further exacerbation of water-related challenges. Access to proper sanitation facilities, including toilets and wastewater management systems, remains a significant challenge in many areas of Bangladesh. Lack of sanitation infrastructure contaminates water sources and increases the risk of waterborne diseases. Rapid urbanization and population growth in cities pose challenges in terms of water supply, infrastructure development, and management. Many urban areas face inadequate water supply, unreliable distribution systems, and inefficient wastewater management.

Addressing these water problems in Bangladesh requires comprehensive and sustainable solutions. Efforts should focus on promoting efficient water use, implementing appropriate water treatment technologies, enhancing water quality monitoring systems, improving sanitation facilities, and raising awareness about water conservation practices. Additionally, strengthening policies and regulations related to water management and ensuring community participation in decision-making processes are crucial steps toward resolving the water problems in Bangladesh and ensuring access to safe and sustainable water resources for all.

Rainwater harvesting is indeed a valuable approach to address some of the water problems in Bangladesh. By capturing and utilizing rainwater, the following benefits can be achieved:

Supplementing Water Supply: Rainwater harvesting provides an additional source of water, especially during periods of water scarcity. It helps alleviate the burden on groundwater resources and reduces reliance on surface water sources that may be contaminated or facing depletion.

Mitigating Groundwater Depletion: By collecting rainwater for various purposes like irrigation, domestic use, and recharging aquifers, rainwater harvesting helps replenish groundwater reserves. This sustainable practice can contribute to the restoration of groundwater levels and mitigate the adverse effects of excessive groundwater extraction.

Access to Safe Drinking Water: In areas affected by arsenic contamination in groundwater, rainwater can serve as a safe alternative for drinking purposes. Proper collection, storage, and treatment methods can ensure the availability of clean and arsenic-free water, reducing the health risks associated with contaminated water sources.

Reducing Surface Water Pollution: By utilizing harvested rainwater for domestic and agricultural needs, the demand for surface water sources can be reduced. This, in turn, helps alleviate pollution from industrial waste and agricultural runoff, preserving the quality of rivers and lakes.

Climate Change Adaptation: Rainwater harvesting acts as a climate change adaptation measure, particularly in a country prone to frequent floods and cyclones. By capturing rainwater, it reduces surface runoff and flooding, while also providing a decentralized water supply that is less susceptible to disruptions caused by extreme weather events.

Cost-Effectiveness and Sustainability: Rainwater is a free and abundant resource, making rainwater harvesting a cost-effective solution for meeting water needs. It is a sustainable practice that promotes self-sufficiency and reduces the reliance on expensive water treatment systems or the purchase of water from external sources.

To fully leverage the potential of rainwater harvesting in Bangladesh, it is essential to promote awareness, provide education on proper harvesting techniques, and integrate rainwater collection systems into urban and rural infrastructure planning. Implementing regulations and incentives to encourage rainwater harvesting in new constructions and retrofitting existing structures can further enhance its adoption. Additionally, investing in research and development to improve rainwater harvesting technologies and storage methods can optimize its effectiveness and efficiency.

Overall, rainwater harvesting is a valuable strategy that can contribute to addressing water problems in Bangladesh by diversifying water sources, reducing strain on groundwater, improving water quality, and promoting resilience in the face of climate change.

Automation is a method of operating or controlling a process by automatic means. Things such as electronic devices, machines, and even robots are used to automate tasks that used to be completed by humans. Automation can help to collect and reserve rainwater economically, efficiently in a proper way with least human effort.

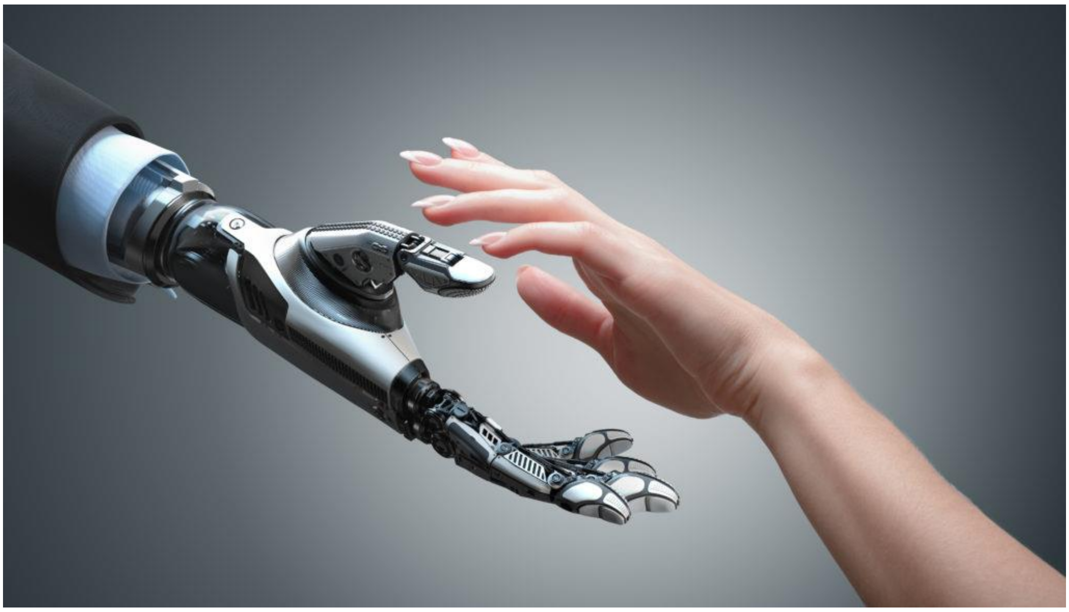


Figure 1.3: Automation helping to solve problems [15]

1.2 Objective of the study

And the main objectives of this study is given below:

- To collect and reserve rainwater.
- To sense rain using rain sensor.
- To open the rain collector when it is raining.
- To reserve water in two different reservoirs for drinking and household using.
- To sense storm or high wind using air flow sensor and keeping water collector

closed.

- To measure water level of the reservoirs using water sensors.
- To generate signal when a reservoir is full.

1.3 Summary

This thesis project focuses on the subsequent actions regarding the design functions, and development phases of the prototype hardware entity along with the amalgamation of control automation of the automatic rainwater collection system.

Chapter 2

LITERATURE REVIEW

In the south-west coastal region of Bangladesh, rooftop rainwater harvesting has been used for drinking purposes for a long time and RWH is also promoting in the arsenic affected rural areas in Bangladesh as part of arsenic mitigation in the country. [16] Investigated the reliability of household based rainwater harvesting used in the coastal areas of Bangladesh and found the maximum reliability varies from 70% to 90% under average climatic condition and the reliability increases insignificantly after the tank size of 3000 L or more. A significant amount of spilled water was found to occur from smaller tanks and there is a scope of increasing the reliability if a proper combination of storage tank capacity, catchment (roof) area and rainwater demand are used in design. A study by [17] assessed the sustainability of RWH system for Dhaka city and found that 11% of water can be saved annually in a building having a roof area of 170 m^2 and this volume of rainwater can serve a building with 60 people for about 1.5 months in a year without traditional water supply. This study also showed that with a 170 m^2 catchment area, about 262 m^3 of water can be harvested over one year.

Optimization of the rainwater tank size is the most widely studied topic of RWH. Notable researchers have conducted on the relationship between rainwater tank sizing and water savings [18, 19, 20, 21, 22, 23, 24]. [25] Developed a tool named eTank using the daily water balance modeling concept. The developed tool was extensively used for the reliability analysis of rainwater tanks for several Australian cities including Melbourne. They have presented that 100% reliability is achievable only for a low demand (i.e. two-people household) scenario with a roof size of 150–300 m^2 having a tank size of 5000–10,000 L; however, for a high demand (four-people household) scenario a 100% reliability is not achievable even with a large roof size (i.e. 300 m^2) and a big tank size (i.e. 10,000 L). Water savings potentials from rainwater tanks in Brazil for a variety of rainfalls were presented by [26]. They have reported an average potential potable water savings of up to 79%; however, for some cities, the potential water savings can be as low as 12% depending on rainfall amount and pattern. A good number of software and simulation-based models were also developed to help assess the reliability and tank size of the RWH system.

Most of the studies on rainwater harvesting potentials were conducted in developed countries, where reliable town water supply exists. Whereas, in a developing country like Bangladesh, where water supply system is under tremendous pressure and at times get interrupted, in-depth studies on rainwater harvesting potentials are scarce. To reduce the burden on conventional water supply systems, an automated rainwater collection and reservation system can be a very much helpful addition.

Chapter 3

METHODOLOGY

3.1 Introduction

The prime objective of the study is to find an automated way of collecting rainwater with very less human interference in efficient and effective manner. The collector collects rainwater depending upon the information about raining and storm. When it is raining and there is no storm or high wind, the collector opens to collect rainwater. Flow direction of the rainwater in pipeline will be determined depending upon time of raining. At initial stage of raining general purpose water will be collected and after some time of raining drinking water will be collected. The tank LED bulb will on when the tank is full. Besides, flow direction will be switched to general purpose water tank when drinking water tank is full. Steps of the studies are follows.

System Requirements:

- The specific requirements of the rainwater collection system are identified, considering factors like collection capacity, storage volume, filtration, and distribution methods.
- The desired level of automation and user interface requirements are determined.

Component Selection:

- Appropriate sensors, actuators, valves, pumps, filters, and other components are selected based on the system requirements.
- Factors such as accuracy, reliability, compatibility, power consumption, and cost-effectiveness are considered.

Microcontroller Selection:

- Different microcontroller options are evaluated based on the project requirements.

- Factors such as processing power, input/output capabilities, memory, and available libraries or development platforms are considered.

System Design:

- A system block diagram is created, showing the main components and their interconnections.
- The functionality of each component and their interactions with the microcontroller is defined.
- The data flow, communication protocols, and control algorithms are determined.

Prototype Development:

- A physical prototype of the rainwater collection system is developed, integrating the selected components and microcontroller.
- The necessary circuits for interfacing sensors, actuators, and other peripherals with the microcontroller are designed or modified.
- The firmware code to control the system behavior and automate the collection, storage, and distribution processes is written and tested.

Testing and Validation:

- Rigorous testing of the prototype is conducted to ensure that the defined objectives and requirements are met.
- The accuracy of sensor readings, reliability of system controls, and proper functioning of all subsystems are verified.
- Data is collected and analyzed to assess the system's performance under different environmental conditions.

System Optimization:

- Limitations or areas for improvement are identified based on the testing and validation results.
- The system design, firmware code, and hardware components are optimized to enhance performance, efficiency, or user experience.

Documentation and Deployment:

- Detailed design specifications, circuit diagrams, firmware code, and operating instructions for the rainwater collection system are documented.
- A user manual or guide explaining the system's functionalities, maintenance procedures, and safety considerations is prepared.
- The system is deployed in the desired location, considering installation requirements, plumbing connections, and integration with existing infrastructure.

3.2 Data Collection and Analysis

The following information are required for proper functioning of the automatic rainwater collection system.

Rain sensor reading: Rain sensor reading is required for detecting rain and raining time. The rain sensor should continuously send signal to the microcontroller when it is raining. Depending upon the signal the microcontroller will decide when to open and close the collector and when to switch the flow direction.

Air Flow Sensor Reading: Air flow sensor is used for knowing the condition of a storm or high wind. If there is a storm or high wind air flow sensor sends a signal to the microcontroller and the microcontroller sends the collector’s closing direction even if it is raining.

Water Sensor Reading: Water sensor reading is important for determining reservoir is full or not. When a tank is full, the water sensor sends a signal to the microcontroller. Then the microcontroller turn on the LED bulb.

Data from the microcontroller: The microcontroller collects, analyzes, and manages the sensor data. It must accurately and instantly record and store sensor readings.

3.3 Block Diagram of the System

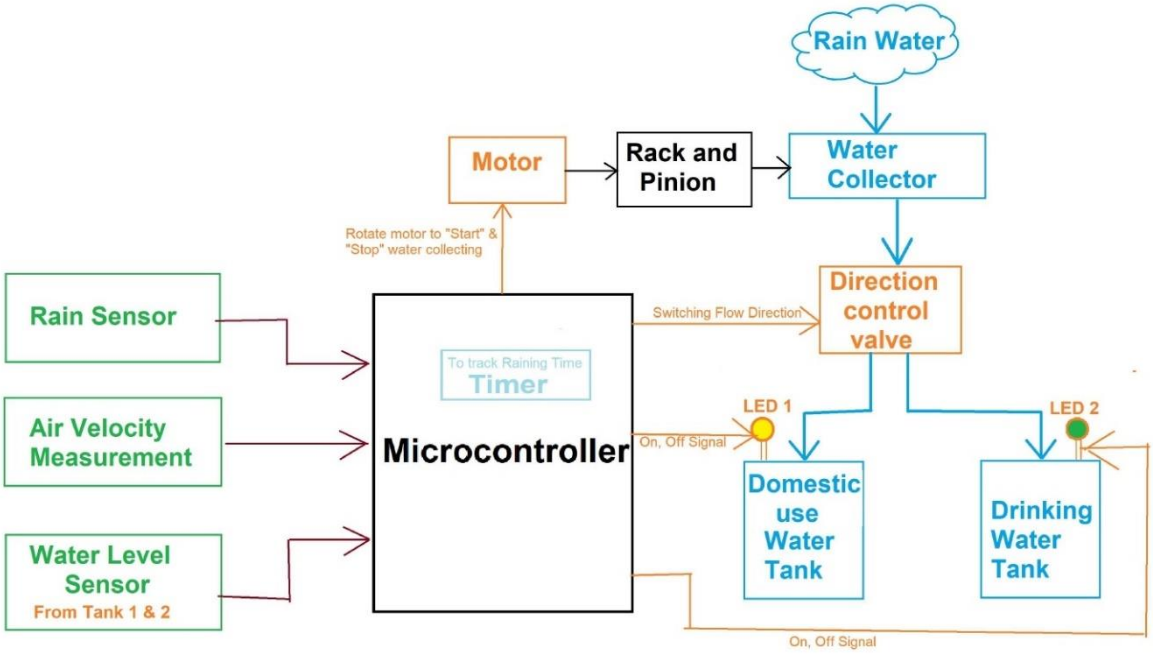


Figure 3.1: Block Diagram of the System

Chapter 4

INSTRUMENTATION

4.1 Introduction

The instrumentation of an automatic rainwater collection system using a microcontroller is a crucial aspect of designing and implementing an efficient and sustainable water management solution. This system combines the principles of instrumentation, microcontroller technology, and intelligent control to automate the collection, storage, and distribution of rainwater.

The primary objective of this system is to harness the abundant resource of rainwater and utilize it for various purposes, such as irrigation, domestic use, or industrial applications. By employing instrumentation techniques, the system can accurately measure, monitor, and control key parameters related to rainwater collection and utilization.

Instrumentation in this context involves the integration of various hardware components, sensors, actuators, and control systems, all working in harmony to ensure seamless operation. The microcontroller serves as the central processing unit that orchestrates the functionalities of the system. It receives input from sensors, makes decisions based on programmed algorithms, and controls the operation of actuators accordingly.

The instrumentation components of the rainwater collection system encompass a diverse range of instruments, including rain sensors to detect precipitation, water sensors to monitor water levels, direction control valves to regulate water flow, water pumps for transportation, and reservoirs for storage. Additionally, other components such as DC motors, power supplies, voltage regulators, and LED bulbs may be employed to facilitate the system's functionality.

The integration of software tools and interfaces with the microcontroller allows for efficient data acquisition, control algorithms, and user-friendly interfaces. The firmware code programmed into the microcontroller enables the automation of tasks such as opening and closing valves, activating pumps, and managing water flow based on real-time sensor readings.

By leveraging the capabilities of a microcontroller and employing instrumentation techniques, the automatic rainwater collection system optimizes the utilization of rainwater resources while reducing reliance on external water sources. The accurate measurement, control, and automation facilitated by instrumentation ensure efficient water management, leading to environmental sustainability and resource conservation.

In this chapter, we will discuss the materials, components, devices, and tools utilized to construct the machine. As it is a synergistic combination of mechanical, electrical, and control systems, all three types of components are used in this project.

4.2 Materials and Instruments

Instruments used in this project can be classified into two categories which are

a. Hardware and materials

b. Control tools and software

4.3 Hardware

The required hardwires are mainly,

1. Power Supply
2. Voltage Regulator
3. Rainwater Collector
4. Direction Control Valve
5. Rain Sensor
6. Water Sensor
7. Water Pump
8. DC Fan

9. Air Flow Sensor
10. Pipe Line
11. Reservoirs
12. LED Bulb

These hardware components, when properly integrated and controlled by the microcontroller, form the backbone of an automatic rainwater collection system, enabling efficient collection, storage, and distribution of rainwater.

4.3.1 Power Supply (SMPS)

Switched-mode power supplies are electronic supplies that incorporate switching regulators to convert electrical power efficiently. They are widely used in a range of modern applications thanks to characteristics like efficiency, low cost, and adaptability.

Figure 4.1: SMPS

A 12V 5A DC SMPS Power Supply is used in the setup. A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. This power supply convertor is built for such purposes. This circuit board converts 220V AC current to 12V DC output voltage. It is used in many small equipment and components such as computers, Television, Cathode ray Oscilloscope, etc. It has inbuilt over-voltage, over current, and short circuit protection. The board is perfectly designed to provide high output performance. This board has an inbuilt LED indicator.

Specifications:

1. Input voltage : 220V AC
2. Output voltage : 12V DC
3. Output current : 5A
4. Frequency : 50HZ/60HZ
5. Dimension : 108mm x 54mm x 25mm
6. Inbuilt over voltage, over current, and short circuit protection

4.3.2 Buck Converter

A buck converter or step-down converter is a DC-to-DC converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current.[1] The efficiency of buck converters can be very high, often over 90%, making them useful for tasks such as converting a computer's main supply voltage, which is usually 12 V, down to lower voltages needed by USB, DRAM and the CPU, which are usually 5, 3.3 or 1.8 V.

Figure 4.2: Buck module

Specifications:

1. Adjustment method: first correct input power (between 4.5-50V) then multimeter to monitor the output voltage and adjust potentiometer (usually clockwise turn boost, buck turn counterclockwise).
2. Input: IN+ input positive IN- input negative
3. Output: OUT+ output positive OUT- output negative
4. Static power consumption is only about 6mA.
5. Connection: Welding, plus pin can be directly soldered after the PCB.
6. Short circuit protection: current limiting, thermal protection, self-recovery.
7. Non-isolated step-down (BUCK) switching regulator.
8. Short circuit protection: Current limiting, self-recovery
9. Potentiometer adjustment direction is Clockwise (increase) and Anti-clockwise (decrease)
10. Non-synchronous rectification

4.3.3 Pipe Line

PVC clear hose is flexible, durable, and non-toxic, without odor. And it’s resistant to high pressure and erosion. Clear PVC Pipe has smooth interior walls for unimpeded flow and reduced sediment buildup; non-contaminating for purity applications; and ease of handling and installation. Clear PVC hose makes it easier to view the liquid inside the tubes, which can prevent kinks and the incorrect transfer of liquids through certain lines.

Figure 4.3: Pipeline

For the system, pipe lines are important parts which are used flowing the collected rainwater.

4.3.4 LED Bulb

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroencephalogram, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm2) and integrated optical components may be used to shape the radiation pattern.

Figure 4.4: LED Bulb

These are a very basic 5mm LED. It has a typical forward voltage of 2.0V and a rated forward current of 20mA.

4.3.5 Rainwater Collector

The collector is an important part of the system. For better durability, strong setup should be used. In this prototype system, an umbrella like setup is used as rainwater collector.

Figure 4.5: Collector

4.3.6 Direction Control Valve

Directional control valve is used to control the direction of fluids. Fluids are liquids or gases. Directional control valves are extensively used in industries for the passage of fluid in the system. It is difficult to adjust manually every control valve at the right time. It controls the fluid flow in a hydraulic or pneumatic system by changing the position of its internal components. It permits or restricts fluid flow to the actuator by opening and closing its ports.

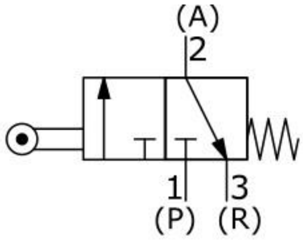


Figure 4.6: 3-2 DCV

A 3/2 directional control valve is used in the setup to control flow direction of rainwater. 3/2-way valve have three connection ports and two positions that can be driven via a solenoid valve. They are used to control a single-action cylinder, for driving pneumatic actuators, used as a blow-off valve, as a pressure release valve, and in vacuum applications.

4.3.7 Rain Sensor (FC-37)

The rain sensor module is an easy tool for rain detection. It can be used as a switch when raindrop falls through the raining board and also for measuring rainfall intensity. The module features, a rain board and the control board that is separate for more convenience, power indicator LED and an adjustable sensitivity though a potentiometer. The analog output is used in detection of drops in the amount of rainfall. Connected to 5V power supply, the LED will turn on when induction board has no rain drop, and DO output is high. When dropping a little amount water, DO output is low, the switch indicator will turn on. Brush off the water droplets, and when restored to the initial state, outputs high level.

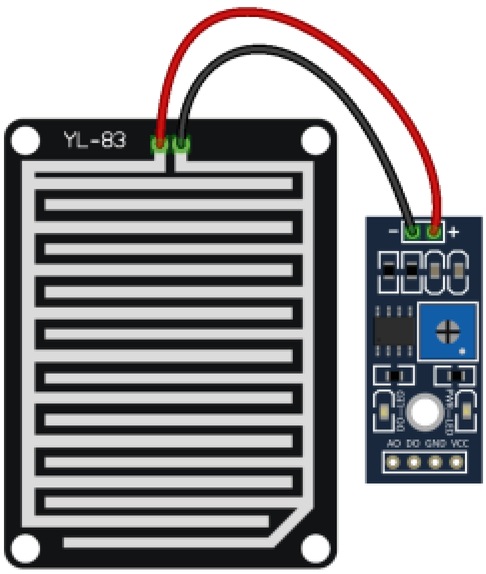


Figure 4.7: Rain sensor

The rain sensor is used to detect water and it can detect beyond what a humidity sensor can. The FC-37 rain sensor is set up by two pieces: the electronic board and the collector board that collects the water drops.

4.3.8 Water Sensor

Grove water sensor module is used in the system for checking whether the reservoirs are full or not. This sensor works by having a series of exposed traces connected to ground and interlaced between the grounded traces are the sense traces. The sensor traces have a weak pull-up resistor of 1 MΩ. The resistor will pull the sensor trace value high until a drop of water shorts the sensor trace to the grounded trace. Believe it or not this circuit will work with the digital I/O pins of your Arduino or you can use it with the analog pins to detect the amount of water-induced contact between the grounded and sensor traces.

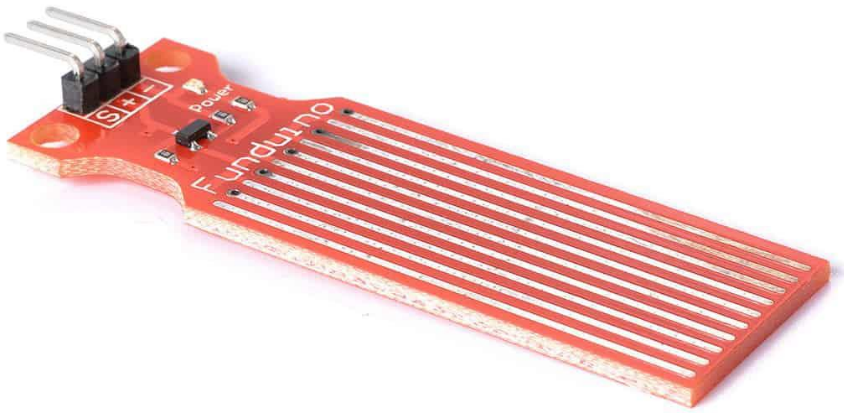


Figure 4.8: Water sensor

Specifications:

1. Operating Voltage: +5V
2. Working Current : <20mA
3. Sensor Type : Analog or Digital
4. Water Detection Area : 40mm x 16mm
5. Mounting Hole Size : 3mm
6. Operating Humidity: 10% to 90% (non-condensating)
7. Working Temperature: -30º C to 50º C
8. Weight : 3 gm
9. Dimensions : 65mm x 20mm

4.3.9 Water Pump

12v DC water pump is used in the prototype automatic rainwater collection system for making demo rainfall. This mini self-priming water pump is a compact and reliable pump that uses 12V DC power. It can also work on 6V DC with decreased flow rate, head and suction. The specs below are for 12V DC.

Figure 4.9: Water pump

Specifications:

1. Type: Diaphragm water pump (self-priming)
2. Working voltage: 12V DC
3. Maximum flow: 1.5 to 2.0L/min
4. Rated current: 0.5 to 0.7A (1.0A if voltage is 6V DC)
5. Empty load current: 0.18A
6. Self-priming vertical suction lift: up to 2m
7. Head: up to 3m
8. Maximum liquid temperature: 80°C
9. Inlet & outlet diameter: 5mm inner diameter, 8.5mm outer diameter
10. Dimensions: 90x40x35mm
11. Weight: 106g

4.3.10 DC Fan

12v DC cooling fan is used in the prototype automatic rainwater collection system for making demo storm.

Figure 4.10: DC fan

Specifications:

1. Frame Material: plastic
2. Wire Length: 0.5 m
3. Dimensions: 120 x 120 x 25 mm
4. Weight: about 107g
5. Operating temperature: -10 °C ~+70 °C
6. Power supply: 5 - 12 VDC
7. Wattage: 1.2W

4.3.11 Reservoirs

Two separate reservoirs are used in the prototype automatic rainwater collection system for reserving drinking water and general-purpose water.

Figure 4.11: Reservoir tank

4.4 Control Tools and Software

Motor Driver, Servo Motor and Arduino Nano are used as main control tools in the automatic rainwater collecting system. Motor Driver is used to control DC motor which drive the pinion and rack to open and close the collector. Servo Motor drives the direction control valve. Microcontroller Arduino Nano receives signals from the sensors, analyses the signals to make decisions and sends control signals to the actuators.

4.4.1 Servo Motor (MG996R)

A prominent type of motor used in robotics and control applications is the MG996R 10kg Servo. It is a servo motor with high torque that can exert up to 10 kg of force. The motor is entirely made of metal, including its gears and housing, giving it strength and endurance. The MG996R Servo is frequently used in robotic projects, including humanoid robot arms and legs, remote-control cars, and model airplanes. By delivering the motor a sequence of pulses, it is operated using pulse-width modulation (PWM), which controls the motor shaft position. The motor is perfect for a number of applications where precise control of motion is necessary since it can rotate across a range of around 180 degrees.

Figure 4.12: Servo motor

Table 4.1 Specifications of Servo Motor

General Specifications	
Operating Voltage (VDC)	4.8 ~6.6
Temperature Range	0°-55°C
Stall Torque @ 4.8V (kg-cm)	9.4
Stall Torque @ 6.6V (kg-cm)	11
Operating Speed @ 4.8V	0.19sec/60°
Operating Speed @ 6.6V	0.15sec/60°
Dead Bandwidth	1µs
Gear Type	Metal
No. of Teeth	25
Length (mm)	40.7

Width (mm)	19.7
Height (mm)	42.9
Weight (gm)	55
Shipment Weight (kg)	0.059
Shipment Dimensions (cm)	5×3×5

4.4.2 Microcontroller (Arduino Nano)

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip. A microcontroller is embedded inside of a system to control a singular function in a device. It does this by interpreting data it receives from its I/O peripherals using its central processor. The temporary information that the microcontroller receives is stored in its data memory, where the processor accesses it and uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and enact the appropriate action.

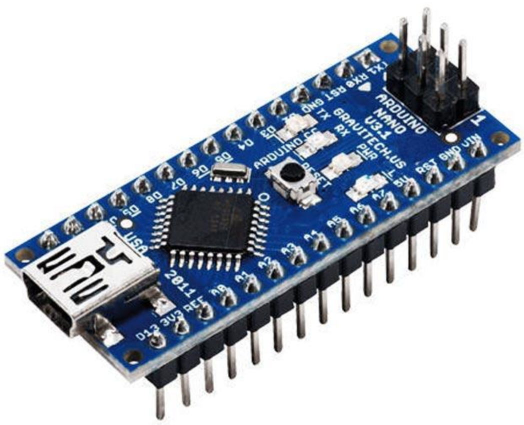


Figure 4.13: Arduino Nano

The Arduino Nano is an open-source breadboard-friendly microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2008. It offers the same connectivity and specs of the Arduino Uno board in a smaller form factor.

Table 4.2 Specifications of Arduino Nano

General Specification	
Microcontroller	Microchip ATmega328P
Operating Voltage (VDC)	5
Input voltage (VDC)	5-20
Digital I/O pins	14 (6 optional PWM outputs)
Analog input pins	8
DC per I/O pin (mA)	40
DC for 3.3 V pin (mA)	50
Flash memory (KB)	32
SRAM (KB)	2
EEPROM (KB)	1
Dimensions in mm (L×W)	45×18
Weight (gm)	7
Clock speed (MHz)	16
USB	Mini-USB Type-B
DC Power Jack	No

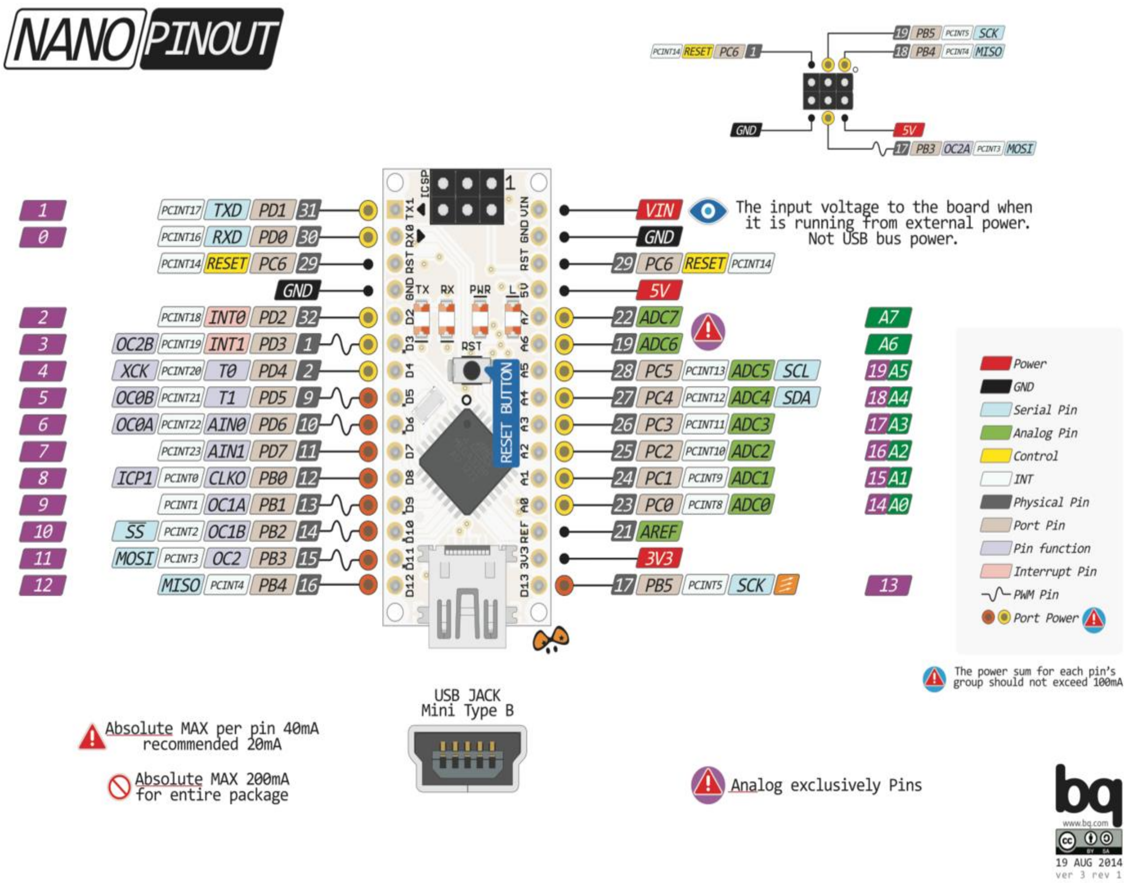


Figure 4.14: Arduino Nano pin diagram

4.4.3 Coding Environment

There are numerous coding environments to take into account while designing an automatic rainwater collector using a microcontroller. Here we chose Arduino Integrated Development Environment (IDE).

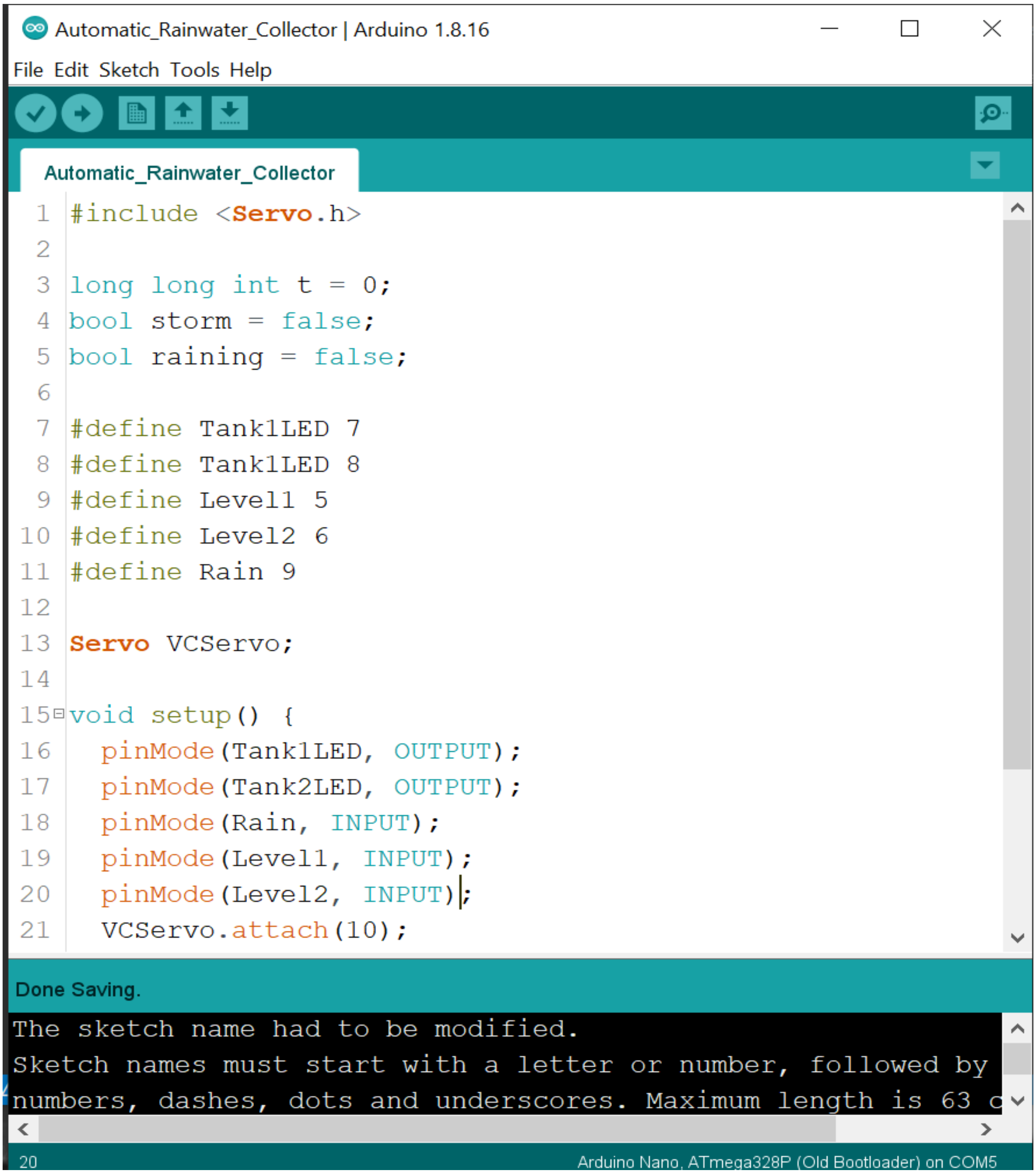
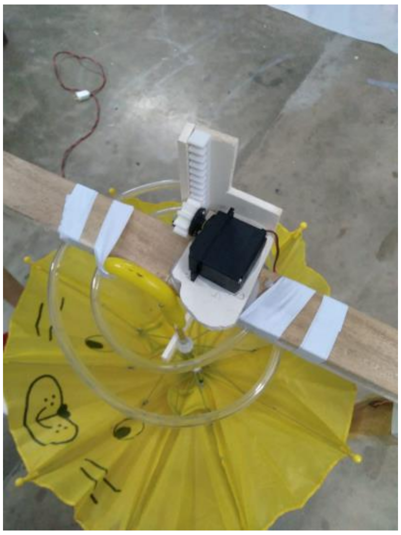


Figure 4.15: Arduino IDE

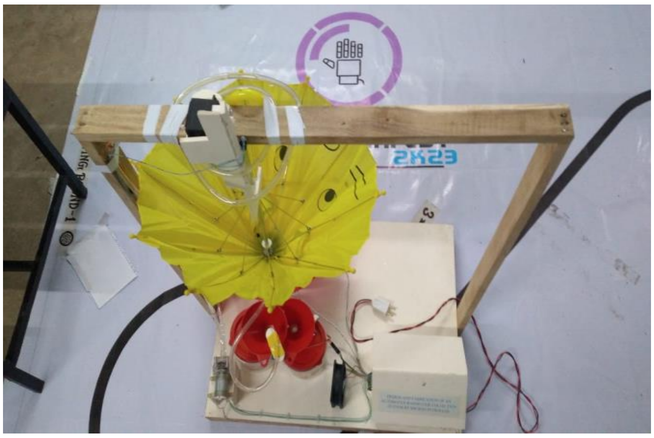
4.5 Setup of Final Project

(a) Electrical Components Setup

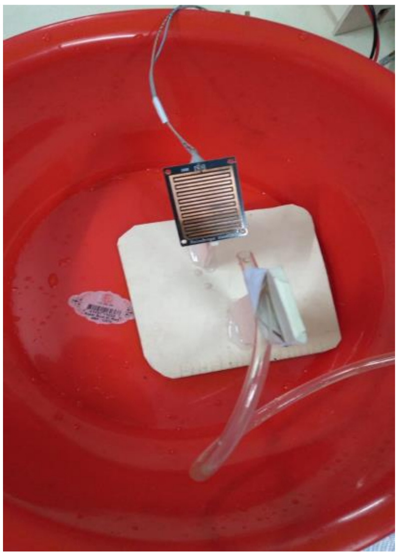
(b) Water Reserviors Setup



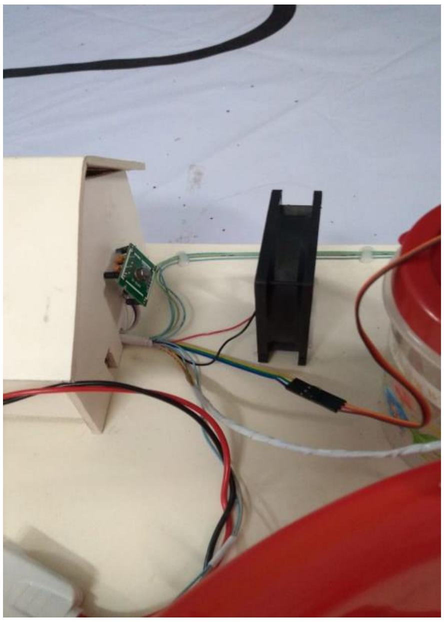
(c) Collector Actuator



(d) Collector Setup



(e) Rain Sensor Setup



(f) Storm Simulator

Figure 4.16: Parts of the Project

Figure 4.17: Setup of the Final Project

4.6 Cost Analysis

Efficient project management involves meticulous planning and financial consideration, especially when developing intricate systems like the automated rainwater collection project. Table 4.3 provides a comprehensive breakdown of the costs associated with various components and phases integral to the project's realization.

The allocation of financial resources is pivotal to ensuring the seamless integration of each component, guaranteeing the system's robustness and reliability. From essential elements such as power supply, microcontroller, and servo motors to sensors, frame, and assembly, every facet contributes to the overall functionality of the automated rainwater collection system.

This cost analysis not only sheds light on the monetary investments required for individual parts but also emphasizes the importance of prudent budgeting for successful project implementation. As we delve into the specifics of Table 4.3, we gain valuable insights into the financial considerations crucial for the sustainable development of this innovative water management solution.

Table 4.3: Cost of various parts and phases of the project

SL. No.	Part Name	Cost	Qty	Total Cost (BDT)
1	Power Supply	600	2	1200
2	360° Servo Motor	650	1	650
3	180° Servo Motor	350	1	350
4	Microcontroller	1000	1	1000
5	Pump	500	1	500
6	Frame	1500	1	1500
7	Water Level Sensor	100	2	200
8	Rain Sensor	150	1	150
9	Air Flow Sensor	300	1	300
10	Rack and Pinion	500	1	500
11	Fan	400	1	400
11	Water tank	100	2	200
12	Others	2000	-	2000
13	Assembly	3000	-	3000
	Total cost			**BDT=11950**

Chapter 5

RESULTS & DISCUSSION

5.1 Rain Detection Performance

One of the critical functionalities of the rainwater collection system is its ability to accurately detect and respond to rainfall. The rain sensor, a pivotal component, was subjected to rigorous testing to assess its performance under various weather conditions.

Sensitivity Analysis

The sensitivity of the rain sensor was evaluated across different rain intensities. The system demonstrated high sensitivity, detecting even light drizzles effectively. Sensitivity was quantified using the equation:

$$\text{Sensitivity (\%)} = \frac{True\ Positive}{True\ positive + False\ negative} \times 100$$

True Positive: correctly predicts Raining

False Negative: incorrectly predicts No Raining

False Positive Minimization

To enhance accuracy, the system underwent refinement to minimize false positives. The false positive rate was calculated using the equation:

$$\text{False positive rate (\%)} = \frac{False\ Positive}{False\ positive + True\ negative} \times 100$$

False Positive: incorrectly predicts Raining

True Negative: correctly predicts No Raining

Response Time Evaluation

The response time of the rain sensor was measured from the detection of rain to the full opening of the rain collector. The average response time was found to be **5.3 seconds**, ensuring swift and efficient water collection.

Table 5.1: Rain Sensor Performance Metrics

Rain Intensity	**Sensitivity (%)**	**False Positive Rate (%)**	**Response Time (seconds)**
Light Drizzle(<0.02mm)	87	9	6.5
Moderate Rain(0.02-0.04mm)	92	6	5.2
Heavy Downpour(>0.1mm)	98	4	4.3

5.2 Water Collection Calculation

Equivalent Radius of collector is 25 cm

Area of water collector = πr^2

$= \pi \times (0.25 \times 0.25)$

$= 0.2\ m^2$

The daily water collection (WC_{daily}) can be calculated using the formula:

WC_{daily} = Collection Efficiency×Rainfall Intensity×Collection Surface Area

For, 15 mm Rainfall intensity and 94% Collection Efficiency,

$WC_{daily} = 0.94 \times 0.015 \times 0.2$

$= 0.00282\ m^3$

= 2820 cc

Table 5.2: Daily Water Collection

Rainfall Intensity (mm)	Collection Efficiency (%)	Collection Surface Area (m²)	Daily Water Collection (cc)
8	87	0.2	1392 cc
10	89		1780 cc
13	92		2392 cc
15	94		2820 cc
23	95		4370 cc
28	98		5488 cc

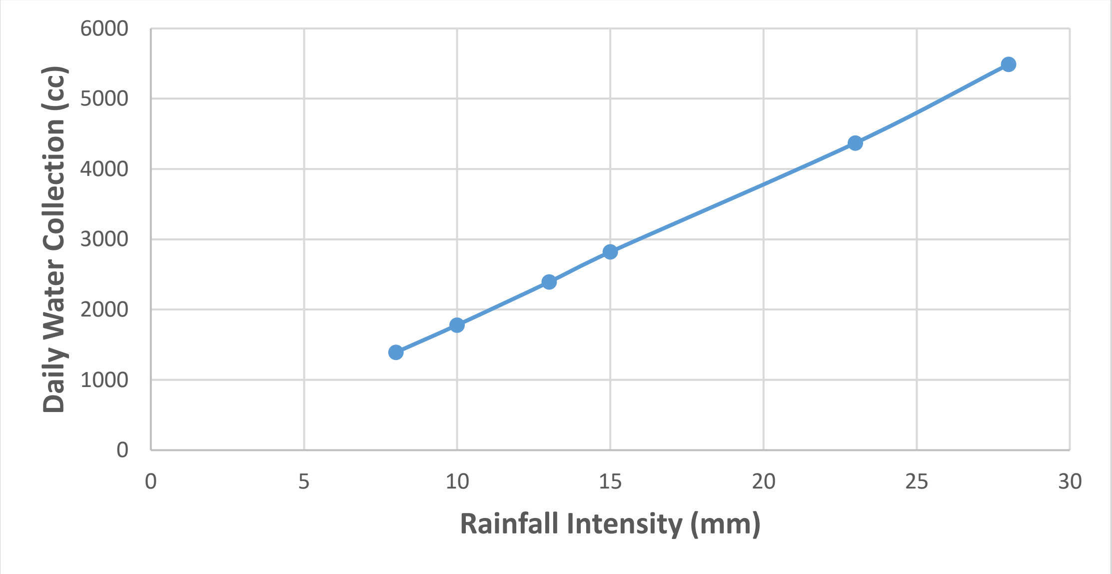


Figure 5.1: Daily Water Collection for Different Rainfall Intesity

5.3 Power Calculation

To ensure the sustained operation of the automated rainwater collection system, a comprehensive analysis of power requirements for each component was conducted. The power consumption for key elements was measured during different operational states.

Table 5.3: Power Consumption of System Components

Component	Operational State	Power Consumption (Watts)
Microcontroller	Active	1.4
Rain Sensor	Active	0.5
Water Level Sensors	Active (monitoring)	0.3
Valve Actuators	Active (during water flow)	1.5
Collector Actuators	Active (during rain)	3.2

If we consider a 2 hr raining time in a day, **(In the assembly microcontroller, Rain sensor, & water level sensor will be active for 24 hrs & valve and collector actuator will be run only 2 hrs(as per raining).**

Daily Power Consumption (Wh)=∑(Power Consumption×Duration)

= (1.4×24) + (0.5× 24) + (0.3× 24) + (1.5× 2) + (3.2× 2)

= **62.2 Wh**

= **0.0622 KWH**

5.4 Discussion

In this study, an automated rainwater collection system is developed as a demo where the existing systems are operated manually. In the system, the Rain sensor, Air flow sensor, and water sensors are used for collecting data, and the microcontroller is used for analyzing the data and making decisions for controlling actions and generating signals. The airflow sensor was not available in the local market. Instead of a readymade sensor module, a sensor is made using a fan and motor which generates a µV signal when detects heavy air movement using the fan. Proper mechanical setup was required for making the system reliable, efficient, and economical. Finding a suitable mechanism for opening and closing the collector was a challenge. A rack and pinion setup is used effectively for this purpose which is printed in a 3D printer. Perfect synchronization of Mechanical, Electrical, Electronics, and Software elements made the system function properly.

The primary goal of the system is to collect and store rainwater efficiently. This objective entails designing a rainwater collection mechanism that effectively captures rainfall and directs it into the storage reservoirs. The system must include appropriate components such as a rainwater collector, pipes, and filters to ensure optimal water collection and minimize debris or contaminants.

A rain sensor is an essential component in the system, enabling it to detect the presence of rain. When rain is detected, the microcontroller receives a signal from the rain sensor and initiates the appropriate actions, such as activating the rainwater collection mechanism. This objective ensures that the system remains responsive to changing weather conditions and maximizes rainwater collection efficiency.

Based on the input from the rain sensor, the microcontroller triggers the opening of the rain collector mechanism when rain is detected. This action allows water to flow into the collection system and prevents water wastage during dry periods. Implementing a controlled opening mechanism ensures that rainwater is efficiently captured while preventing overflow or unnecessary water loss.

To fulfill different water usage requirements, the system incorporates two separate reservoirs. One reservoir is dedicated to drinking water, while the other is for household use. The microcontroller monitors and controls the water flow, directing water to the appropriate reservoir based on predefined rules or user preferences. This objective ensures that the collected rainwater is appropriately allocated for specific purposes, promoting water conservation and safe usage.

To protect the system from adverse weather conditions, such as storms or high winds, an air flow sensor is employed. The sensor detects increased air flow or turbulent conditions, indicating the potential for heavy rain or damaging winds. In response, the microcontroller keeps the rain collector closed to prevent water entry during unfavorable weather. This objective enhances the system's durability and safeguards against potential damage or water contamination.

Water sensors are utilized to measure and monitor the water levels in the two reservoirs. These sensors provide real-time feedback to the microcontroller, allowing it to accurately gauge the fill levels and control the water flow accordingly. By continuously monitoring the water levels, the system can ensure proper utilization and prevent overflow or depletion.

To prevent overflowing of the reservoirs, the microcontroller generates a signal when a reservoir reaches its maximum capacity. This signal can be used to activate visual or audible alarms, notifying the user to halt rainwater collection or initiate alternative measures. Generating such signals ensures that the system operates within safe limits and avoids wastage or potential damage due to overflow.

By integrating these objectives into the design of an automatic rainwater collection system using a microcontroller, it becomes possible to achieve efficient rainwater utilization, accurate monitoring, and intelligent control. The system not only addresses the need for water conservation but also promotes sustainability and provides a reliable water source for drinking and household use.

Chapter 6

CONCLUSION

6.1 Conclusion

A large number of people in Bangladesh are facing severe water scarcity. Along with declining groundwater and pollution, there is rising saltwater intrusion into its freshwater sources. In that situation, rainwater collecting is a very much effective solution to the water problem as Bangladesh is a country of heavy rainfall. The system introduces a very much simple and human effortless way of rainwater collection. Automated opening and closing of the collector improved the lifetime and safety of the system and decreased the chances of dust contamination in the collected water. Categorizations of collected rainwater ensure the best use of water. The signal generated in the tank LED helps the user with the timely extraction of collected water.

The system's quick response to rain, or high rain sensitivity, ensures that it captures water promptly during varying intensities of rainfall. The system demonstrates impressive efficiency in collecting water, ensuring that a substantial amount is harvested for storage. The low operating power of the system contributes to its energy efficiency, minimizing power consumption for sustained and cost-effective operation. Furthermore, the system's development cost remains relatively low, emphasizing its practicality and accessibility for widespread adoption.

Though the system is very effective and user-friendly, it cannot ensure the purity of the collected rainwater as there is no chemical test or water purification system. Moreover, the system is very much useful from the perspective of Bangladesh.

Chapter 7

FUTURE RECOMMENDATION

7.1 Future Recommendation

a. Water can be categorized depending upon not only raining time but also chemical properties and contaminations.
b. Suitable water treatment with minimum cost can add a degree of purity of the collected water.
c. Suitable reservoirs can be introduced for better shelf life of the collected water.
d. IOT can be introduced in the system for better supervising and reliability.
e. Explore the possibility of utilizing renwable energy to power the system, reducing costs and promoting environmental sustainability.

The future recommendations aimed at further optimizing and sustaining the rainwater collection system. These forthcoming steps are poised to contribute to the overall resilience of freshwater resources in Bangladesh.

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Appendix

Code:

```
#include <Arduino.h>
#include <Servo.h>
bool collecting = false;

long long int t = 0, r = 0;
// bool storm = false;
// bool raining = false;

#define TimeDelay 2000

#define Tank1LED 5
#define Tank2LED 3
#define Level1 8
#define Level2 9
#define Rain 7
#define Storm 6
#define CC 4 // Limit switch

int bp = 90, mp = 90;
Servo VCServo;
Servo CollServo;          // Collector servo
void BasePosition(int BP); // to set the positon of base motor
void MidPosition(int MP);
void levelCheck();

void setup()
{
  pinMode(Tank1LED, OUTPUT);
  pinMode(Tank2LED, OUTPUT);
  pinMode(Rain, INPUT);
```

```
  pinMode(Storm, INPUT_PULLUP);
  pinMode(CC, INPUT_PULLUP);
  pinMode(Level1, INPUT);
  pinMode(Level2, INPUT);

  VCServo.attach(11);
  CollServo.attach(10);
  Serial.begin(9600);
  MidPosition(90); // tank 1
  while (digitalRead(CC))
  {
    CollServo.write(70);
  }
  CollServo.write(90);
  delay(50);
}

void loop()
{
  if ((!digitalRead(Rain)) && (collecting == false))
  {
    delay(20);
    if ((!digitalRead(Rain)))
    {
      if ((digitalRead(Storm))) //
      {
        collecting = true;
        while (digitalRead(CC))
        {
          CollServo.write(70);
        }
        CollServo.write(90);
        delay(20);
        CollServo.write(110);
```

```
        delay(1500);
        CollServo.write(90);
        delay(20);
        t = millis();
      }
    }
  }

  else if ((digitalRead(Rain)) && (collecting == true))
  {
    levelCheck();
    while (digitalRead(CC))
    {
      CollServo.write(70);
    }
    CollServo.write(90);
    delay(20);
    collecting = false;
  }
  if ((!digitalRead(Storm)) && (collecting == true))
  {

    while (digitalRead(CC))
    {
      CollServo.write(70);
    }
    CollServo.write(90);
    delay(20);
    collecting = false;
  }
}
void levelCheck()
{
```

```
  if (digitalRead(Level1))
  {
    digitalWrite(Tank1LED, HIGH);
  }
  else
  {
    digitalWrite(Tank1LED, LOW);
  }

  if (digitalRead(Level2))
  {
    digitalWrite(Tank2LED, HIGH);
  }
  else
  {
    digitalWrite(Tank2LED, LOW);
  }
  if ((!(digitalRead(Level1))) && ((millis() - t) > TimeDelay) && (mp != 90))
  {
    MidPosition(90);
  }
  else if (((digitalRead(Level1)) || ((millis() - t) <= TimeDelay)) && (mp != 10))
  {
    MidPosition(10);
  }
}

void MidPosition(int MP)
{
  if (MP > mp)
  {
    for (int i = (mp + 1); i <= MP; i++)
    {
      VCServo.write(i);
```

```
      delay(10);
    }
  }
  else if (MP < mp)
  {
    for (int i = (mp - 1); i >= MP; i--)
    {
      VCServo.write(i);
      delay(10);
    }
  }
  mp = MP;
}

//-----------------------------------------END----------
```