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Arduino based smart sensor for membrane based point of use in water purifiers

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Master of Technology

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CERTIFICATE

This is to certify that the project work contained in this thesis titled **"Arduino based smart sensor for use in membrane based point of use water purifiers"** by **"Deepa Das"** has been carried out under our supervision and to be accepted in partial fulfilment of the requirement of the degree of **Master of Technology in Electronics & Communication Engineering**, Tripura university and it has not been submitted elsewhere for a degree.

The project work has been prepared as per the regulation of Tripura University and qualifies to be accepted in partial fulfilment of the requirement for the **Master of Technology in Electronics & Communication Engineering**.

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Yours faithfully

(**Deepa Das**)

DECLARATION

I declare that this written submission represents my ideas and my work in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

Water is indeed a necessary component for humanity's existence. It is one of most crucial and necessary parts for living beings. The body cells contain water in a percentage of about 70%. Many substances, along with the blood, lymph, saliva, digestive enzymes, urine, and others, are derived from drinkable water. The controller of all bodily processes is water. That is the primary means of delivering power to all of the body's cells. Because of its many applications, it seems to be in limited supply. Massive sources of water, such as ponds, rivers, and the sea, provide the majority of the water. As a result, it's a great way to keep an eye on its purity to guarantee its safe to eat. Water testing is now done in conventional laboratories, which is complex and time-consuming and error-prone. The water directly from unstructured sources is not drinkable. As a result, it must be treated using a variety of chemical agents as well as various filtration processes.Various preliminary parameters, such as TDS, temperature, conductivity, pH, dissolve oxygen, BOD, etc., must be known.The current emphasizes on the development of ardiuno based automated water purification device which can sense the fluctuation of source water TDS and automatically adjust the sensors in order to treat the feed water using appropriate method thereby retaining the mineral content.

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ACRONYM

A

- API -Application programming interface

B

- BOD -Biochemical Oxygen Demand

C

- CRT - Cathode-ray tube

G

- GSM - Global System for Mobile communication

I

- IOT -Internet of Things
- ISE's - Ion-Selective Electrodes

L

- LCD -Liquid Crystal-display
- LED - Light-emitting diode
- LPH -Liter per hour

M

- MCU -Microcontroller Unit

N

- NC - Normally Closed
- NC -Normally Closed

P

- PIR - sensor passive infrared sensor
- ppm - parts per million
- ppm -parts per million
- Psi -Pound force per square inch

R

- RC - resistor capacitor circuit
- RFID - Radio-Frequency Identification
- RO -Reverse Osmosis

T

- TDS - Total Dissolved solids

U

- UF -Ultrafiltration
- USB - Universal serial bus

W

- WSN -wireless sensor network

CHAPTER 1

INTRODUCTION

Water is most important components of activity and foundation of a successful economy, since it is required as the existence of all living things as well as the preservation of the environment. In actuality, safe and potable water is a valuable and essential source of life, and its purity does have a considerable impact on individual very well health. Waterborne infections are expected to cost India roughly 600 million $ per year in economic costs. Most of the population in India has no access to clean drinking water. It is expected that water is contaminated with chemicals, primarily fluoride and arsenic, in almost 20 lakh homes in our country. According to the WHO, excessive fluoride and arsenic in India may affect a huge number of people across several parts of the country[1]. So assessing the quality of drinking water involves close monitoring of a range of physical, chemical, and biological features[2]. Human activities use around 1% of water resources such as rivers, lakes, and oceans for water supply, agriculture, and leisure. As the population grows, these water resources get contaminated with trash, hazardous wastes, agricultural fertilizer, and other pollutants. Water resources physical, chemical, and biological characteristics should be checked on a regular basis to guarantee that they are safe to use.

As a result, the demand for water purification devices has increased. Before getting into it deeply, it's necessary to give a brief description of the current water purification system. Eureka Forbes launched the 1st water purification device in 1984. Water purifiers have become an absolute necessity in all homes. It guarantees that people have access to safe and pure water whenever they want, preventing waterborne infections. There are various water purification techniques available on the market in the form of point of use water purifiers, namely

1. RO Water Purifiers
2. UF Water Purifiers
3. UV Water Purifiers

UF complies to force the water to run through a membrane, leaving the impurities behind. But the particles which size is beyond the range of 0.001–0.05 μm will be pass through it. Here comes the RO. It is among the most widely used water filtration systems. It drove the water through a membrane, which blocked the majority of the contaminants and dissolved particles. According to scientific evidence, drinking RO water causes greater health hazards and quicker kills than most toxins found in tap water. It eliminates the majority of the water's pollutants but also 99 % of its useful minerals.

In recent decades, India has lost several children under the age of five due to diarrhoea, accounting for approximately 30% of the global total. Water contamination processing is crucial in the fight against these[3]. Inadequate drinking water quality services are responsible for 88% of diarrhoea fatalities. Impeding is considered to be responsible for more than one-third of all under-5-year fatalities worldwide. India has the most impaired youngsters, with more than 40 percent being mildly or extremely underweight[4].

1.1 Background analysis of water supply in India

The path of concerted action in sanitation facilities Started in India in 1949, The ESC of the Government of India recommended a target of giving clean water to 90 percent of the country's population over the next forty years. Water was included in the Indian Constitution in 1950. State governments are tasked by Article 47 with ensuring safe drinkable water and enhancing PHS. This laid the groundwork for subsequent 5 year plans on water governance and management[5].

1.2 Present scenario of drinking water quality in India

According to the JMP, 97 percent of urban regions and 90 percent of Indian districts have connections to an upgraded supply of water. Nevertheless, the availability of good water quality does not imply the safety of the water given. Microbial contamination and biochemical pollution have resulted in water supplies providing major health risks, particularly to the most sensitive parts of the community. Underground water has historically been seen as a safe supply, particularly in terms of microbial pollution. But it is a myth now. Poor industrial waste treatment, use of excessive fertilizer & chemicals are the key reasons for contamination's of surface water sources as well as underground sources[5].

1.3 Objective

The objective of this study is to overcome this situation and provide a automated water purification. Here Arduino platforms plays a vital role accomplish the work. Micro-controllers are tiny cognitive elements placed on ICs that feature a CPU, memory, and additional input and output pins. Arduino is already a micro-controller that delivers a basic platform as well as an ecosystem for rapid software development. Arduino platform compels with various components like detectors, sensors like (TDS, PH etc.), displays & other tools which is easily programmable for such kind of automated system design[6]. The significant advantage for developers is that they can implement even if they do not understand the inner workings of Arduino's hardware and software. was designed for non-technical people also.

The ultimate purpose is to design a smart automated water purification device that measures the TDS value. To understand how the quality of water is co-related with the TDS value the below table is shown. These relations are based on the guidelines set by WHO shown in table:1.1[7].

Table 1.1: Co-relation between water quality and TDS value

Level of TDS (ppm)	**Rating**
Below 300	Excellent
300 to 600	Good
600 to 900	Fair
900 to 1200	Bad
Greater than 1200	Unacceptable

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CHAPTER 2

LITERATURE REVIEW

Freshwater is a limited and essential element needed across the world. Farming, manufacturing, as well as the existence of all live organisms on earth, especially people, rely on this important resource. Water quality assessment has become highly significant as the number of different sources of contaminants and pollutants grows. [1] explains how to make a limited, actual in-situ water quality monitoring system with a Micro controller. The recommended technique aims to build a low-cost system for real-time and on-site water quality assessment using reduced and accurate industrial off-the-shelf equipment and the Arduino software language.

Water quality must be monitored on a regular basis to ensure that it remains within permissible limits. In [2] researched the creation of clean and cheap water quality assessment appliances for real-time monitoring utilizing Internet of Things (IoT) technology. The Kolora meter is an alternative to commercially available monitoring equipment. The microcontroller and Wi-Fi connection were created using the open-source platform Arduino UNO model and Node MCU board, respectively. In the early stages of Kolora meter development, two sensors were chosen to be installed: temperature and turbidity. The physical characteristics of water (temperature and turbidity) were measured, and the gathered data may be accessed and monitored on a mobile phone through a Wi-Fi connection using the Kolora Mobile Application. As a result, due to the restricted mobility of the COVID-19 pandemic, this surface water quality device has the potential to be used in real-time monitoring for early pollution identification and during COVID-19 pandemic spread.

A detection system (WSN) for monitoring system is made up of iot devices that have network connectivity and may be utilized for temporary or continual tracking. The devices take real-time measurements of variables that affect quality of the water, such as pH, salinity, and heat, and send the data to the base station or control/monitoring room. [3] explains how to establish any such monitoring program, with an emphasis on low cost, rapid ad hoc installation, and ease of handling and management. Remote monitoring devices not only reduce total remote monitoring costs as a result of facilities installation and maintenance, but they also provide flexibility when it comes of distance or location. They describes the basic design and construction of a WSN employing Zigbee-based high-power transmission technology and an IEEE 802.15.4 compliant transceiver. The platform that was built is low-cost and easy to use. Customization. In order examine the system's reliability and performance, certain initial values obtained are often provided.

Use of a network of sensors to monitor urban sewage land for irrigation usage provides a smart technique for checking water quality, with the value obtained shown on a Display. The main aim of [4] is to approximate quality of water like pH, turbidity, temperature, BOD, and TDS, that will help to identify deviations in the parameters and sent the out-warning message when the amount reaches the specified limit or basic value set in the Arduino Mega 2560 Controller. Such high readings might indicate chemical spills, sewage treatment difficulties, or connection with the services concerns, all of which may be problematic for growing crops and soil conditions. Groundwater resources abnormalities were detected using a GSM technology. The information is kept in the internet, as well as the computer is connected to an Internet to send signals to the governments, providing a solution to this issue and assisting farmers in boosting their sales activities.

Mosul is an Iraqi city that has been under siege by violent terrorist organizations known as ISIS since 2014, destroying the city's infrastructure. After Iraqi troops liberated the city from ISIS, it was necessary to restore to regular life and rebuild all of the city's damaged areas. The most essential of these concerns is to restore drinking water and eliminate water pollution by testing and monitoring water in real time using contemporary technologies in order to utilize the best drinking water, as well as to make Mosul a smart city. [5] created and constructed a system that uses the internet of things to test drinking water in real time for several critical characteristics such as temperature, pH, TDS, turbidity, and conductivity at a low cost and with quick results. The sensor has the ability to measure each parameter. All of the sensors attached to the Arduino UNO model may be utilized as a core controller, with data being sent to the internet via the Wi-Fi module (ESP 8266). Finally, the sensor data may be accessed on the internet using the thing Speak API for the purposes of gathering data, processing it, and transmitting it to an LCD, mobile device, or laptop for display. The findings were compared to those obtained at the "Right water project/Mosul" laboratory. The suggested system was extremely powerful, quick to implement, inexpensive, and highly efficient. The suggested system's results are 98.6 percent similar to the laboratory results.

A smart surveillance system with PIR sensors is developed to provide home protection against theft. The Internet of Things (IoT) now plays a significant role in several areas through automating applications. PIR and temperature sensors were employed. PIR is an electrical sensor that detects motion by measuring the amount of IR radiation emitted by objects. The visitor entering the residence is detected using this approach. A camera and a temperature sensor are used to monitor and manage a fire that occurs in a home. To spray chloroform, a sub motor arrangement with a solenoid value is utilized. This action is carried out, putting the stranger in a condition of unconsciousness. The camera and PIR sensor are connected in such a manner that any movement in the room instantly turns on the camera. The house owner may see a live broadcast of the stranger's activities within the residence. [6] includes a letter and phone call service to notify the owner of the odd activity. They suggested to create a smart home automation system that detects theft.

The creation of a simple, compact total dissolved salts (TDS) sensor for application in restricted sterile settings is described in this work. It works with a microcontroller to monitor the overall nutrient content in plant tissue culture liquid medium. The system works by charging a capacitor (C) in series with a resistive probe (R) submerged in liquid medium and then measuring the RC circuit's time constant. Because the time constant is proportional to the solution's electrical conductivity, it may be used to calculate TDS concentration. The sensor was tested for TDS as well as different specific main salt concentrations. Following extensive testing, an equation was developed that may be used to determine TDS concentration for a given time constant. [7] described here is part of a broader effort involving continuous environmental monitoring and control within a sterile plant tissue culture vessel.

The goal of [8] is to create an automated Water System of Quality Control based on the Internet of Things (IoT). Many sensors are utilized to monitor the various water characteristics. Arduino is used to interface the sensors, and a GSM module is used to remotely monitor the data. Solar energy is used to power the entire system. The gadget may be used to check the water's purity. It can keep track of various water bodies in real time. They describe the concept and development of a low-cost real-time water monitoring system. The gadget may also measure the water's other physical and chemical characteristics. Turbidity Sensor, pH Sensor, Temperature Sensor, and TDS Sensor are among the modules included in the apparatus. Arduinois used to link all of the sensors. Arduino transforms the signal into a system-readable format before sending it to the GSM module. Through the IOT platform, the GSM Module will communicate the detected data to smart devices/cloud. The outcome can be viewed on a daily, weekly, or monthly basis.

Identifying patterns in large, real-time, data sets (e.g., sales volume over time, mobile phone usage trends; sensor networks capturing data sets from cars, or even persons wearing smart computers) remains to spark interest. [9] describe an interdisciplinary research effort that integrates deep learning in huge environmental databases using biological or chemical sensing networks drinking the water security and safety choice.

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CHAPTER 3

METHODOLOGY

In this section the complete work plan has been elaborated. The block diagram is show in below Fig.3.1. At the preliminary stage it is necessary to check the inlet TDS of the water, thus the 1st TDS sensor is connected with the inlet section with "T" connector. Once the Inlet TDS has been sensed the solenoid valves on both arms are triggered through relay-1 and relay-2 respectively. Now the sensed TDS values will be analyzed by the central processing unit which is nothing but the Ardiuno here. After these values been analyzed the Ardiuno send the signals to the specific relays to trigger the respective solenoid valves which further controls the UF and RO filtration process with specific timing constrain. Both the outlet will be connected to a common line and dump the water in a storage tank, that is the output tank. Here also a TDS sensor will be there to monitor the output water quality. It is also necessary to mention here that the Ardiuno board and its corresponding components has been powered by a 9 Volt power supply.

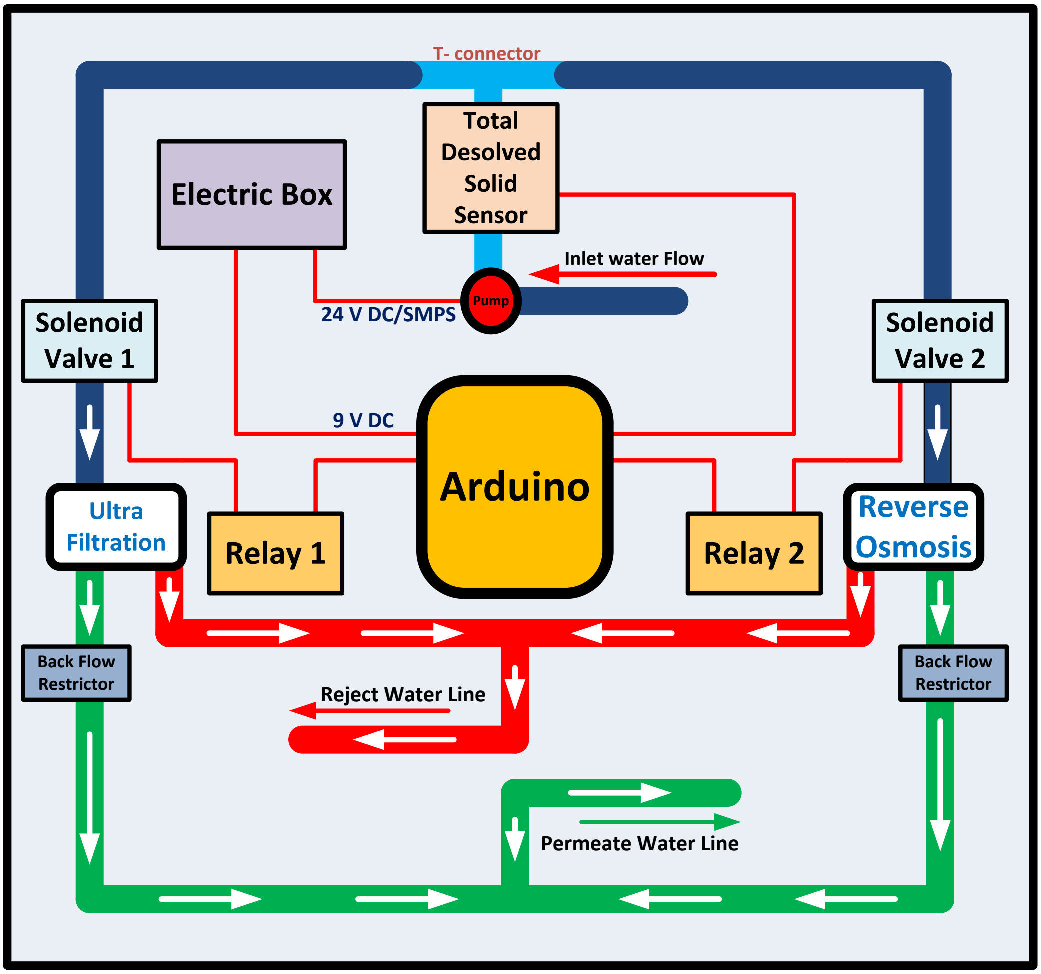


Figure 3.1: Block Diagram

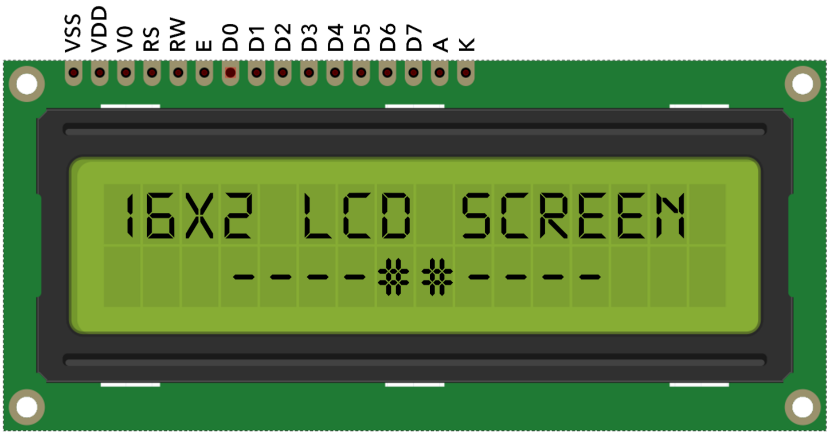
3.1 Materials & Elememts

The materials and elements used to build this device are discussed below. All the Ardiuno peripherals used here are :

- LCD Display
- Arduino UNO
- TDS Sensor
- Solenoid Valve
- Relay

3.1.1 LCD Display

LCD (Display) is a form of flat panel display that uses chemical reagents as its primary source of illumination. LEDs are commonly utilized in phones, tv, computers screens, and panels, and that they have several consumer and business uses. LCDs were a major step ahead from the technology they superseded, such as light-emitting diode (LED) and fuel screens. Compared to cathode ray tube (CRT) technology, LCD technology enables for much smaller screens. LCDs consume considerably less energy than LED and gas-display displays because they block rather than transmit light. It's being used to measure the temperature and TDS levels here.



No	Symbol	Function
1	VSS	Ground
2	VDD	5V +
3	V0	Contrast
4	RS	Register
5	RW	Read/Write
6	E	Enable
7	D0	Data bus
8	D1	Data bus
9	D2	Data bus
10	D3	Data bus
11	D4	Data bus
12	D5	Data bus
13	D6	Data bus
14	D7	Data bus
15	A	Anode (5V+)
16	K	Cathode (GND)

Figure 3.2: 16 X 2 LCD Display

3.1.2 Arduino UNO

The ATmega328P microprocessor is used in this Arduino board (fig 3.3). It is relatively simple compare to another boards. It has six analog inputs, 14 numbers of digital I/O pins, power jack, reset button, and a USB connection, as well as a reset button, a power jack, and USB connection. Apart from all Arduino Boards, Uno is most used and good form. Beginners will benefit much from this board. In the below Fig.3.3 the pin configuration of Ardiuno UNO is shown.

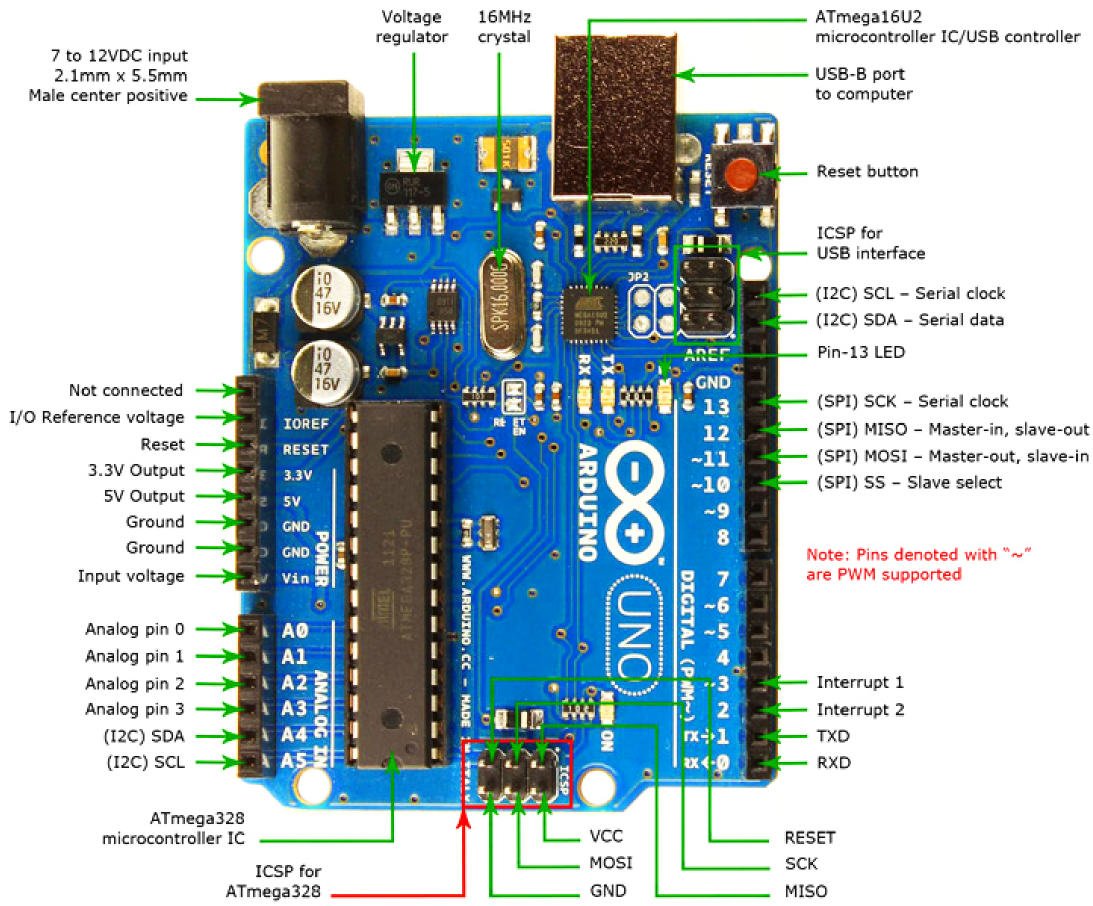


Figure 3.3: Arduino UNO pin Configuration

3.1.3 TDS Sensor

A TDS detector is a tiny hand device that detects the quantity of overall dissolved solids in a liquid, most often water. Since absorbed ionized particles, like salts, improve the conduct of a solutions, this TDS sensor measures overall conductance of such a way to solve and determines the TDS after that value. In the above figure:3.4 the gravity sensor has been shown.

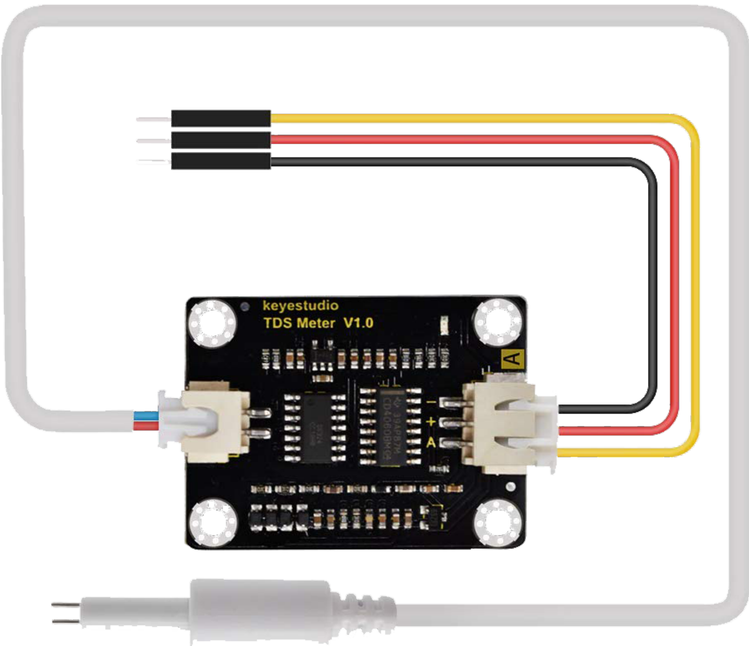


Figure 3.4: Gravity TDS Sensor

3.1.4 Solenoid Valve

Control devices known as solenoid valves might shut off or permit fluid flow whenever electrically energized or de-powered.

Figure 3.5: Solenoid Valve

3.1.5 Relay

Relays are devices that work both electro-mechanically and electronically to close and open circuits. It regulates how an electrical circuit's circuit connections open and close. The relay is not powered while the connector on the relay is open (NO). The relay is not powered up, though, if the contact is closed (NC). The nations are, nevertheless, susceptible to change when energy (electricity or charge) is given.

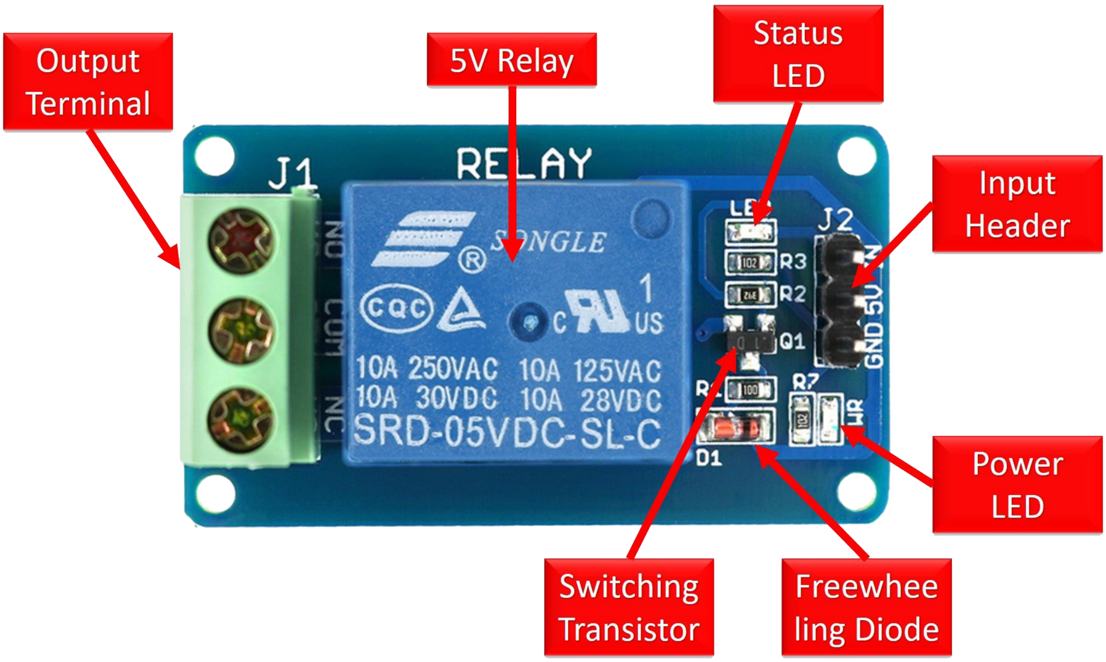


Figure 3.6: Realy

3.2 Circuit Diagram

Main objective of this thesis is to provide an automated purification system to purify variable TDS input water to an adjustable permit able drinking water. In this system two filter membrane used, one is UF and other is RO.

In the Fig.3.7, all the connection has been shown. Arduino pin 10 & 8 are connected to Relay-1 and Relay-2 respectively. Relay is connected to the both solenoid valve. Inlet of the valves are directly connected to the source through

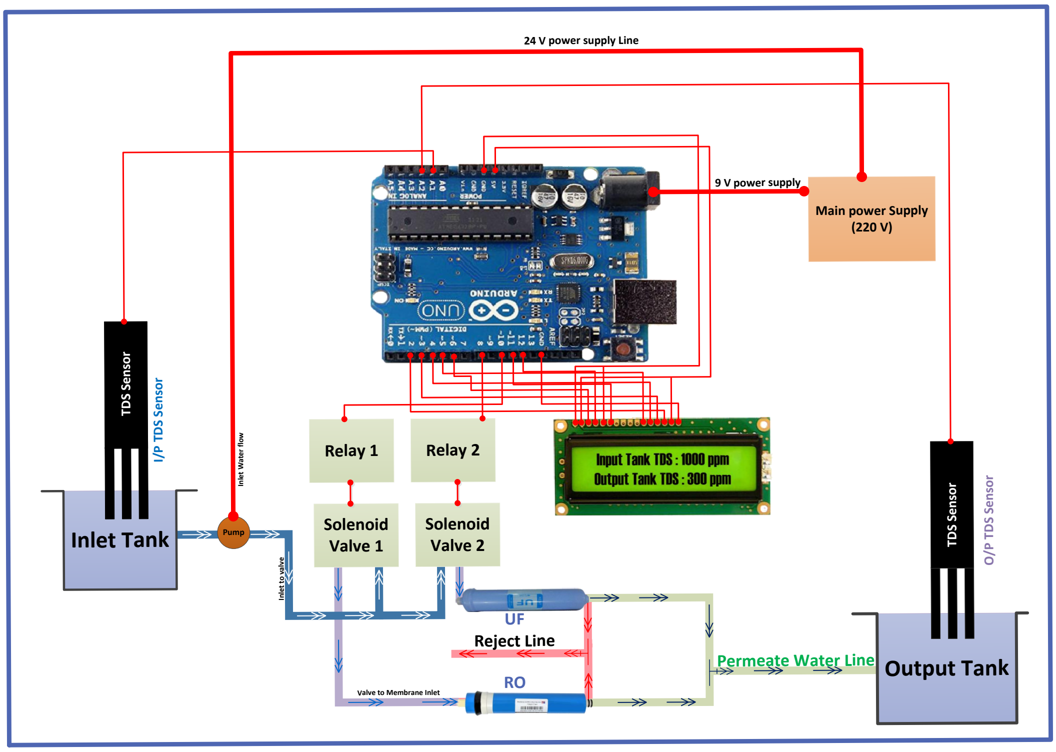


Figure 3.7: Circuit Diagram

pump. The output of the solenoid valve-1 and 2 are connected to the input of RO and UF respectively. The output of the RO and UF are connected to the output take and both the reject line is connected with BFR. In both outpout and source tank a TDS meter is submersed whose reading are reflected in LCD screen connected to the board. The Arduino board in powered through a 9 volt supply line.

Figure 3.8: Set-Up

In the above Fig.3.8 the set-up has been shown. As mentioned in the circuit diagram, the input of the solenoid valves are connected to the source through the pump. A pressure gauge is also connected to monitor the inlet water pressure. From the output line of the both filters (UF & RO) i.e. in permeate water line pure drinkable water collected to a storage tank and the reject is connected to the drainage through BFR.

CHAPTER 4

RESULTS & DISCUSSION

4.1 RO based experiment Results

Experiment have been carried out to check the functionality of the RO & UF membranes which is to be controlled by the Arduino coding is fixed both of TDS is above 100ppm RO works as if below 100ppm UF work to retain minerals.Initially the performance of the RO & UF membranes are checked by varying the pressures values selected depending on the tolerable limit of the the membranes.

The RO membrane is only connected in this step standard Water of 104ppm & 0.5NTU is taken for feed. Inlet pump pressure varied between 20 psi, 30psi, 40psi, 50 psi, 60 psi respectively and flow rate is different here, shown in table:4.1 It is observed that when pressure is low, TDS of permeate water is high,flow rate of permeate water is low, TDS of reject water is high.

Table 4.1: 104 ppm/0.55NTU

Pressure (psi)	**Flow Rate of water (LPH)**	**Flow Rate of permeate water (L)**	**TDS of permeate water(ppm)**	**Turbidity of permeate water (NTU)**	**TDS of reject water (ppm)**
20	110	1.343	17	0.37	103
30	110	3.913	12	0.45	105
40	53	6.429	6	0.44	124
50	95	7.5	5	0.48	115
60	80	10	6	0.49	119

In table: 4.2 inlet water TDS is to set as 50ppm. Inlet pump pressures are varied between 10psi, 20psi, 30psi, 40psi respectively and flow rates are constant here (Using rota meter) at 15LPH. It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is high.

Table 4.2: 50 ppm (2nd /15 LPH)

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**
10	0.24	33	0.37
20	4.5	33	0.34
30	6.2	32	0.37
40	11.39	28	0.35

In table: 4.3 inlet water TDS is 150ppm.Inlet pump pressures are varied between 40psi,30 psi,20psi,10psi respectively and flow rate is constant(using rota meter) at 15 LPH.It is observed that when pressure is high flow rate of permeate water is high,TDS of permeate water is low,TDS of reject water is high.

Table 4.3: 150ppm/0.35 NTU/15LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	1.9	9	0.04	173
30	2.5	9	0.01	185
20	0.89	9	0	156
10	1.23	11	0	148

In table: 4.4 inlet water TDS is 100ppm.Inlet pump pressure are varied between 40psi, 30 psi, 20psi, 10psi respectively flow rate is constant(using rota meter) at 15LPH.It is observed that here when pressure is high flow rate of permeate water is high,TDS of permeate water is low, TDS of reject water is high.

Table 4.4: 100ppm/0.35NTU/15LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	3.12	9	0.11	168
30	1.78	8	0.01	158
20	0.71	8	0.03	148
10	0.6	12	0.08	136

In table: 4.5 inlet water TDS is 250ppm. Inlet pump pressures are varied between 40psi,30 psi,20psi,10psi respectively flow rate is constant(using rota meter) at 15 LPH.It is observed that here when pressure is high flow rate of permeate water is also high,TDS of permeate water is low,TDS of reject water is high.

Table 4.5: 250ppm/15LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	12.8	65	0	292
30	7.75	64	0.01	278
20	4.61	68	0.02	272
10	0.71	111	0.02	249

In table: 4.6 inlet water TDS is 100ppm.Inlet pump pressure are varied between 40psi,30psi,20psi,10psi respectively flow rate is constant(using rota meter) at 20LPH .It is observed that when pressure is high flow rate of permeate water is high,TDS of permeate water is low,TDS of reject water is high.

Table 4.6: 100ppm/0.31NTU/20LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	11.69	23	0.03	200
30	7.5	15	0.06	130
20	3.86	16	0.11	116
10	0.21	26	0.13	103

In table: 4.7 inlet water TDS is 50ppm.Inlet pump pressure are varied between 40psi,30psi,20psi,10psi respectively flow rate is constant at 20LPH.It is observed that when pressure is high flow rate of permeate water is high,TDS of permeate water is low,TDS of reject water is high.

Table 4.7: 50 ppm/20LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	11.39	8	0.08	63
30	6.20	7	0.13	59
20	4.5	9	0.03	56
10	0.24	11	0.08	55

In table: 4.8 inlet water TDS is 250ppm.Inlet pump pressure are set to 40psi,30psi,20psi,10psi respectively flow rate is constant at 15 LPH.It is observed that here pressure is low permeate water TDS is also low.

Table 4.8: 250ppm/15LPH

Pressure (psi)	**Flow Rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of permeate water (NTU)**	**TDS of Reject Water(ppm)**
40	12.8	65	0	292
30	7.75	64	0.01	278
20	4.61	68	0.02	272
10	0.71	111	0.02	249

4.2 UF based experiment Results

UF Membrane is only connected & result shown in table 4.9. Consider the inlet water TDS is 100 ppm. Inlet pump pressures are varied between 20psi, 18psi, 15psi, 5psi respectively flow rate is constant (using rota meter) at 15 LPH.It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is high,TDS of reject water is high.

Table 4.9: 100ppm/15 LPH

Pressure (psi)	**Flow rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of Permeate water (NTU)**	**TDS of Reject water (ppm)**
20	56.25	57	0.01	113
18	37.5	57	0.02	107
15	13.23	56	0.02	109
5	3.46	56	0.03	109

In table: 4.10 inlet water TDS is 105 ppm. Inlet pump pressures are varied between 20psi,18psi,15psi,5psi respectively flow rate is constant (using rota meter) at 15 LPH.It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is low,TDS of reject water is also low.

Table 4.10: 105ppm/15 LPH

Pressure (psi)	**Flow rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of Permeate water (NTU)**	**TDS of Reject water (ppm)**
20	56.25	113	0	116
18	37.5	114	0	115
15	13.23	122	0.01	119
5	3.46	118	0.01	119

In table: 4.11 inlet water TDS is 50 ppm. Inlet pump pressures are varied between 20psi,18psi,15psi,5psi respectively flow rate is constant (using rota meter)at 15 LPH.It is observed that when pressure is low flow rate of permeate water is also low,TDS of permeate water is high,TDS of reject water is same for all pressures.From above preliminary experiments we prepared the below table to perform the experiment to set the timings.

Table 4.11: 50ppm/15 LPH

Pressure (psi)	**Flow rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of Permeate water (NTU)**	**TDS of Reject water (ppm)**
20	49	50	0	60
18	20.7	49	0	60
15	6	48	0.02	61
5	4.2	45	0.02	60

The coding for all the experiments from table:4.1 to table:4.11 referred in **Annexure-1**.

4.3 RO & UF combination based experiment Results

RO membrane & UF membrane both are connected and results are shown in table:4.12 if TDS is less than 100. In that case RO & UF both are turned on for 5 min. Inlet pump pressure are varied between 10psi,20psi,30psi,40psi respectively and flow rate is constant here (using rota meter) at 15LPH. It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is high and TDS of reject water is low. Refer **Annexure-4** for coding used in-case of TDS is less than 100 & both RO and UF turned on for 5 minutes.

Table 4.12: Flow rate - 15 LPH (if TDS < 100, RO = UF = 5 min)

Pressure (psi)	Flow rate of permeate water (Ltr)	TDS of permeate water (ppm)	Turbidity of Permeate water (NTU)	TDS of Reject water (ppm)
10	25	40	0.08	32
20	26.2	35	0.08	33
30	29.8	32	0.05	33
40	32	32	0.02	34

In table:4.13 shows that if TDS is less than 100, RO will turn on for 8 minutes and UF will be on for 2 minutes. Inlet pump pressure are varied between 10psi, 20psi, 30psi, 40psi respectively flow rate is constant here (using rota meter) at 15LPH. It is observed that when pressure is low flow rate of permeate water is high, TDS of permeate water is high, TDS of reject water is also high. Refer **Annexure-5** for coding used in-case of TDS is less than 100 & RO turned on for 2 minutes and UF turned on for 8 minutes.

Table 4.13: Flow rate - 15 LPH (if TDS < 100, RO = 2 min & UF = 8 min)

Pressure (psi)	Flow rate of permeate water (Ltr)	TDS of permeate water (ppm)	Turbidity of Permeate water (NTU)	TDS of Reject water (ppm)
10	12	33	0.03	25
20	15	38	0.03	22
30	13.2	32	0	23
40	11.8	32	0	22

In table:4.14 shows that if TDS is greater than 100, RO & UF both are turned on for 5min. Inlet pump pressure are varied between 10psi,20psi,30psi,40psi respectively flow rate is constant here (using rota meter) at 15LPH.It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is low,TDS of reject water is high. Refer **Annexure-2** for coding used in-case of TDS is greater than 100 & both RO and UF turned on for 5 minutes.

Table 4.14: Flow rate - 15 LPH (if TDS > 100, RO = UF = 5 min)

Pressure (psi)	**Flow rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of Permeate water (NTU)**	**TDS of Reject water (ppm)**
10	26	98	0.07	22
20	27	98	0.06	23
30	28.9	105	0.05	24
40	30	106	0.00	23

In table:4.15 shows that if TDS is greater than 100, RO will turn on for 2 minutes and UF will be on for 8 minutes. Inlet pump pressure are varied between 10psi,20psi,30psi,40psi respectively flow rate is constant here (using rota meter) at 15LPH.It is observed that when pressure is low flow rate of permeate water is low,TDS of permeate water is high,TDS of reject water is low. Refer **Annexure-3** for coding used in-case of TDS is greater than 100 & RO turned on for 8 minutes and UF turned on for 2 minutes.

Table 4.15: Flow rate - 15 LPH (if TDS > 100, RO = 8 min & UF = 2 min)

Pressure (psi)	**Flow rate of permeate water (Ltr)**	**TDS of permeate water (ppm)**	**Turbidity of Permeate water (NTU)**	**TDS of Reject water (ppm)**
10	18	70	0.08	102
20	19.2	65	0.06	100
30	20	63	0.04	101
40	22.3	60	0.02	108

From all the above experimental results we can summarised that when the TDS of the inlet water is less than 100, it is better to use the table:4.13 configuration rather than table:4.12. Because at higher pressure in table:4.13 configuration the permeate water turbidity is less. Similarly when the TDS of the inlet water is greater than 100, it is better to use the table:4.15 configuration rather than table:4.14. Because at higher pressure in table:4.15 configuration the permeate water TDS is significantly lowered than table:4.14 configuration. These timing configuration is summarised in table:4.16 below. **Annexture-6** coding used for testing purpose for combining both RO & UF.

Table 4.16: Timing Table

TDS	**Total Time = 10 min**
If <= 100	RO = 8 min & UF = 2 min
If >= 100	RO = 2 min & UF = 8 min

CHAPTER 5

CONCLUSION & FUTURE SCOPE

Here the conclusion summarised in below points.

1. The proposed device can automatically sense the TDS fluctuation in source and adjust the parameters by itself without any human intervention.
2. As it developed in Ardiuno platform, the device is simple, cost effective and easily up-gradable.
3. It will consume very less power in compare to other water purification devices available in the market.

Although the findings appear to reflect the quality of the water source, additional testing is needed to confirm the data validity and operability of the existing system before it can be applied elsewhere. The prototype still lacks a number of features, necessitating improvements and extensions, such as the ability to send data via a wireless network to a remote laptop or mobile device at any time and location, as well as a more powerful memory drive or the capacity to store data in databases. IoT devices might be utilized in conjunction with the present system to achieve higher accuracy. A GSM module would also make it easier to communicate with the Arduino.

ANNEXURE

Annexure-1

```
/***********Notice and Trouble shooting***************
 1. This code is tested on Arduino Uno with Arduino IDE 1.0.5 r2 and 1.8.2.
 2. Calibration CMD:
     enter -> enter the calibration mode
     cal:tds value -> calibrate with the known tds value(25^c). e.g.cal:707
     exit -> save the parameters and exit the calibration mode
 ****************************************************/

#include <EEPROM.h>
#include "GravityTDS.h"

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;


float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;

void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
}

void loop()
{
    //temperature = readTemperature();  //add your temperature sensor and read it
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();

    tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
    output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
    Serial.print(tank_tds_Value,0);
    Serial.println("ppm");
    Serial.print(output_tds_Value,0);
    Serial.println("ppm");
    delay(1000);
}
```

Annexure-2

```
#include <EEPROM.h>
#include "GravityTDS.h"
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>
int Contrast=8;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;

float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;
int RelayPin1 = 10;     ////RO
int RelayPin2 = 8;     ////UF


void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
    pinMode(RelayPin1, OUTPUT);
    pinMode(RelayPin2, OUTPUT);
    analogWrite(6,Contrast);
    lcd.begin(20,4);
}

void loop()
{
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();


    tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
    output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
    Serial.print(tank_tds_Value,0);
    Serial.println("ppm");
    Serial.print(output_tds_Value,0);
    Serial.println("ppm");
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("I/P TDS:");
    lcd.print(tank_tds_Value,0);
    lcd.print(" PPM");
    lcd.setCursor(0, 1);
    lcd.print("O/P TDS:");
    lcd.print(output_tds_Value,0);
    lcd.print(" PPM");
    delay(100);
    digitalWrite(RelayPin2,LOW);
    digitalWrite(RelayPin1,LOW);

    if(tank_tds_Value > 100)
    {
// This part is for .........................condition true...........................................
    digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
    delay(300000); //............................................................... 5 min RO water flow
    digitalWrite(RelayPin1,LOW); //it will OFF the RO relay
    digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
    delay(300000); // ...............................................................5 min UF water flow
    digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
    lcd.clear();
    lcd.print(" Cycle Completed");
    delay(2000);
    }
}
```

Annexure-3

```
#include <EEPROM.h>
#include "GravityTDS.h"
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>
int Contrast=8;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;

float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;
int RelayPin1 = 10;      ////RO
int RelayPin2 = 8;      ////UF


void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
    pinMode(RelayPin1, OUTPUT);
    pinMode(RelayPin2, OUTPUT);
    analogWrite(6,Contrast);
    lcd.begin(20,4);
}

void loop()
{
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();


    tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
    output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
    Serial.print(tank_tds_Value,0);
    Serial.println("ppm");
    Serial.print(output_tds_Value,0);
    Serial.println("ppm");
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("I/P TDS:");
    lcd.print(tank_tds_Value,0);
    lcd.print(" PPM");
    lcd.setCursor(0, 1);
    lcd.print("O/P TDS:");
    lcd.print(output_tds_Value,0);
    lcd.print(" PPM");
    delay(100);
    digitalWrite(RelayPin2,LOW);
    digitalWrite(RelayPin1,LOW);

    if(tank_tds_Value > 100)
    {
// This part is for .........................condition true...........................................
    digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
    delay(480000); //.............................................................. 8 min RO water flow
    digitalWrite(RelayPin1,LOW); //it will OFF the RO relay
    digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
    delay(120000); // ..............................................................2 min UF water flow
    digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
    lcd.clear();
    lcd.print(" Cycle Completed");
    delay(2000);
    }
}
```

Annexure-4

```
#include <EEPROM.h>
#include "GravityTDS.h"
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>
int Contrast=8;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;

float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;
int RelayPin1 = 10;     ////RO
int RelayPin2 = 8;     ////UF


void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
    pinMode(RelayPin1, OUTPUT);
    pinMode(RelayPin2, OUTPUT);
    analogWrite(6,Contrast);
    lcd.begin(20,4);
}

void loop()
{
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();


     tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
     output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
     Serial.print(tank_tds_Value,0);
     Serial.println("ppm");
     Serial.print(output_tds_Value,0);
     Serial.println("ppm");
     lcd.clear();
     lcd.setCursor(0, 0);
     lcd.print("I/P TDS:");
     lcd.print(tank_tds_Value,0);
     lcd.print(" PPM");
     lcd.setCursor(0, 1);
     lcd.print("O/P TDS:");
     lcd.print(output_tds_Value,0);
     lcd.print(" PPM");
     delay(100);
     digitalWrite(RelayPin2,LOW);
     digitalWrite(RelayPin1,LOW);

     if(tank_tds_Value < 100)
     {
// This part is for .........................condition true..........................................
     digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
     delay(300000); //................................................................ 5 min RO water flow
     digitalWrite(RelayPin1,LOW); //it will OFF the RO relay
     digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
     delay(300000); // ...............................................................5 min UF water flow
     digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
     lcd.clear();
     lcd.print(" Cycle Completed");
     delay(2000);
     }
}
```

Annexure-5

```
#include <EEPROM.h>
#include "GravityTDS.h"
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>
int Contrast=8;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;

float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;
int RelayPin1 = 10;      ////RO
int RelayPin2 = 8;      ////UF


void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
    pinMode(RelayPin1, OUTPUT);
    pinMode(RelayPin2, OUTPUT);
    analogWrite(6,Contrast);
    lcd.begin(20,4);
}

void loop()
{
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();


    tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
    output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
    Serial.print(tank_tds_Value,0);
    Serial.println("ppm");
    Serial.print(output_tds_Value,0);
    Serial.println("ppm");
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("I/P TDS:");
    lcd.print(tank_tds_Value,0);
    lcd.print(" PPM");
    lcd.setCursor(0, 1);
    lcd.print("O/P TDS:");
    lcd.print(output_tds_Value,0);
    lcd.print(" PPM");
    delay(100);
    digitalWrite(RelayPin2,LOW);
    digitalWrite(RelayPin1,LOW);

    if(tank_tds_Value < 100)
    {
// This part is for ..........................condition true...........................................
    digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
    delay(120000); //................................................................... 2 min RO water flow
    digitalWrite(RelayPin1,LOW); //it will OFF the RO relay
    digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
    delay(480000); // .................................................................8 min UF water flow
    digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
    lcd.clear();
    lcd.print(" Cycle Completed");
    delay(2000);
    }
}
```

Annexure-6

```
#include <EEPROM.h>
#include "GravityTDS.h"
#include <LiquidCrystal.h>
#include <OneWire.h>
#include <DallasTemperature.h>
int Contrast=8;

LiquidCrystal lcd(12, 11, 5, 4, 3, 2);

#define TdsSensorPin_1 A1   //tank_tds_Value
#define TdsSensorPin_2 A2  //output_tds_Value
GravityTDS gravityTds_1,gravityTds_2;

float temperature = 25,tank_tds_Value = 0,output_tds_Value = 0;
int RelayPin1 = 10;     ////RO
int RelayPin2 = 8;     ////UF


void setup()
{
    Serial.begin(9600);
    gravityTds_1.setPin(TdsSensorPin_1);
    gravityTds_2.setPin(TdsSensorPin_2);
    gravityTds_1.setAref(5.0);
    gravityTds_2.setAref(5.0);  //reference voltage on ADC, default 5.0V on Arduino UNO
    gravityTds_1.setAdcRange(1024);  //1024 for 10bit ADC;4096 for 12bit ADC
    gravityTds_2.setAdcRange(1024);
    gravityTds_1.begin();
    gravityTds_2.begin();  //initialization
    pinMode(RelayPin1, OUTPUT);
    pinMode(RelayPin2, OUTPUT);
    analogWrite(6,Contrast);
    lcd.begin(20,4);
}

void loop()
{
    gravityTds_1.setTemperature(temperature);  // set the temperature and execute temperature compensation
    gravityTds_2.setTemperature(temperature);
    gravityTds_1.update();  //sample and calculate
    gravityTds_2.update();



    tank_tds_Value = gravityTds_1.getTdsValue();  // then get the value
    output_tds_Value = gravityTds_2.getTdsValue();  // then get the value
    Serial.print(tank_tds_Value,0);
    Serial.println("ppm");
    Serial.print(output_tds_Value,0);
    Serial.println("ppm");
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("I/P TDS:");
    lcd.print(tank_tds_Value,0);
    lcd.print(" PPM");
    lcd.setCursor(0, 1);
    lcd.print("O/P TDS:");
    lcd.print(output_tds_Value,0);
    lcd.print(" PPM");
    delay(100);
    digitalWrite(RelayPin2,LOW);
    digitalWrite(RelayPin1,LOW);

    if(tank_tds_Value >= 100)
    {
// This part is for .........................condition true...........................................
    digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
    delay(420000); //............................................................... 7 min RO water flow
    digitalWrite(RelayPin1,LOW); //it will OFF the RO relay
    digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
    delay(180000); // ..............................................................3 min UF water flow
    digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
    lcd.clear();
    lcd.print(" Cycle Completed");
    delay(2000);
    }
```

```
    else if(tank_tds_Value < 500)
    {
// This part is for.......................... condition false...............................................
    digitalWrite(RelayPin2,HIGH); //it will ON the UF relay
    delay(420000); //.................................................................. 7 min UF water flow
    digitalWrite(RelayPin2,LOW); //it will OFF the UF relay
    digitalWrite(RelayPin1,HIGH); //it will ON the RO relay
    delay(180000); //.................................................................. 3 min RO water flow
    digitalWrite(RelayPin1,LOW); //it will OFF the RO relay

    lcd.clear();
    lcd.print(" Cycle Completed");
    delay(2000);
    }
}
```

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