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Samir Koirala

Water Quality Monitoring System

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The purpose of this Thesis is to dive into parameters to acquire the quality of water. The quality of water is mainly determined by three aspects; physical, biological, and chemical. In this study, the purpose was to find out the standards of water, how it gets deteriorated, parameters of the water quality system, and sensors available in the market helping to purify the water quality.

This thesis work also aimed to design a sensor monitoring water quality system by using several sensors, microcontroller, and wireless system.

This project focused on researching how to improve the quality of water through different aspects explained in this thesis. The common sensors are temperature, pH, and turbidity sensors. These three parameters are considered because pH determines whether the water be acidic or basic, turbidity helps to find the number of solid particles, whereas these data may differ with the temperature change.

Keywords	Waste Water, Sensors, PH, Temperature, Turbidity

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List of Abbreviation

BOD	Biochemical oxygen demand
CSIRO	Commonwealth scientific and industrial research organization
DO	Dissolved oxygen
MIROC	Model for interdisciplinary research on climate
ODW	Oxygen-demanding waste
PO	Pathogenic organisms
TOC	Total organic carbon
WQMS	Water quality monitoring system
WQT	Water-quality testing

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1. Introduction

Water plays a vital role in the creation of human beings and other natural phenomena. About 80% of diseases in the developing country are caused by the consumption of polluted water. As we all know, water is not only used for drinking purposes, it has other uses too such as; economic aspects, industrial sites, agriculture, fishing, and other constructive activities. The quality of water is mainly affected by physical, chemical, and biological aspects.

The main sources of water are lakes, rivers, glaciers, groundwater, rainwater, etc. Water is available in every part of the earth whether it is polluted or not. About 80 percent of Earth's land is covered by water. In our day-to-day life water plays one of the most important roles for living beings on earth.[1.] Quality of water is getting very serious attention in our generation. So, to live a healthy and prospective life, checking the water quality is very important.

In the past, water quality has been measured by taking the water samples and sending them to the laboratories, and examining them, which is very costly, time-consuming, and involves more human resources.[2.] This process will not provide real-time data and lead us to the impure quality of water. The proposed water quality monitoring systems consisting of a microcontroller with common sensors are compact and very useful for pH, turbidity, conductivity, water level detection, temperature and humidity of the atmosphere, continuous and real-time data.

This thesis aimed to design the water quality monitoring system using smart sensors, microcontrollers, and wireless systems. Although any definite result was not obtained due to the constraints of the environment, the possibility to get good quality measurement data wirelessly to any system was realized. ATmega2560 and NodeMUC ESP8266 are the components that can build the theoretical water quality monitoring system as discussed in the paper.

2. Deterioration of Quality of Water

Deterioration of quality of water as calculated from three factors mainly(i.e. chemical, physical and biological basis). It occurs every day in the period of supply and consumption of water. The quality of water is very essential for living organisms. Daily human beings drink around two liters of water every day. Around 70% of the human weight is covered by water. Water covers almost 80 percent of the earth's surface. If we calculate the amount of water available on the earth it is 1,011 million km3 out of which we can only use 33,400 km3 of water for drinking, agriculture, domestic and industrial purposes. [3.]

Major Causes/Issues	*Major Related Issues*[1]	*Space Scale*	*Time Scale*		*Major Controlling Factors*	
			Contamination[2]	*Clean-up*[3]	*Biophysical*	*Human*
Population	Pathogens	Local	<1 yr.	<1 yr.		Density & treatment
	Eutrophication*	Regional	<1–10 yr.	1–100 yr.		Treatment
	Micro-pollutants	Regional	<1–10 yr.	1–100 yr.		Various
Water Management[4]	Eutrophication*	Regional	<1 yr.	10->100 yr.	Hydrodynamics	Flow
	Salinization	Regional	10–100 yr.	10->100 yr.		Water Balance
	Parasites	Regional	1–10 yr.	>100 yr.		Hydrology
Land Management	Pesticides	Local-regional	<1 yr.	1–100 yr.		Agrochemicals
	Nutrients (NO_3)	Local-regional	10–100 yr.	>10 yr.		Fertilizer
	Suspended Solids*	Local-regional	<1–10 yr.	10–100 yr.		Construction/clearing
	Physical Changes	Local	<1–10 yr	>100 yr		Cultivation, Mining Construction & Clearing
Atmospheric Transport	Acidification*	Regional	>10 yr.	10 yr.		Cities, melting & fossil-
	Micropollutants	Regional	>10 yr.	1–100 yr.		fuel emissions
	Radionuclides	Regional-global	<1 yr.	>>100 yr.		Industry
Concentrated Pollutant Sources:						
Mega Cities	Pathogens	Local	<1 yr.			Population & treatment
	Micropollutants	Local-regional	<1 yr.			
Mines	Salinization	Local-regional	10–100 yr.			Types of mines
	Metals	Local-regional	<1 yr.			
Nuclear Industry	Radionuclides	Local-global	<1 yr			Waste management
Global Climate Change	Salinization	Global	>10 yr.	>100 yr.	Temperature & precipitation	Fossil-fuel emissions & Greenhouse gases
Natural Ecological Conditions	Parasites*	Regional	Permanent	Permanent	Climate & hydrology	
Natural Geochemical Conditions	Salts	Regional	Permanent	Permanent	Climate & lithology	
	Fluoride**	Local-regional				
	Arsenic**, Metals**	Local-regional			Lithology	

[1]* is relevant primarily to surface water and ** is relevant primarily to groundwater

[2] space scales: local — <10,000 km^2; regional — 10^4 to 10^6 km^2; and global — 10^7 to 10^8 km^2

[3] lag between cause and effect

[4] longest time scale is for groundwater, followed by lakes, and shortest for rivers and streams

Figure 1: Spatial and temporal constraints on water quality evolution.[4.]

The above figure 1, its shows that the major causes of water deterioration are population, water management system, land management, rises of industrial sectors, climate changes, and Natural geochemical conditions. Figure 1 also mentions space scale, time scale, and what are the major controlling factors. Among those, the factors which have been deteriorating the quality of water have been described below. [4.]

2.1 Oxygen-demanding Waste

Water pollutants have been occurring for decades because of oxygen-demanding waste(ODW). The main sources of ODW come from; wastewater from household uses, industrial uses(paper industries, food industries), and wastewater from agriculture.

In the past decades, the growth of industries and agriculture sectors has boomed in the European countries after the 1940s which led to water pollution. On the other hand, the treatment of wastewater management has increased throughout Europe over the past 15 to 30 years.

In the 1970s, the river Rhine was almost dead because of the high use of organic matter. The biochemical oxygen demand (BOD)(which is the measurement of a mixture of organic matters) and ammonia reached pick levels. In 1971, the yearly oxygen concentration was some 5 mg O_2/l and the invertebrate species were extremely low as shown in Figure 2.

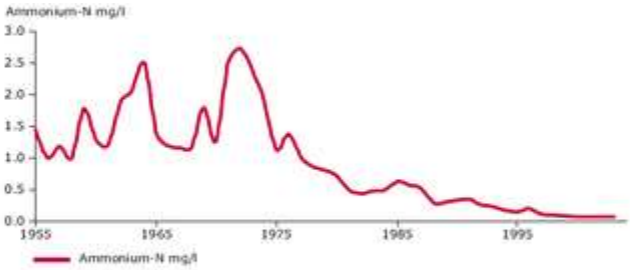


Figure 2: Annual average concentration of ammonium N measurements at Bimmen/Lobith(Rhine). [5.]

The progress of biological treatment has been high and the organic waste being controlled over the past 30 years can be seen from figure 3. In conclusion, the increase of invertebrate species has been high and the organic waste has been low.[4.]

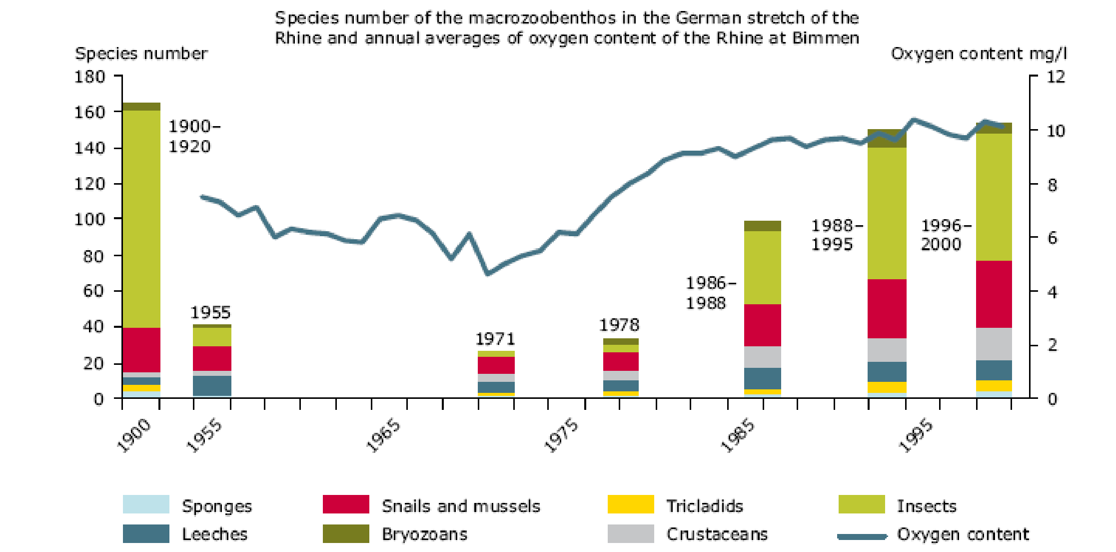


Figure 3: Development of aquatic community and oxygen concentration of the Rhine at Bimmen. [5.]

2.2 Pathogenic Organisms

Pathogenic organisms(PO) are water-borne bacteria that have been the major issue for the deterioration of the quality of water. Pathogenic contamination will affect freshwater like; rivers, lakes, groundwater, reservoirs, and saline water resources.

In developing countries like; India, Nepal, Africa, Bangladesh, people will depend on rivers, reservoirs, and lakes to be used for drinking purposes and other household activities. Water pathogens are associated with diseases like diarrhea, gastrointestinal illness, pneumonia, and food allergy. These have been the major issues in these developing countries. People have been using water directly from the rivers which are impure for drinking purposes. [6.]

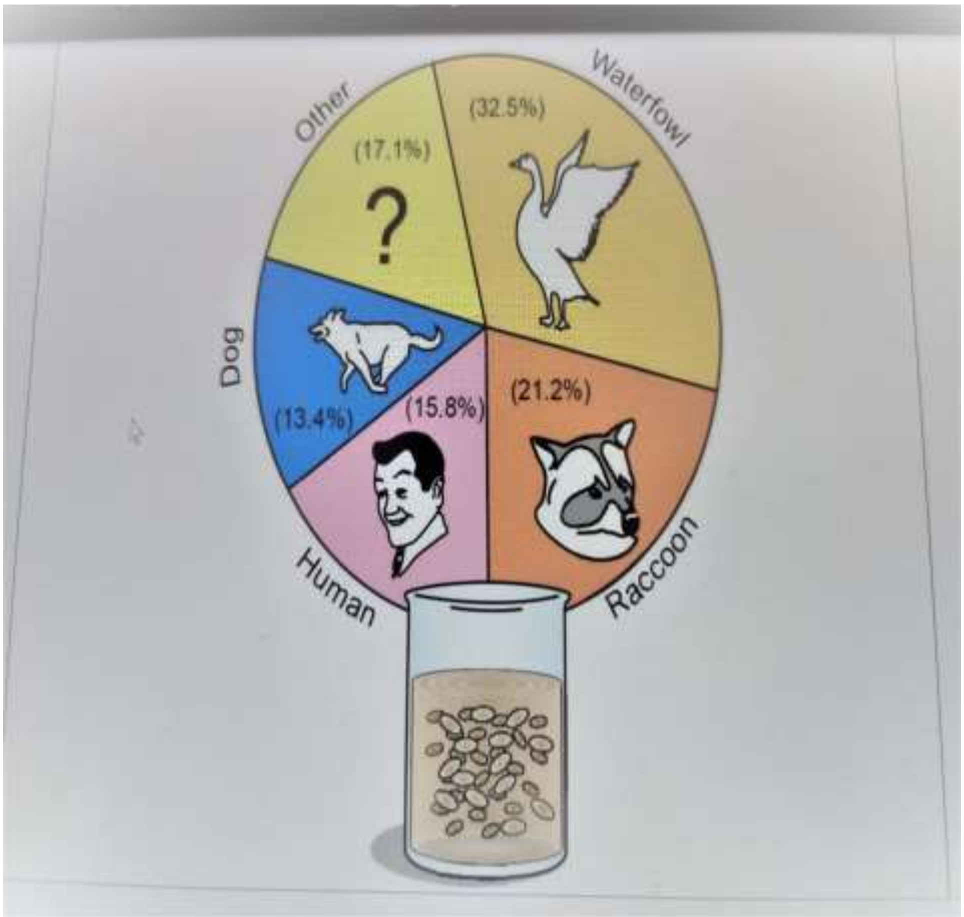


Figure 4: Pathogenic sources.[6.]

The development of pathogenic sources is from human waste, animal waste, waterfowl, and more as shown in figure 4 above. E. coli is the most common transmission bacteria which has been transferred in contact with feces or stool of humans or animals. [6.]

2.3 Nutrients

Nutrients are very essential for human beings. The compounds from which we get nutrients are carbohydrates, fats, vitamins, minerals, and water. Water has deteriorated in the process of being realized by human activities. Nitrogen and phosphorus are two main compounds of nutrients. [7.]

In the nitrogen process, it goes through biological and non-biological transformations in the Environment. Inorganic nitrogen occurs in the state of nitrate (No_3^-), nitrite (No_2^-), ammonium ion (NH_4^+), and molecular nitrogen(N_2). Inorganic nitrogen is converted into organic one from plants and microorganisms. In the process of changing, the water has been mixed with chemical substances, fluids, and other unwanted compounds that came from the nitrogen process which occurs in polluting the water. [7.]

2.4 Oil Spills

Oil on the shore has been another major issue of getting water deteriorated. Annually around 9 million barrels of oil have been mixed with oceans, lakes, and rivers. From 9 million about half of the oil had been spilled from natural activities like; 35% from human activities, 12% from the shipment(tankers, barges, and pipelines), and 3% from petroleum production.[8.] The water pollution not only fully gets polluted from oil spills but also types of oil, weather conditions, human activities, and organisms exposed in the oceans, rivers, or lakes. [9.]

3. Parameters of Water Quality System

Water quality parameters encompass physical, chemical, and biological values along with monitoring concerns or testing provided samples. Temperature, pH, conductivity and salinity, turbidity, and dissolved oxygen are the frequently applied parameters to obtain water quality. Nevertheless, measuring algae, ISEs (ammonia, nitrate, chloride), and laboratory variables can also be considered as a water monitoring guideline. It is essential to monitor the water quality on open systems if the water is being used for humans or industrial purposes. [10.] Moreover, the description of a few parameters can be found below:

3.1 Temperature

The measurement of the average kinetic energy of water molecules on a scale of Fahrenheit or Celsius degrees is referred to as a temperature. It also determines the internal heat or the intensity of heat inside the objects. The kinetic energy results in the movement of the molecules with internal thermal energy. [10.] Thus, it affects the concentration of the dissolved gases and the saturation of the water. To be precise, oxygen amount, rate of photosynthesis by plants inside the water, metabolic rates of aquatic animals are adversely impacted by the increased temperature. The change in the temperature varies with the layers of the water and the duration of the time, i.e, colder at night and warmer at broad daylight. As a result, the temperature is considered an important criterion for water quality. [11.]

3.2 pH

The measurement of hydrogen-ion (H^+) or negative logarithm of the hydrogen ion concentration is pH scale. Its value determines the acidity and base of the water where acidic water holds an extra amount of hydrogen ions and base water with extra hydroxyl ions (OH^-). It is important to have a pH measurement to determine the state of water, and it is favorable for plants, aquatic animals, or even for drinking purposes. [10.] Figure 5 depicts the visual representation of the pH value that ranges from 0 to 14. The lower the value more the water is acidic whereas the pure water has a value of 7.0 and is considered neutral.

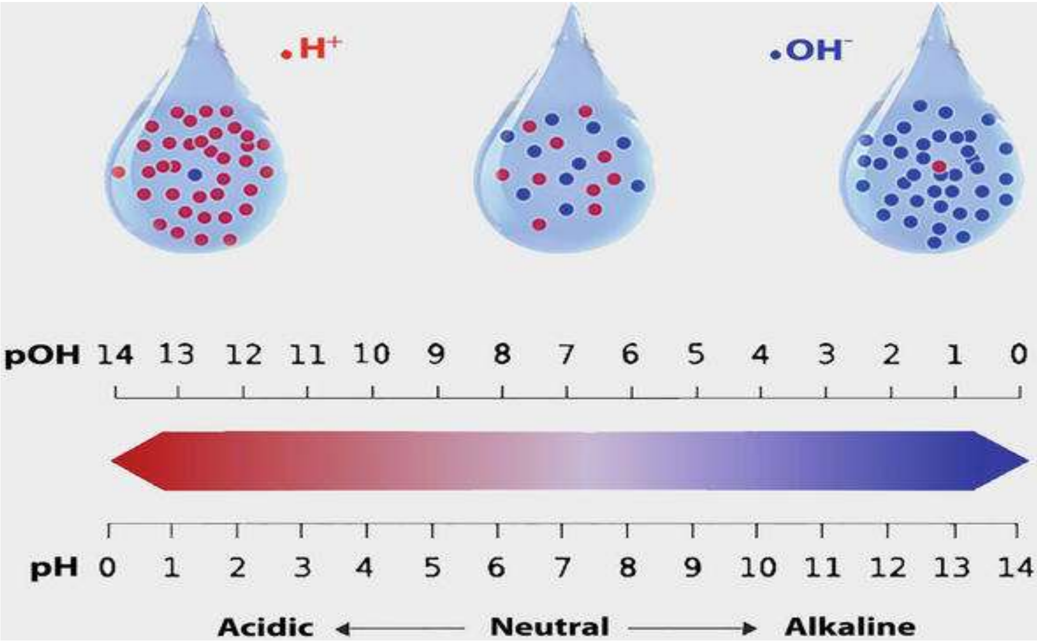


Figure 5: A visual presentation of pH scale. [12.]

The varying value of pH can result in several chemical reactions and could affect the lifestyle of aquatic animals since those are adaptive to certain pH scales. Besides, low pH can be more deadly to humans as heavy metals can readily dissolve in the water. So, it is important to govern the pH scale for water quality and is considered as the topmost parameter. [12.]

3.3 Dissolved Oxygen

Dissolved oxygen is a basic test of water pollution and one of the important parameters. The water with a higher concentration of oxygen is evaluated as pure water. Although the dissolved oxygen might not have severe consequences on human health, it can bring changes in the taste of water. Atmospheric pressure, temperature, pollution level, the concentration of salt are the several aspects that differentiate the dissolved oxygen (DO) concentration. Due to being a significant parameter, several Sensor technologies are out in the market to measure the concentration of DO. [12.]

3.4 Electrical Conductivity and Salinity

The ability of water to conduct electricity is referred to as electrical conductivity and functions of the types and quantities of dissolved substances in water. Both positive and negative ions present in the water sample are the reason behind the electrical conductivity. This parameter also relates to the number of dissolved solids as it is with ions, i.e. higher the total dissolved solids in the solution, higher the ion concentration, and finally affects the conductivity. [11.]

The amount of salt present in the water or concentration of the dissolved salt in water is salinity. Sodium chloride (NaCl) is generally called a common salt that is present on water bodies along with its ions. Its presence determines the ability for the growth of crops as maximum salinity affects the growth. Salinity is generally measured on PSS or practical salinity scale. [11.]

3.5 Turbidity

Turbidity is one of the physical parameters of water quality and is a measurement of the number of suspended particles in the water. The amount of light scattered determines the turbidity of water. The basis to define is solid objects like clay or silt and even algae. The more the water is cloudy, the less it is unhealthy for living organisms. The water treatment could be costly due to this parameter. [11.]

Nephelometric turbidimeter is used for its measurements and value can be represented in NTU or TU. 1 TU is equal to 1 mg/L of silica in suspension. Most polluted water could have a value up to 100 NTU whereas a lower value of less than 5 NTU is considered normal visibility. Ideally, normal drinking water's value must be below 1 NTU. [11.]

4. Sensors Available for Water Quality Testing

Although many technologies available commercially on the market are used for detecting routine water quality parameters such as free chlorine and TOC, there is a need for further online monitoring systems that can track and record real-time data which is currently not possible with the existing laboratory-based testing methods that are too time-consuming.

Different sensors, both prototype and commercially available will be further explained in detail in this part of the thesis. Since all the data obtained are from manufacturers of these devices, the usability and effectiveness of these technologies will vastly vary depending upon the location and water characteristics. [13.]

4.1 Prototype and Pre-industrial Scale

At the forefront of innovation, fluorescence technology has been leading the way for optical sensors that detect dissolved organic matter in polluted water. The United States Geological Survey has used this technology to research sensors for over a decade to develop fluorescence dissolved matter(FDOM) sensors which can provide high-resolution insight into the dissolved organic carbon (DOC) and other biochemicals such as trihalomethane (THM)presurors and methyl mercury (MeHg) concentrations. [13.]

Recently, a pre-industrial scale sensor was developed by SecurEau to monitor water quality, the sensor named KaptaTM 3000 OT3 measures transmission at 254 nm for organic matter and 625 for turbidity measurements by the use of two light-emitting diodes (LEDs). The use of two wavelengths is to avoid the condition of fouling. In Europe, this sensor is used in two drinking water systems where 40 of these devices measure water quality and send the measurements to the operation center. Some specifications of the KaptaTM 3000 OT3 are detailed in Table 1.

Table 1. KaptaTM 3000 OT3 pre-industrialisation specifications [13.]

Parameter	Range	Resolution	Fidelity	Maintenance	Precision	Response time
Organic matter TOC equivalent	0.1–10 mgC/L	0.1 mgC/L	±5 %	The multi-parameter probe should be replaced every year	±5 %	<6s
UV absorbance (254 nm)	0.01–0.3 AU/cm	0.01 UA/cm	±5 %		±5 %	<6s
Turbidity equivalent	2–50 NTU	1 NTU	Not evaluated yet		Not evaluated yet	<6s

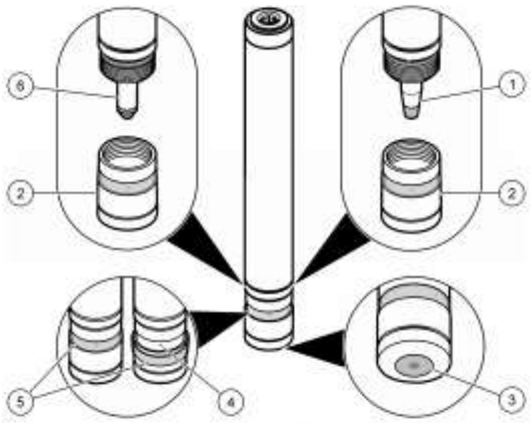
4.2 Commercially Available Sensors

Sensors readily available on the market are focused on one of the many detection methods, such as residual chlorine sensor, TOC sensor, turbidity sensor, and so on. One sensor from each of the categories will be discussed in detail with the use case and specifications.[13.]

4.2.1 Residual Chlorine Sensor

The free chlorine sensor and total chlorine sensor are relentless, electrochemical sensors that continuously measure the chlorine concentration in water. The free chlorine sensor measures the concentration of free chlorine in water generated from inorganic chlorine products, while total chlorine sensors measure the total chlorine i.e free chlorine and combined chlorine in the water. [14.]

Variations in the pH can affect the accuracy of the sensor, the accuracy can sometimes differ by about 10% which can be mitigated by the use of an internal temperature sensor. The internal temperature sensor can automatically adjust to compensate for the pH of the water. [16.] Figure 6 shows one of the free chlorine and total chlorine sensor



1	Electrode of the free chlorine sensor	4	Vent hole in membrane cap
2	Membrane cap	5	Rubber band
3	Membrane	6	Electrode of the total chlorine sensor

.

Figure 6: Sensor construction overview[14.]

The sensor in figure 6 is a potentiostatic three-electrode instrument with a specially placed counter electrode. The reference electrode and measuring electrode are both in the electrolyte, while the measuring electrode is covered by a membrane that separates the electrode area from the special electrolyte.

The chlorine concentration is measured by the use of an amperometric method, in which the chlorine species in the sample pass through the membrane and react with the working electrode. This process results in the production of electrical current which is proportional to the chlorine concentration in the sample. Produced electrical current is then amplified by the electronics in the sensor and transmitted in the voltage format (mV). To maintain measurement stability a third electrode is put into the sample and is used to maintain a constant working potential on the working electrode.

pH fluctuations can cause the measurement to be incorrect so to mitigate the problem a highly buffered electrolyte inside the membrane cap supplies internal compensation which compensates for the inaccuracies. The buffer helps by immediately changing the hypochlorite ions permeating the membrane into hypochlorous acid molecules. Thus, the final readings are independent of either the pH values or the temperature of the measured water due to the internal compensation. [17.]

4.2.2 Total Organic Carbon (TOC) Sensor

TOC is the measure of organic contamination in the water, which are measured as Carbon molecules, these contaminations are introduced through various processes from purification to distribution which is needed to be measured for TOC to satisfy regulatory requirements. The main objective of the technology involved in the sensor is to completely oxidize the organic matter thus forming carbon dioxide (CO_2) which can be measured and expressed as the carbon concentration in the sample. The sample might contain organic as well as nonorganic carbon which may be present in the water, these sensors must be able to differentiate between those carbons. One way they discriminate is by deduction of inorganic carbon (IC) from total carbon (TC) which gives the total organic carbon.

TOC = TC - IC

Based on the method of oxidation of organic matter, TOC is differentiated into different types, such as Non-dispersive infrared (NDIR), Direct Conductometric, and Membrane Conductometric Detection. The method of oxidation and detection is what sets one TOC apart from the other.[25]

Photocatalytic sensors are one of the TOC sensors which use light to oxidize organic matter as shown in figure 7. TiO_2 is used either alone or with other oxides. ZnO alone can also be used which gives acceptable outcomes. [16.]

In a photocatalytic mechanism, a semiconductor surface is illuminated with energy greater than 3.1 eV (380nm) to excite the electron which then jumps from the valence band to the conduction band, leaving a positive hole. This electron can be transferred to oxygen or H++, initiating various reactions. The hole can produce hydroxyl radical. Free radicals are strong oxidants that can mineralize organic matter to form carbon dioxide and water in the process as shown in figure 7. [15.].

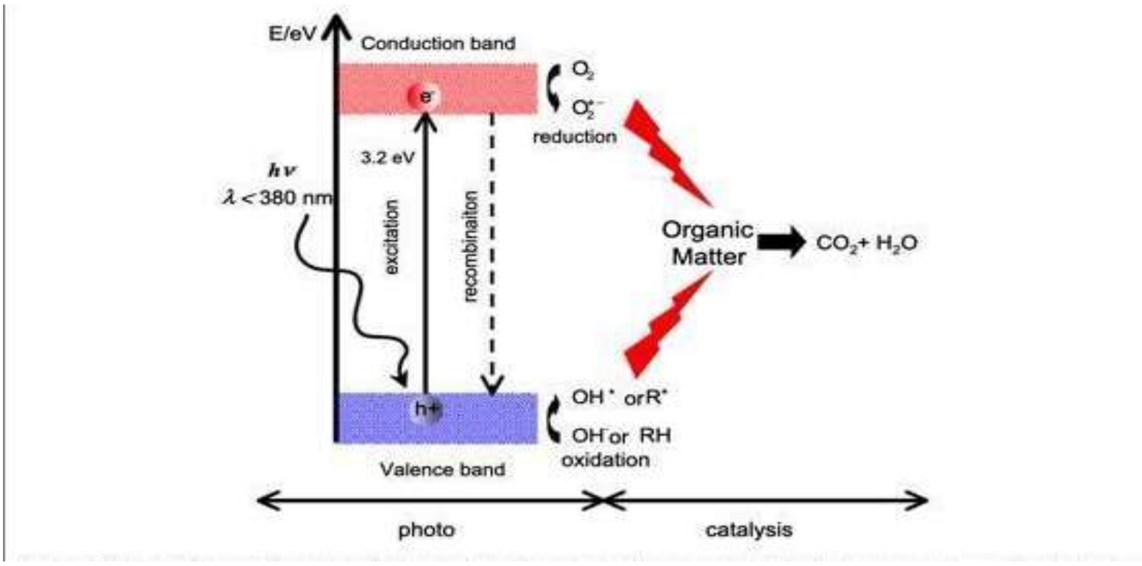


Figure 7: Photocatalytic mechanism on a semiconductor surface, where organic matter is oxidized with the help of strong oxidant radicals. [15.]

4.2.3 pH Sensors

The term pH is derived from “p”, the mathematical symbol for negative logarithm, and “H”, the chemical symbol for Hydrogen. It is measured on a scale of 0 to 14. The pH value of a substance is directly affected by the ratio of the concentration of hydrogen ion (H+) and hydroxyl ion (OH-). pH testers provide measurable data for the degree of activity of an acid or base in terms of hydrogen ion activity.

Digital pH meters are used for more accurate pH measurements, and water quality measurement requires a precise measurement nonetheless. A digital pH meter consists of three main parts, a pH probe, a reference pH electrode, and a high input impedance meter. The pH probe is sensitive to the hydrogen ion, it is a glass bulb with a millivolt output that changes concerning the change in concentration of hydrogen ion inside and outside of the bulb.[17.]

A combination pH sensor is most widely available and used in the testing of water quality, this is also the case for the reasons that this type of sensor can act as a base for the creation of laboratory sensors and process sensors.[17.]

4.2.4 Temperature Sensors

The temperature of the water plays a vital role in controlling the metabolic, reproductive, and life cycles of aquatic life. The fluctuations in the temperature of the water may disrupt these activities or may cause them to stop completely. These changes in the water temperature are sometimes caused by natural factors such as seasons, the intensity of the sun, and so on. But sometimes the changes are not so natural, humans have used water for many purposes such as electricity generation and cooling agents for massive factories. Therefore, to negate the effects of water temperature fluctuations caused by human activities, water temperature sensors are implemented so the water can be safely released from man-made storage into natural reservoirs such as lakes or rivers. There are various types of temperature sensors such as thermistors, thermocouples, and solid-state temperature sensors which can be used to measure the temperature of the system accurately. [20]

LM35 series sensors are one of the choices in this sensor type. These sensors are accurate integrated circuit temperature sensors whose output voltage is linearly proportional to the temperature of the system. Since the sensor is directly calibrated in Celsius the user does not need to manually calculate the result in centigrade scaling. This sensor is recalibrated as it does not need any external calibration to provide accurate results.

PT100 is a sensor classified under RTD (Resistance Temperature Detectors), these sensors include a resistor that changes the value of resistance with a temperature change. These sensors are used for many years in laboratories and research as the reputation and accuracy of these sensors are very high. The internal circuit diagram of the sensor is shown in the figure below. [21]

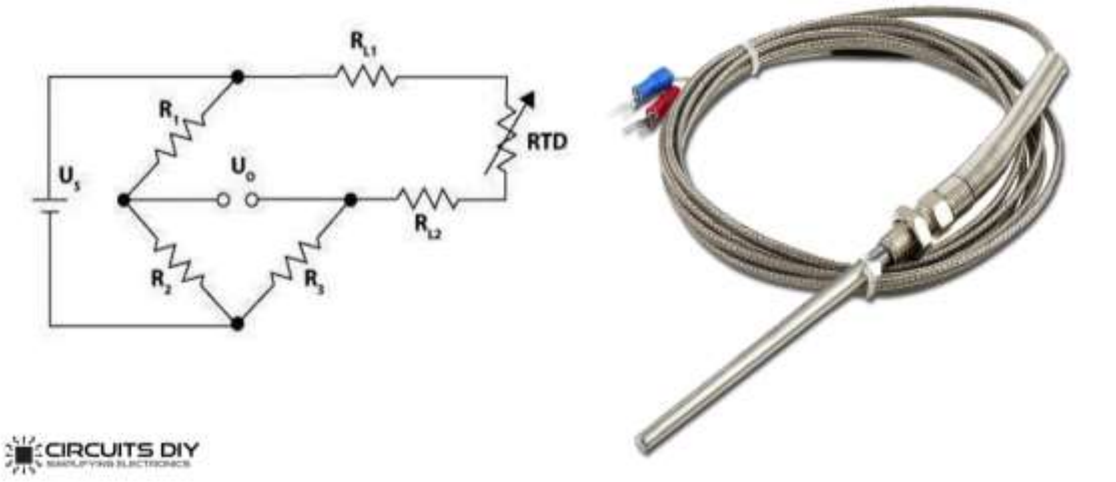


Figure 8: PT100 sensor with 2 wires is commonly used. The sensor consists of a resistance element and insulated copper wires for better protection. The resistance element is usually platinum because of its wide working temperature range. The circuit diagram also further simplifies the inner working of the sensor. [22]

4.2.5 Turbidity Sensor

A turbidity sensor is a measurement of the number of suspended particles in the water, the amount of light scattered determines the turbidity of water. For example; sand, plant waste, clay, slit impact the sunlight in the water. If the amount of turbidity is high in water, it will affect marine life as well as human beings too. This sensor works in the 5V input voltage with an analog output varying from 0 to 4.5V. The maximum temperature it will hold is from 100 C- 900 C. NTU(Nephelometric Turbidity Units) is the unit of a turbidity sensor.[23.]

4.2.6 Ultrasonic Sensor

The HC-SRO4 is the ultrasonic distance sensor, which is available economically. It has contactless calculation functionality varying from 2 cm to 400 cm. This sensor has four pins; VCC(power), trigger, echo(receive), and ground. The accuracy of this sensor ranges up to 3 mm.[27.]

5. Wireless Monitoring Sensor Design

In this thesis, different types of sensors were researched to achieve the precise measurement of the water quality parameters as mentioned above. pH, turbidity, ultrasonic, and DHT-11 are the four sensors used for the proposed system, whereas the microcontroller unit and ESP8266 wi-Fi module(NodeMCU) are used for the main processing unit and one data transmission module. The main part of this system development for water quality measurement is the microcontroller unit. Arduino Mega has been used for a microcontroller unit that consumes low power and its small size, which is effective for sale technology criteria too.

The four sensors can be used to collect the data, out of four sensors, two of them were used to collect data in the form of analog signals where the MCU has an on-chip ADC which translates the analog signals into the digital form, these two sensors will be connected to the MCU's analog pins, whereas other two sensors will be connected to the MCU units of the digital pins. All the data will be recorded and processed to the Thingspeaker server with the help of the Wi-Fi data communication module ESP8266(NodeMCU) to the main server. The block diagram of the prospects for water quality measurement is shown in Figure 9.

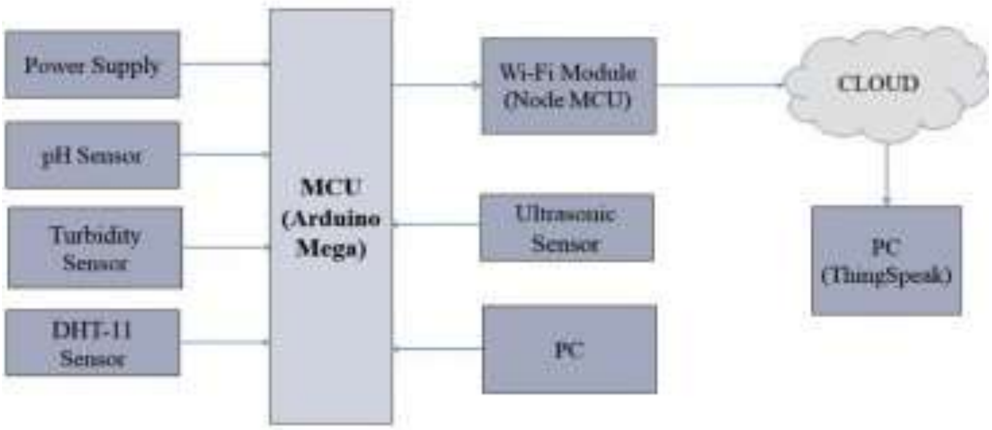


Figure 9. Block diagram

The water quality monitoring system uses sensors to collect data on pH, turbidity, level of water, temperature, and humidity. Arduino Mega and NodeMCU are the boards that can be used in the proposed Future system.[23.]

5.1 Arduino Mega

It is a microcontroller board based on the ATmega2560. It consists of 54 digital input/output pins from which 15 can be used as PWM outputs. Moreover, it has 16 analog inputs, 4 UARTs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button as shown in figure 10. This board is compatible and easily connects to a computer with a USB cable. It can be powered with a USB connection or with an external power supply(which can come from either AC to DC adapter or battery). An external supply of 6 to 20 volts can operate this board but the recommended range is 7 to 12 volts. The Arduino Mega2560 formally called an Arduino Mega without the ‘2560’ extension because it was the replacement of the old Arduino Mega. Arduino mega is frequently found in complex projects like Radon detectors, 3D printers, temperature sensing, IoT applications, real-time data monitoring applications, etc. As shown in figure 10, the circuit diagram of ATmega2560, has an analog comparator, external interrupt and software interrupt, power saving mode, inbuilt temperature sensor, RTC, and many more features.[24.]

Figure 10. Diagram of ATmega2560 [24.]

5.2 NodeMCU

NodeMCU is an open-source firmware for IoT platforms, it consists of Espressif systems ESP8266 Wi-Fi chip and ESP-12 module-based hardware. The power supply can easily be done through the USB port. It is used to measure analog voltage in the range of 0-3.3V, and it has 16 general purpose input-output pins on its board of which four pins are available for serial peripheral interface(SPI) communication. NodeMCU has two UART interfaces, UART0(RXD0 & TXD0) and UART1(RXD1 & TXD1) as shown in figure 11. UART1 is used to upload the program. NodeMCU is a small-sized module that will fit smartly inside our projects. It supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. To store data and programs it has 128 KB RAM and 4MB of flash memory. It is ideal for IoT projects because of its high processing power with Wi-Fi/Bluetooth and deep sleep operating features.[25.]

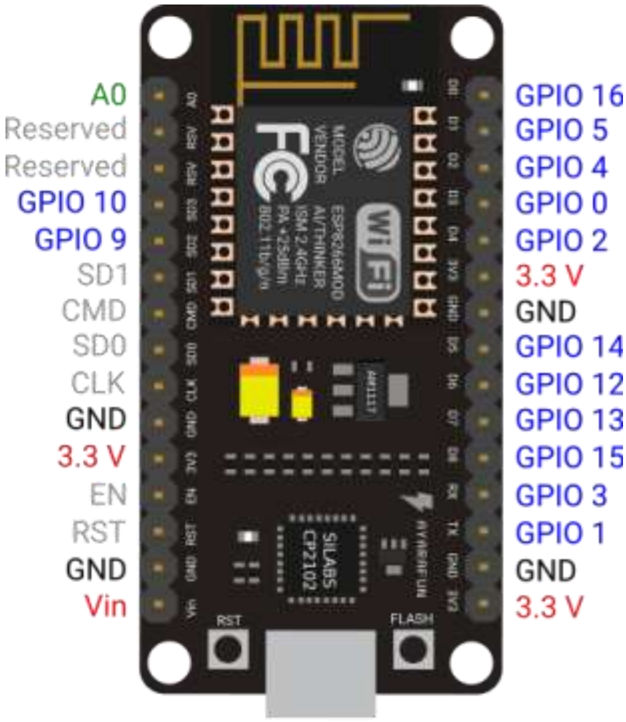


Figure 11. Diagram of NodeMCU ESP8266[25.]

5.3 Thingspeak Server

Thingspeak is the application that is used to collect data from various sensors, like; temperature, pH, turbidity, moisture, distance, etc. It is an IOT application, to use this server the user needs to log in first. The data collector will collect the data and send it to the Wi-Fi module(NodeMCU

ESP8266) after that the data will be sent to the Thingspeak server and the data will be modified and processed into MATLAB code and the data will be reacted by some alerts sound.[23.]

5.4 DHT-11 Sensor

The sensor is used to calculate the temperature and humidity values of the encompassing atmosphere. The operating voltages of this sensor range from 3.5V to 5.5V and the operating current is 0.3 mA(measuring), it gives the output in serial data both for temperature and humidity. The temperature and humidity range of this sensor are from 0 C to 50 C and 20% to 90%. The accuracy levels of this sensor are ±1 C and ±1%.[26.]

6. Future Prospects of Water Quality Assessment

Water Quality has been a major issue in the world, especially in developing countries because of the shortage of technical manpower for operation and maintenance. Due to the rise of population in Asia, river water quality has deteriorated due to human activities, climate change, petroleum products, inorganics substances, and biochemical oxygen demand(BOD).

CSIRO-Mk3.0 and MICRO 3.2 are two general circulation models which have been used for climate change projection. The CSIRO models estimated the drier climate whereas, on the other hand, MICRO estimated the wetter climate by 2050. 1 out of 8 people are at big risk of water pollution from BOD, 1 out of 6 people are at risk from nitrogen pollution and 1 out of 4 people are at a risk from phosphorus pollution. These cases mostly affect people who stay in developing countries in Asia by 2050 as shown in the table 2.[18.]

Table 2: High risk of the population from Water Pollution[18.]

	BOD	N	P
Today	1 in 8 people or 651 million	1 in 6 people or 973 million	1 in 4 people or 1,287 million
2050 CSIRO-medium	1 in 5 people or 1,589 million	1 in 3 people or 2,645 million	1 in 3 people or 2,948 million
2050 MIROC-medium	1 in 6 people or 1,372 million	1 in 4 people or 2,311 million	1 in 3 people or 2,522 million

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we can achieve a greener world, reduce water pollution and support the Sustainable Development Goals. The optimistic scenario need simplified municipal wastewater cure, improvements in nutrient use efficiency, slower population growth and rapid growth in the global economy. Under the "optimistic" scenario, the rate of municipal wastewater cure will rise by 30% over the base period, and nutrient use efficiency (NUE) in crop production (expressed in kg crop yield per kg nutrients applied) is assumed to improve by 40% (except for the least developed countries). With medium population and GDP growth, the presumed rate of increase in municipal wastewater cure is 15% and the NUE improvement is only 20%. No changes in the municipal wastewater cure rate and

NUE are presumed under pessimistic predictions. Under the drier future projected by the CSIRO global circulation model, global crop harvested area expands by 15-18%, and livestock numbers increase by 14-28%. The expected growth rates of crop harvested area and animal counts under the wetter MIROC model range from 17-21% and 16-27%, respectively as shown in table 3.[18.]

Table 3: Elements of the six scenarios assessed out to 2050.[18.]

	CSIRO medium	CSIRO optimistic	CSIRO pessimistic	MIROC medium	MIROC optimistic	MIROC pessimistic
Population in 2050	9.3 billion	8.1 billion	10.6 billion	9.3 billion	8.1 billion	10.6 billion
Annual, average rate of GDP growth	3.2%	3.6%	1.9%	3.2%	3.6%	1.9%
Crop harvest area	+17.5%	+14.7%	18.4%	+20.0%	+17.2%	20.9%
Nutrient use efficiency (expressed in crop yield (kg) per kg nutrient applied)	+20%	+40%	No change	+20%	+40%	No change
Livestock numbers	+26%	+28%	+14%	+25%	+27%	+16%
Improvement in municipal wastewater treatment levels	+15%	+30%	No change	+15%	+30%	No change

For example; In Japan, a company named Hitachi sticks to the concept of an intelligent water system in 2010, presenting the key approach to acquiring the best results from management of water resources and infrastructure at the city or catchment level. At the end of 2015, Japan had 97.9% reportage for water supply and 77.8% for sewerage services. The main issues behind the improvement of aging infrastructure, which was built in the 1960s and 70s.

It is predicted that elements such as sensors and the telecommunication and the process of regional coordination of water supply and sewerage services in Japan will increase in the future for the request of things like remote monitoring of equipment, regional management, and the centralized administration of information as shown in figure 12.[19.]

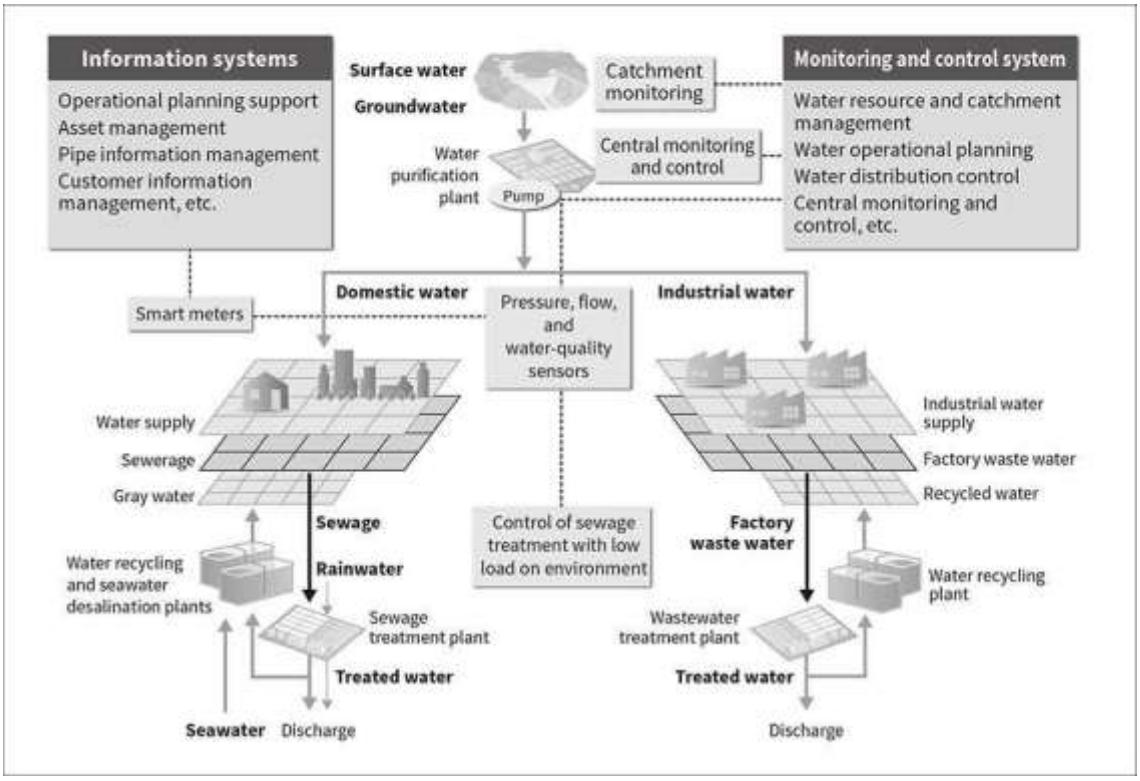

Figure 12: Examples of Intelligent water systems [19.]

This idea helps improve the distribution of water throughout a city or region through the wide-area integration of water management and treatment systems with information and control systems. This is a idea of thinking about how to implement IT and control technologies at a regional level to acquire goals such as improved reliability, more systematic regional management, and lowered load on the environment as shown in figure 12.[19.]

7. Conclusion

This thesis has provided an overview of the water quality monitoring system(WQMS), which includes how water has deteriorated, parameters of WQMS, sensors available for WQT, and prospects of WQT mainly focus on developing countries. The scarcity of quality water is increasing day by day in developing countries. In this thesis, the parameters for water quality degradation such as temperature, pH, turbidity, and conductivity are also explained in detail. It also shows how the water quality assessment technology will be developed in the future, and their implementation to control the dire need of water scarcity will be resolved.

The goal of this thesis was to design the water quality monitoring system using smart sensors, microcontrollers, and wireless systems. Although any definite result was not obtained due to the constraints of the environment, the possibility to get good quality measurement data wirelessly to any system was realized. ATmega2560 and NodeMUC ESP8266 are the components that can be used to build the theoretical water quality monitoring system as discussed in the paper.

The future of water quality does not look better as the development and industrialization of the developing countries have just begun. Although, if the precautions are applied soon and the systems placed at the right time then it can be prevented well in developing countries. If the designs explored in the paper were to be implemented in the future then the need for human intervention would be minimal and there will be more chances of getting good quality water in developing countries.

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