Smart Water Quality Monitoring and Purification System Development for Domestic Application.

By

Md Thamid Hossain
18121119
Tasbiah Binte Hossain
18121103
Shafkat Haque
18121025
MD Saif Fida
18321012

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science

Electrical and Electronics Engineering
Brac University
October 2022

© [2022]. Brac University
All rights reserved.

Smart Water Quality Monitoring and Purification System Development for Domestic Application.

By

Md Thamid Hossain
18121119
Tasbiah Binte Hossain
18121103
Shafkat Haque
18121025
MD Saif Fida
18321012

A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science

Academic Technical Committee (ATC) Panel Member:

Dr. Abu S.M Mohsin (Chair)
Associate Professor, Department of EEE, BRAC University
Taiyeb Hasan Sakib (Member)
Lecturer, Department of EEE, BRAC University
Md. Ehsanul Karim (Member)
Lecturer, Department of EEE, BRAC University

Electrical and Electronics Engineering
Brac University
October 2022

© [2022]. Brac University
All rights reserved.

Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

[Md Thamid Hossain] [18121119]	**[Tasbiah Binte Hossain]** [18121103]
[Shafkat Haque] [18121025]	**[MD Saif Fida]** [18321012]

Approval

The Final Year Design Project (FYDP) titled “Smart Water Quality Monitoring and Purification System Development for Domestic Application.” submitted by

1. Md Thamid Hossain 18121119
2. Tasbiah Binte Hossain 18121103
3. Shafkat Haque 18121025
4. MD Saif Fida 18321012

of Summer 22, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronics Engineering (EEE) on 1st Sept, 2022.

Examining Committee:

Academic Technical Committee (ATC):
(Chair)

_____
Dr. Abu S.M Mohsin
Associate Professor, Department of EEE
BRAC University

Final Year Design Project Coordination Committee:
(Chair)

_____
Dr. Abu S.M Mohsin
Associate Professor, Department of EEE
BRAC University

Department Chair:

_____
Md. Mosaddequr Rahman, PhD
Professor, Department of EEE
BRAC University

Ethics Statement

The plagiarism was checked for this paper and found to be 9% similar with other papers. Basically the similarity was with the data that we have collected from different soures.

Abstract/ Executive Summary

Scientists have been working on finding alternative effective way other than boiling and filtering in which everyone can trust with their closed eyes. Using UV light in water filtration for drinking water and monitoring the water quality is the new generation thing with better assurance. This report is on water filtration process using UV light with basic RO filters and monitor that filtered water's quality parameters through some sensors. Surface water mostly contains more contaminants and microorganisms those can't be filtered through basic filters whereas UV light can destroy these contaminants with its radiation. Also, people use market available filters without knowing those are actually working or not. But this UV based water filter can show some data on the water quality. This project has IOT based monitoring system where the quality parameters can be shown and stored to cloud as well. In addition, UV light is being used directly to the water to secure the highest safe drinking water. Results and comparison of supplied water and this project are shown in the report for better understanding.

Keywords: Monitor, Filtration, Results, Comparison

Acknowledgement

We would like to convey our appreciation and gratitude to everyone who helped us and provided us the opportunity to finish this project. Our supervisor Dr. Abu S.M. Mohsin and Taiyeb Hasan Sakib deserve special gratitude for their assistance, inspirational ideas, persistent mentoring, and encouragement as they helped us create the system and finish the report. Additionally, we would like to thank the Electrical and Engineering Department of Brac University for letting us utilize their equipment and facility to complete this research.

Table of Contents

List of tables

Table of Figure

Chapter 1: Introduction

1.1.1 Problem Statement

Water is an indispensable natural resource for sustaining human life. Clean water is an important factor for economic development and food production. However, there are approximately 2.2 billion people in the world without safe drinking water [1]. In our country only 34.6% people get safe drinking water according to a report of UNICEF in 2018. Approximately 100 million people do not get safe drinking water. 8.5% of deaths of our country are related to use if contaminated water. Moreover, pathogenic microorganisms in drinking water frequently affect human health, it is necessary to develop a device for easy and rapid monitoring of water quality and purifying it. In addition, in our country the quality of water is not the same. In different region of our country the water quality is different such as in Dhaka district there are found to be that the supply water is contaminated with bacteria, in costal districts like Comilla, Chandpur, Madaripur etc. most of the water contain huge amount of iron, most of the water in our country is contaminated with arsenic etc. On another note, today majority of adults suffer from dehydration daily as a consequence of improper drinking habit while countless others find themselves sick due to contaminated water. An adult should drink 2 Liters of water on average daily basis [2]. There are many skin diseases due to dehydration. There are many ways of disinfecting or purifying water such as heating, chemicals, filtering etc. However, these processes are with full of complications. By heating we use a lot of fuel or wood which effect the environment and time consuming. The chemicals like chlorine are not much effective against bacteria and viruses also not that much available in the country side. Addressing these problems we are hoping to build a smart water bottle which will help most of the problems to resolve. Furthermore, from these we will be able to collect data from this device and research for better things in future. There are many well established water purifying company like KENT, Aquafine, Alfaa UV, American Air & Water, Applied Membranes, Aquionics etc. are using UV based system for purifying water. Lastly, UV based portable water purifier will be most efficient, eco-friendly system for water purification. Furthermore, we can collect data from our project. We will be able to collect data on how much a family or a individual person drinks or uses water. What are the quality of our supplied water and what are the health benefits of using pure water. We can get these information from our project. Analyzing these information for health research can be valuable. We can use these data for future research and making a good purification system.

1.1.2 Background Study:

There are many ways of disinfecting or purifying water such as heating, chemicals, filtering etc. However, these processes are full of complications. By heating we use a lot of fuel or wood which affects the environment and is time consuming. The chemicals like chlorine are not much effective against bacteria and viruses also not that much available in the countryside. Addressing these problems we are hoping to build a smart water bottle and a water carrier

which will help most of the problems to resolve. Furthermore, from these we will be able to collect data from this device and research for better things in future. UV-C purification can be a great solution for the mass people depriving them of safe drinking water as its cost efficient as well as eco-friendly.6 stages filters will be filter the supply water and filtered water will go to UVC not only cleans dirt and dust but also destroys microorganisms so the water can be safe completely.

Therefore, people with busy schedules often forget to drink water on time and also face health issues for dehydration. Again, from 6.5 to 8.5 pH value is considered satisfactory for water as <7 pH is acidic and >7 is alkaline can imbalance the electrolytes of the human body [3]. A paper from ATIPT described water temperature from 50° to 72° is best for rehydration. [4] It also stated that cold water is beneficial in the case of losing calories up-to 8 units per cup. Water that we collect from various water sources is often mixed with solid suspension. The World Health Organization established the fact that drinking water can't have turbidity more than 5 NTU. All these standard values will be considered while monitoring data.

An individual requires at least 2 liters of water daily and one takes more or less 1 liter of water in his work time. So our plan is to make a portable disinfecting carrier of 1 liter capacity that can be carried outside and can purify water anytime anywhere. Secondly, we searched for the capacity of filter for one family and found 20 to 25 liters of capacity are on average needed for one household drinking purpose.

Furthermore, we can collect data from our project. We will be able to collect data on how much a family or a individual person drinks or uses water. What are the quality of our supplied water and what are the health benefits of using pure water. We can get these information from our project. Analyzing these information for health research can be valuable. We can use these data for future research and making a good purification system.

For individual research a survey was done based on some general requirements.

All these surveys lead us to understand the necessity of building 6 stages of filters that can be portable and will have facilities to monitor the water quality parameters altogether. Therefore, the survey fulfilled all our objectives such as almost 87.5% votes agreed to monitor the water qualities, 85.4% people voted on having portable carrier and 90.2% people really want to trust using filters for water filtration as well as using 6 stages of filters.

Water qualities were researched from different areas of Dhaka and choose our location for doing the project is Mirpur. Though in Dhaka we received drinkable water from WASA but sadly a significant amount of microorganisms and dirt can be found in the WASA supplied water because of water logging, drainage system, damage of water pipe.

Sensors can be used to Monitor Domestic Water quality:

1. Turbidity- For cloudiness of water
2. TDS- To measure Total dissolved Solids in water

3. Temperature
4. Electric Conductivity- For Electrical Conductivity
5. pH- Alkalinity, acidity.
6. spectrophotometer or color comparator test kit- Chlorine
7. colorimeter or test strip- Hardness
8. BOD- To test Biological Oxygen Demand

Filters and sensors used

Table 1: Filters and Sensors usage [5]

Filters	Usage
RO Membrane	Remove dissolved solids, large amount of contaminant(chloride, copper, chromium and lead)
Post Carbon	Removes residual Chlorine and volatile organic compounds, bad taste and odor as well as hardness.
GAC	Remove VOCs, pesticides, nitrates, hydrogen sulfide and chemicals (specially chlorine & chloramine
Carbon	Removes organic compounds, industrial cleaners, chlorine
PP/Sediment	Removes sand, slit, dust and rust. Protects UV sterilizer
Sensors	Usage
Turbidity	Detect microorganism , mercury, cadmium, lead and other heavy metals
TDS	Detects total dissolved solid. Calcium Chloride Magnesium Potassium Zinc Aluminum Copper Lead Arsenic Iron Chlorine Sodium Fluoride Bicarbonates Sulfates Pesticides Herbicides.
Temperature	Identify the temperature
pH	Measure the acidity or alkalinity

1.1.3 Literature Gap

Literature gap is the missing areas and insufficient information of any project. Our project also have many gaps we couldn't finish or look over.

- Our first attempt was detecting microorganisms and destroying them through our device. Though we are working on destroying the reproduction of those with UVC sterilizer but couldn't find any situation device, sensors to count and detect the microorganisms. We have done pathology tests from the microbiology lab to detect the existing microorganisms from the water of our filter and bottle. So making or finding microorganisms detecting device was a gap.

- Secondly, we couldn't work with all the ideal water quality parameters. For testing ideal water quality parameters, we need to check these- turbidity, hardness, solids, taste and odor, color, temperature, electric conductivity, pH level, chlorine, dissolved oxygen, heavy metals of the water. All these have standard values for drinking water. In our project we have worked with turbidity, solids, heavy metals, pH level, temperature, taste and odor, chlorine, electric conductivity parameters. So, the rest of the parameters are our another literature gap.
- After that, we have used turbidity and TDS sensors for identifying heavy metals (Lead, Mercury, Cadmium)and pollutants (sand, slit, rust)as well as salt and other chemicals elements(Chlorine, Potassium, Calcium, Zinc, Sodium, Arsenic etc.). Our LCD shows safe or unsafe water depending on the standard value range and the cloud store the exact value. Still we had leaks in getting specific values of each chemical element, solids. We did test for Chlorine and lead of our water, so we got to know only their specific values but the other pollutants (sand, Zinc, Dissolved oxygen, Mercury, Arsenic, Iron etc.) scale, we couldn't measure.
- We did all our analysis by taking water from Mirpur-2. In addition, we have only used surface water in this project. Water from different areas in Dhaka and surroundings as well as water from different sources can show a bit different values which is also another literature gap of ours.

1.1.4 Relevance to current and future Industry

There are many models for portable uvc based water purifiers. According to a report of WBOC commercial uvc water purifier market size 2021 with a CAGR of 6.20%, research by business opportunities, top companies data report covers are Aquafine, Atlantic Ultraviolet, BWT. The global Industrial UV Water Purifier market is expected to reach million USD by the end of 2025, growing at a CAGR of 6.20% between 2019 and 2025. In 2020, the market for water purifiers was estimated to be worth $29,998.15 million. By 2031, it is expected to have grown to $92,082.60 million, with a CAGR of 10.1% from 2022 to 2031.[6]

1.2 Objectives, Requirements, Specification and constant:

1.2.1 Objectives:

Objectives are what is wanted to achieve throughout our whole project. The basic things want to gain are:

- Monitoring the water qualities.
- Disinfecting through UVC based system
- Making a portable disinfecting carrier
- Notifying the user to drink water at a regular interval to solve dehydration problem

Through the project, there are going to design and building of disinfecting carrier where UVC light based purification will be the main focus. Also, for removing dirt and dusts from water, we will be adding 6 stages filters (RO membrane, ultrafiltration, polypropylene, active and post

carbon filter, sediment, incline). These filters will remove solid suspensions, dirt, some chemicals from the water and the remaining chemical and bio microorganism will be destroyed by UVC. The project will have two parts, one is non-portable and will have capacity of 25 liters and another one is portable of 1 liter of capacity. RTC sensor and alarm will notify the user to drink water after regular intervals so that the water demand of the body is fulfilled completely. The project is a microcontroller based automated sensor control system. If the system is properly successful, there will be a high possibility to produce it industrially and make a market for it as in the future, people will depend on automatic systems mostly where they can monitor by themselves.

1.2.2 Functional Requirements and Non-functional Requirements:

Our first and foremost requirement for the project is to purify household water with the help of UVC light. Secondly, we are going to monitor the water quality of household water sources to ensure safe water for one family consisting of 5 members which is non-portable and for 1 person's portable water bottle who travels to remote areas. We will use TDS sensor (conductivity sensor), ultrasonic sensor for measuring volume of the remaining water, turbidity sensor for scaling turbidity percent, pH sensor will measure the pH level in the water, and temperature sensor will check temperature. Again, we are going to add an IOT system based mobile app, WIFI module in our project to collect continuous data from the sensors for users and notify them. ESP32, an open source microcontroller will be working to process all sensors. There will be systems for notifying the water qualities in numbers and for that there will be LCD display and alarm .Disinfecting through UVC light (till 99%) is our main goal. Quartz is another essential thing for protecting water and users from UVC light. As we will be going to work with household water and provide that water to the families for drinking purpose, we definitely have to add some carbon filters to absorb contaminants. Ultrafiltration, RO membrane and polypropylene are the other important parts for our filtration tasks.

RTC sensor to count time to alert users, flow sensor will measure the flow rate of water from the supplied line. Through a flow sensor we can measure water volume while coming into filters. Clock sensor or RTC sensor can be used to count times and alert users for drinking water as well show them to state if water is purified or not. Filter alarm can be set to let them know when the filters need to be replaced. Cloud storage is also non-functional here as we are already using here LCD for displaying water quality parameters where cloud will store and save all those data online. We can also use mineralizer filters in addition to enhance the water quality.

Here is the functional and non-functional requirements

Table 2: Difference between system and component based functional and non-functional requirements

Requirements	System Based	Component Based

Functional	Water disinfection system (portable and non-portable)	UVC light , RO based filters
	Monitoring water qualities	Sensors: pH, TDS, Turbidity, Temperature
	Filtration system	RO based filters
	Notification system	LCD, Alarm
Non- Functional	Water volume measurement	Sensors: Ultrasonic, Flow
	IOT based system	Cloud server
	Filter condition monitoring	Condition detecting indicator

1.2.3 Specification:

System based Specification:

In our project the portable water bottle will be cylindrical and it will hold 1000ml of water. There will be an extra part under the bottle where all the sensors will be placed and the pH sensor will be placed beside the cylindrical part. The UVC light will be placed in the middle of the bottle and the bottle will be covered by a shield so that the irradiation can't go outside. There will be another part that is non-portable and almost rectangular shaped and can carry 25 liters of water. Now this filter will have two portion, upper portion contains in all the filters and lower portion will carry water, UVC light will be set in the middle and sensors with ESP32 will be set at the lower part of it.

There will be an ultrasonic sensor for measuring the remaining water volume , pH sensor for pH testing so user can have preferable water , ORP sensor will work for measuring the ratio of oxidized to reduced form of all the chemical species in water. Also there will be a turbidity sensor that will test how much solid suspension is added to water as well as microcells to check if it is drinkable. Turbidity sensor also responds if its presence is too high as that time UVC purification can't be done. There will also be a system for detecting microorganisms and destroy their reproduction quality through UVC. We will also add an RTC sensor and alarm for notifying user to have water timely. UV light will be safely protected by quartz so that it can reflect UV into water but don't get connected with water as well as make no harm to human .We are going to use ESP32 as a microprocessor to run all the sensors. In addition, the data that we are going to receive from sensors will be stored in the cloud. Here, we will use RO membrane, Ultrafiltration, active carbon filter, post carbon filter, sediment, incline and polypropylene filter to remove solid suspensions and contaminants from water. Also, some of the filters (alkaline filter, mineraliser filter) will work as well for improving the taste of water.

Table 3: System based specification's leading points

System		**Specification**
	Water disinfection system (portable and non portable)	Portable one is cylindrical in shape and has capacity of 1L water

Functional		Non portable one has capacity of 25 litres of water
	Monitoring water qualities	Sensors are added at the lower part of both devices, connected with water to take values
	Filtration system	RO based 6 stages filters strain pollutants, organic chemical from supply water before entering the water tank that consists of UVC light
	Notification system	LCD is set to show the values from sensors whereas alarm is for alerting the user to drink after certain interval
Non- Functional	Water volume measurement	For monitoring the usage of water quantity, set on tank tap mouth
	IOT based system	For further observation or needs , all the data are uploaded saved to cloud server
	Filter condition monitoring	To check if the filters are working properly

Component based Specification:

For our project we need RTC, turbidity sensor, ultrasonic sensor, microorganism detector, ESP32, low pressure uvc light. We need pH sensor to measure the pH level of the water. RTC for keeping track of the time to notify the user to drinking water. Temperature sensor to measure the temperature. Ultrasonic sensor to measure the volume or water level and know how much water user consumed and water is needed to be fully hydrated. ESP32 is for processing all the sensors. UVC light to purify the water. Battery is for power supply. Quartz will be used to water-proofing the UV light.

Table 4: Component based specifications and purpose

Component Name	Specifications	Purpose
UVC Light	Low pressure UVC light	To purify the water
ESP32	Esp32 Dev kit V1	To process all the sensors and internet connectivity
pH Sensor	Analog pH sensor	To measure the pH level of the water

Turbidity Sensor	SKU_SEN0189-D	To measure the amount of light that is scattered
Battery	5- or 12-volts battery	For power supply
5 Stage filter	PP, GAC, Activated Carbon, RO membrane, Post Carbon filter.	Filters the water
PCB design and making		Brings electronic circuits to physical form
Temperature sensor	LM35	Measures the temperature

1.2.3 Technical and Non-technical consideration and constraint in design process

There are many things to consider in the project. Firstly in technical consideration we have to consider the software part. In our project we are going to use the Arduino IDE which is compatible with esp32. Moreover, this software is easy to use for the sensors we used.

How to get the power supply to the light and the microcontroller is also a technical matter to consider. We are using a 9V battery with a Buck or boost converter to power up the system.

In the non-technical part we can see there are many things to consider. The water tank size is needed to considered. We need to consider the water bottle size. The calculation of time needed to purify water through UVC light. Moreover, pcb design is also an important part of the project. Furthermore, we need to consider waterproofing the system.

There are a lot of constraints in the project. Designing the water bottle and the filter is a very big challenge. Waterproofing the system and the UVC Light is another constraint. Design of all the sensors in the short space of a water bottle is a constraint. These are the Non-technical constraints.

There are a lot of technical constraints. Applying the right code for the sensors and running the algorithm in the code, connecting the microcontroller to a server are some of the constraints.

Surely while doing the design we faced some limitations. Firstly, identifying the dose and irradiation of UVC light from water inside the filter is a tough task. In addition, finding special filters for removing some bio and chemical particles is problematic too. While doing the simulation we were in lack of some library equipment. Also buying components with the same model, ports that have been used in PSB design was complicated too

1.2.4 Applicable compliance, standards, and codes

There are many applicable codes for the proposed system. Below a table is given for the applicable codes and their purposes.

Table 5: Applicable Codes and purposes

Serial Number	Applicable Codes	Purpose
1	IEEE 802.15.4	Defines low rate wireless personal network. [7]
2	IEEE 802.11ax-1999:	For implementing local wireless network, from device to cloud server in the project. [8]
3	IEEE 2700-2017	For sensor's performance specification terminology, conditions, units and limits definitions.
4	ISO 15858:2016(en)	Defines a minimum human safety required for using UV lamp devices. [9]
5	ISO 10523:2008	Specifies a method to determine the pH value.[10]
6	ISO 11923:1997	This code is also for determining the dissolved solids through filtration by glass fibre filters. [11]
7	ISO 7027-1:2016	For the determination of turbidity of water. [12]

1.3 Systematic Overview/summary of the proposed project

This Project is basically a purification and quality monitoring system of water. It can measure the parameters of water and it can also purify the water through UVC light. UVC light can disinfect through killing the microorganisms in the water. In our project we will also have sensors and a notification system which will remind users to drink water. Moreover, this whole project will be IOT based. It will be connected to a server where users can watch their water quality. Furthermore, this project will be for a whole family of 5-6 persons and a water bottle for travelers.

1.4 Conclusion:

In this chapter we have done a lot of things. We researched and found many useful and necessary things which can be used in the next part of our project. Here we did some research on the problem and the background of that problem. We figured out the literature gap and we made the objectives requirements and the constraints.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

Project design, the first phase of the project lifecycle, is where ideas, processes, tools, and deliverables are arranged. Because it offers a big picture while the project plan contains more precise specifics, the project design comes first.

There are seven steps involved in creating a project design, including goal-setting and using a visual aid to communicate objectives. A variety of tools, like as flowcharts, Kanban boards, and Gantt charts, are used in these visual components. By presenting a visual representation of your project strategy, you can increase transparency among stakeholders and clarify a number of project-related issues, including its overall feasibility. [13].

We are doing a smart water quality monitoring system and purification system. It can be done for a single family. We are looking to build the purification and quality monitoring system for a household. The design will be for 4-6 persons in a house. Moreover, we want to make a portable system for one person. It will only be for one liter.

2.2 Identify multiple design approach

In search of designs we have done a lot of research. There are many ways to design our designated objectives and requirements. We have calculated the cost, efficiency, usability, manufacturability, impact, sustainability, maintainability etc. and found 3 best solutions. Below are the 3 designs.

Design 1:

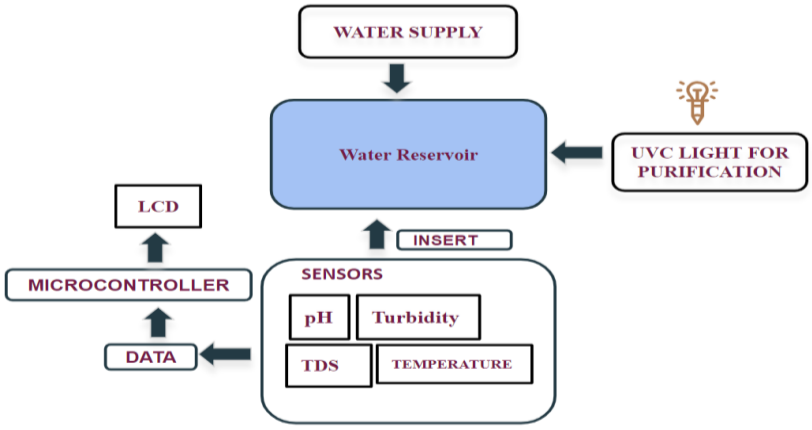


Figure 1 UVC Based Filter Design

Design 2:

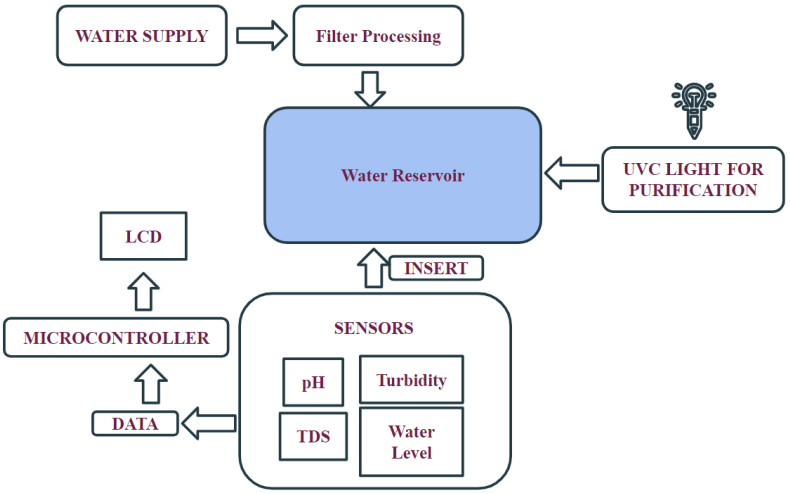


Figure 2 UVC+RO Based Filter Design

Design 3

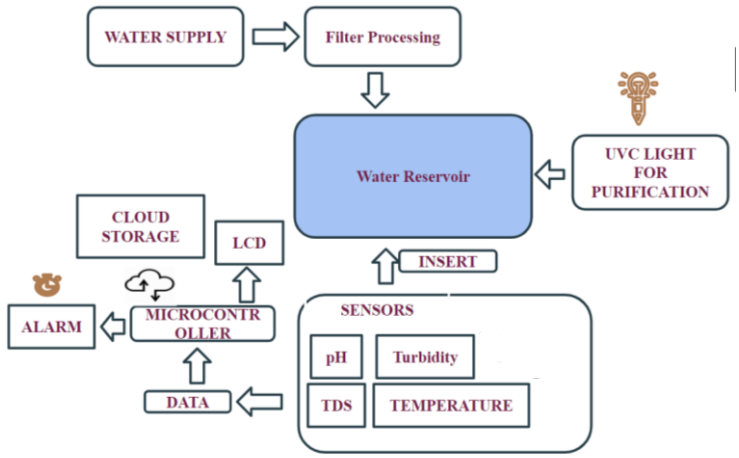


Figure 3 UVC+RO+IOT Based Non-portable Filter Design

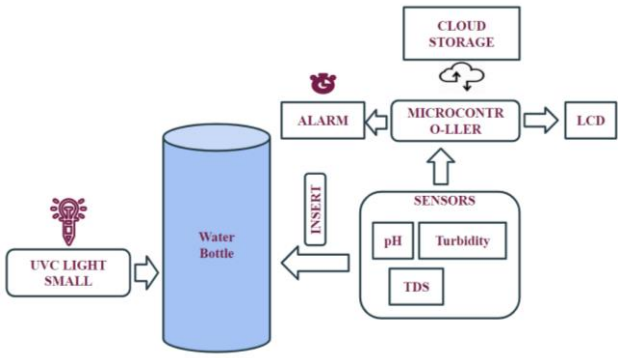


Figure 4 UVC+RO+IOT Based Portable Filter Design

2.3 Describe multiple design approach

Understated are the descriptive information of our proposed designs

Design 1:

This approach is only UVC based. In this design there will be water directly supplied into the water reservoir. In the water reservoir there will be UVC light and there will be water quality monitoring sensors like pH, turbidity, TDS, temperature. Then the sensors will feed data to the microcontroller and the microcontroller will show the data in the LCD.

Design 2:

This approach is UVC and RO based. In this design the basic difference is that the water will be filtered before it goes into the water reservoir. There are also some changes in the sensors as well.

In the water reservoir there will be UVC light and there will be water quality monitoring sensors like pH, turbidity, TDS, Water level. Then the sensors will feed data to the microcontroller and the microcontroller will show the data in the LCD.

Design 3:
This approach is UVC, RO and IOT based. There are two parts of this design. One is portable part and another one is the non-portable part.
For the non-portable part in this design the water will be filtered before it goes into the water reservoir. There are also some changes in the sensors as well. In the water reservoir there will be UVC light and there will be water quality monitoring sensors like pH, turbidity, TDS, ORP, temperature. Then the sensors will feed data to the microcontroller and the microcontroller will show the data in the LCD. Also microcontroller will send the data to the cloud storage. Moreover it will alarm the use to drink water after a certain interval of time.
Portable part design there are less sensors. However it will also do the same work as the non-portable part will do. It is more suitable for caring.
This design is the best suitable design for a smart purification system. We can get the water quality data in our cloud storage for further more research and we can know the water qualities and see the water is being purified.

2.4 Analysis of multiple design approach

Analyzing all the designs, there have been found all kinds of similarities and dissimilarities. There are lot of advantages and disadvantages for all of the designs.

Starting with design 1 we can say that it is a very simple design. It is very user friendly and it will be very much fulfill our some of the objectives. In design 1 the approach is only UVC based purification system and water quality monitoring system. Here we can kill all the microorganism or biological particles in water. However, we cannot remove the chemicals and dissolved solids from the water. Moreover, in this design it cannot notify user to remind them to drink water.

Secondly, in design 2 we are using RO and UVC based purification system and it will be very effective for removing all the particles and chemicals. In case of disadvantages, with this design users can not store the water quality data and there is no notifying system.
Lastly design 3 is RO, UVC and IOT based. Therefore, it can remove all the particle, biological things and chemicals. It can send data to the server which can help people to get their water quality in their smartphone or in the internet. Moreover, it covers our all the objectives and requirements also it has a portable part for people travelling. However, this design is very much costly and it is very difficult to process.

2.5 Conclusion

In this chapter we have researched and found out the best solutions of our problem and discovered 3 designs and explained briefly. These designs are analyzed in order to find out the best design.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

Modern Engineering includes technology that is involved with development and understanding of technological systems. Also includes the products output, validation, affects and appropriateness of technology. Modern Engineering is also concerned with its non-technological approaches. Modern Engineering requires appropriate IT tools to solve its complex design, modeling, development and lastly to provide valid solutions. IT tools are not only involved with final device outcome but also for project management, asset and resources management.

3.2 Select appropriate engineering and IT tools

Software:

In this software part there are a lot of things to consider. The simulation and the 3D modeling part will be done by the software. Now, for simulation we could have used a lot of software like Proteus, Labview, Thinkercad, Matlab simulink etc. However, in all of those we chose Proteus to work with. There are many reasons to choose proteus. Those are

- Familiar working with proteus.
- Huge Collection of Library.
- Can be operated easily.
- Libraries can be installed.
- PCB design can be done easily.

Fig 5: Proteus

All the mentioned above reasons we choose to use proteus for our simulation. In proteus we installed some libraries of sensors and arduino. Then we set the arduino and and the sensor in the proteus and connected with wires and then simulated it. The sensor libraries we couldn't find we made by ourselves. For the arduino code we used arduino IDE. We wrote the code in the arduino IDE then we generated a HEX file which we uploaded in the proteus arduino to simulate.

Design:

3D model design we used blender. We have chosen Blender as its a free, open source that supports the entire 3D presentation sequence. Then we used Marmoset Toolbag for baking (coloring, costume designing,collage) because it gives a full featured real time look of our model and also easy to use . Finally we have used Substance Painter for texturing (making it a more life-like design than that of static one) because it can edit and create very quickly. It has built in filters for fast physical effects.

Fig 6: Blender

Fig 7: Marmoset Toolbag 4

Fig 8: Substance Painter

Platform:

ThingSpeak is an open source free software that collects and stores live data from device's sensors in the cloud. We have been using Thingspeak for IOT based analysis that helped us to sum, visualize, and examine live data streams in the cloud. Thingspeak can display multiple tables for different sensors at the same time so we have used that to observe all parameters together.

Fig 9: Substance Painter

Hardware:

RO Membrane:

Fig 10: RO filter

RO membrane is a thin, semi-permeable layer that has holes as small as pores on it to give access only purified water passing through it. Reverse osmosis membrane is commonly used as a filter to remove different types of dissolved solids like - ions, large molecules from liquid by applying pressure to the liquid when it is on one side of a selective membrane.RO membrane removes common contaminants, such as- aqueous salts, sodium, chloride, copper, chromium and lead. It may reduce arsenic, fluoride, radium, sulfate, calcium, magnesium, potassium, nitrate and phosphorus. The membrane pore sizes can vary from 0.1 to 5,000 nm depending on different filter type. Particle filtration removes particles up to as small as 1 µm or larger. RO membrane continues its process under pressure as a vacuum. RO membrane is one of the most effective filter for removing a large percentage of contaminants along with waterborne bacteria. This membrane's cleaning frequency is once in every 3 to 12 months.RO is used partially clean up tap water up to 90% to 99%pure. [14]

Granular Activated Carbon Filter:

Granular activated carbon, or GAC for short, is made up of tiny, loose carbon granules. GAC filters can effectively remove a variety of contaminants because to its high adsorption capacity. GAC filters are widely used to get rid of impurities such VOCs, pesticides, nitrates, hydrogen sulfide, and others. Municipal water treatment facilities use disinfectants such chlorine and chloramine, which can impart an unpleasant taste and odor to drinking water. Due to their ability to enhance flavor and odor, GAC filters are frequently employed as one or two stages in a reverse osmosis system. However, it cannot be used to purify other compounds, most notably iron and nitrate.15]

Fig 11: GAC filter

PP/Sediment Filter:

Sedimentation is a common procedure for treating water. It is a technique for eliminating floating and settling particles from water. The accumulated sediments, often referred to as sludge, accumulate at the sedimentation tank's bottom and need to be regularly removed. Coagulants are frequently added to water before sedimentation to speed up the settling process. Sand, sand particles, grime, and rust are all removed from water using sediment filters. Sediment filter protects water treatment equipment like UV water sterilizers by removing these impurities. Additionally, this sediment filter functions as a carbon block water filter that can filter 56,000 gallons of water at a flow rate of up to 6 gallons per minute to remove pollutants like chlorine. [16]

Fig 12: PP filter

Post Carbon Filter:

To make drinking water as pure as possible, a filter called the post-carbon filter function is used. Metals can still be present, and excessive chlorine is a common cause for concern. Because of this, we occasionally refer to the taste of the water as "metallic." After the RO process, a post carbon filter is used to improve the taste of the water. Additionally, residual chlorine and volatile chemical compounds are eliminated (VOC). The foul taste and odor in the water are eliminated by a post-carbon water filter. A post carbon filter improves water flavor and eliminates odors from the water. However, several substances, including nitrates, fluoride, salt, microorganisms, and compounds that harden water, cannot be removed by it. [17]

Fig 13: Post Carbon filter

Carbon filter:

In the course of filtering water, carbon is a media that is frequently utilized. Adsorbing contaminants is how carbon filters operate. Adsorption happens when contaminants are attracted to the surface of the activated carbon and held there, much as how a magnet draws and holds iron filings. By serving as a catalyst, carbon filters can also modify the chemical composition of some contaminants. Activated carbon can remove chlorine, organic chemicals like pesticides, THMs like chloroform, and several VOCs found in gasoline, solvents, and industrial cleansers. [18].

Fig 14: Carbon filter

Sensors

We have been using 4 sensors to measure safe drinking water parameters. TDS, turbidity, pH and temperature sensors are being used for respectfully detecting microorganisms, heavy metals, total dissolved solids, identifying pH level of water and temperature.

Turbidity Sensor

Turbidity basically refers to the cloudiness of water. High value of turbidity contains much concentration of chemical elements, organic materials, clay, rust and slit in water. High level of turbidity in water makes it look dirty and works as a shield for microorganisms. Different suspended particles act as adsorption medium for lead, cadmium, mercury and other heavy metals. These heavy metals and dirt absorption is counted by the turbidity sensor.

Fig 15: Turbidity Sensor

Temperature Sensor

To some aspects, water quality is influenced by water's temperature that include chemical reactions, odor, taste, solubility, density and palatability. Some processes in water like- chlorination, biological oxygen demand and sedimentation depend on water temperature. For measuring ideal water quality, we can measure temperature with a temperature sensor.

Fig 16: Temperature Sensor

PH Sensor

PH is considered as a vital parameter for drinking water as it indicates the water's acid or acid- neutralizing capacity. If the water has pH over 7 that means it has a high presence of carbonate ions, hydroxide ions and bicarbonate ions. Also if the water has pH below 7 that means there are presence of acids like- carbon dioxide, mineral acids, hydrolyzed salts. In both cases, they affect biological processes, chemical reactions in water. These acidity and alkalinity are measured by a pH sensor.

Fig 17: pH Sensor

TDS Sensor

TDS sensor is basically for measuring the number of solids in water. From this sensor's value we can overview the value of calcium, chlorine, arsenic, iron, potassium, magnesium, zinc, aluminum, sulfate, pesticides, herbicides, and bicarbonates altogether.

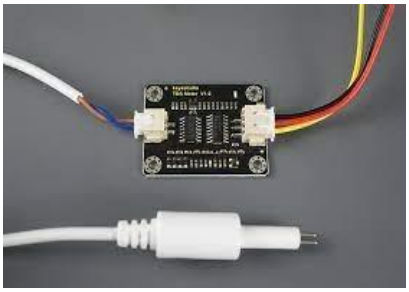


Fig 18: TDS Sensor

ESP32

ESP module is another essential component as the project is IOT based. ESP module has integrated protocol stack that provides any microcontroller access to wifi network.ESP module is an open source basic as well low cost interpreter that is specifically designed for IOT .ESP 32 supports direct wifi means peer connection without any access point and much easier setup with fast data transfer. ESP 32 follows the full 802.11 security protocol.ESP module is small in size and can be worked with Arduino IDE.[19]

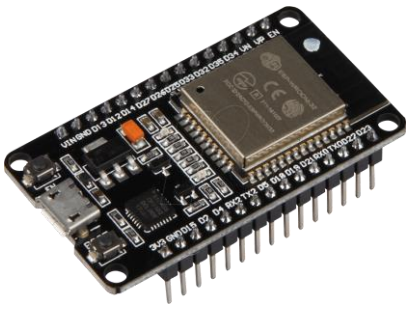


Fig 19: ESP32

3.3 Use of modern engineering and IT tools

Firstly for the optimization of our design, we did simulation on Proteus by setting Arduino Uno and the sensors connecting with wires. We could not find all the sensors there but downloaded and installed them for use. We have used the Arduino code from Arduino IDE and uploaded that to simulate the Proteus file.

After that we need to show a 3-D design of our project. We have used Blender, Marmoset Toolbag for giving a full featured real time look as well as Substance Painter for better developed modeling of our design.

Therefore we have designed a PCB board for our desired portable and non-portable device where we have chosen the ESP32 module as a microprocessor chip because it gives better performance in case of connection with WiFi or Bluetooth. As our project is IOT based so we had to choose a microprocessor that can connect to the internet and store data in the cloud. Then we connected all the sensors modules on it. We did our PCB design on fusion 360 software.

Then we have worked on hardware settings. We have bought the 5 stage filter (RO membrane, Granular active carbon filter, carbon filter, post carbon filter, sediment filter) and installed in

house with direct water tap line .Water will first go to RO membrane and will remove contaminants like- chromium, nitrate, fluoride, arsenic, radium and other salt or metals. RO membrane will also remove the microorganisms causing waterborne diseases.RO membrane provides osmotic pressure to salt or solid solution so that it stops passing the excess salt and metals. In order to determine the RO membrane's condition, TDS sensor can be installed to check the water conductivity. Then water will go to the carbon filter and it will remove maximum chlorine, organic compounds and industrial cleaners. After that water will flow to the post-carbon filter and will remove the rest of the residual chlorine, organic compounds and bad odor as well as taste. Carbon filters simply use an active carbon layer to absorb impurities from liquid. Granular active carbon filter and sediment filter respectfully remove chemical materials and sand, rust, slit but not minerals. Sediment filter works in chemical filtration process. Most importantly all the filters work for protecting the UVC sterilizer.

We have made a small rectangular box where we set our PCB board and the modules are connected with it. Modules are connected with sensors through wires. Sensors are put in the lower part of both portable and non-portable devices to take values from water and send the live data to the cloud server through ESP module. Meanwhile the water comes from filters, stored in reservoir and the UVC sterilizer works as disinfector and destroys the rest of the microorganisms or dissolved solids.

We have added TDS, turbidity and pH to get not only the water quality parameters but also check our filters and UVC sterilizer performance. As TDS value is going to show whether the water contains excess salt, metals, and chemicals elements or not. On other hand turbidity sensor's value will show the existence of chemical materials and solids like- sand, slit and rust. If the value is high, our device will automatically show it as unsafe water. The overall working mechanism of pH sensor depends on the exchange of ions from sample solution to the inner solution (pH 7 buffer) of electrode through the glass membrane of the sensor. We have set the WHO standard range of TDS, turbidity, pH and temperature in our code. So, if the water belongs to a higher range than the standard one, it shows unsafe water on the LCD screen and if the parameters maintain standard value then it shows safe water. We have used two 9V batteries as the power source for portable water bottle and non-portable power source from line voltage.

3.4 Conclusion

Modern engineering is a place where research and developments are only the only thing. All the tools and technologies have been used, for managing the project, plan, assume and visualize the design and then device. From researching to build the final device modern engineering and IT tools are that obvious part that can't be ignored.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution.

4.1 Introduction

The practice of engineering involves using natural laws to construct useful things. A new engine, a car suspension, or a robot are all designs by mechanical engineers. A bridge or building is designed by a civil engineer. A distillation tower or a chemical procedure is designed by a chemical engineer. A computer or integrated circuit is created by an electrical engineer [20].

An engineer might not only be interested in a design that works at some sort of nominal level, but also in a design that is the best design in some way, for a variety of reasons, not the least of which is the competitive market. Optimization is the process of choosing the optimum design. Therefore, we might want to create the smallest heat exchanger possible that achieves

the needed heat transfer, or we might want to create the site's cheapest bridge, or we might want to increase the amount of weight a robot can lift [20].

Engineering optimization is frequently done subconsciously. The engineer makes design decisions that, in theory, should result in the best design by combining judgment, experience, modeling, other people's perspectives, etc. This is something that certain engineers excel at. However, this kind of experience-based optimization may not be able to find the best design if there are numerous factors that need to be altered together with numerous conflicting aims and/or limitations. In order to establish the ideal design based just on the interactions, there are simply too many variables and complex interactions [20].

4.2 Optimization of multiple design approach

We have done some research to analyze our three designs considering some different parameters such as efficiency, sustainability, impact, safety, cost, maintainability etc. By this research and analysis, we found out the optimal solution for our project.

The efficiency of design 1 is low because in this design only UVC light will be used in order to eliminate the microbes like bacteria, viruses and protozoans but other particles may remain.

In design 2 the efficiency is moderate because in this design there will be a RO filter along with UVC light. So, there will be no risk of having other particles in water. UVC light will eliminate the microorganisms and the RO filter will eliminate the remaining particles. The efficiency of design 3 is the highest because the data will always be stored as it is IoT based.
So, users can always check whether water needs purification or not. In this design purification will be done by both RO filters and UVC and data will be monitored by sensors and stored in the cloud. That’s why design 3’s efficiency is highest.
Also, there is a portable carrier in design 3 which is a smart water bottle. It is basically a portable purifier with a data monitoring system. Because of it design 3 is more portable than design 1 and 2 as there are no portable purifiers in both the designs. Next, design 1 is not sustainable as direct tap water can be harmful for UVC sometimes. On the other hand, design 2 & 3 is sustainable as filtered water is much safer for UVC for better purification. Also, no replacement is needed before 12 months if no sudden technical issue occurs. But design 3 is more sustainable because it is an IoT based system and users can know the condition by seeing the data.
Furthermore, the safety of design 1 is low as only UVC is being used. In design 2 it is moderate as it has both UVC light and RO filters. But design 3 assures 99.99% germ killing so it is totally safe for our users. Impact of design 1 is moderate as only UVC light can not provide perfect healthier water.
Design 2 & 3 provides users to receive the safest and healthiest water and because of that the impact of these designs are very high. But design 3’s impact is slightly higher because it is also providing the water quality data as proof to the users.

Cost of design 1 is quite low as here only UVC light will be used. For design 2 cost is moderate as along with UVC there will be 6 stage RO filters. And for design 3 the cost will be highest because here along with UVC and 6 stages filters there will be many extra sensors like ORP, Temperature sensor, then an alarm system and also WIFI module to store data. Also, there is a portable water bottle in design 3. That's why its cost is higher compared to other 2 designs.
Manufacturability of design 1 is easy as the setup will consist only of UVC light along with digital display. For design 2 it is moderate as the setup will consist of UVC, 6 stage RO filter. For design 3 it is quite hard as there will be setup for UVC, 6 stage RO filter, a real time monitoring system along with some extra sensors.
Usability of design 1 & 2 is quite easy because water will go into the system and will be purified automatically. Users just have to wait for some minutes and then can drink water. But in case of design 3 it is much easier as water purification will be done in various stages and it will give data to users through our server. Also, there will be an improved monitoring system so users can see when the water is pure and then they can drink it.
Maintainability of design 1 is easy as users just need to check the UVC only. For design 2 it is also easy. Users need to check the UVC and RO filter if these are performing accordingly or not. For design 3 maintainability is quite challenging because users need to monitor the performance of UVC and RO filters along with different sensors and also have to check and monitor the data through our app regularly.
Risk of design 1 and 2 is medium but risk of design 3 is very low if the maintenance is done perfectly.
Moreover, simulation were done for all the three designs proposed. The simulation was done in Proteus as it has a vast library and user can create library.

Simulation of Sensors:

Design 1 simulation:

Here the pH sensor library and the other library were made.

This is the first design model simulation. Here a pH sensor, turbidity sensor, Conductivity sensor and temperature sensor were used. The sensors were simulated and the data was shown into the LCD screen. Here a library was added in the Proteus for the pH sensor the LCD and the arduino. In the pH sensor there a voltage regulator which can control the pH and a power and a ground were connected. A power and ground is also connected to the other sensors. The sensors gives values to the arduino and it process the value and shows in the LCD. A arduino code was generated as a hex file and uploaded in the proteus for the processing.

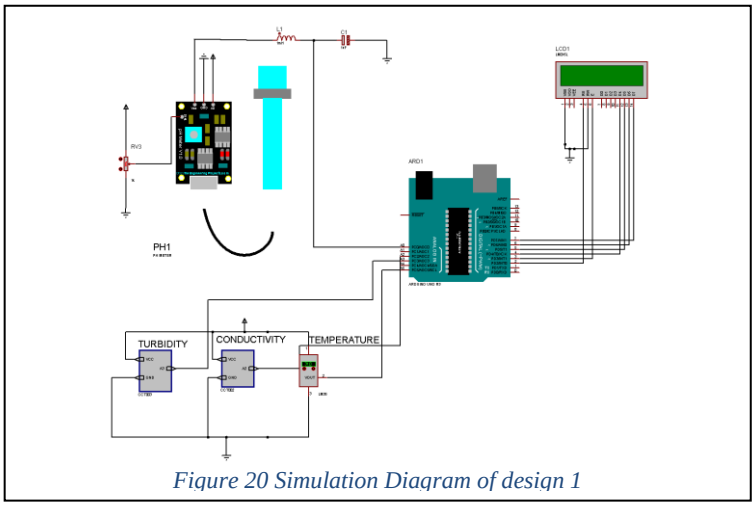


Figure 20 Simulation Diagram of design 1

Design 2 simulation

This is the second design model simulation. Here a pH sensor, turbidity sensor, Conductivity sensor and ORP sensor, Ultrasonic sensor, Water Level sensor were simulated and the simulated data was shown into the LCD screen. The ultrasonic sensor, pH sensor, arduino and the water level sensor library needed to be added in the proteus. Then all the other sensors like TDS, ORP, Turbidity sensor was created. After that, a code generated as hex file was uploaded in the proteus to run the simulation as it showed values of the sensors.

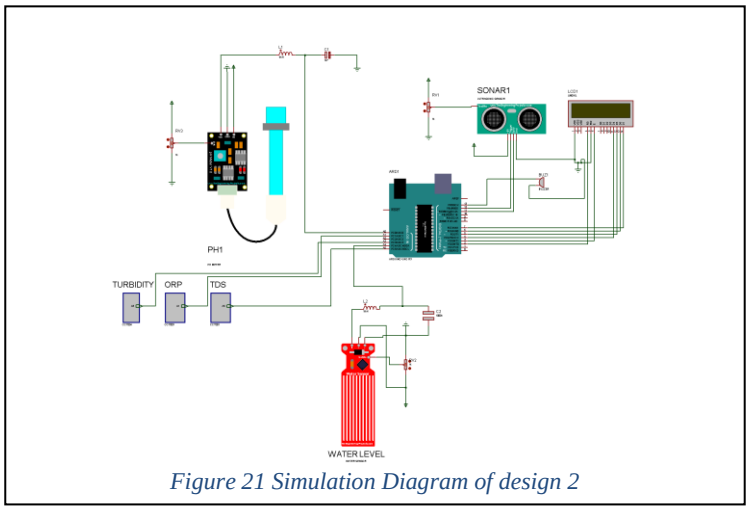


Figure 21 Simulation Diagram of design 2

Design 3 simulation:

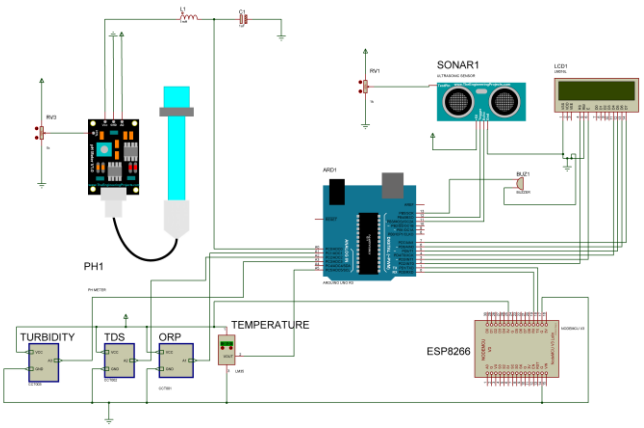


Figure 22 Simulation Diagram of design 3

This is the third design model simulation. Here a pH sensor, turbidity sensor, Conductivity sensor and ORP sensor, Ultrasonic sensor, Temperature sensor were simulated. Showed the data into the LCD screen. Moreover, there is a wifi module it will show send the data in the cloud server. The wifi module is ESP8266. The ultrasonic sensor, pH sensor, arduino and the alarm library needed to be added in the proteus. Then all the other sensors like TDS, ORP, Turbidity sensor was created. After that, a code generated as hex file was uploaded in the proteus to run the simulation as it showed values of the sensors.

Simulation of UVC light

Simulating UVC light an online software was used. The software is called edu-media. In the online software, there is a simulation of light of different wavelengths which hits an electric plate which ejects electron if it gets enough energy from the light. It is basically based on Max Planck's theory **E = hν** (h is a constant that is $6{,}626.10^{-34}$ J.s). [21]

Now the wavelength was 256.33nm which is like the UVC light using in the built system it can be seen that with 66% of intensity electrons are ejecting from one plate to another and 2.6A of current is flowing the simulating system. From the Planck's theory it can be said that 256.33nm wavelength can generate energy. Moreover there are photon rays which are visible in the simulation, which can be proven to kill germs.

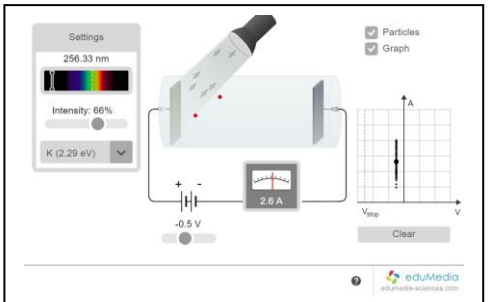


Fig 23: UVC light simulation with 256.33nm and 66% intensity

Simulation was also done with 100% intensity of 256.33nm where it was seen that it gives 4A current. So, more the intensity more the photon will be released and better for germ killing.

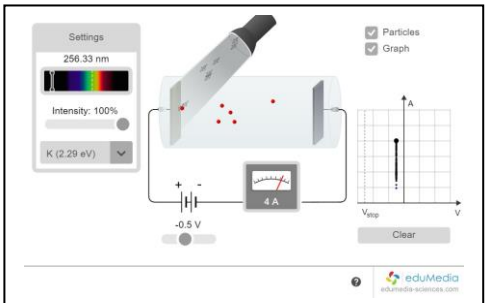


Fig 24: UVC light simulation with 256.33nm and 100% intensity

However, simulation with visible light proves that there are no energy and no photons are released and no current are flowing. So, only lower wavelength light can emit energy like UVC which can kill germs but higher wavelength can not emit energy.

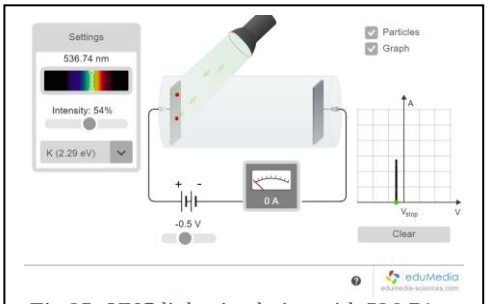


Fig 25: UVC light simulation with 536.74nm and 54% intensity

4.3 Identify optimal design approach

Moreover, optimal solution can be identified by the simulations results. All 3 proposed designs were simulated and below is the results.

For the simulation part there is a weightage table to find out the optimum solution or the best solution.

Table 6: Optimal solution based on simulation of sensors

Features	Marks	Design 1	Design 2	Design 3
TDS sensor	20	0	20	20
Turbidity sensor	20	20	20	20
pH sensor	20	20	20	20
WIFI module	10	0	0	10
ORP sensor	5	0	5	5
Sonar sensor	10	0	5	5
LCD screen	5	10	10	10
Temperature sensor	10	10	0	10
Total	**100%**	**60%**	**80%**	**100%**

Based on the table it can be said that design 3 is the optimal solution.

Identifying the optimal design solution we need to find out the best solution. In this project comparison between the 3 designs to find out the best solution. The optimal design solution was found based on a marking system. The design can be marked on

Table 7: Optimization based on simulation

Criteria	Design 1	Design 2	Design 3
Features(40)	24	32	40
UVC light Intensity(30)	15	15	20

Safety (10)	4	8	10
Impact (20)	5	7	8
Total out of 100	**48**	**62**	**78**

Based on analysis, research and some calculations the weight marking of different parameters for our three designs which is given in the table above. According to the table design 3 has got the maximum score out of hundred compared to the other designs. So, design 3 was chosen as the optimal solution for this project.

4.4 Performance evaluation of developed solution

For performance evaluation first thing needed to be done is to set up the prototype. The prototype setup was completely finished. Here is the picture.

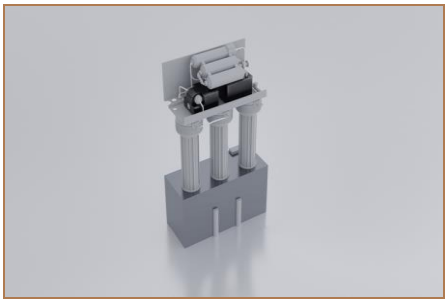


Fig 26: Non-Portable System Prototype Design

Fig 27: Portable System Prototype Design

Then the water parameters needed to be calculated with our system. Before calculating the parameters, the values were not exactly correct. There were lot of problems in the code we used. All the sensors had to be calibrate.
pH sensor was the most difficult to calibrate. A buffer solution of 7.01 pH was used to calibrate it. Moreover, the sensor needed to be fixed as we were using esp32. Esp 32 is 12 bit microcontroller whereas arduino is only 10 bit. Therefore the code needed to be fixed.
Furthermore, the code for TDS and Turbidity was also needed to be changed as we were using esp32.
After fixing all the codes and calibrating all the sensors we could get the exact data from the system.

Results

Design 1 results

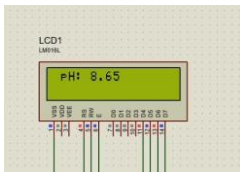


Figure 28: pH value

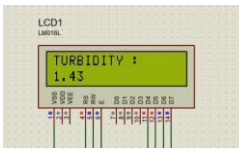


Figure 29 Turbidity value

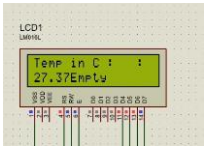


Figure 30 Temperature value

For design 1 three values were gotten.

Design 2 results

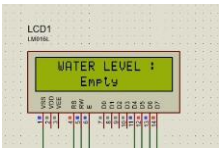


Figure 31 Water Level value

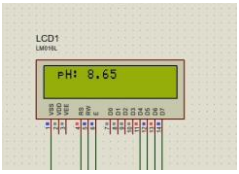


Figure 32: pH value

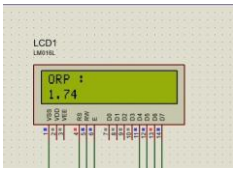


Figure 33 ORP value

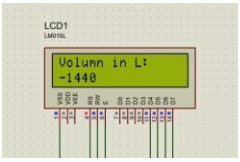


Figure 34: Volumn value

In this design there are more sensors and got all the values form all the sensors.

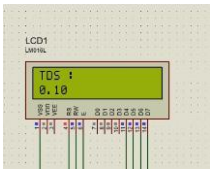


Figure 35: TDS value

Design 3 results

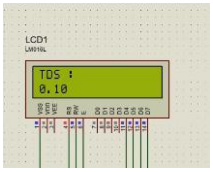


Figure 36: TDS value

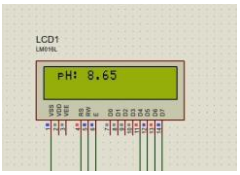


Figure 37: pH value

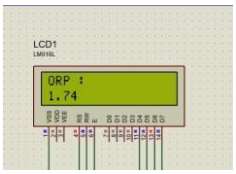


Figure 38 ORP value

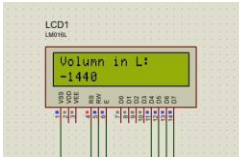


Figure 39: Volumn value

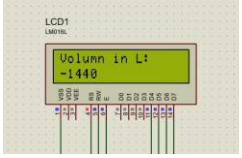


Figure 40: Volumn value

Now For the result part it can be said say that in every simulation the results will be shown in the LCD display. So, there are some pictures of the LCD display for results

In the model 3 or design 3 the wifi connectivity by serial connection was simulated so that it can be sure that the design will send the data to the cloud server.

Here is the serial port output.

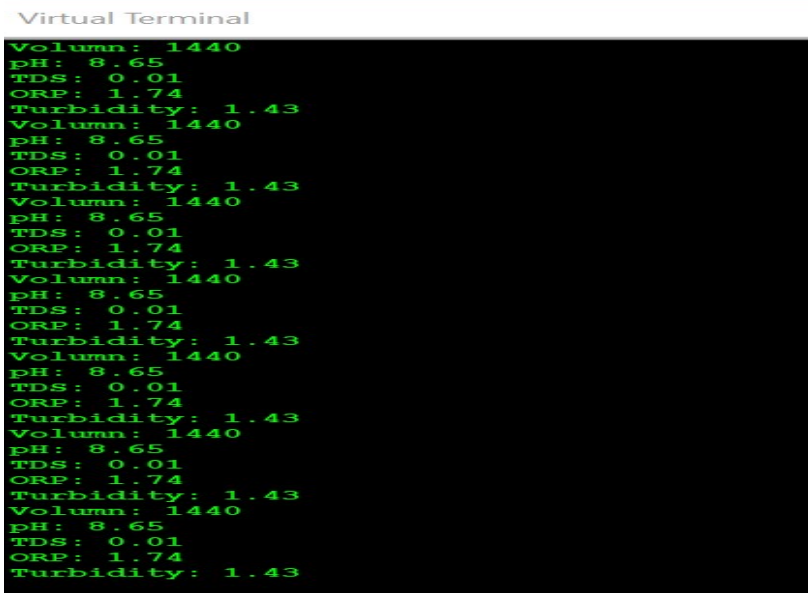


Figure 41 Serial communication output

Calculations:

Calculated the exact time to use the UVC light.
Here is the calculation.
Radius of the filter tank= 11.5 cm
With 1 UV light,
Voltage=0.05 and warm up time= 3 seconds
So, readout= 0.05*5= 0.25mW/cm^2 =0.00025 W/cm^2
Dose= 1.5 J/ cm^2
Time to reach the irradiance= [(1.5 J/ cm^2) / (0.00025 W/cm^2)]
= 6000 seconds = 100 minutes
With 2 UV light,
Voltage=0.65 and warm up time= 3 seconds
So, readout= 0.65*5= 3.25mW/cm^2 =0.00325 W/cm^2
Dose= 1.5 J/ cm^2
Time to reach the irradiance= [(1.5 J/ cm^2) / (0.00325 W/cm^2)]
= 461.54 seconds = 7.69 minutes
From the calculation we can see that we need to use the UVC light in the water tank for at least 7.69 minutes. It is safe to use the UVC light for 8 minutes.
Calculations for water bottle
Diameter of the bottle= 8 cm
With 1 UV light,
Voltage=1.792 and warm up time= 3 seconds

So, readout= 1.792*5= 8.96 mW/cm2 =0.00896 W/cm2
Dose= 1.5 J/ cm2
Time to reach the irradiance= [(1.5 J/ cm2) / (0.00896 W/cm2)]
= 167.4 seconds = 2.79 minutes

4.5 Conclusion

In conclusion, it can be said that we did simulation in Proteus with sensors, voltage regulator and got features efficiency on that. Therefore we did test for UV light to get its intensity and dose. Doing all those simulation for all 3 designs, we analyzed the designs and found design 3 as the most optimizing one based on the simulation results.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

Final design means the complete and the best design of a project and validation means proof of project work. In this chapter we are going to explain the final design of our smart water purification system. The changes made will be described in this part of the report. Moreover, the complete design will be shown in the project. Furthermore, the project will be validated in this chapter. Whether the project is working properly, the core objectives are fulfilled or not, the project's functionality etc. will be fully mentioned in the chapter.

5.2 Completion of final design

After many research and experiments we have completed the design. In the previous chapter our design 3 was the best optimal design. However, there were many things that needed to be considered. Many changes were made in the design to make it more usable. There were many complications.

The main complications were in the portable part of our design. The portable part is very small. It does not have enough space to put all the sensor modules in that tight place. Therefore, we needed to change the design so that we can fit all the things in the small space.

Here is the first design of the portable system.

Fig 42: Portable System first design

In the first design it was thought that all the modules and sensors can be put in round shape below the water bottle. It was found to be very difficult to do this. Moreover, there were no space for the lcd display to fit.

So, the design was changed to a square shape box below the water bottle. This square shape box will hold all the sensors and modules and it will also hold the LCD 16*2 display.

Furthermore, the UVC Light was in the water bottle in the first design. In the new design the light position was changed so that we can use it more. The light was put in the water bottle cap.

Fig 43: Portable System final design

There were many steps for making the water bottle. Firstly, the 3D design was completed. The design was made in a software. Fig 36 was the final design. Then the design was given in a 3D printer. It took more than 3 days to print the water bottle. As in fig 37 it is seen that the water bottle in being printed.

Fig 44: Printing in 3D printer

After printing the water bottle in the printer the whole and the sensors insert points were measured. It was tested by putting the sensors in the hole under the water bottle. In fig 38 the holes in the water bottle can be seen.

Then all the sensor module was inserted in the designated place. Like in fig 39 the modules are placed in the designated spot. After that all the sensors were sealed with super glue and gum for water resistance. Doing that we finished our water bottle.

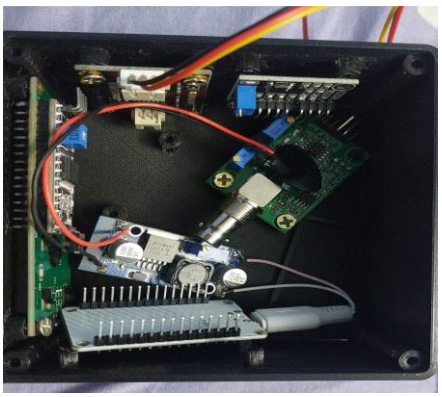


Fig 45: Sensor module placed

Fig 46 Portable system prototype

The Non-portable part of the system is basically the same. There is no major changes. The water tank under the filter was thought to be made of SS 304 grade. However, This SS 304 grade is highly costly for single tank. Therefore, a food grade water filter was bought replacing the SS tank.

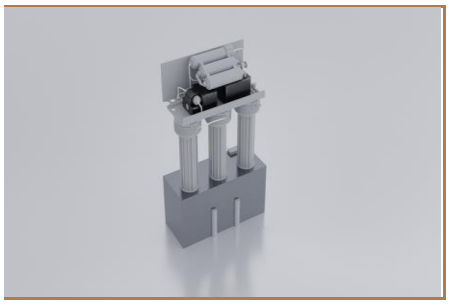


Fig 47: Non-Portable System 3D design

For the non-portable part the design was same so firstly started working with the UVC light to test its intensity and its fitting. The water container of the water filter was bought according to the UVC light as in fig 48. Then all the sensors of the water filter was combined and arranged together through jumper wires and power was given by 9V battery for testing. As it can be seen in fig 49 that testing were done putting all the sensors in a small cup of water. After that, a small controlling unit was made with pvc board for displaying and setting all the sensor modules shown in fig 50. Then, all the sensors were sealed in the water container to prevent water leakage. After that to make the system more compact a 2 layer PCB was designed shown in fig 51 and 52

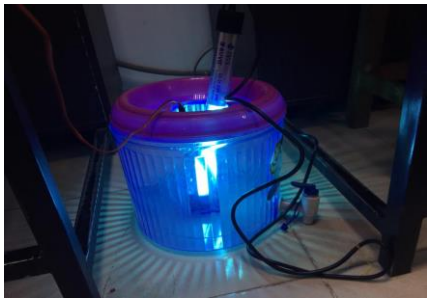


Fig 48: UVC light and water container

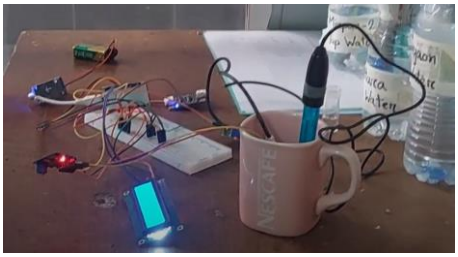


Fig 49: testing of sensors

Fig 50: Non-Portable System Control box with PCB

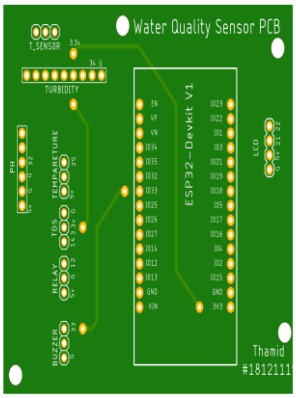


Fig 51: PCB design top part

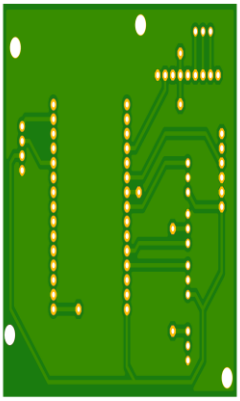


Fig 52: PCB design bottom part

Here is the prototype picture of our system

Fig 53: Non-Portable System Prototype

5.3 Evaluate the solution to meet desired need

In this part it is going to explained that developed system is going to fulfil all the requirements and our core objectives. Mainly there are four main objectives in our system. If these four objectives are completed, then we can say that all the requirements are fully satisfied.

The first and foremost need of the project is to have a purification system through UVC light. The project needed to have such a system where we can purify water through UVC light. In the system there is a UVC light that is in the water tank of the system. This UVC light have 254nm wavelength which kills all the bacteria, viruses and algae in the water and makes the water purified.
Secondly, our need is to monitor the water quality. There are a lot of parameters of safe water. However, we cannot measure all the parameters in our system. Although, we are measuring the fundamental parameters of water. In the developed solution there are pH measurement system, Temperature, Turbidity and TDS (Total Dissolved Solids) measurement system. These are the basic parameters of water which will tell us the quality of water. Moreover, developed algorithm will also tell the user if water quality is safe to drink or unsafe.
Thirdly, this objective is to make a portable purification system. The project has a water purification which is portable and has a UVC based purification system. Furthermore, this portable device will also measure water quality and the system is IOT based.
Lastly, in the project we should be able to notify users to drink water after a regular interval. The developed project has an alarm system and through our algorithm we notify the users that it is time to drink water.

Hardware tests:

UVC Intensity and Germ killing test:

UVC were tested for the intensity level and killing of germs.

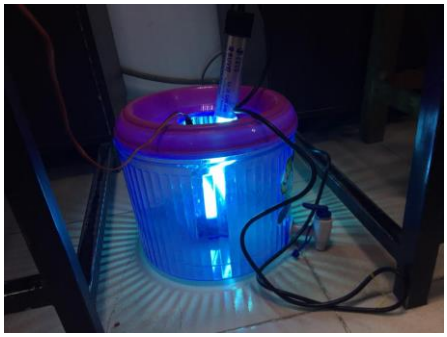


Fig 54: UVC intensity test

A voltage of 0.65 voltage reading and readout= 0.65*5= 3.25mW/cm^2 =0.00325 W/cm^2 were found.
Then 193 (95.1%) of the 203 baseline samples tested positive for bacteria, with a keyboard-specific CFU (colony forming unit) median of 120. Numerous bacteria, such as Staphylococcus, Streptococcus, Enterococcus, Pseudomonas, Pasteurella, Klebsiella, Acinetobacter, and Enterobacter, have been related to health care-associated infections (HAIs). 25 (12.3%) of the 193 keyboards contained gram-negative organisms. 205 (94%) of the 218 postinstallation samples were sterile. Six of the 13 samples that demonstrated bacterial growth

yielded a single CFU. A >99% reduction in bacteria was seen when pre- and post-UV decontamination median CFU levels (120 and 0, respectively) were compared [22].

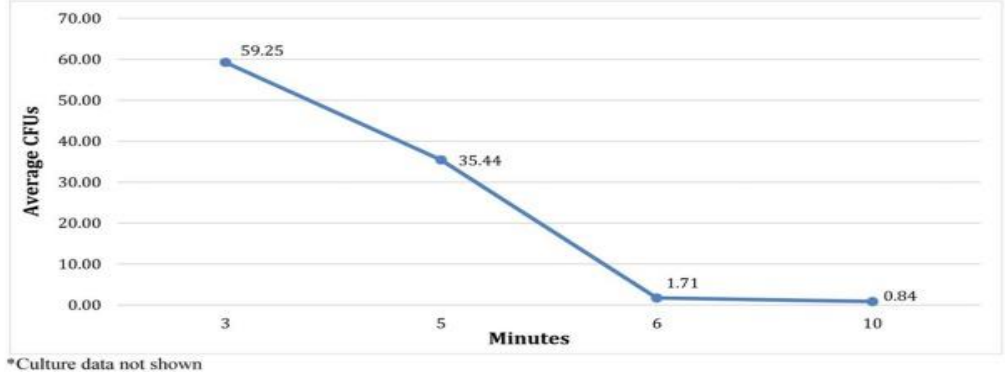


Fig 55: UVC irradiation test [22]

Parameter testing of different cases:

Calculating the water parameters with the system.

Now for tap water or WASA water of Mirpur,

Table 8: Parameters and values before purification

Parameters	Values
pH	7.45
TDS	154 ppm
Turbidity	1.35NTU
Temperature	27 Degree Celcius

After only using UVC light the results were same.

Table 9: Parameters and values after UVC purification

Parameters	Values
pH	7.45
TDS	154 ppm
Turbidity	1.35NTU
Temperature	27 Degree Celsius

Different values were received when RO+UVC were used

Table 10: Parameters and values after UVC and RO purification

Parameters	Values
pH	7.45
TDS	81 ppm
Turbidity	0.98 NTU
Temperature	27 Degree Celcius

When getting the tap water the system is showing unsafe water values also the system is showing unsafe water. After only using UVC light we also see that there is no change is the values. However, after using RO+UVC we get to see that the pH value is the same 7.45 but the

TDS value came down from 154 ppm to 81 ppm. This value was expected. Moreover, the Turbidity value was also decreased from 1.35 ntu to 0.98 NTU which is a safe range. This decrease of turbidity value was also expected from our system.
Here, is a table comparing the system values with range

Table 11: Status of parameters

Samples	Parameters	Values	Range	Status
Tap Water(Before Purification)	pH(Alkalinity, Acidity)	7.45	6.5-8.5	Good
	TDS(Iron,Chlorine)	154 ppm	<500ppm	Moderate
	Turbidity(Lead,Mercury)	1.35 NTU	<1NTU	**High**
	Temperature	27 degree celsius	25-30	Good
Only UVC Purified Water	pH(Alkalinity, Acidity)	7.45	6.5-8.5	Good
	TDS(Iron,Chlorine)	154 ppm	<500ppm	Moderate
	Turbidity(Lead,Mercury)	1.35 NTU	<1NTU	**High**
	Temperature	27 degree celsius	25-30	Good
UVC and RO Purified water	pH(Alkalinity, Acidity)	7.45	6.5-8.5	Good
	TDS(Iron,Chlorine)	81 ppm	<500ppm	Good
	Turbidity(Lead,Mercury)	0.98 NTU	<1NTU	Good
	Temperature	27 degree celsius	25-30	Good

System Reliability:

A reliability test for the developed system is calculated. There are many kinds of parameters in the water. In total there are 13 parameters. There are sensors for the parameters to measure. In total there are more than 9 sensors. Those are:

1. **Turbidity-** For cloudiness of water
2. **TDS-** To measure Total dissolved Solids in water
3. **Temperature**
4. **Electric Conductivity-** For Electrical Conductivity
5. **pH-** Alkalinity,acidity.
6. **spectrophotometer or color comparator test kit-** Chlorine
7. **colorimeter or test strip-** Hardness
8. **BOD-** To test Biological Oxygen Demand
9. **Microscope or pathological test-** For biological parameters.

In an ideal water quality monitoring system there should be all the sensors available to measure the water quality parameters. Below is a chart which compare between developed system and the ideal system through a marking process:

Table 12: Comparison between Ideal and Our System

Sensors	**Ideal System Marks**	**Our System Marks**	**Range**
Turbidity	20	20	<1NTU
TDS	20	20	<500ppm
pH	20	20	6.5-8.5
Temperature	15	15	<30 degree celsius
BOD	5	0	1-2ppm
Electric Conductivity	5	0	200-800mS/cm
Colorimeter	5	0	<75mg/L
Spectrophotometer	5	0	<4ppm CCD
Total	100	75	

In the table it can be seen that we found only 4 quality sensors to measure our water quality parameters. Therefore, it can be said that our system is only 75% reliable.

System Accuracy:

Some test were done before and after purifying water by the developed system in the Bangladesh Council of Scientific and Industrial Research (BCSIR). We tested for lead to get the turbidity accuracy and chlorine for TDS. However, it is known that turbidity have mercury, cadmium, lead, and other heavy metals and TDS have Calcium Chloride Magnesium Potassium Zinc Aluminum Copper Lead Arsenic Iron Chlorine Sodium Fluoride Bicarbonates Sulfates Pesticides Herbicides.
Below is the table of accuracy of our system.

Table 13: Percentage of accuracy of the system

Water Sample	**Test Result From BCSIR**	**Test Result From Our System**	**Accuracy**
Tap Water (before purification)	pH = 7.27	pH = 7.45	97.58%
	Lead(Pb) = 0.01 mg/L [Turbidity]	Turbidity= 1.35 NTU or 0.45mg/L	~56% (calculated with one data)
	Chlorine(Cl) = 0.2 mg/L [TDS]	TDS= 15.4 mg/L	~96.96%(calculated with one data)
UVC Water (after purification)	-	pH = 7.45	97.58%
	Lead(Pb) = 0.01 mg/L [Turbidity]	Turbidity= 1.35 NTU or 0.45mg/L	~56% (calculated with one data)
	Chlorine(Cl)=0.2 mg/L [TDS]	TDS= 15.4 mg/L	~96.96%(calculated with one data)
UVC+RO Water(after purification)	-	pH = 7.45	97.58%
	Lead(Pb) = 0.01 mg/L [Turbidity]	Turbidity= 0.98 NTU or 0.33 mg/L	~99.03%(calculated with one data)
	Chlorine(Cl) = 0.2 mg/L [TDS]	TDS= 8.1 mg/L	~97.53%(calculated with one data)
	Average Accuracy		**~66.67%**

As mentioned earlier, the tests were only for one element for turbidity and TDS, where as there are many. Therefore, an exact value of accuracy cannot be determined. However, the average accuracy for our system is 66.67% approximately.

5.4 Conclusion

In conclusion, it can be said that the prototype was made and run fir the designed project. All the bugs in the code were fixed and the sensors was calibrated. The UVC light intensity and its germs killing was tested. Moreover, calculations for the time to kill all the germs and tests for reliability. The developed system is 75% reliable and approximately 66.67% accurate.

Chapter 6: Impact Analysis and Project Sustainability.

6.1 Introduction

A serious health risk that is frequently disregarded is water pollution. Even though it can't be seen, it exists. Water pollution is defined as any undesirable, hazardous, life-threatening bacteria or bacterium that can harm our bodies' health and wellbeing. People who use polluted water run the risk of contracting infections, which occasionally pose a serious threat to their lives. The water contamination is constantly being fought by our immune system. However, excessive contamination might seriously injure us and kill our immune system.

6.2 Assess the impact of solution

Our system's ability to purify 99.99% of the water will enable it to be free of 99.99% of the microorganisms that may be present in water. Our initiative will now significantly affect the customers' daily lives because it will guarantee them access to clean, fresh water. People will be protected from the numerous pathogens, bacteria, and potentially fatal effects that contaminated water may bring.

Legal Impact

We are extremely careful and wary of any potential legal repercussions as we construct our project. However, as our system is unrelated to personal information, we predicted that neither any legal restrictions nor any interference with intellectual property would be present. Our suggested system’s users will be in responsibility of keeping it updated, and the system will also remind them to do so. Additionally, it will not result in any legal consequences under environmental laws. We have created and put out a plan that will benefit our environment rather than harm it, and we will keep doing so for the duration of the project.

Safety Impact

The major goal of our initiative in terms of safety is to produce water that is clean and safe to drink. We have taken the necessary steps to get rid of any potentially dangerous bacteria and germs that may be present in the water. Before the project is finished, more safety issues will be resolved. Because we haven't used our system to its full potential, we haven't yet run into any problems caused by a component failing to produce the desired output.

Cultural Impact

An essential component of a society's cultural identity is how it uses and values water. Cultural differences greatly influence how individuals may regard water, its purification, and its use. For instance, American fresh water sources are so pure that most of the time people can drink directly from them, but this is not the case in third-world countries (eg. Bangladesh). Additionally, we must meticulously filter the water in order to make it drinkable due to the

seriousness of water contamination. However, because they are accustomed to drinking tainted water, the rural, uneducated population may see this as lengthy and unnecessary process.

Social Impact

A friendly effect is referred to as the aspect of social sufficiency, equity, and impact of particular hardware or new creative developments that will result in a better quality of life. Our suggested purifying method will be well received by the public because it is so simple to use and accessible. For water to be fresh enough to drink, it must first be purified. Our method will enhance the feeling of having filtered water if it is used in communities and by families. Additionally, this will be a breakthrough in the field of purified water, enabling people to acquire safe water at a reasonable price and lead healthy lives. Around the world, about two billion people lack access to clean drinking water. If we can implement our system in micro level of society, it will have a great impact. Therefore, this method will have a significant impact on reducing water-related illness, and a huge population will gain socially as a result. These concerns will make an effort to grab the public's attention and will help in gaining societal acceptance. We are confident that our water purification system will have a positive impact on society.

Environmental Impact

The ecosystem, especially the living things, is impacted by water pollution. Every species uses water for a variety of purposes, including insects, frogs, birds, and bats. Any living thing can become affected by water pollution, which poses a major risk to its organs. The issue of water pollution is particularly serious for rural poor people since they rely on supplied water, natural water resources, and because they also have limited access to fresh water and cannot afford to purchase technology to cleanse it. Our method is capable of cleaning water of turbidity, pathogens, and germs. Therefore, the lack of fresh drinking water may be appropriately addressed and people's lives could be saved if our filtration system could be installed in those places.

6.3 Evaluate the sustainability

To evaluate our project, firstly we have to talk about the components lifetime.

Table 14 Component life-time [23]

Component	Life-time
UVC	9000 hr
RO	12-24 months
Block Carbon Filter	3-6 Months
GAC	3-6 Months
Sediment filter	6 months
Post Carbon Filter	10-12 Months
Microfilter	12-24 months

Quality monitoring tools (TDS, pH, turbidity, temperature sensor; sensor module, WiFi module, wire, battery, switch)all are electric components. They have a guarantee for 1 to 2 years depending on usage and brand. Below there is a graph that shows the battery performance of a 9V battery.

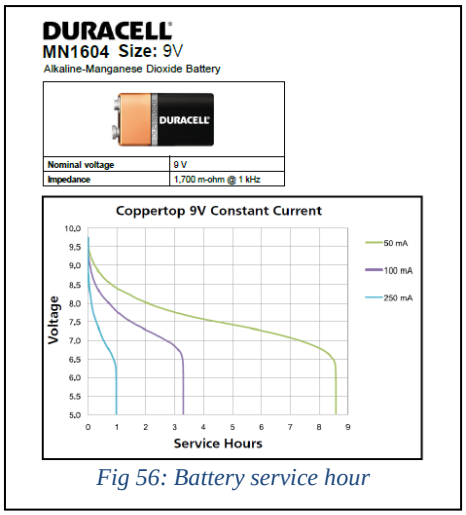


Fig 56: Battery service hour

Here it needs to be mentioned that, in a non-portable filter, the 23 liters of water take 7 minutes and 1 liters of water in a smart bottle take 4 minutes to disinfect. So electricity and power source cost will be compatible for our project.

All the components are replaceable, so after they get wicked, consumers can easily buy and replace them.

We are not using any harmful chemicals or nonrenewable resources that can be a threat to the environment.

Nowadays the market for filters and smart disinfecting bottle's market is rising because of not getting proper safe drinking water. Therefore, people are now more health conscious. With our project people not only will get safe water but also can monitor their health by checking the water quality parameters.

UVC is the safest, cleanest and abundant natural resource. We can even use only UVC light or steripen to disinfect the water.

Our project has a positive impact on the environment, society and health. It is not harming the environment. Moreover, it is an eco-friendly domestic water treatment process that introduces consumers with new technologies and saves their life and time. The UVC disinfection system is the most reliable in the modern world .Where it is a matter of disinfecting and monitoring water qualities, it is surely health beneficial.

6.4 Conclusion

Our water purification technology makes it possible for people to always have access to safe drinking water. Aside from that, it is clear that the system will have a meaningful and positive impact on the families and individuals who use it since they will be protected from water-related illnesses and will benefit physically and psychologically from drinking fresh water.

Chapter 7: Engineering Project Management.

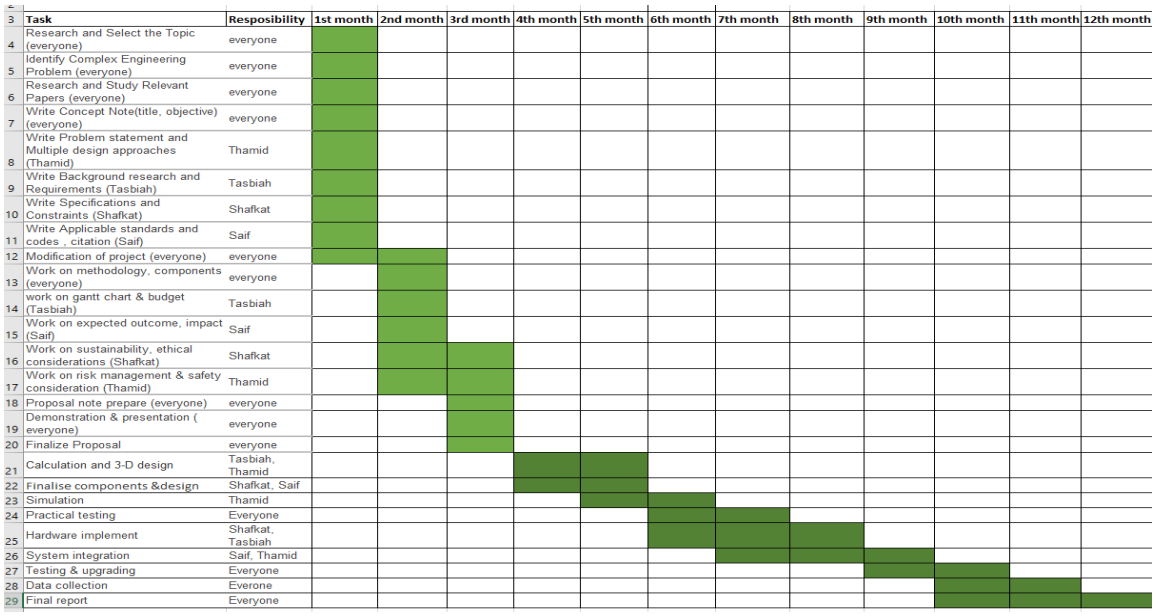
7.1 Introduction:

Project management is a crucial aspect of any project. It is the practice of initiating, planning, controlling, executing and closing the work of a team to achieve specific goals and meet specific success criteria at the specified time. Planning the entire progress with a designed plan helps to organize the whole project and works like a backbone. To maintain the project smoothly, assigning specific responsibilities helps to deal with outcome issues and risk factors. Teamwork is the key to solving associated risks and generating constant accurate outcomes. Regarding that our project is temporary in that it has a defined beginning and ending in time, and therefore defined scope and resources.

7.2 Define, Plan, and Manage Engineering Project:

Our project had started with a routine operation, but a specific set of operations designed to accomplish a singular goal. As we have a strict timeline to complete our project work, we initially made a Gantt chart at the very beginning in order to work according to the timeline. The Gantt charts puts us on notice that the project is being started and that it has management's acknowledgement and commitment. Also, it helps our project plan to be flexible and we can replan at any time and update them easily as needed throughout the project.

All the group members are individually involved in the project design and delivery. Furthermore, we divided the tasks and assigned them to each member. We also record everything regarding our project from the beginning. For that we have maintained a Logbook to keep record on our responsibilities and working details.



	Task	Resposibility	1st month	2nd month	3rd month	4th month	5th month	6th month	7th month	8th month	9th month	10th month	11th month	12th month
4	Research and Select the Topic (everyone)	everyone												
5	Identify Complex Engineering Problem (everyone)	everyone												
6	Research and Study Relevant Papers (everyone)	everyone												
7	Write Concept Note(title, objective) (everyone)	everyone												
8	Write Problem statement and Multiple design approaches (Thamid)	Thamid												
9	Write Background research and Requirements (Tasbiah)	Tasbiah												
10	Write Specifications and Constraints (Shafkat)	Shafkat												
11	Write Applicable standards and codes , citation (Saif)	Saif												
12	Modification of project (everyone)	everyone												
13	Work on methodology, components (everyone)	everyone												
14	work on gantt chart & budget (Tasbiah)	Tasbiah												
15	Work on expected outcome, impact (Saif)	Saif												
16	Work on sustainability, ethical considerations (Shafkat)	Shafkat												
17	Work on risk management & safety consideration (Thamid)	Thamid												
18	Proposal note prepare (everyone)	everyone												
19	Demonstration & presentation (everyone)	everyone												
20	Finalize Proposal	everyone												
21	Calculation and 3-D design	Tasbiah, Thamid												
22	Finalise components &design	Shafkat, Saif												
23	Simulation	Thamid												
24	Practical testing	Everyone												
25	Hardware implement	Shafkat, Tasbiah												
26	System integration	Saif, Thamid												
27	Testing & upgrading	Everyone												
28	Data collection	Everone												
29	Final report	Everyone												

Figure 57: Gantt Chart of the project

7.3 Evaluate Project Progress:

Project Planning and Establish Project Timeline:

Project management is mandatory to maintain a constant outcome by completing all the tasks which are assigned in a planned manner. Initially a plan is being made with an estimation but the initial plan does not go as planned. So, the plan needs to be updated throughout the project timeline. Sometimes, it becomes imminent to bring some changes in the project plan. Therefore, a revised plan was designed with a new timeline that provides more accurate project progress.

Establish Detailed Budget:

Table 15 Detailed Budget

	Component	Specific Name	Quantity	Unit Price (BDT)	Price (BDT)
1	UVC Light	Low pressure UVC light	1	2500	2500
2	UVC Light mini	Low pressure UVC light	1	1610	1610
3	ESP 32	ESP V-ROOM 32	2	400	800
4	Conductivity Sensor	TDS Sensor	2	1800	3600
5	pH Sensor	Analog pH sensor	2	2500	5000
6	Turbidity Sensor	SKU_SEN0189-D	2	1000	2000
7	Filter	6 stages (RO,PP,GAC,SEDIMENT, CTO,POST CARBON)	1	10000	10000
8	PCB design		2	1000	2000
9	Temperature sensor	LM35	1	120	120
10	Water reservoir		1	800	800
11	Water bottle		1	250	250
12	Battery (9V)		2	100	200
13	Switch		2	120	240
14	Miscellaneous			1000	1000

Risk Management and Contingency Planning:

Risk is an uncertain moment where it could bring many unknown consequences. Several risks such as design malfunction, short circuit, damage of any components, server jam etc. might occur if any accident happens. Many components were damaged throughout the project and some troubleshooting was also done. But these constraints did not impede our progress as contingency plans were already made. We made a risk management analysis where we added all the risk factors that may hamper our project.

Table 16 Risk Factors and Contingency

Risk Factor	**Level of Risk**	**Risk Contingency Plan**
Finding actual UVC light	Low-Medium	Measuring the irradiation of UVC light
Sensor Malfunction	Medium	Continuous monitoring of data using sensors
UVC irradiation	High	Covering the filter so that irradiation cannot go out

7.4 Conclusion:

Project management works as a backbone for any project. It helps us to be updated on what tasks were accomplished, who was involved in completing particular tasks, and when the tasks started and finished. An organized project plan helps us progress and work on solutions as soon as an error or accident occurs. So, risk management is an integral part of project management. Finally, improvising the project plan as the project progresses is crucial in achieving a great project.

Chapter 8: Economical Analysis.

8.1 Introduction

Economic analysis is the economic and financial aspects observation and evaluation of cost benefit of any certain project. This analysis helps to compare the value of impact of the invention with the cost of making it. It mainly focuses on getting the amount of benefit or impact in comparison of its total cost. It helps to find out the percentage of effectiveness and sustainability of the product. It describes the project's efficiency from an economic perspective. This analysis is very important for designing well balanced and cost-effective projects, avoiding unnecessary delay costs and foolish investments. The main sectors of analysis are the demand for different services, how tax can be fixed to improve general peoples' utilizing finances. Both economic and financial assessments are essential for project monitoring, judging and observing.

8.2 Economic analysis

Economic analysis uses the economic price of the project that is converted from market price by cutting profit, other sales and costs, tax to evaluate the legality of using national resources to any project. Before analyzing this, we have to consider some factors. Suppose where the water came from (such as- ground water, surface water, well water or sea water). Secondly the level of using technology for its different features and lastly the strategies, principles are taken for the approaching of water treatment.

As we are working on domestic water, our priority will be ensuring the basic needs with safety and safeguarding the ecosystems. Here safeguarding is essential for an infinite number of resources.

Apart from all the safety and quality stages of drinking water, there are still some other health and environmental issues. So all the qualitative and quantitative data should be presented (such as- use of natural and chemical resources, waste emissions, reuse of the elements, health risk decreased)

Demand analysis is very important for our project as the product will be for general people's use. This demand can be dependent on factors like- average household members, household income, metering rate, changes in cost of water, city and economic status of household, quality of water. A report shows that the water usage is 192 liters per day when monthly income is 3,000 BDT and daily usage is over 441 liters per day when monthly income is over 9,000 BDT. [24]

Economic estimation of cost of drinking water:

Capital cost, Operation & maintenance cost:

In our project, operation and maintenance also the capital cost includes the cost of materials (wire, sensors, module, battery, UVC light, filters, LCD display). Again maintaining and building all these will be included too. The electricity or power source, water supply needed for it, will be added here too. Using technology (all the software), installation rate, running operation or testing everything costs.

Opportunity cost

Our project is for domestic use saying it more specifically that we are treating surface water and aiming to get drinking water. But the operation and maintenance cost is higher for surface water than groundwater. Also, the water we are getting from the filter and the water bottle will be consumed by users. So there is no option for reusing the water and the electronic components that got wicked. Here, our opportunity cost is near to zero.

Environmental cost

Environmental cost of ours is low as well. As we are disinfecting for drinking purposes, there is no waste released to the environment. Also UV light (photons with high energy) is the cleanest renewable energy that can't run out and the other components are recyclable. So, it can be said that our project is not directly causing any pollution.

Economic externalities

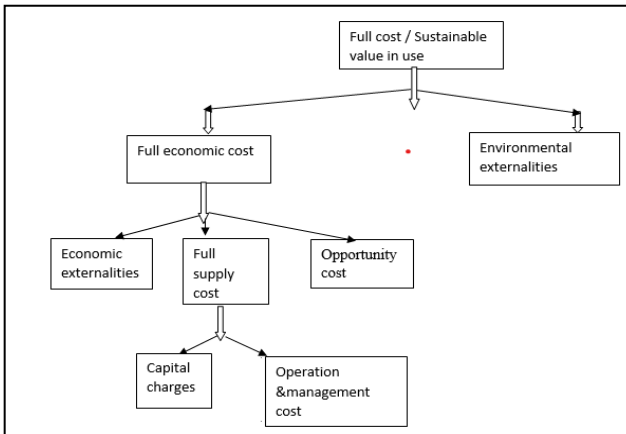


Fig 58: Economic estimation of cost of drinking water [25]

The features we are providing specially monitoring water quality is new in the water purifier sector. Nowadays, people of Dhaka city and nearby areas mostly depend on water filters. Our pricing will be less than the other competitive products in the market. So, we are hoping that our project will be beneficial for economics. On the other hand, the smart bottle we have built is another new interesting thing for people who go outside regularly or travel often because with this bottle they are getting safe drinking water from the water of any water source. There are some negative externalities as well for establishing the market [25].

Considering different demands on filtration, the project proposed 3 design of 3 different budgets.

Table 17: Design 1 price (UV based non-portable filter)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
UVC Light	1	2500	2500
Sensors (TDS, pH, Turbidity, Temperature)	Each 1	5400	5400
Water Reservoir	1	800	800
Others (LCD, Microcontroller)	Each 1	300	300
		Total=	9000

Table 18: Design 2 price (UV+RO based non-portable filter)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
UVC Light	1	2500	2500
Sensors (TDS, pH, Turbidity, Temperature)	Each 1	5400	5400
RO Based filters	1	9500	9500
Water Reservoir	1	800	800
Others (LCD, Microcontroller)	Each 1	300	300
		Total=	18500

Table 19: Design 3 price (UV+RO+IOT based non-portable filter)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
UVC Light	1	2500	2500
Sensors (TDS, pH, Turbidity, Temperature)	Each 1	5400	5400
RO Based filters	1	9500	9500
Water Reservoir	1	800	800
Others (LCD, Microcontroller, ESP Module, Battery)	Each 1	500	1500
PCB Design	1	500	500
		Total=	20200

Table 20: Design 3 price (UV+RO+IOT based portable smart bottle)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
UVC Light	1	1610	1610
Sensors (TDS, pH, Turbidity, Temperature)	Each 1	5400	5400

Water Bottle	1	250	250
Others (LCD, Microcontroller, ESP Module, Battery)	Each 1	500	1860
PCB Design	1	500	500
		Total=	9620

8.3 Cost - benefit analysis

System cost

Before any analysis, showing the actual cost is made to build our project. Here, the current price of the components along with quantity is given below.

Table 21: Detailed Budget of non-portable system for Cost Benefit Analysis

	Component	**Specific Name**	**Quantity**	**Unit Price (BDT)**	**Price (BDT)**
1	UVC Light	Low pressure UVC light	1	2500	2500
2	ESP 32	ESP V-ROOM 32	1	400	400
3	Conductivity Sensor	TDS Sensor	1	1800	1800
4	pH Sensor	Analog pH sensor	1	2500	2500
5	Turbidity Sensor	SKU_SEN0189-D	1	1000	1000
6	Filter	6 stages (RO,PP,GAC,SEDIMENT, CTO,POST CARBON)	1	9500	9500
7	PCB design		1	500	500
8	Temperature sensor	LM35	1	120	120
9	Water reservoir		1	800	800
10	Battery (9V)		1	100	100
11	Miscellaneous			1000	1000
	Total cost				20,220

Table 22: Detailed Budget of portable system for Cost Benefit Analysis

	Component	**Specific Name**	**Quantity**	**Unit Price (BDT)**	**Price (BDT)**

1	UVC Light mini	Low pressure UVC light	1	1610	1610
2	ESP 32	ESP V-ROOM 32	1	400	400
3	Conductivity Sensor	TDS Sensor	1	1800	1800
4	pH Sensor	Analog pH sensor	1	2500	2500
5	Turbidity Sensor	SKU_SEN0189-D	1	1000	1000
6	PCB design		1	500	500
7	Temperature sensor	LM35	1	120	120
8	Water bottle		1	250	250
9	Battery (9V)		2	100	200
10	Switch		2	120	240
11	Miscellaneous			1000	1000
	Total cost				9,620

Total Cost of the project is 20220+9620 = 29,840 BDT

Operating Cost

This portable system has capacity of 25 liter. If there are 6 members in a family who take 2 liters of water each regularly, so according to the filter capacity, water for two days can be reserved in it. Also, it's been calculated that a 254 nm 24 V UVC light can disinfect 25 liters of water within 8 minutes at maximum.

So the light runs in a year,

(8× 365) minutes= 2920 minutes= 48.67 hours.

Again one UVC light consumes power,

(24×60)/1000= 1.44 kw

So the electricity power will be, (1.44× 48.67) kw/hr=70.08 kw/hr

If 1 unit of electricity is 5.614 BDT,

Then the filters maintenance cost annually is, (5.614× 70.08) BDT = 393.43 BDT

Therefore, a better 9V battery can work from 7.5 to 10 hours and according to the calculation steripen take approximately 2 minutes to disinfect.

So, the steripen runs annually, (2×365) = 730 minutes or, 12.167 hours.

Also, steripen consumes (12×60)/1000= 0.72 kw.

So, electricity power will be, (0.72×12.167) kw/hr = 8.76kw/hr

Further, the annual maintenance cost of it is,

(5.614× 8.76) =49.18 (if the lithium battery is rechargeable)

On the other hand, if the battery is replaceable, it can be noted that the battery can run up to 10 hours where the steripen run 12.167 hours annually. So, it can be considered that, with one battery the steripen can run up to 10 months.

Maintenance Cost

Here, it is estimated that, all the components can survive at least 1 year to 2.5 years. But if any electrical equipment is witched, so for replacement annually 300 BDT has been considered Also, labor cost or building cost will be added to it.

8.4 Evaluate economic and financial aspects

Our non-portable part has production cost 20200 and portable one's production cost is 9400. If we add labor cost and maintenance cost to it, we are still hoping to get 500 BDT for each non-portable filter and 200 for each portable smart bottle.

Table 23: Estimating annual profit

Non portable Filter	Smart Water Bottle
system cost= 20200 BDT operating cost =394 BDT labor and maintenance cost= 300 BDT total cost= 20894 BDT	system cost= 9410 BDT operating cost = 50 BDT labor and maintenance cost= 200 BDT total cost= 9660 BDT
profit for each product= 500 BDT assume, each month sell= 10 piece total = 5000 BDT annual profit= 60000 BDT	profit for each product= 200 BDT assume, each month sell= 10 piece total = 2000 BDT annual profit= 24000 BDT

Each year the market grows 30%. So for the next year,

Table 24: Estimating annual profit

Non portable Filter	Smart Water Bottle
profit for each product= 500 BDT assume, each month sell= 13 piece total = 6500 BDT annual profit= 78000 BDT	profit for each product= 500 BDT assume, each month sell= 13 piece total = 2600 BDT annual profit= 31200 BDT

On another next year,

Table 25: Estimating annual profit

Non portable Filter	Smart Water Bottle
profit for each product= 500 BDT assume, each month sell= 17 piece total = 8500 BDT	profit for each product= 500 BDT assume, each month sell= 17 piece total = 3400 BDT

annual profit= 102000 BDT	annual profit= 40800 BDT

World is now deprived of safe drinking water because of excess heat, pollution, and losing safe water resources. Now, city people mostly depend on filters for drinking water. Each year the market is increasing because of high demand and less supply of safe water. Though we made this annual profit sheet with assumption but hoping our project will be sustainable and stable enough next 3 to 5 years. Investing on this will be profitable as the government itself is involved in this research field.

Comparing all the items and features our bottles price is compatible for the market, for regular users.

Table 26: Comparison between market products and designed project

Category	Market's non portable filter	Our designed non portable filter	Market's disinfecting bottle	Our designed non portable filter
Features	UV+RO+MF	Water quality monitoring, UVC And RO Purification,MF, IOT	Steripen	Water quality monitoring, UVC Purification, IOT
Cost	23000 BDT—28000 BDT	21000 BDT	4600 BDT	9800 BDT
Maintenance cost	600 BDT	600 BDT	450 BDT	400 BDT
Annual profit	N/A	60,000 BDT	N/A	24,500 BDT

8.5 Conclusion:

At the end, it can be said that the economic and financial analysis is for understanding whether the project is solid, stable and profitable enough to invest. This analysis is for evaluating the market, making policies and taking long term plans for further industry. Also, finding projects or companies for investment is part of it.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Focusing on the ethical and professional responsibilities in engineering situations and making informed decisions is very important for an engineer to become a skilled and matured practitioner in every perspective of engineering. Ethical Considerations can be specified as one of the most important parts of the research. Individuals trained in engineering are granted certain benefits by society, one of which is the ability to apply their education to purposeful and respected work. Engineers, on the other hand, have ethical devotion to a variety of contributors in society. Engineering professional responsibility encompasses the ethical accountabilities of engineers in their professional relationships with clients, employers, other engineers, and the public.

9.2 Identify ethical issues and professional responsibility

Engineering must take into account how its effects on human safety may affect public's trust in the field. There is universal agreement that engineering has a primary duty to ensure public's health, safety, and welfare in the codes of ethics of engineering professional societies worldwide. The primary goal of any engineering project is to develop a long-lasting, trustworthy, and incredibly effective hardware system that can alter people's perspective and make their lives more comfortable and easier. However, engineers should be mindful of their ethical duties and obligations in order to simplify the lives of these individuals and maintain public confidence in the projects that new engineers or business owners hope to build or provide.

We have conducted our project while ensuring public safety and health. We have tried our best to avoid engineering-related failures and problems that may result in an injury, by using good quality components and materials. Not only that, but we also try to demonstrate our project within safe limits to minimize the chances of accidents. Our project revolves mostly around UVC light, so for most of the part it does not pose any health hazards to the demonstrators and inspectors. Still there can be minor inconveniences such as dangerous ultraviolet radiation which can be harmful for the environment and also can cause health risks for the users as the radiation can be straining for the eyes and it can also cause cancer. Besides, we have identified the professional responsibilities in our project such as using good components, applying standard code related to our project, acquiring all the permissions needed, satisfaction of the user in terms of convenience, accuracy, safety, cost, and user friendly.

9.3 Apply ethical issues and professional responsibility

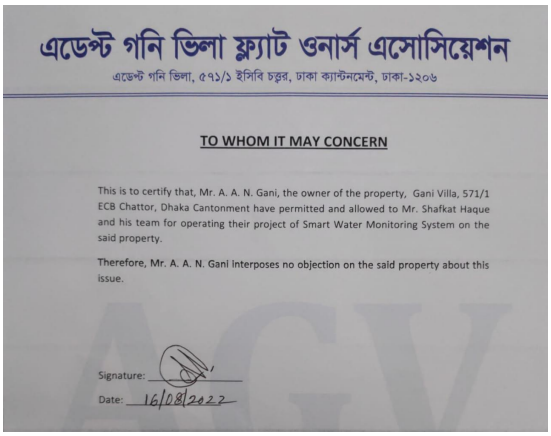
Environmental Ethics:

The designed project will not bring any harmful impact on the environment because we are ensuring that no dangerous ultraviolet radiation will scatter in the environment. As we are

working with UVC light in our project, we will be using quartz in order to stop the ultraviolet radiation and to protect the UVC light. UVC light is also safest and abundant natural resource. So, we can use it easily to disinfect water without causing any harm to environment. Furthermore, this project is eco-friendly as we are not using any harmful chemicals or non-renewable resources that can be a threat to the environment. Also, we are not working with any kind of components which will pollute the environment.

Legal Issues:

Before factorization of our product, we will acquire approval from BSTI so that we do not have to face any legal issue in future and we can use our product legally in Bangladesh. Moreover, we will take government and user's permission in order to collect all sorts of data of our users for the application. Furthermore, before setting up our water purification system we will acquire permission from government to collect data of our user's health by which we will notify them when to drink water.


এডেপ্ট গনি ভিলা ফ্ল্যাট ওনার্স এসোসিয়েশন

এডেপ্ট গনি ভিলা, ৫৭১/১ ইসিবি চত্বর, ঢাকা ক্যান্টনমেন্ট, ঢাকা-১২০৬

TO WHOM IT MAY CONCERN

This is to certify that, Mr. A. A. N. Gani, the owner of the property, Gani Villa, 571/1 ECB Chattor, Dhaka Cantonment have permitted and allowed to Mr. Shafkat Haque and his team for operating their project of Smart Water Monitoring System on the said property.

Therefore, Mr. A. A. N. Gani interposes no objection on the said property about this issue.

Signature:

Date: 16/08/2022

Fig 59: Agreement with the stakeholder

We also took permission from building owner to use the device there in order to use it there. Here is a NOC letter from a building owner where we run our device to aquire datas shown in fig 43.

Project Efficiency:

To run the project effectively, all of the equipment must be kept in good operating order. Because each piece of equipment is essential for this project. If any of the components fail, the whole project may be halted. Since we are specifically building these structures, we think it is essential to evaluate all hazards associated with upcoming designs and constructions. Before being used on a broader scale, these factors will need to be further analyzed.

9.4 Conclusion

Engineers have a great responsibility to society as professionals. The profession is devoted to serving humanity in an honest and selfless manner. All engineers must be dedicated to the standards to which they commit themselves if the honor of engineering as a profession is to endure. The project we are working on is fundamentally a unique technology which has a potential to ensure safe drinking water for users. It is solely our job as engineers to uphold all moral and professional standards that an engineer ought to abide. People will be more motivated to use this project for their daily needs if these rules are followed. Additionally, it

will improve communication between clients and stakeholders, which will eventually help our project's reputation.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

The project has been successfully developed a solution for a smart water quality monitoring system and a purification system. A design was made for a whole family of 5-6 persons and a portable system for travelling person. In the project, the purification system in basically through the UVC light. Using UVC light for 8 minutes user can purify the water in the water tank which is 23 liters. Moreover, the UVC light in the travelling or portable system takes 90 seconds to 120 seconds to purify water.

Furthermore, in both portable and non-portable system there are a water quality monitoring system. These monitoring system includes TDS, Turbidity, Temperature and pH sensors. Through these sensors we can identify the remaining iron, lead, cadmium, mercury, chlorine, magnesium, VOC etc. We can measure 4 of the water parameters. These systems also have server connection which updates the data of the sensors in a server where users can see the data.

In addition, many researches have been made. Many experiments and tests of the system was done. It has been found that the developed solution is 75% reliable and approximately 66.67% accurate.

Lastly, the system has the best prototype which works accurately. However, many things can be done in future.

10.2 Future work

The project which is developed can be upgraded. There are many scope of works in the future. The project is not fully 100% efficient. There can be work on a new sensor to detect microorganisms. All the sensors of water quality parameters for water quality monitoring is not calibrated and gathered. So, work can be done regarding this matter. The system can not specifically identify which parameter is high in the water, in the project is shows the summation of all the dissolved solids is high or low. Therefore, here is a scope of work in future. Moreover, work can be done in the matter of power supply of the system.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

P1. Depth of knowledge required

This simply means that we cannot continue our assessment without extending knowledge of complex engineering. In-depth knowledge includes all that we have learned in our whole engineering school and how to use it to solve any complex problems. To be accurate, the project must be complex and need the application of the knowledge we have learned in theory in our classes. The issue must be challenging enough to be considered academic work. Without this crucial quality, we will be unable to perform our investigation.

P2. Range of conflicting requirements

This attribute stands for the conflicting issues of engineering, technical, technology and other difficulties. The project's qualities describe any problem we may have and how we can plan to handle them. When we solve a problem in a project we ever come up with a conflict that both resolves and corrects the other.

P3. Depth of analysis required

If there is a problem that we are trying to solve but can't find any proper solution, we need to think critically and creatively to come up with a workable solution. Sometimes the engineering problem can be so difficult that we might have to solve it carefully and generate original new solutions. To solve those problems, we require critical thinking skills and in-depth analysis.

P4 Familiarity of issues:

When introducing new or unfamiliar problems yet still needing to be familiar with the old ones. Sincerely speaking, if we solve a problem that is brand-new, many people are unaware of it or we are addressing brand-new issues that need to be clarified.

P5 Extent of applicable codes:

To perform our research, we must adhere to the applicable professional engineering standards or standard codes. If the research conducted in this project is well-liked, there must be established government or professional engineer standards that must be adhered to. Students are required to abide by these rules. This step might be skipped if there is an issue that was never encountered before or is fully original and does not have any applicable codes.

P6 Extent of stakeholder involvement and needs:

This attribute represents including many stakeholder types and attending to their needs in our project. This characteristic basically suggests that our solution must take into account the needs of all the stakeholders.

P7 Interdependence:

In our project, all of the issues that were previously described will be more complicated. However, the difficulties themselves could depend on minor issues or elements. This partial solution can only exist mathematically and not physically.

Attributes of Complex Engineering Problems (EP)

	Attributes	**Put tick (√) as appropriate**
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	
P3	Depth of analysis required	√
P4	Familiarity of issues	√
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	

Note: Project must have P1, and some or all from P2-P7

11.2: Provide reasoning how the project address selected attribute (EP)

We have studied articles, papers and journals related to our project. We have worked for making it a complex engineering problem, found problems, searched for solutions, found preferable methods, worked for finding proper components, analyzed budget making, sustainability, risk management and safety considerations. We have tried to justify our notes by citing quantitative information. So yes, our project belongs to the depth of knowledge and analysis required. Also, the problem we are working with is quite a familiar issue, but the solutions we are expecting to give is a bit uncommon or new for all of us. So, that's the fulfilling attribute number P4.

11.3 Identify the attribute of complex engineering activities (EA)

A1 Range of resources:

It involves utilizing a variety of resources, including people, cash, tools, materials, and information, which is a crucial component of every project aimed at solving problems. The completion of projects is impossible without these resources. To effectively use the resources, creating strategies such as a budget and time management can be a smart idea.

A2 Level of interaction:

We must communicate with project managers, technical engineers, and other staff members in order to manage our projects, and this interaction might lead to serious concerns and problems. It will be our responsibility to reconcile these differences and come up with the best solution possible to meet everyone's needs.

A3 Innovation:

This mostly shows that the problem-solving humans do involve creativity, whether or not engineering is used. This also exemplifies how we'll bring new methods or innovations to boost the effectiveness of our project. To be more effective, innovative solutions need to be more creative.

A4 Consequences for the society and the environment:

The attribute describes our influence and outcomes after introducing this problem-solving. If we use this solution to improve our society, the project must have some negative effects. The question that will follow is what are the repercussions and how will this impact our lives.

A5 Familiarity

Sometimes during the process of fixing a problem, we could run across situations that have never happened before, or sometimes we might face problems that are entirely brand-new, or they might even make communication more challenging. Our ultimate objective will be to find solutions and establish efficient communication.

Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	√

Note: Project must have some or all of the characteristics from attributes A1 to A5

11.4 Provide reasoning how the project address selected attribute (EA)

For completing the project we would need a lot of resources like financial funds, components, elements for software development, venue and structural building for hardware installation. We need to work in our thesis lab .We would need to interact with the users where our system will be installed, also the necessary authorities for the permission and legal issues. Thus, our project fulfills A1. As it will be an unfamiliar solution to our familiar issues, so this automatic

modern system would definitely give impact to the society directly and the environment indirectly. The problem statement for our project is to insure save water, decrease hygienic water scarcity as well there is already projects on water purification based on UVC and RO, so this is quite a familiar issue. But in our project, we are not only doing work for purification but also keeping monitoring and notifying system. So, it can be said our project completing A4, A5 attributes as well.

References

[1}P. Martínez-Santos, "Does 91% of the world's population really have "sustainable access to safe drinking water"?", *International Journal of Water Resources Development*, vol. 33, no. 4, pp. 514-533, 2017. Available: 10.1080/07900627.2017.1298517.

[2]B. Popkin, K. D'Anci and I. Rosenberg, "Water, hydration, and health", *Nutrition Reviews*, vol. 68, no. 8, pp. 439-458, 2010. Available: 10.1111/j.1753-4887.2010.00304.x.

[3]Akter, T., Jhohura, F.T., Akter, F. et al. Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study. J Health Popul Nutr 35, 4 (2016). https://doi.org/10.1186/s41043-016-0041-5

[4]"Benefits of Drinking Cold or Room Temperature Water", Atipt.com, 2022. [Online]. Available: https://www.atipt.com/blog/water-cold-vs-room-temperature. [Accessed: 04- Jan- 2022].

[5]N. Hassan Omer, "Water Quality Parameters", *Water Quality - Science, Assessments and Policy*, 2020. Available: 10.5772/intechopen.89657 [Accessed 18 September 2022].

[6]L. Reports, "Water purifier Market Size, Share | Industry Analysis Report, 2031", Allied Market Research, 2022. [Online]. Available: https://www.alliedmarketresearch.com/water-purifier-market. [Accessed: 28- Aug- 2022].

[7]D. Coppens, A. Shahid, S. Lemey, B. Van Herbruggen, C. Marshall and E. De Poorter, "An Overview of UWB Standards and Organizations (IEEE 802.15.4, FiRa, Apple): Interoperability Aspects and Future Research Directions", *IEEE Access*, vol. 10, pp. 70219-70241, 2022. Available: 10.1109/access.2022.3187410.

[8]K. Kosek-Szott and K. Domino, "An Efficient Backoff Procedure for IEEE 802.11ax Uplink OFDMA-Based Random Access", *IEEE Access*, vol. 10, pp. 8855-8863, 2022. Available: 10.1109/access.2022.3140560.

[9]V. Nenova, M. Nenova, D. Georgieva and V. Gueorguiev, "ISO standard implementation impact in COVID-19 erra on UV-lighting devices", Bulgaria, 2020.

[10]L. Lipus, B. Ačko and B. Neral, "Influence of magnetic water treatment on fabrics' characteristics", *Journal of Cleaner Production*, vol. 52, pp. 374-379, 2013. Available: 10.1016/j.jclepro.2013.03.014.

[11]R. Fernández-González, M. Martín-Lara, J. Moreno, G. Blázquez and M. Calero, "Effective removal of zinc from industrial plating wastewater using hydrolyzed olive cake: Scale-up and preparation of zinc-Based biochar", *Journal of Cleaner Production*, vol. 227, pp. 634-644, 2019. Available: 10.1016/j.jclepro.2019.04.195.

[12]M. Metzger et al., "Low-Cost GRIN-Lens-Based Nephelometric Turbidity Sensing in the Range of 0.1–1000 NTU", *Sensors*, vol. 18, no. 4, p. 1115, 2018. Available: 10.3390/s18041115.

[13]Asana.com, 2022. [Online]. Available: https://asana.com/resources/project-design. [Accessed: 08- Sep- 2022].

[14J. Qin, B. Liberman, K. A. Kekre and A. Gossan, "Direct Osmosis for Reverse Osmosis Fouling Control: Principles, Applications and Recent Developments", *The Open Chemical Engineering Journal*, vol. 3, no. 1, pp. 8-16, 2009. Available: 10.2174/1874123100903010008.

[15]T. Lin, W. Chen and L. Wang, "Particle properties in granular activated carbon filter during drinking water treatment", *Journal of Environmental Sciences*, vol. 22, no. 5, pp. 681-688, 2010. Available: 10.1016/s1001-0742(09)60163-7.

[16]L. AOS Treatment Solutions, "What Is Sedimentation in Water Treatment | Types of Settling Tanks", AOS Treatment Solutions, 2022. [Online]. Available: https://aosts.com/what-is-sedimentation-in-water-treatment-types-settling-tanks/#:~:text=Sedimentation%20is%20a%20common%20way,may%20be%20used%20after%20sedimentation. [Accessed: 28- Aug- 2022].

[17]J. Gao et al., "Integration of autotrophic nitrogen removal, ozonation and activated carbon filtration for treatment of landfill leachate", *Chemical Engineering Journal*, vol. 275, pp. 281-287, 2015. Available: 10.1016/j.cej.2015.04.012.

[18]"What are Carbon Filters for Water Filtration", Espwaterproducts.com, 2022. [Online]. Available: https://www.espwaterproducts.com/carbon-filters/#:~:text=Carbon%20filters%20can%20effectively%20remove,fluoride%2C%20pesticides%20and%20much%20more. [Accessed: 30- Apr- 2022].

[19]A. Maier, A. Sharp and Y. Vagapov, "Comparative Analysis and Practical Implementation of the ESP32 Microcontroller Module for the Internet of Things", in *Comparative Analysis and*

Practical Implementation of the ESP32 Microcontroller Module for the Internet of Things, Plas Coch, Mold Road, Wrexham, LL11 2AW, UK, 2017.

[20]"Introduction to Optimization", Apmonitor.com, 2022. [Online]. Available: http://apmonitor.com/me575/index.php/Main/OptimizationDesign. [Accessed: 28- Aug- 2022].

[21]I. Levine, *Physical chemistry*. Boston: McGraw-Hill, 2017, pp. 27,28,30.

[22]A. Gostine, D. Gostine, C. Donohue and L. Carlstrom, "Evaluating the effectiveness of ultraviolet-C lamps for reducing keyboard contamination in the intensive care unit: A longitudinal analysis", American Journal of Infection Control, vol. 44, no. 10, pp. 1089-1094, 2016. Available: 10.1016/j.ajic.2016.06.012.

[23]"Forever 6 Stage RO System with UV Light Water Filter - Communication Networks Solution", Communication Networks Solution, 2022. [Online]. Available: https://cnsb.com.bd/product/forever-6-stage-ro-system-with-uv-light-water-filter/. [Accessed: 29- Aug- 2022].

[24]M. Shuvra, "The growing water gap in Dhaka, one of the world's fastest growing cities - The Good Feed", The Good Feed, 2022. [Online]. Available: https://blog.brac.net/the-growing-water-gap-in-dhaka-one-of-the-worlds-fastest-growing-cities. [Accessed: 28- Aug- 2022].

[25]"12.3. Economic and Financial Procedures of Drinking Water Treatment Plants - Page 4", Pure-h2o-learning.eu, 2022. [Online]. Available: https://pure-h2o-learning.eu/randd-managers/chapter-12-economics-of-drinking-water?start=3. [Accessed: 28- Aug- 2022].

Appendix

Logbook

	Final Year Design Project (C) Summer 2022		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Md Thamid Hossain	md.thamid.hossain@g.bracu.ac.bd	
Member 2	Tasbiah Binte Hossain	asbiah.binte.hossain@g.bracu.ac.bd	

Member 3	Shafkat Haque	shafkat.haque@g.bracu.ac.bd	
Member 4	MD Saif Fida	md.saif.fida@g.bracu.ac.bd	
ATC Details:			
ATC 1			
Chair	Dr Abu S.M Mohsin	asm.mohsin@bracu.ac.bd	
Member 1	Taiyeb Hasan Sakib	taiyeb.sakib@bracu.ac.bd	
Member 2	Md. Ehsanul Karim		

General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP-P

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
23.10.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Need to research and propose topics for project	Task 1: All	
30.10.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1. Need to find a problem in IOT 2. Need to find an problem in Nanotechnology 3. Need to find a problem in renewable energy. 4. Need to find a problem in Machine learning	Task 1: Thamid Task 2: Rintu Task 3: Saif Task 4: Shafkat	. Task done Nicely

5.11.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Finalized a topic for project 1. Need to write Tentative Problem Statement. 2. Need to write objectives 3. Need to research multiple approaches	Task 1: Saif Task 2: Rintu Task 3: Thamid, Shafkat	Task done Nicely
9.11.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Selected another topic 1. Need to write Tentative Problem Statement. 2. Need to write objectives 3. Need to write Specifications, Requirements, Constrains 4. Need to write Project title.	Tasks will be done by all of the members.	Task done Nicely
10.11.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Shared knowledge among us about the findings of selective topic for project. 1.Wrote Tentative Problem Statement 2.Wrote Project Title. 3. Discussed on the possible Specifications, Requirements and Constraints.	Tasks are done by all of the group members.	Improve Task 2 and 3
13.11.2021	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	Showcased works done so far to ATC Chair & Member. 1.ATC chair advised us to be specific on our Project Title & Tentative Problem Statement. 2.We further discussed on our approach for the project.	Tasks are done by all of the group members.	Task done nicely
16.11.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Completed the concept note.	Tasks are done by all of the group members.	Task done nicely

		2.Made Slides and finished bibliography for the presentation		
30.11.2021	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	1. Discussed on the project. 2. Sir advised us further to rectify and bring improvements in our project. 3. Discussed on components, systems and what could be done to polish the project further.	Tasks are done by all of the group members.	Improve slide for the presentation
4.12.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Further refurbished Project Concept Note. 2.Made list components need for the system. 3.Sketched possible diagram for the system.	Tasks are done by all of the group members.	Task done nicely
9.12.2021	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	1.Discussed on the final concept note. 2. Advised to improve multiple approach 2. Need to list down components, materials price for the project.	Tasks are done by all of the group members.	Task done nicely
14.12.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Improved multiple approach for the system. 2.Listed all the components and its price. 3.Prepared a possible budget.	Tasks are done by all of the group members.	Task done nicely
26.12.2021	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif	1.Sir advised us to create a gant chart 2.Sir advised to specify Expected Outcome 3.Need to write Sustainability and have to clarify the slides and proposal note	Tasks are done by all of the group members.	Rewrite multiple design approach

	5.Rintu 6.Shafkat			
27.12.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Completed and edited project presentation slides for mock up presentation	Tasks are done by all of the group members.	Task done nicely
29.12.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Again scale some slides for presentation as per sir advised	Tasks are done by all of the group members.	Improve gantt chart
02.01.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	divided tasks for proposal note preparation	Tasks are done by all of the group members.	Task done nicely
05.01.2022	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	sir advised us to bring some changes in proposal note	Meeting was done by everyone. Tasks are done by Thamid and Rintu	Task done nicely
09.01.2022	1.Thamid 2. Rintu	Corrected and scaled the details in proposal note and send it to sir.	Tasks are done by Thamid and Rintu	Task done nicely

FYDP-D

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
19.01.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1. Had a meeting in university regarding design of our project	Task : Carried out by all	Start doing software test
08.02.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Sorted out and calculated appropriate calculation for project designs	Task : Mainly done by Rintu, other supported.	Task done nicely

12.02.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Finalized PCB design for bottle and further calculation and verification were done.	Task was successfully carried out by group members.	Asked for some improvement
17.02.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Respected professor briefed us about components of our project and made us familiar with the instruments.		Wished for completing the task
24.02.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	We drew the design of our filter and in proteus, unsuccessful simulations were done.	Tasks are done by all of the group members.	Asked for more accurate simulation results
02.03.2022	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	Sorted out water filter size, probable water need for family, component selection.	Tasks are done by all of the group members.	Task done nicely
7.03.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Started working on the project report. 2. Probable drawbacks of our design were also discussed.	Tasks are done by all of the group members.	Task done nicely
19.03.2022	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	1.Discussed on the project. 2.Sir advised us further to rectify and bring improvements in our project. 3.Discussed on components, systems and what could be done to polish the project further.	Tasks are done by all of the group members.	Advised to bring more improvements

30.03.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Prepared a draft regarding some of our design and reported to ATC.	Tasks are done by all of the group members.	Suggested some better options on this
4.04.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1.Selected a filter that we are going to use to make the tank.	Tasks are done by all of the group members.	Task done nicely
10.04.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Simulated the designed diagram in software.	Tasks are done by all of the group members.	Task done nicely
17.04.2022	1.Thamid 2.Saif 3.Rintu 4.Shafkat	1. Discussed on the design report. 2. Made presentation slide. 2. Wrote the report	Tasks are done by all of the group members.	Marked some mistakes and asked to correct
26.04.2022	1. Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Saif 5.Rintu 6.Shafkat	1. Sir advised us to create a Gantt-chart 2. Sir advised to edit the slides. 3. Need to write references and have to clarify the slides.	Tasks are done by all of the group members.	Task done nicely
27.04.2021	1.Thamid 2.Saif 3.Rintu 4.Shafkat	Completed and edited project presentation slides for presentation	Tasks are done by all of the group members.	Task done precisely

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
31.05.2022	1.Thamid 2.Saif 3.Tasbiah 4.Shafkat	1. Start designing the project 2. Need to buy a filter suitable for the project	Tasks are done by all of the group members.	Tasks were nicely completed
07.06.2022	1.Thamid 2.Saif 3.Tasbiah 4.Shafkat	1. Need to finalize 3-D design according to the calculation 2. Need to finalize the required components and make a list of it and buy those accordingly	Task 1: Thamid Tasbiah Task 2: Shafkat Saif	Suggested to make a list of components and show it for approval
14.06.2022	1.Thamid 2.Saif 3. Tasbiah 4.Shafkat	1. Order all the required components 2. Need to buy a UVC light for using in the bottle	Thamid	Tasks were nicely completed
28.06.2022	1.Thamid 2.Saif 3. Tasbiah 4.Shafkat	1. Need to test the UVC light using the components to see if it gives accurate data	Thamid Tasbiah	Advised to use water from different locations for testing
05.07.2022	1.Thamid 2.Shafkat 3. Tasbiah	1. Need to start working on 3-D Design and PCB design	Thamid Tasbiah	Tasks were nicely completed
26.07.2022	1.Professor Abu Mohsin (Sir) 2. Taiyeb Hasan (Sir) 3.Thamid 4.Shafkat 5. Tasbiah 6.Saif	Showcased works done so far to ATC Chair & Member for the progress presentation 1. ATC chair advised us to show device pictures with functionality 2. Also advised us to focus on design implementation	Tasks are done by all of the group members.	Need improvement and need to complete the final design as soon as possible
02.08.2022	1.Thamid 2.Shafkat 3. Tasbiah	1. Completed the PCB Design 2. Discussed on how we are implementing the smart water bottle	Thamid	Tasks were nicely completed

11.08.2022	1.Thamid 2.Saif 3. Tasbiah 4.Shafkat	1.Discussed on the parameters we need for safe drinking water 2.Sir advised us further to rectify and bring improvements	Thamid Tasbiah	Tasks were nicely completed
16.08.2022	1.Thamid 2.Shafkat 3. Tasbiah	1. Need to go to BCSIR to run those tests 2. Need to do the microorganisms testing in microbiology lab 3. Need to get permission to use the lab	Thamid Tasbiah	Need to run the tests quickly and collect a reference letter
23.08.2022	1.Thamid 2.Shafkat 3.Tasbiah	1. Need to complete the final report 2. Need to make slide for the final presentation and prepare accordingly	Thamid Tasbiah	Tasks were nicely completed
30.08.2022	1.Thamid 2.Saif 3.Tasbiah 4.Shafkat		Tasks are done by all of the group members.	Tasks were nicely completed

Related code

The code is run in arduino IDE. To run the code there must be WiFi, ThingSpeak, Wire, LiquidCrystal_I2C, OneWire, DallasTemperature and Esp32 libraries installed. Below is the code for project.

```
#include <WiFi.h>
#include "ThingSpeak.h"
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <OneWire.h>
#include <DallasTemperature.h>

int a = 0;
#define buzzer = 33;
LiquidCrystal_I2C lcd(0x27, 16, 2);
const char* ssid = "Ami";   // your network SSID (name)
const char* password = "15995112";   // your network password
```

```
WiFiClient  client;

unsigned long myChannelNumber = 1810325;
const char * myWriteAPIKey = "3OYVXYA45VE50AQ9";

// Timer variables
unsigned long lastTime = 0;
unsigned long timerDelay = 30000;
//temprature sensore
#define SENSOR_PIN  25
OneWire oneWire(SENSOR_PIN);
DallasTemperature DS18B20(&oneWire);

float tempC; // temperature in Celsius

// pH sensor
float calibration_value = 14.7;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10],temp;
float ph_act;

//tds sensor
#define TdsSensorPin 12
#define SCOUNT  30           // sum of sample point
float VREF=3.3;              // analog reference voltage(Volt) of the ADC


int analogBuffer[SCOUNT];     // store the analog value in the array, read from ADC
int analogBufferTemp[SCOUNT];
int analogBufferIndex = 0;
int copyIndex = 0;

float averageVoltage = 0;
long tdsValue = 0;
float temperature = 30;       // current temperature for compensation


// median filtering algorithm
int getMedianNum(int bArray[], int iFilterLen){
  int bTab[iFilterLen];
  for (byte i = 0; i<iFilterLen; i++)
  bTab[i] = bArray[i];
  int i, j, bTemp;
```

```
  for (j = 0; j < iFilterLen - 1; j++) {
    for (i = 0; i < iFilterLen - j - 1; i++) {
      if (bTab[i] > bTab[i + 1]) {
        bTemp = bTab[i];
        bTab[i] = bTab[i + 1];
        bTab[i + 1] = bTemp;
      }
    }
  }
  if ((iFilterLen & 1) > 0){
    bTemp = bTab[(iFilterLen - 1) / 2];
  }
  else {
    bTemp = (bTab[iFilterLen / 2] + bTab[iFilterLen / 2 - 1]) / 2;
  }
  return bTemp;
}

//Turbidity sensor
int sensorPin = 34;  // connect to 3.3v
float volt;
float ntu;

void setup() {
  Serial.begin(115200);  //Initialize serial

  WiFi.mode(WIFI_STA);

  ThingSpeak.begin(client);  // Initialize ThingSpeak

    // initialize the LCD
  lcd.begin();

  // Turn on the blacklight and print a message.
  lcd.backlight();
  lcd.print("Water Bottle");
  delay(1000);
  lcd.clear();
  DS18B20.begin();    // initialize the DS18B20 sensor
  pinMode(TdsSensorPin,INPUT);
}

void loop() {
  if ((millis() - lastTime) > timerDelay) {
```

```
// Connect or reconnect to WiFi
if(WiFi.status() != WL_CONNECTED){
  Serial.print("Attempting to connect");
  lcd.print("Connecting...");
  while(WiFi.status() != WL_CONNECTED){
    WiFi.begin(ssid, password);
    delay(5000);
  }
  Serial.println("\nConnected.");

}

// Get a ph reading


    for(int i=0;i<10;i++)
 {
 buffer_arr[i]= analogRead(32);
 delay(30);
 }
 for(int i=0;i<9;i++)
 {
 for(int j=i+1;j<10;j++)
 {
 if(buffer_arr[i]>buffer_arr[j])
 {
 temp=buffer_arr[i];
 buffer_arr[i]=buffer_arr[j];
 buffer_arr[j]=temp;
 }
 }
 }
 avgval=0;
 for(int i=2;i<8;i++)
 avgval+=buffer_arr[i];
 float volt=(float)avgval*3.25/1024/6;
  ph_act = -10 * volt + calibration_value;
 Serial.println(volt);
 Serial.println("pH Val: ");
 Serial.println(ph_act);
 lcd.clear();
 lcd.setCursor(0,0);
 lcd.print("pH Value");
```

```
    lcd.setCursor(0,1);
    lcd.print(ph_act);

    delay(2500);



   //get tds reading

   static unsigned long analogSampleTimepoint = millis();
  if(millis()-analogSampleTimepoint > 40U){     //every 40 milliseconds,read the analog value from the ADC
   analogSampleTimepoint = millis();
   analogBuffer[analogBufferIndex] = analogRead(TdsSensorPin);     //read the analog value and store into the buffer
   analogBufferIndex++;
   if(analogBufferIndex == SCOUNT){
    analogBufferIndex = 0;
   }
  }

  static unsigned long printTimepoint = millis();
  if(millis()-printTimepoint > 800U){
   printTimepoint = millis();
   for(copyIndex=0; copyIndex<SCOUNT; copyIndex++){
    analogBufferTemp[copyIndex] = analogBuffer[copyIndex];

    // read the analog value more stable by the median filtering algorithm, and convert to voltage value
    averageVoltage = getMedianNum(analogBufferTemp,SCOUNT) * VREF / 4096.0;

    //temperature compensation formula: fFinalResult(25^C) = fFinalResult(current)/(1.0+0.02*(fTP-25.0));
    float compensationCoefficient = 1.0+0.02*(temperature-25.0);
    //temperature compensation
    float compensationVoltage=averageVoltage/compensationCoefficient;

    //convert voltage value to tds value
    tdsValue=(133.42*compensationVoltage*compensationVoltage*compensationVoltage - 255.86*compensationVoltage*compensationVoltage + 857.39*compensationVoltage)*0.5;

   }
  }
    Serial.print("voltage:");
```

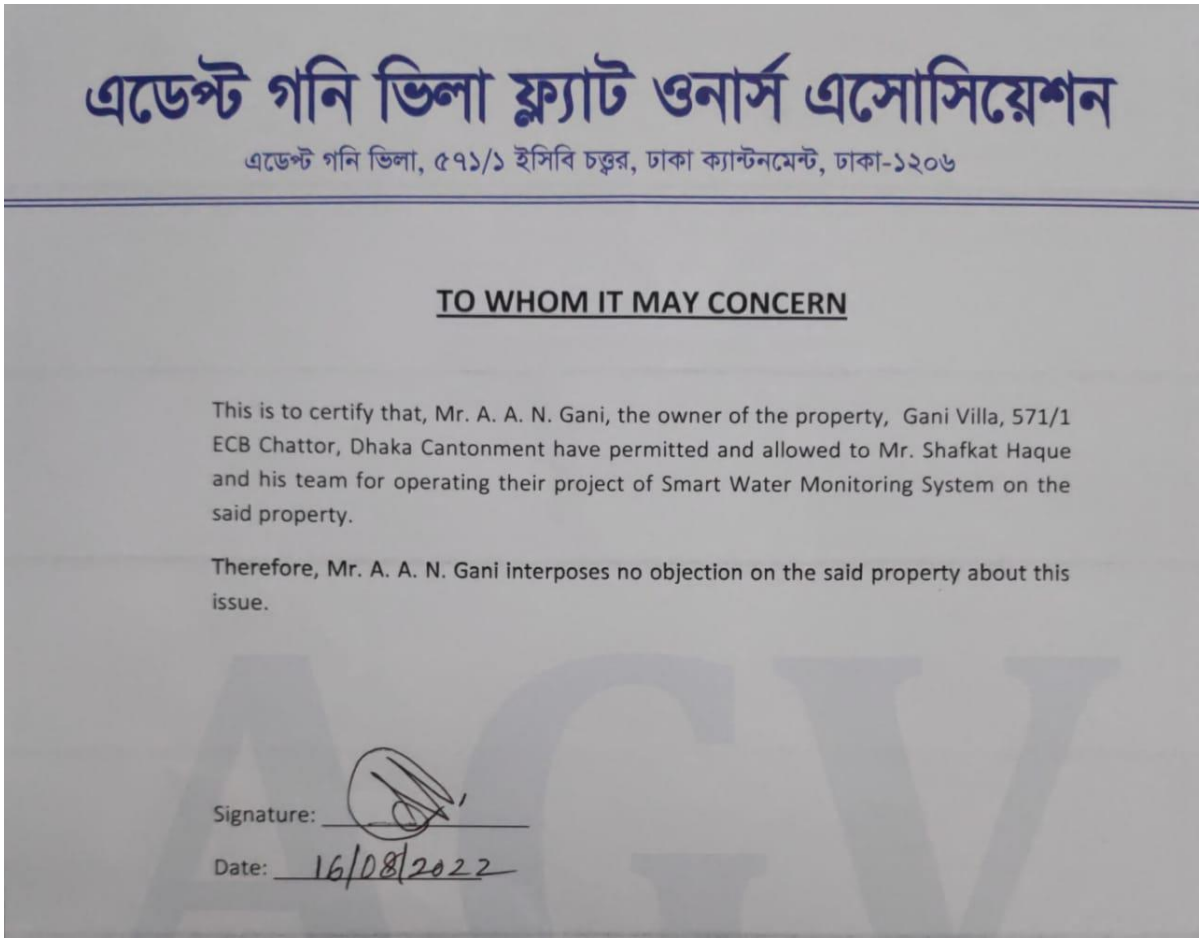
```
      Serial.print(averageVoltage,2);
      Serial.print("V   ");
      Serial.print("TDS Value:");
      Serial.println(tdsValue);
      Serial.println("ppm");
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("TDS Value");
      lcd.setCursor(0,1);
      lcd.print(tdsValue);
      delay(2500);
//get turbidity sensor reading

volt = 0;
    for(int i=0; i<800; i++)
    {
        volt += ((float)analogRead(sensorPin)/4095)*3.5;
    }
    volt = volt/800;
    volt = round_to_dp (volt,2);
    if(volt < 1.65){  //2.5for 5v, 1.65for 3.3v
      ntu = 3000;
    }
    else if(volt >= 2.772){
      ntu = 0;
    }else{
     // ntu = -1120.4*sq(volt)+5742.3*volt-4352.9; //5v equation
     ntu = -2572.2*sq(volt) + 8700.5*volt - 4352.9; //3.3v equation
     ntu = ntu/2000;
    }
    Serial.println(volt);
    Serial.println(ntu);
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Turbidity Value");
    lcd.setCursor(0,1);
    lcd.print(ntu);
  delay(2500);
// get temparature reading

 DS18B20.requestTemperatures();       // send the command to get temperatures
  tempC = DS18B20.getTempCByIndex(0);  // read temperature in °C
```

```
  Serial.print("Temperature: ");
  Serial.print(tempC);    // print the temperature in °C
  Serial.println("°C");
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Temparature");
  lcd.setCursor(0,1);
  lcd.print(tempC);
  delay(2500);


    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Sending data");

    // set the fields with the values
    ThingSpeak.setField(1,ph_act);
    //ThingSpeak.setField(1, temperatureF);
    ThingSpeak.setField(2, tdsValue);
    ThingSpeak.setField(3, ntu);
    ThingSpeak.setField(4, tempC);

    // Write to ThingSpeak. There are up to 8 fields in a channel, allowing you to store up to 8
different
    // pieces of information in a channel.  Here, we write to field 1.
    int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);

    if(x == 200){
      Serial.println("Channel update successful.");
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Successful");
      delay(1500);
    }
    else{
      Serial.println("Problem updating channel. HTTP error code " + String(x));
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Unsuccessful");
      delay(1500);
    }
    lastTime = millis();
  }
```

```
  if(ph_act<6.5||ph_act>8.5){    //according to healthline
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Unsafe Water");
    delay(4000);
    lcd.clear();
    }else if (tdsValue>1000){    //according to WHO
      lcd.clear();
      lcd.setCursor(0,0);
      lcd.print("Unsafe Water");
      delay(4000);
      lcd.clear();
      } else if (ntu>1){           //according to WHO
        lcd.clear();
        lcd.setCursor(0,0);
        lcd.print("Unsafe Water");
        delay(4000);
        lcd.clear();
        } else {
          lcd.clear();
          lcd.setCursor(0,0);
          lcd.print("Safe Water");
          delay(4000);
          lcd.clear();
          }
          lcd.clear();
          a++;
          if(a>250){
            pinMode(33,OUTPUT);
            buzzer = 1;
            delay(5000);
            a = 0;
            }

}
float round_to_dp( float in_value, int decimal_place )
{
  float multiplier = powf( 10.0f, decimal_place );
  in_value = roundf( in_value * multiplier ) / multiplier;
  return in_value;
}
```

Agreement between the Landlord and the project students:

There were an agreement between the Landlord and the students for the cause of installing the project of the students in the house of the landlord. In the agreement the landlord gave permission to the project students to conduct their experiment in his/her house. Below is the image attached of the agreement mentioned above.



এডেপ্ট গনি ভিলা ফ্ল্যাট ওনার্স এসোসিয়েশন

এডেপ্ট গনি ভিলা, ৫৭১/১ ইসিবি চত্তর, ঢাকা ক্যান্টনমেন্ট, ঢাকা-১২০৬

TO WHOM IT MAY CONCERN

This is to certify that, Mr. A. A. N. Gani, the owner of the property, Gani Villa, 571/1 ECB Chattor, Dhaka Cantonment have permitted and allowed to Mr. Shafkat Haque and his team for operating their project of Smart Water Monitoring System on the said property.

Therefore, Mr. A. A. N. Gani interposes no objection on the said property about this issue.

Signature: _____

Date: 16/08/2022