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Acronyms

I2C Inter-Integrated Circuit

WQS Water Quality system

WQI Water Quality Index

EPI Environmental Performance Index

GIS Geographical Information Systems

WSN Wireless sensor network

DMS Data Management Systems

USGS United States Geological Survey

CPS Cyber-Physical System

IoT The Internet of Things

WHO World Health Organization

EWS Early warning systems

BOD Biological Oxygen Demand

EWS Early warning systems

DIY Do It Yourself

SD Secure Digital

I/O Input/Output

PWM Pulse Width Modulation

USB Universal Serial Bus

ICSP In-Circuit Serial Programming

HID Human Interface Devices

UART Universal Asynchronous Receiver/Transmitter

COD Chemical Oxygen Demand

BOD Biochemical Oxygen Demand

LED Light Emitting Diode

ORP Oxidation-Reduction Potential

SRAM Static Random Access Memory

EEPROM Electrically Erasable Programmable Read Only Memory

TDS gravity sensor

RTC Real-Time Clock

CSV Comma Separated Values

SPI Serial Peripheral Interface

EC Electrical Conductivity

ADC Analog-to-Digital Converter

STL Stereolithography

SRAM Static Random-Access Memory

GENERAL INTRODUCTION

Water pollution is a significant global concern that poses serious threats to both human health and the environment. As industrialization and urbanization progress, the sources of water pollution become more diverse and challenging to manage. Effective water pollution control systems are crucial for monitoring and mitigating the adverse effects of contaminants on water bodies.

This project aims to design and implement a comprehensive water quality monitoring system that leverages modern sensor technologies . The system is built around the Arduino Mega platform, integrating various sensors to measure parameters such as pH, Total Dissolved Solids (TDS), turbidity, and temperature. By employing both traditional and innovative methods, this project seeks to enhance the reliability and efficiency of water quality monitoring, ultimately contributing to better water management practices.

The following sections will cover the theoretical background of water pollution and monitoring systems, the design and implementation of the proposed system, and the results of experimental validations. Through this detailed exploration, we aim to demonstrate the effectiveness and potential applications of our water quality monitoring system.

CHAPTER

1

WATER POLLUTION CONTROL SYSTEMS

Introduction

Water is a fundamental resource for all living organisms, and its quality is essential for the health of ecosystems, human well-being, and economic development. However, the increasing industrialization, urbanization, and agricultural activities have led to widespread contamination of water bodies globally, posing a serious threat to the environment and public health.

Water pollution control systems encompasses a comprehensive framework aimed at mitigating the adverse impacts of pollutants on water quality. These systems integrate a variety of strategies and technologies to prevent, reduce, and manage pollution from diverse sources. By combining regulatory measures, technological innovations, and community involvement, water pollution control systems strive to ensure the availability of clean and safe water for all uses.

1.1 Water pollution

1.1.1 Definition

Water pollution happens when certain substances or conditions reach levels that make it unsuitable for specific purposes. This occurs when excessive quantities of hazardous substances (pollutants) are present, making the water unfit for drinking, bathing, cooking, or other essential uses. Pollution happens when contaminants are introduced into the environment, often stemming from industrial and commercial waste, agricultural practices, everyday human activities, and various modes of transportation. Regardless of location or activity, remnants of human impact persist in the Earth's environment, affecting both ecosystems and inhabitants in numerous ways[1].

When discussing water pollution in the context of the seas, the focus is often on the harm caused by humans through substances such as oil, diesel, petrol, and plastic. This discussion typically emphasizes the potential dangers to human health as well as the detrimental effects on sea creatures. On the other hand, when addressing water pollution in rivers or lakes, the conversation usually centers around industrial and domestic waste.

Figure 1.1: Industrial waste water

1.1.2 History of water pollution

Water pollution has been a longstanding issue for humankind, dating back to ancient civilizations such as Rome, Babylon, Assyria, and Sumer, all of which had sewage systems. The problem persisted and even worsened with the industrial revolution in the 18th and 19th centuries, as factories began dumping untreated waste into rivers due to increased production. The 20th century brought about a chemical revolution, with a surge in the use of chemicals in consumer products, industry, and agriculture, further contributing to pollution and health problems. However, there have been positive developments, such as the implementation of

The Clean Water Act in the United States in 1972, aimed at protecting water quality. Many other governments have also enacted legislation and new laws to regulate pollutant discharges. In recent decades, technological advances have led to significant improvements in wastewater treatment, including sewage and industrial waste.

1.1.3 Sources of water pollution

It's true that water pollution is mainly caused by human activities driven by self-interest, leading to a range of actions contributing to pollution. The expansion of human population, combined with industrial and agricultural practices, stands as a top cause of pollution. Urban overcrowding exacerbates water pollution, with agricultural, domestic, and industrial wastes emerging as the primary pollutants of aquatic habitats. Sewage is a significant pollutant when discharged into freshwater bodies without treatment. The release of untreated sewage into rivers leads to a rapid decrease in dissolved oxygen levels, primarily due to the organic matter triggering decomposers, notably bacteria, which consume suspended solids within the sewage. Consequently, as decomposers respire, they deplete dissolved oxygen (O2), resulting in a reduction in Biological Oxygen Demand Biochemical Oxygen Demand (BOD). This alteration in the river's ecosystem leads to changes and a decline in the flora and fauna population, primarily due to suffocation-induced deaths[1].

Water pollution is indeed a complex issue with a multitude of sources contributing to the degradation of our water bodies. Inadequate infrastructure and improper waste management lead to sewage leakages that introduce harmful contaminants into rivers, lakes, and oceans. The problem is compounded by high population density, which increases the volume of waste generated and its impact on water quality. Industrial activities and transportation accidents can result in oil spillage, posing a significant threat to aquatic ecosystems. Rapidly proliferating invasive species, such as Nipa palm and water hyacinth, can choke waterways and disrupt natural habitats. Industrial waste, including chemicals and by-products, is also a major contributor to water pollution when disposed of directly into water bodies. Groundwater contamination from drilling activities and waste deposits from flooding during the rainy season further exacerbate pollution levels. Improper sanitation practices, such as overflowing lavatories near water sources, contribute to microbial contamination. Additionally, radioisotopes, heavy metals, combustion emissions, and toxic waste disposal at sea pose significant risks to water quality. Mineral processing plants, erosion from deforestation and mining, littering, pesticide and fertilizer runoff, failing septic systems, household chemicals, and animal wastes all play a role in compounding the problem, highlighting the multifaceted nature of water pollution[1].

1.1.4 Effect of water pollution

The impact of water pollution on both living organisms and the environment is significant and diverse. Each day, approximately 14,000 deaths occur due to water pollution, mainly attributed to the contamination of drinking water by untreated sewage in developing nations. For instance, in India, an estimated 700 million people lack access to proper toilet facilities, resulting in the deaths of 1,000 children from diarrhea each day. Similar challenges are faced by many other countries. Nearly 500 million individuals in China also lack access to safe drinking water.[1]

Water pollution poses a significant threat to human health by introducing disease-causing agents such as bacteria and viruses into surface and groundwater sources, leading to various health hazards. The contamination of drinking water can have severe consequences. Moreover, the direct harm to the nutritional balance of plants and animals affects human health, as excessive accumulation of nutrients like nitrogen and phosphorus can lead to algal blooms and overgrowth of weeds, resulting in odorous, off-tasting, and discolored water. This ultimately disrupts the ecological equilibrium of water bodies. Additionally, emissions of sulfur dioxide and nitrogen oxides contribute to acid rain, lowering the pH value of soil. Furthermore, carbon dioxide emissions contribute to ocean acidification, an ongoing decrease in the pH of Earth's oceans as CO2 dissolves, which has wide-ranging ecological implications.[1]

Water pollution not only affects humans but also has a significant impact on fish in rivers, lakes, and oceans, as well as on other sea creatures. Toxic waste and sewage can be particularly harmful to sensitive species, often leading to the death of these organisms. This is concerning as these species are often desired as food sources by humans and their decline can significantly impact fishing productivity.

Water Pollution and Skin Diseases

Contrary to the common belief that swimming is beneficial for health, studies dating back to the 1950s have shown that the overall disease incidence among swimmers was significantly higher than among non-swimmers. Surveys have indicated that the incidence of diseases in people under the age of 10 is about 100% higher than in those over 10 years old, with skin diseases accounting for a significant proportion. A prospective epidemiological study conducted in Hong Kong during the summers of 1986 and 1987 investigated beach water pollution. The study found that swimmers at Hong Kong's coastal beaches were more likely than non-swimmers to report systemic ailments, including skin and eye issues. Additionally, swimming in more polluted beach waters greatly increases the risk of contracting skin diseases and other illnesses. The rate of swimming-related disease symptoms was found to correlate with the cleanliness of the beach[2].

Water Pollution and Cancer

According to World Health Organization (WHO) statistics, the number of cancer patients diagnosed in 2020 reached 19.3 million, while the number of deaths from cancer rose to 10 million. Currently, one-fifth of the global population is expected to develop cancer during their lifetime. The types and amounts of carcinogens present in drinking water can vary depending on where contamination occurs: at the water source, during water treatment processes, or when the water is delivered to users.

From the perspective of water sources, substances like arsenic, nitrate, and chromium are highly associated with cancer. Ingestion of arsenic from drinking water can cause skin cancer, as well as kidney and bladder cancer. The risk of cancer from arsenic in the United States water supply may be comparable to the risk from tobacco smoke and radon in the home environment. However, individual susceptibility to the carcinogenic effects of arsenic can vary.[2]

Water Pollution and Child Health

Diarrhea is a common and serious disease, particularly affecting young children. Diarrheal diseases, including cholera, tragically claim the lives of 1.8 million people each year, with 90 percent of these deaths occurring in children under the age of five, predominantly in developing countries. A staggering 88% of diarrheal diseases are attributed to inadequate water supply, sanitation, and hygiene. Microbially infected water and food are significant contributors to these diseases. In infants and young children, diarrhea can lead to malnutrition and reduced immune resistance, increasing the likelihood of prolonged and recurrent diarrhea. Furthermore, pollution exposure during critical developmental periods is associated with height loss in adulthood [2].

1.2 Water Quality Monitoring Systems

The field of water quality monitoring is rapidly advancing and includes a broad and complex array of disciplines. This science involves addressing various aspects such as environmental decision-making, aquatic ecology, statistical analysis of data, water chemistry, toxicity of chemicals to biological organisms, data management (both hardware and software), large-scale hydrology, and numerous other scientific fields. However, individuals responsible for implementing water quality management laws and developing monitoring systems often lack expertise in all these areas required for the successful design, implementation, and operation of a comprehensive water quality information system. Unfortunately, there are few available courses specifically focused on the design of water quality monitoring systems.[3]

1.2.1 Definition of a water monitoring system

A monitoring system can be defined based on the flow of ”information” through a series of components. This flow of information typically starts with the interface between water and monitoring system personnel during the collection of a sample. For the purpose of this discussion, no specific measurements are being specified, as measurements can be physical, chemical, or biological in nature. After collection, the sample can be analyzed either in the field or in a laboratory. Therefore, by following the sample or the information it contains, a water quality monitoring (or information) system can be defined.[3]

1.2.2 Water Quality Index WQI

The Water Quality Index Water Quality Index (WQI) is a numerical indicator that summarizes water quality by combining measurements of various parameters such as dissolved oxygen, pH, nitrate, phosphate, ammonia, chloride, hardness, metals, and others. Typically, a higher score indicates better water quality (e.g., excellent, good), while a lower score indicates degraded quality (e.g., bad, poor). This index provides a straightforward and concise way to assess the quality of water bodies for various purposes such as recreation, swimming, drinking, irrigation, or fish spawning. Recognizing the critical role of water resources in the environment, the significance of the WQI is evident. Moreover, it has been identified as one of the 25 environmental performance indicators in the comprehensiveEnvironmental Performance Index (EPI) [4].

1.2.3 Weighted Arithmetic Water Quality Index Method

The weighted arithmetic water quality index method classifies water quality based on the degree of purity, utilizing commonly measured water quality variables. This method has been widely adopted by various scientists. The calculation of WQI is performed using the following equation:

$$\mathrm{WQI} = \frac{\sum Q_i W_i}{\sum W_i} \tag{1.1}$$

Such that:

- The quality rating scale Q_i for each parameter is calculated using the following expression:

$$Q_i = 100\left(\frac{V_i - V_o}{S_i - V_o}\right) \tag{1.2}$$

Where:

- V_i: is the estimated concentration of the i-th parameter in the analyzed water.
- V_o: is the ideal value of this parameter in pure water.
- $V_o = 0$ (except pH =7.0 and DO = 14.6 mg/l)
- S_i: is the recommended standard value of i-th parameter.

The unit weight (Wi) for each water quality parameter is calculated by using the formula (1.3):

$$W_i = \frac{K}{S_i} \tag{1.3}$$

Where:

- K: is the proportionality constant and can also be calculated with the equation (1.4) [5].

$$K = \frac{1}{\sum \frac{1}{S_i}} \tag{1.4}$$

The water quality can be classified and rated according to the WQI value as shown in table (1.1).

Merits

1. A mathematical equation integrates data from various water quality parameters to assign a numerical rating to the health of a water body.
2. It requires fewer parameters compared to assessing all water quality parameters for specific purposes.

WQI Value	Rating of Water Quality	Possible usage
0-25	Excellent water quality	drinking, irrigation and industrial
25-50	Good water quality	drinking, irrigation and industrial
50-75	Poor water quality	irrigation and industrial
75-100	Very Poor water quality	irrigation
Above 100	Unsuitable for drinking purpose	proper treatment required before use

Table 1.1: Water Quality Rating as per Weight Arithmetic Water Quality Index Method

3. This method facilitates the communication of comprehensive water quality information to stakeholders, including citizens and policymakers.
4. It reflects the combined impact of different parameters, essential for assessing and managing water quality effectively.
5. It evaluates the suitability of both surface and groundwater sources for human consumption[5].

Demerits

1. The Water Quality Index WQI may not provide comprehensive information about the actual quality status of water.
2. Numerous applications of water quality data cannot be addressed solely through the use of an index.
3. There's a risk of overshadowing or overemphasizing a single poor parameter value.
4. A single numerical value cannot fully capture the complexity of water quality; many other parameters are excluded from the index.
5. However, a WQI based on key parameters can serve as a simplified indicator of water quality[5].

1.2.4 Architecture of a modern environmental monitoring and information system

The demand for an integrated system to enable monitoring, forecasting, and warning of pollution situations has been and will be increasing in the future. The key features of the modern environmental information system include an integrated approach that enables the user, in a user-friendly way, not only to access data quickly but also to use the data directly in the assessment and planning of actions[6]. Figure (1.2) depicts The components of the system. The system should include data collectors such as sensors and monitors, data transfer systems, and data quality assurance/control procedures. It should also incorporate databases including emission and discharge modules, statistical and numerical models (such as air pollution dispersion models and meteorological forecast procedures), user-friendly graphical presentation systems including Geographical Information Systems Geographical Information Systems (GIS), a decision support system, and data distribution systems and communication networks for dissemination of results to 'outside' users [6].the figure (1.3) disciple architecture of the system.

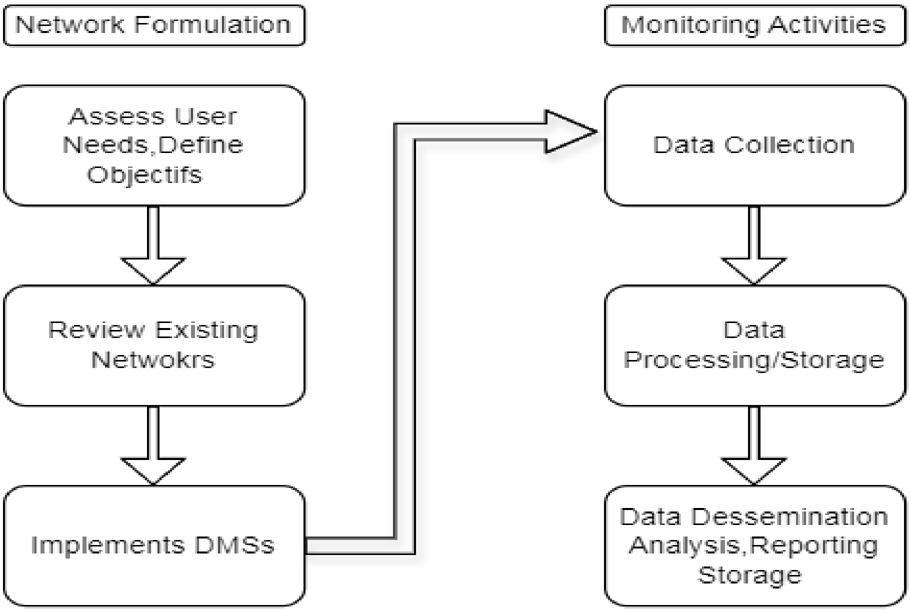


FIGURE 1.2: Architecture of a modern environmental monitoring and information system

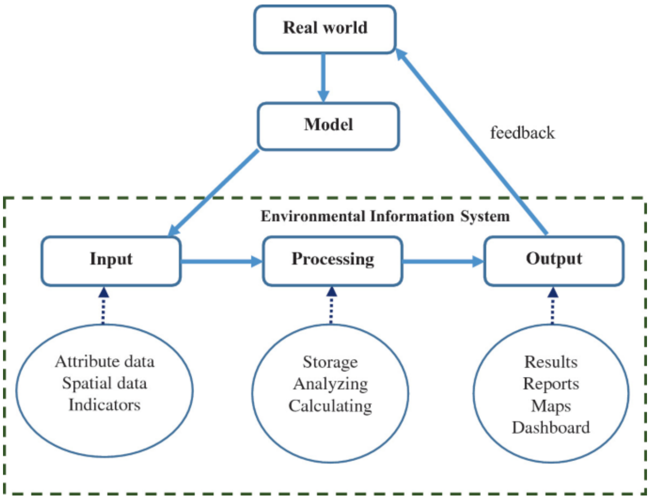


FIGURE 1.3: Modern environmental monitoring and information system

Wireless sensor network WSN

Wireless sensor network Wireless sensor network (WSN) is an important and exciting new technology with great potential for improving current applications in intensive aquaculture. In contrast to wired sensors, the obstacle has been to develop hardware that is capable of transmitting data under difficult circumstances and developing low-cost, long-term energy sources for the sensor nodes. WSN are in intimate connection with the immediate physical environment allowing each sensor to provide detailed information on the environment of material that is otherwise difficult to obtain by means of traditional wired instrumentation [7].

Data Processing and Storage

Data processing involves receiving records of observed field data, performing validation checks, infilling missing values in a data series, compiling data in different forms, and analyzing the data to support decision-making. In the process, the data must be validated for quality and reliability, as errors can occur in the monitoring sensor, data recorder, interruptions in transmission, and human entry. Field data, as observed and recorded, may contain many gaps and inconsistencies that must be identified, flagged, and, if possible corrected so that users understand the quality of the data. Data processing activities are typically carried out at more than one level within an implementing agency, making it essential to have adequate data transport/communication links between them. Functionality in many data management systems Data Management Systems (DMS) supports the processing. Protocols must be established for the long-term use and archiving of the observed and processed data [8].

Data Dissemination, Analysis, and Reporting

Processed data can be presented directly to the user or given in the form of analysis or reports, where analysis and reports require customization to ensure the reported information is relevant to user needs. The use of intranet and Internet systems facilitates data dissemination and exchange. we can cite an example of a web portal that allows anyone to identify and download the large amounts of monitoring data collected by the United States Geological Survey (USGS) as well as the reports they generate [8].

1.3 The different water quality monitoring systems technologies

The development and upkeep of robust water pollution control systems are critical for protecting public health, preserving aquatic ecosystems, and ensuring the sustainable use of water resources. As the challenges of water pollution continue to evolve, it is essential to adapt strategies and technologies to effectively address them. With comprehension and analyse of the complexities of water pollution, we can strive towards a future where clean and safe water is accessible to all. water quality monitoring systems utilize various technologies to measure and assess the quality of water. we illustrate some key technologies commonly used:

1.3.1 Chemical Sensors

A chemical sensor is a device that measures and detects chemical properties within an analyte (which refers to the substance being observed). It then converts this sensed chemical data into electronic information. The process typically involves two stages:

- Recognition or Detection: The sensor identifies a specific chemical property of the analyte.
- Transduction: The sensor converts this chemical information into a measurable physical signal, such as electrical, optical, or mechanical output.

Chemical sensing encompasses several steps, including analyte conditioning (which involves preconcentration, separation, and control of environmental parameters), recognition or detection of the desired chemical property, signal transduction, quantification, and interpretation using methods like chemometrics or multi-parameter analysis [9].

1.3.2 Optical Sensors

Optical sensors were also recently applied for water quality analysis. However, these are mostly discrete sensors, though tuned sometimes for integral parameters such as watercolor, turbidity, or even (Chemical Oxygen Demand (COD)) and (BOD). Discrete sensors were used to determine chlorophyll in the seawater based on its fluorescence, for evaluation of water opacity and color evolution by (Light Emitting Diode (LED)), for analysis of water turbidity and color in online mode, as well as for determination of heavy metal ions [10].

1.3.3 Water Quality Monitoring Stations

Typical water quality monitoring is currently done using a stand-alone data logger system. However, recent research is concentrating on creating monitoring networks that can combine information from various locations to gain a better understanding of the entire water system under investigation. Establishing these networks, instead of relying on individual stations, brings new requirements for two-way data exchange, such as different telemetry options, safety concerns, and accessibility [11].

Biosensors

A biosensor is an analytical device that converts a biological response into an electrical signal. It consists of two main components: a bioreceptor or biorecognition element, which recognizes the target analyte, and a transducer, for converting the recognition event into a measurable electrical signal [12].

1.3.4 Traditional vs Modern Methods in Monitoring Water Quality

Traditional methods for monitoring water quality involve on-site sample collection followed by chemical, physical, and microbiological analysis conducted in a laboratory setting. While these methods have been relied upon for decades, they are labor-intensive and costly. Results typically take days to be accessible, unlike modern methods that provide real-time output.

An example of traditional methods is the approach adopted by the Central Water Commission, where water samples are gathered from specific points within the processing and distribution system and then analyzed in well-equipped laboratories. Various parameters such as pH, turbidity, and dissolved oxygen are assessed using laboratory equipment. However, this method is susceptible to errors stemming from field sampling and equipment miscalibration, and the sampling process itself can be time-consuming and complex.

Moreover, traditional methods lack continuity and reliability since they rely on human effort and are not continuously operational. Additionally, the testing frequency may be low due to these constraints. Despite the expertise of skilled personnel conducting the analyses, maintaining laboratory facilities and equipment incurs significant expenses.

Overall, while traditional methods have been foundational in water quality monitoring, their limitations in terms of time, cost, and reliability highlight the need for more efficient and continuous monitoring approaches. Modern methods offer significant advantages over traditional approaches, primarily due to their ability to provide real-time output and analyze water quality parameters instantly. This rapid identification of poor water quality enables prompt intervention to address undesirable substances present in the water.

In contrast, traditional methods are prone to delays and manual errors, which can occur during various stages of the sampling and analysis processes. These delays and errors can hinder timely responses to water quality issues, potentially exacerbating the impact on public health and the environment.[13]

1.4 Advancements in Water Quality Monitoring Systems

In recent years, there has been a growing emphasis on the importance of water quality monitoring systems in safeguarding public health and protecting the environment. Advancements in technology have revolutionized the field of water quality monitoring, enabling more accurate, efficient, and cost-effective methods for assessing and managing water resources.

1.4.1 Cyber-Physical System

The concept of Cyber-Physical System (CPS) involves seamlessly integrating physical components into computational algorithms, as shown in the figure (1.4) This approach is considered the future of embedded systems. A typical CPS is set up as a network of interconnected components with physical input and output, rather than operating as standalone devices, which sets it apart from traditional embedded systems. Additionally, CPS offers numerous advantages, leveraging user-friendly decision support systems such as fuzzy logic to handle complex data from multiple sensor nodes, known as sensor arrays [13].

The CPS platform unit comprises both hardware and software working together to generate potential solutions for specific applications. Current technological requirements emphasize reconfigurable and scalable systems, and consequently, the platform units are expected to possess these attributes to keep up with rapidly evolving application needs. The flexibility and scalability provided by these systems add value by facilitating system modifications in response to changing application demands, ultimately enhancing overall system adaptability across various scenarios. CPSs are fundamentally scalable and reconfigurable systems, capable of adjusting based on data volume, bandwidth requirements, power needs, and sensing applications. The

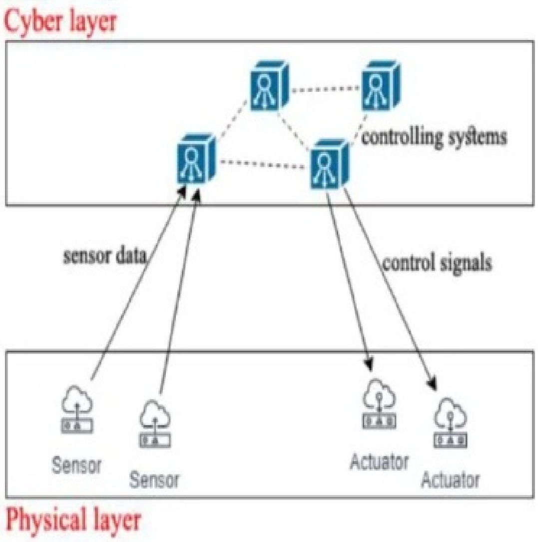


FIGURE 1.4: Cyber-Physical System

CPS platform design is divided into a three-step procedure, as detailed in the subsequent subsections [14].

1.4.2 IoT and Real-Time Implementation of Water Quality Monitoring

The Internet of Things The Internet of Things (IoT) is defined as the network of physical objects/things - devices, vehicles, buildings embedded with sensors, microcontrollers, and network connectivity that enables these objects to collect and exchange data. The IoT can be described as a huge web of embedded objects designed with built-in wireless technologies such that they can be monitored, controlled, and linked within the existing Internet infrastructure [15].

IoT devices use various types of sensors to collect data about turbidity, Oxidation-Reduction Potential (ORP), temperature, pH, conductivity, etc. of water continuously. Also, IoT devices can stream the array of collected data wirelessly to the remote Data Aggregator Server in the cloud. Moreover, the volume of semi-structured data increases with time at such a velocity that only Big Data Analytics applications can efficiently store and analyze the data constantly [16]. The following figure show the shematic bloc of a Water Quality system (WQS) using IoT.

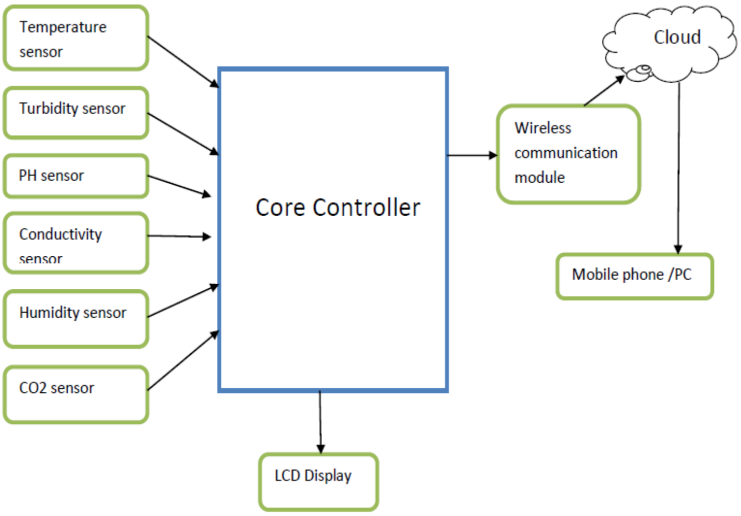


FIGURE 1.5: Iot based smart water quality monitoring

1.4.3 Early warning systems

Early warning systems (EWS) are integral, integrated systems that incorporate monitoring instrument technology capable of real-time analysis and interpretation of results. The primary objective of an EWS is to swiftly identify low-probability/high-impact contamination events, allowing for timely intervention to safeguard public health. These systems should possess the capability to swiftly and accurately differentiate between normal variations, contamination events, and changes in water quality resulting from biochemical and physical interactions.

Ideally, an effective EWS should be able to detect both deliberate and accidental contamination events, exhibiting high reliability with minimal false positives and negatives. Moreover, it should be cost-effective, easy to maintain, and seamlessly integrated into existing network operations. Despite the emergence of a new generation of online monitoring tools based on sensor technology, their practical implementation has faced obstacles. These challenges include failing to meet practical utility needs, unsatisfactory cost, reliability, and maintenance issues, as well as shortcomings in data handling, management, and the ability to generate actionable operational insights.[17]

1.4.4 Virtual Sensing Systems

A virtual sensing system evolves from a fully physical system by leveraging accessible secondary data processed through models to predict target parameters. Unlike physical sensors, virtual or soft sensors utilize this approach to combine inputs from less expensive sensors, mimicking the outputs of more complex and costly sensors. These models typically employ three main approaches: knowledge-based, mechanism-based, and data-derived or machine-learning methods.

Soft sensing techniques can serve as alternative methods for measuring online water quality parameters such as BOD, chlorine, and total phosphorus. Machine learning, in particular, excels at extracting valuable insights from available databases, making it an ideal framework for virtual sensor applications. For instance, a machine learning-based soft sensor model offers an alternative means of estimating BOD levels. This highlights the efficiency, reasonable accuracy, and cost-effectiveness of BOD soft sensors.

Virtual sensing comprises three main constellations: those based solely on physical sensors, those relying exclusively on other virtual sensors, and those integrating both virtual and physical sensors. Virtual sensing involves correlating data collected by physical sensors, which is then embedded into software applications to execute algorithmic analytics using the aggregated datasets.

It offers cost-effectiveness, as it eliminates the need to purchase and maintain additional equipment. Moreover, it is well-suited for high-frequency monitoring due to its avoidance of prolonged chemical reaction processes. Additionally, virtual sensing can be readily scaled across multiple locations without necessitating additional investments. The following figure shows the combination virtual sensors with physical sensors.

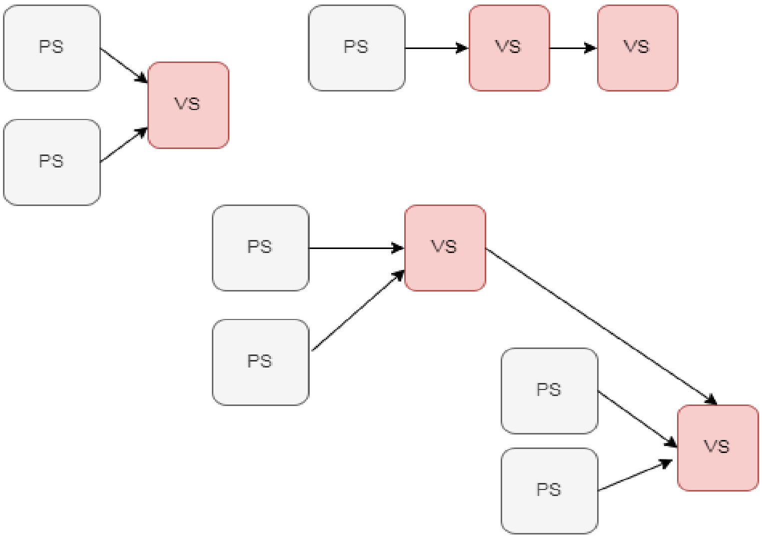


FIGURE 1.6: Virtual-sensor (VS) combinations with physical sensor(PS)

1.4.5 Conclusion

In conclusion, this chapter has provided an overview of water pollution control systems, including the definition and history of water pollution, its sources, effects, and the importance of water quality monitoring systems. We discussed various monitoring technologies, such as the Water Quality Index WQI and Cyber-Physical Systems CPS, as well as advancements like IoT implementation for real-time monitoring.

CHAPTER

2

DESIGN OF WATER QUALITY MONITOTING SYSTEM

Introduction

Water quality monitoring is essential for maintaining the health of ecosystems, ensuring the safety of drinking water, and supporting various industrial processes. This chapter provides a comprehensive overview of a water quality monitoring system designed to measure and analyze critical parameters such as PH, turbidity, and dissolved oxygen. By understanding and monitoring these parameters, we can ensure the water's suitability for different purposes, including consumption, agriculture, industrial applications, and environmental conservation.

This chapter delves into the structure and functionality of a comprehensive water quality monitoring system. It highlights the importance of accurate data acquisition through calibrated sensors and the methods employed to transmit and store this data for subsequent analysis. By understanding the components and processes involved, we can appreciate the critical role such systems play in safeguarding water quality and supporting informed decision-making.

2.1 Presentation of water quality monitoring system

A water quality monitoring system is designed to assess and analyze various water parameters to ensure their safety and suitability for purposes such as drinking, agriculture, industrial processes, and environmental conservation. This system consists of multiple sensors calibrated to measure essential parameters including PH, turbidity, dissolved solids, and temperature. These sensors are connected to data acquisition units that collect and transmit the data to storage devices such as Secure Digital (SD) cards. The gathered data is then analyzed to assess water quality, detect contaminants, and confirm compliance with regulatory standards. Such a monitoring system is crucial for maintaining water quality, supporting sustainable resource management, and safeguarding public health and the environment.

2.1.1 Water quality monitoring system structure

The first step of the project is to calibrate the several sensors for the acquisition of their measurements as the buoy moves in the water, Next, transmit them to an SD card and extract this card after several hours, Then we analyze the measures using MATLAB to get WQI, where the figure (2.1) depict the architecture of our system, and the figure (2.2) shows the Data processing flow chart.

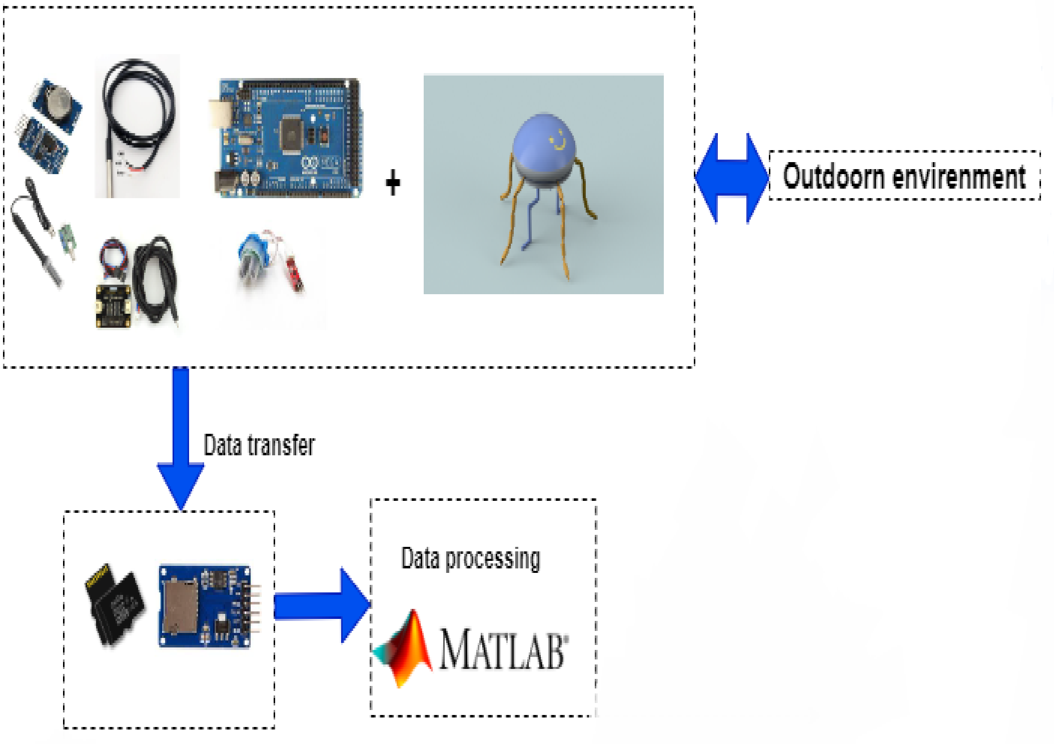


FIGURE 2.1: System architecture

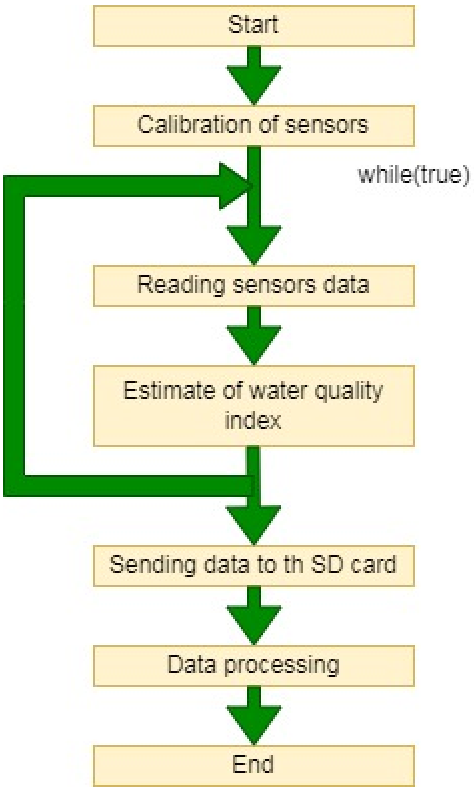


FIGURE 2.2: Data processing flow chart

2.2 Description of components used

2.2.1 Arduino Mega

The crucial first step in the electronic part of this project is to choose a microcontroller capable of handling all the sensors used. To do this, it is essential to consider the specific requirements of each sensor and the needs in terms of communication and data processing. There are several Arduino development boards, each with distinct specifications suited to various projects.

We have opted for the Arduino Mega for several reasons. First, this board offers a significant number of analog and digital pins, which is crucial for interfacing multiple sensors simultaneously. Second, the Arduino Mega has various communication pins, such as UART, I2C, and SPI, allowing for flexible and efficient integration of the different project components. This versatility not only facilitates the connection of sensors but also of other modules like wireless communication modules, displays, and actuators.

Moreover, the Arduino Mega is supported by a vast online community, offering numerous resources, libraries, and code examples. This greatly simplifies development and debugging, enabling quick solutions to any problems encountered. Finally, the reliability and robustness of the Arduino Mega make it an ideal choice for complex projects requiring rigorous signal and data management. In summary, the Arduino Mega perfectly meets the requirements of our project, ensuring seamless integration and optimal operation of all electronic components.

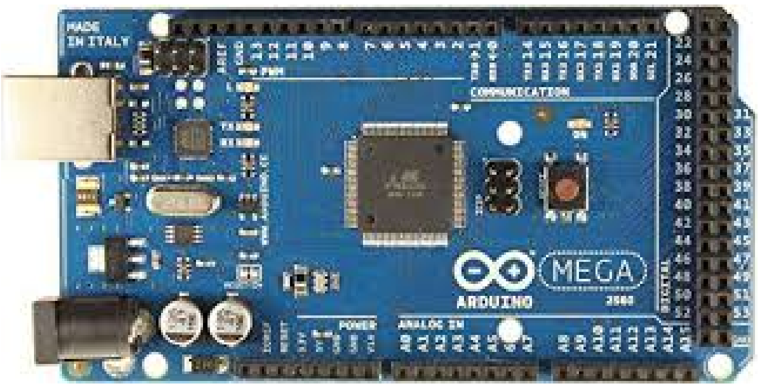


FIGURE 2.3: The Arduino Mega 2560

Figure (2.4) shows the block diagram between the different sensors, transmitter module and the Arduino mega board.

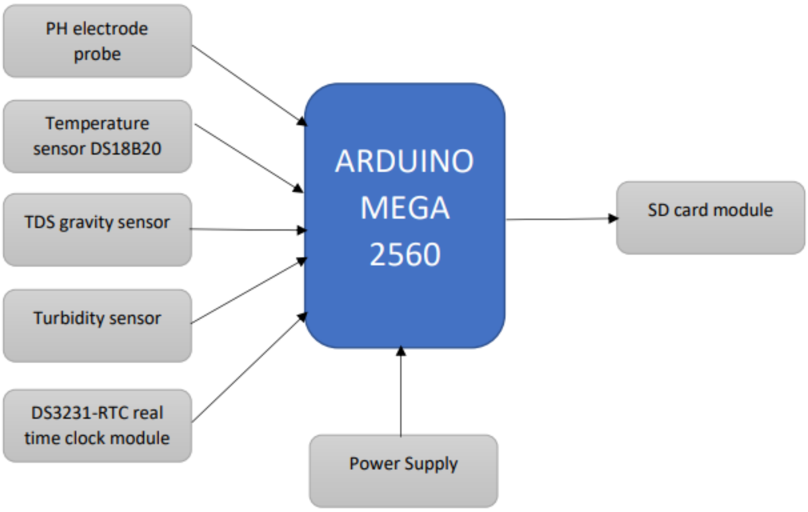


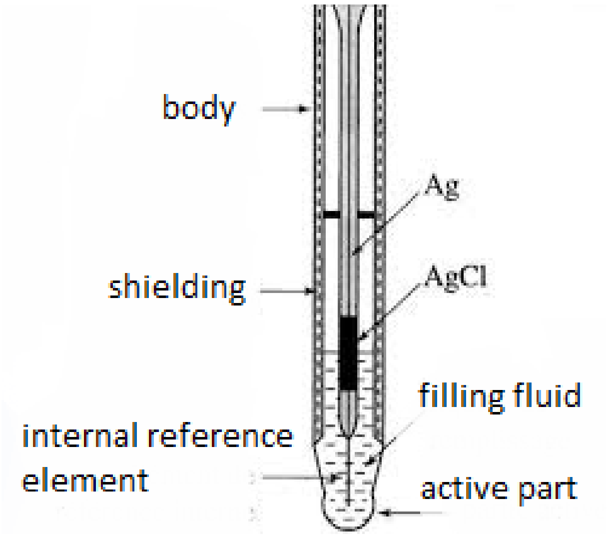
FIGURE 2.4: The Block diagram

2.2.2 Sensors

PH electrode probe

A PH electrode probe is an electrochemical sensor used to measure the acidity or alkalinity of a solution, typically in aqueous solutions. It consists of a glass electrode and a reference electrode immersed in the solution. The glass electrode contains a special glass membrane that selectively interacts with hydrogen ions (H+) in the solution. When the probe is immersed in a solution, the hydrogen ions in the solution interact with the glass membrane, creating an electrical potential difference between the glass electrode and the reference electrode. This potential difference is proportional to the PH of the solution, allowing the PH to be measured. Table (2.1) summarises its technical features:

(A) PH electrode probe



(B) Enter Caption

Module Power	5 V
Measuring range	0- 14 PH
Total Response Time	$\leq 1min$
Temperature measuring range	0-60°C,
Accuracy	$\pm 0.1 PH (25 \deg C)$

Table 2.1: PH sensor technical characteristics

Temperature sensor DS18B20

DS18B20 is a temperature sensor that can measure temperature from -55°C to +125°C with an accuracy of +-0.5°C, protocol, we can control multiple sensors from a single pin of Microcontroller, The DS18B20 is commonly employed in industrial projects requiring high accuracy. Its precision and reliability make it suitable for applications where precise temperature measurements are essential. This sensor is capable of providing accurate temperature readings with a resolution of up to 12 bits, making it ideal for industrial processes where tight control over temperature is necessary. Additionally, its digital interface simplifies integration with microcontrollers and other electronic devices, making it a preferred choice for various industrial monitoring and control systems [18].

(A) temperature sensor DS18B20 (B) Components of temperature sensor probe

Figure 2.6: Temperature sensor DS18B20

The Total Dissolved Solid sensor

The Total Dissolved Solids sensor operates based on the electrical conductivity properties of liquids. It consists of two electrodes that measure conductivity in the fluid. The concentration of ion particles and the electrolyte properties in the fluid can affect the measurement results obtained with the gravity sensor (TDS) sensor. It reflects the cleanliness of the water as shown in the figure (2.7) Thus, it is used in applications such as water quality monitoring, hydroponics, and aquaculture to assess the total concentration of dissolved solids in the liquid [19].

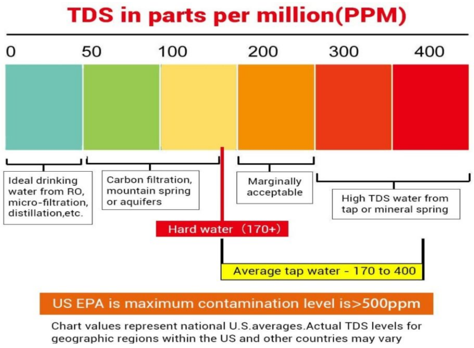


Figure 2.7: The cleanliness of the water according to TDS sensor values

Table (2.2) lists its main technical characteristics:

Turbidity sensor

A turbidity sensor measures the cloudiness or haziness of a fluid caused by suspended solids. It usually consists of a light source and a photodetector positioned on opposite sides of a sample chamber. The light source emits light into the fluid, and the photodetector measures the

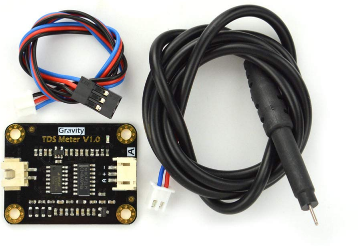


FIGURE 2.8: TDS gravity sensor

Input Volatge	$3.5 - 5.5V$
Detection range	0-1000 ppm
Working current	3-6 mA
measurement Accuracy	$\pm 10\%$ $25 \deg C$
Tds probe Size	83 cm

TABLE 2.2: TDS sensor technical characteristics

amount of light that is scattered or absorbed by the suspended particles as shown in the figure (2.9). Turbidity sensors are crucial in environmental monitoring, water quality assessment, and industrial processes where the clarity of liquids is significant. we can summarize its specifications in the table (2.3).

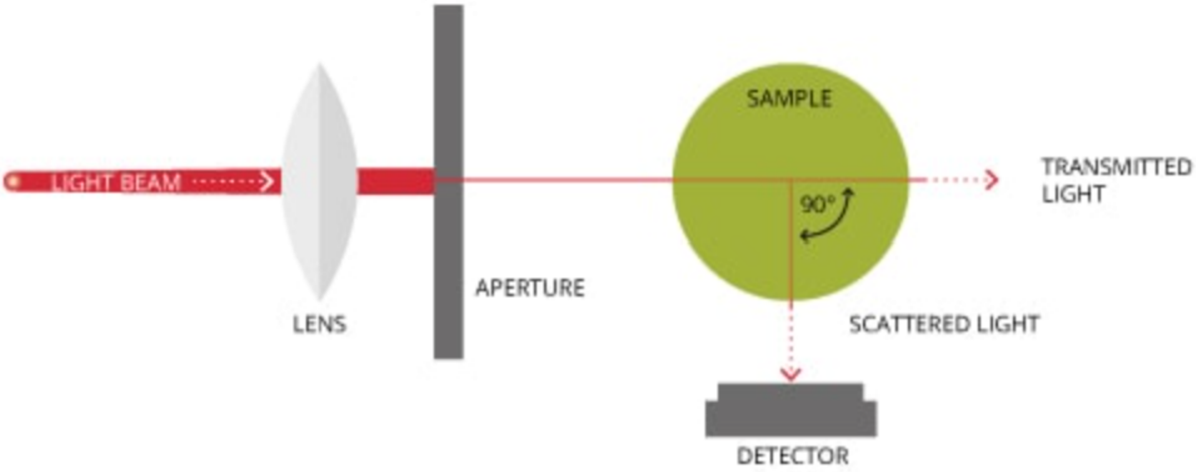


FIGURE 2.9: Turbidity sensor working principle

FIGURE 2.10: turbidity sensor

Module Power	5V DC
Operating current	0- 40 mA
Total Response Time	$\leq 500ms$
Temperature measuring range	5-90°C,

TABLE 2.3: Turbidity sensor technical characteristics

GY-521 sensor

The GY-521 is a popular breakout board that includes the MPU6050 sensor. The MPU6050 is a six-axis motion tracking device that includes a 3-axis gyroscope and a 3-axis accelerometer. It is commonly used in projects requiring motion detection, such as in drones, robots, and other Do It Yourself (DIY) electronics projects.

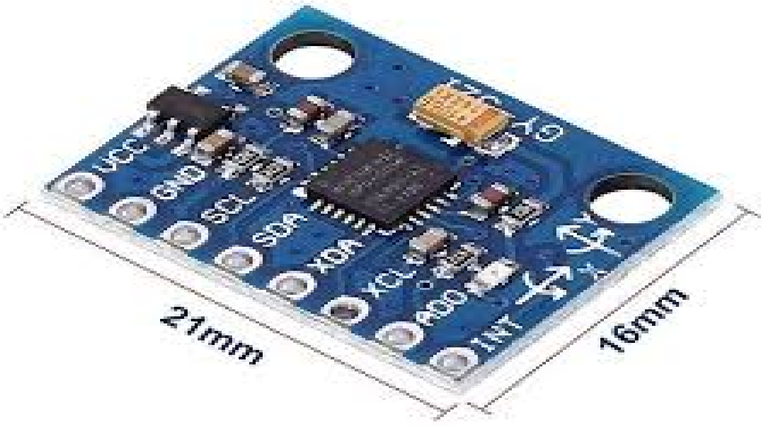


FIGURE 2.11: GY-521 sensor

2.2.3 Additional Components

DS3231-RTC real-time clock module

Real-Time Clock Real-Time Clock (RTC) is an electronic chip capable of accurately counting time from seconds to years and maintaining or storing this time data in real-time. As it operates in real-time, once the time calculation process is completed, its output data is promptly stored or transmitted to another device through an interface system.

FIGURE 2.12: DS3231-RTC

SD card module

An (SD) (Secure Digital) card module for Arduino allows for easy interfacing with SD cards for data storage and retrieval in your Arduino projects. These modules typically include an SD card slot and an SPI interface, making them compatible with most Arduino boards. In my project, all the information collected by the Arduino is stored on the SD card in Comma Separated Values (CSV) (Comma-Separated Values) files. This format is widely used for data storage and is easily readable by many software applications, facilitating data analysis and visualization.

FIGURE 2.13: SD card module

2.2.4 Calibration of the sensors

This section presents the calibration process of each sensor. All the codes are presented in the **Appendix 1**.

Ph sensor

There are two ways to calibrate the PH sensor. The first method involves using a formula to calculate the PH from the voltage reading, the calibration is made every use. According to the data sheet of the sensor, The formula is as follows:

$$\text{voltage} = \text{sensorValue} \times \frac{V_{max}}{N}$$

$$\text{PH} = -2.70 \times \text{voltage} + 14$$

Where:

- V_{max}: is the nominal tension that the sensor can support.
- N: is a digital output value of 1024 corresponds to an input voltage V_{max}.

The following figure shows the relation between the PH sensor value and the voltage:

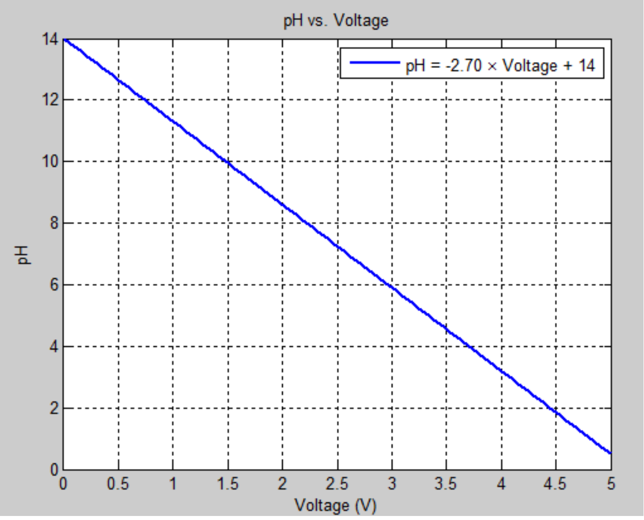


FIGURE 2.14: The relation between the Ph sensor values and the voltage

The first method is to calibrate the PH sensor, the first measurement in distilled water, which has a known PH of 7.0, is used as the reference point. This initial reference voltage is then used to adjust subsequent PH readings. This method ensures that all PH measurements are accurately calibrated relative to the distilled water baseline.

Temperature sensor

We used ”DallasTemperature.h” library that is constructed specially for this sensor that uses the calibrating equations.

$$\text{voltage} = \text{sensorValue} \times \left(\frac{5.0}{1023.0}\right) \tag{2.1}$$

and

$$\text{temperature value} = (\text{voltage} - 0.5) \times 100.0 \tag{2.2}$$

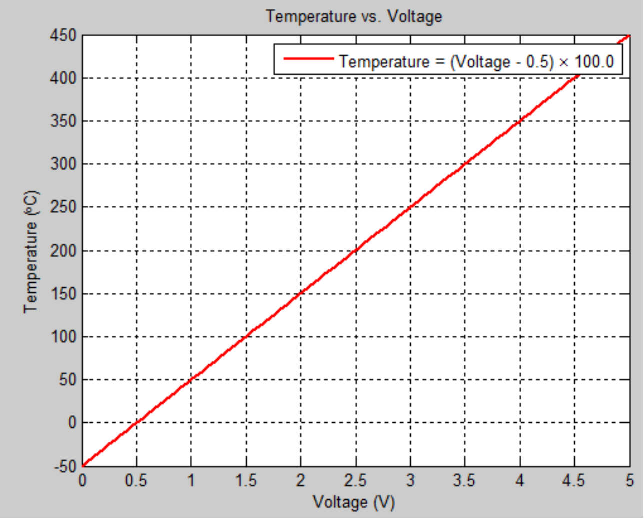


FIGURE 2.15: The relation between the temperature sensor values and the voltage

TDS sensor

Based on ”GravityTDS.h” library formula to calculate TDS from the voltage reading (V) and temperature (T) is as follows:

$$\text{TDS} = K \times V \times (1 + \text{tempCoefficient} \times (T - 25))$$

Where:

- (TDS): is the Total Dissolved Solids value in Ppm.
- K: is the conversion factor specific to your TDS sensor. (the commonly used factor for various TDS sensors is 133.42.)
- V: is the voltage output from the TDS sensor.

- tempCoefficient: is the temperature coefficient for compensation, which is typically around 0.02 (2%).

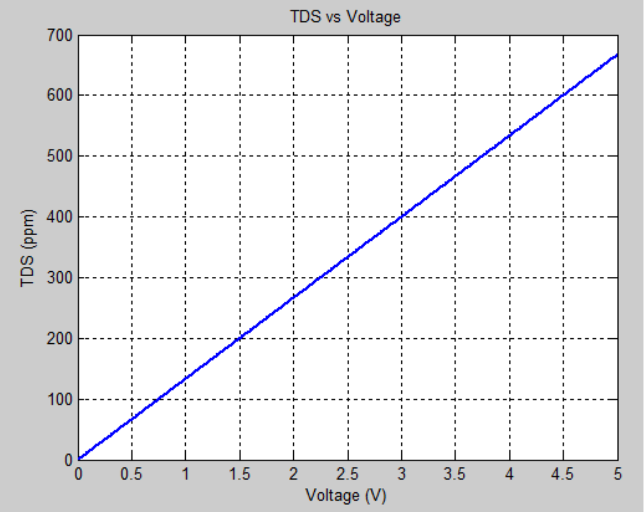


Figure 2.16: The relation between the TDS sensor values and the voltage

The second method is to calibrate the TDS sensor, the first measurement in distilled water, which has a known TDS of 0 ppm, is used as the reference point. This initial reference voltage is then used to adjust subsequent TDS readings. This method ensures that all TDS measurements are accurately calibrated relative to the distilled water baseline.

Turbidity sensor

We apply the same procedure as the previous sensors, we calibrate the turbidity sensor by using the first measurement in distilled water, which has a known turbidity of 0 NTU, as the reference point. This initial reference voltage is then used to adjust subsequent turbidity readings. This method ensures that all turbidity measurements are accurately calibrated relative to the distilled water baseline.

2.3 Estimation of Water Quality Index

Using the Weighted Arithmetic Water Quality Index Method, the parameters of the sensors that we are using are:

PH sensor index

The experimental water bodies were observed to be approximately neutral or slightly alkaline, which is crucial as PH serves as a key indicator of pollution. Measurement of PH in surface

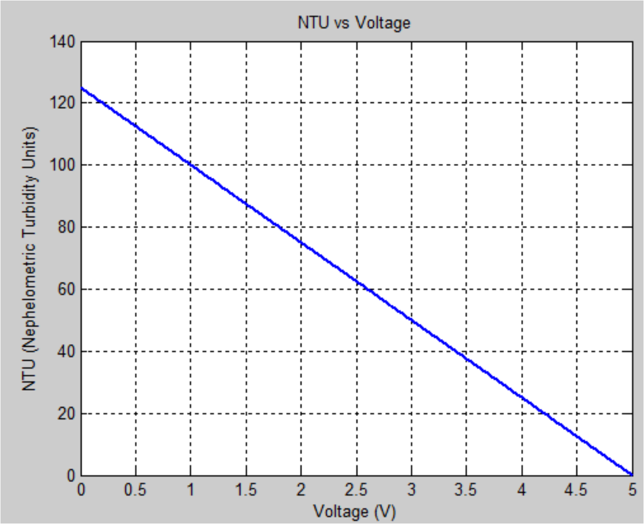


Figure 2.17: The relation between the turbidity sensor values and the voltage

waters is significant because the toxicity of many pollutants increases with changes in PH levels. According to WHO standards, the permissible PH value for drinking water falls within the range of 6.5 to 8.5. This confirms that the nature of the sampled surface water fluctuates from slightly acidic to slightly alkaline [20].

$$V_0 = 7.0,\ S_{PH} = 8.5 \tag{2.3}$$

Electrical conductivity sensor Index

The significance of Electrical Conductivity Electrical Conductivity (EC) lies in its ability to measure cations, which significantly influences the taste of water and consequently affects its acceptability as potable. EC serves as an indirect indicator of total dissolved salts. Elevated conductivity levels may result from natural processes such as the weathering of specific sedimentary rocks, or they may stem from anthropogenic sources. The findings revealed that EC values slightly exceeded the permissible level recommended by the WHO for drinking water.[20]

$$V_0 = 7.0,\ S_{EC} = 5 \tag{2.4}$$

Turbidity sensor Index

Turbidity serves as an indicator of water clarity and is affected by the presence of organic and mineral-suspended matter, as well as substances that produce color. Heightened levels of turbidity are typically a result of suspended particles and other materials. Moreover, soil particles may have been introduced into the water from unstable areas, further contributing to increased turbidity. It's worth noting that turbidity also impacts the temperature of surface waters, with turbid waters exhibiting lower bottom temperatures compared to clear water .[20].

$$V_0 = 0, S_{Turb} = 300 \tag{2.5}$$

To calculate the water quality index, we must calculate K, W_i and Q_i for each parameter. The value of K is calculated using standard values of the parameters that contribute to calculating the water quality index.

$$K = \frac{1}{\sum \frac{1}{S_i}} = \frac{1}{\frac{1}{S_{PH}} + \frac{1}{S_{EC}} + \frac{1}{S_{Turb}}} \tag{2.6}$$

$$\longrightarrow K = 3.115 \tag{2.7}$$

where: K is a constant, but it can be variable with additional parameters.

$$W_i = \frac{K}{S_i} \tag{2.8}$$

$$\begin{gathered} W_{PH} = \tfrac{K}{S_{PH}} = 0.366 \\ W_{EC} = \tfrac{K}{S_{EC}} = 0.010, W_{Turb} = \tfrac{K}{S_{Turb}} = 0.623 \end{gathered} \tag{2.9}$$

W_i is a constant for all the parameters where:

$$Q_i = 100(\frac{V_i - V0}{S_i - V_0}) \tag{2.10}$$

$$Q_{PH} = 100(\frac{V_{PH} - V0}{S_{PH} - V_0}) = 100(\frac{V_{PH} - 7}{1.5}) \tag{2.11}$$

$$Q_{EC} = 100(\frac{V_{EC} - V0}{S_{EC} - V_0}) = 100(\frac{V_{EC}}{300}) \tag{2.12}$$

$$Q_{Turb} = 100(\frac{V_{Turb} - V0}{S_{Turb} - V_0}) = 100(\frac{V_{Turb}}{5}) \tag{2.13}$$

After calculating the unit weight W_i and the quality rating scale Q_i we can calculate water quality index WQI using the following formula:

$$\text{WQI} = \frac{\sum Q_i W_i}{\sum W_i} = \frac{Q_{PH}W_{PH} + Q_{EC}W_{EC} + Q_{Turb}W_{Turb}}{W_{PH} + W_{EC} + W_{Turb}} \tag{2.14}$$

2.4 Challenges and Solutions

During the development of the water quality monitoring system, several challenges arose. This section highlights some of these obstacles and the strategies employed to overcome them.

2.4.1 I2C Communication

Challenge

Integrating multiple I2C devices (RTC and accelerometer) on the same bus without communication conflicts.

Proposed solution

We assigned different addresses to each I2C device to avoid conflicts. The RTC and accelerometer were successfully integrated by carefully managing their addresses, ensuring smooth communication and data collection.

2.4.2 Accuracy and Calibration of Sensors

Challenge

Maintaining accurate measurements from sensors under various environmental conditions.

Proposed solution

We implemented a self-calibration routine that runs every time the system is compiled. During this process, the sensors take an initial reading, which is assumed to be from distilled water. This reading is then used as a baseline for subsequent measurements, ensuring that the sensors are correctly calibrated to current conditions.

2.4.3 Data Storage and Management

Challenge

Organizing and storing large volumes of sensor data in an accessible format.

Proposed solution

An SD card module was employed to store data as CSV (Comma-Separated Values) files. Each reading was timestamped, facilitating easy data analysis later on. The CSV format was chosen due to its simplicity and wide compatibility with many data analysis tools.

2.5 Conclusion

This chapter detailed the structure of a water quality monitoring system, focusing on its key components and their functions. We discussed the transmission layer and described the essential components used in the system. Additionally, we examined the methods for estimating the Water Quality Index WQI by measuring parameters such as PH, electrical conductivity, and turbidity. This overview provides a foundational understanding of how these systems operate and ensures accurate water quality assessment.

CHAPTER

3

RESULTS AND DISCUSSIONS

Introduction

This chapter focuses on the electrical structure, design, and experimental results of the buoy system. It examines power distribution and communication interfaces crucial for the system's operation. The design section details the use of 3D printing for custom components. Results from experiments with temperature, pH, TDS, and turbidity sensors are analyzed, providing insights into environmental conditions. The discussion interprets these findings, emphasizing their implications and suggesting improvements. This chapter aims to provide a clear understanding of the buoy's development and its applications in water quality monitoring.

3.1 Electrical structure

The electrical structure of a water pollution control system is a crucial component that ensures the reliable operation of the sensors and other electronic components. This section will describe the power distribution, wiring, and connectivity aspects of the system, building on the details provided about sensors and other components in the previous chapter.

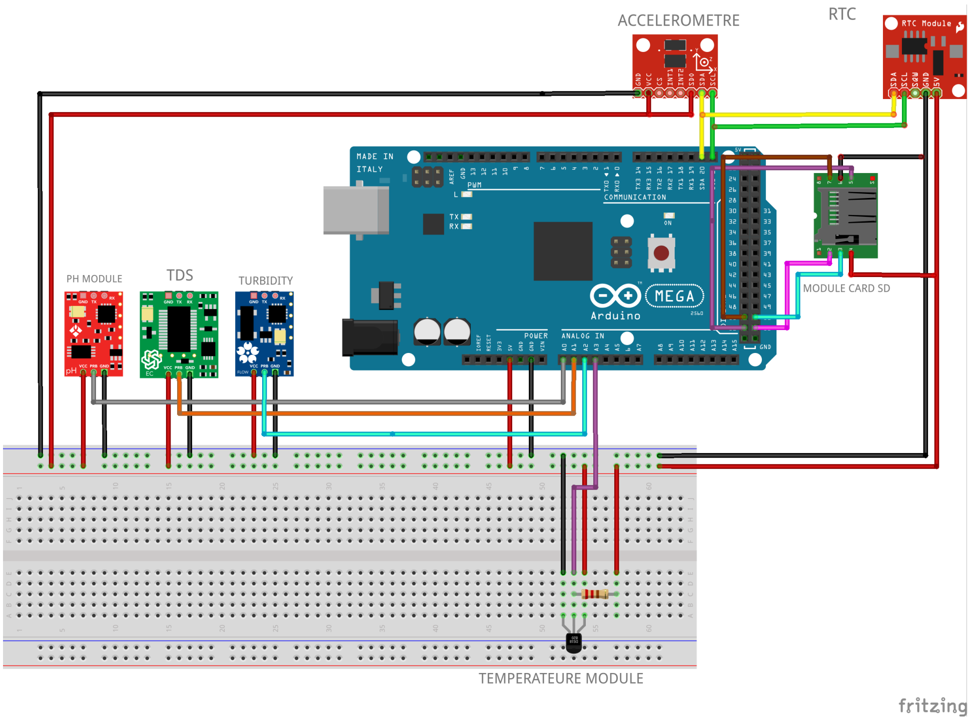


Figure 3.1: The Electrical structure

3.2 Power Distribution

The power distribution network is designed to provide stable and sufficient power to all components of the system. This includes the main microcontroller, sensors, communication modules, and any additional peripherals.

- **Power Supply Source**: The primary power source for this system is a 5000mAh power bank. The power bank supplies power directly to the Arduino Mega, which in turn powers the connected sensors and modules.
- **Voltage Regulation**: Not applicable in this setup as the power bank directly supplies the Arduino Mega, which then regulates power for the connected components.
- **Power Distribution Board**: Not applicable in this setup as the Arduino Mega directly supplies power to the connected components without the need for an additional power distribution board.

3.3 Communication Interfaces

The communication between the sensors and the microcontroller, as well as between the microcontroller and remote monitoring systems, is facilitated by several communication interfaces:

3.3.1 SPI/I2C

These interfaces are used for connecting sensors to the microcontroller. For example, the SD card module uses the SPI interface, with specific pins connected as follows:

- MISO (Master In Slave Out) - Pin 50
- MOSI (Master Out Slave In) - Pin 51
- SCK (Serial Clock) - Pin 52
- CS (Chip Select) - Pin 53

The I2C interface is also used for connecting multiple sensors. In this system, both the RTC (Real-Time Clock) module and the MPU6050 (gyroscope and accelerometer) use the same I2C pins:

- SDA (Serial Data) - Pin 20
- SCL (Serial Clock) - Pin 21

Although they share the same I2C bus, each device has a unique address, allowing the microcontroller to communicate with them separately. This is accomplished by specifying the address of the device in the communication commands. For instance, the RTC module might have the address 0x68, while the MPU6050 could use 0x69. In addition to the digital communication interfaces, several sensors are connected to the analog pins of the microcontroller:

- pH Sensor
- TDS (Total Dissolved Solids) Sensor
- Turbidity Sensor
- Temperature Sensor

These sensors provide analog voltage outputs that correspond to the measurements they take. The microcontroller reads these analog values through its analog-to-digital converter Analog-to-Digital Converter (ADC) pins, enabling it to process and interpret the data from each sensor.

3.4 Design and Implementation

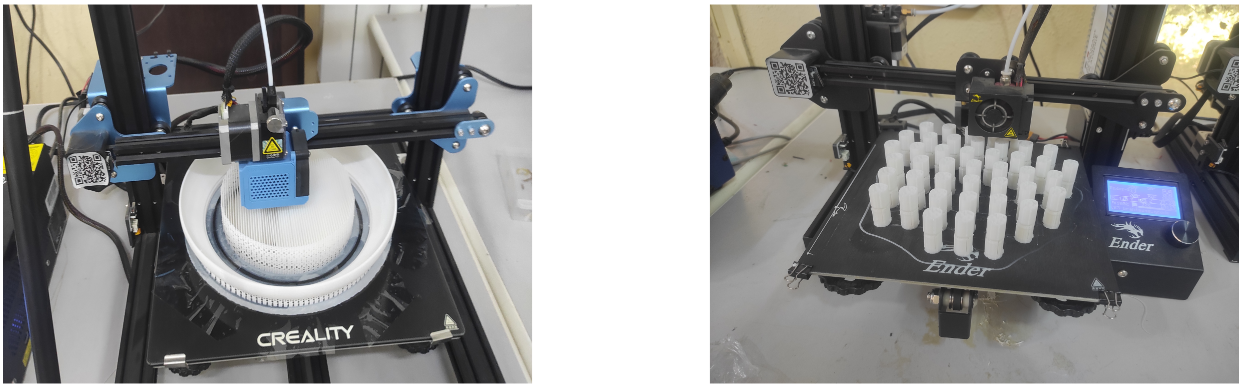
3.4.1 3D Printing

To bring this design to life, 3D printing technology will be utilized. 3D printing offers several advantages for this project, including:

Customization: 3D printing allows for precise customization of the buoy's shape and dimensions, ensuring that the shellfish-like design is both functional and aesthetically pleasing.

- **Prototyping:** Rapid prototyping is possible with 3D printing, allowing for quick iterations and modifications to the design based on testing and feedback.
- **Material Selection:** A variety of materials can be used in 3D printing, providing options for durability and waterproofing necessary for marine environments.
- **Cost Efficiency:** 3D printing can be more cost-effective than traditional manufacturing methods, especially for producing small quantities and unique designs.

By leveraging 3D printing, the buoy's components, such as the head, base, and tentacles, can be fabricated with high precision and assembled to create a robust and reliable water pollution control system.



(A) the head in printing

(B) the tentacles in printing

FIGURE 3.2

3.5 Printing Process from conception to STL to Printing

1. **Design in prototyping software:** The first step is to create a 3D model of the buoy and its components using Fusion 360. This software allows for detailed and precise design, including the intricate shapes and features needed for the buoy.

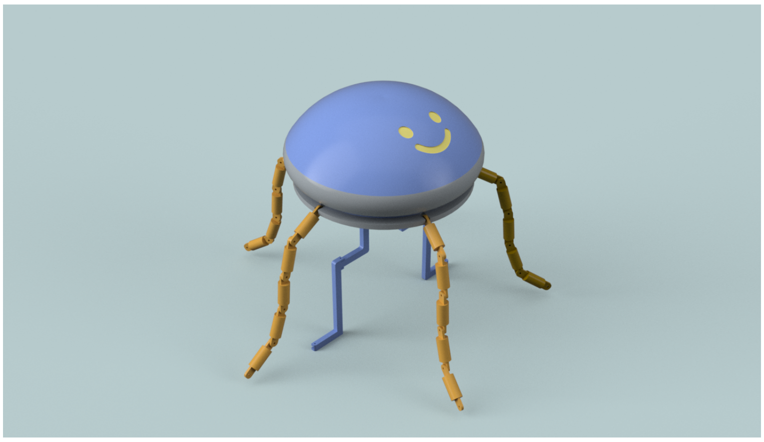


FIGURE 3.3: The 3D design of the system

2. **Export to Stereolithography (STL) File:** Once the design is complete, it is exported as an STL (stereolithography) file. This file format is widely used for 3D printing because it represents the surface geometry of the model in a simple, triangular mesh format.

3. **Prepare for Printing:** The STL file is then imported into a slicing software, such as Cura or PrusaSlicer. This software converts the 3D model into layers and generates the G-code, which is the set of instructions that the 3D printer will follow to build the object layer by layer.

4. **3D Printing:** The prepared G-code file is transferred to the 3D printer. The printer then begins the printing process, building the object layer by layer using the chosen material. This process can take several hours to days, depending on the size and complexity of the design.

5. **Post-Processing:** After printing, the printed parts may require some post-processing, such as removing support structures, sanding, or painting, to achieve the desired finish and functionality.

3.5.1 Buoy Structure

By following this process, the buoy's components can be accurately and efficiently fabricated, ready for assembly and deployment in the water pollution control system. The buoy is designed in the shape of a shellfish and consists of three main parts: the head, the base, and the tentacles.

- **Head:** which can be similar to shape of a jellyfish
- **Base:** The base closes the head from underneath. It has four holes through which the

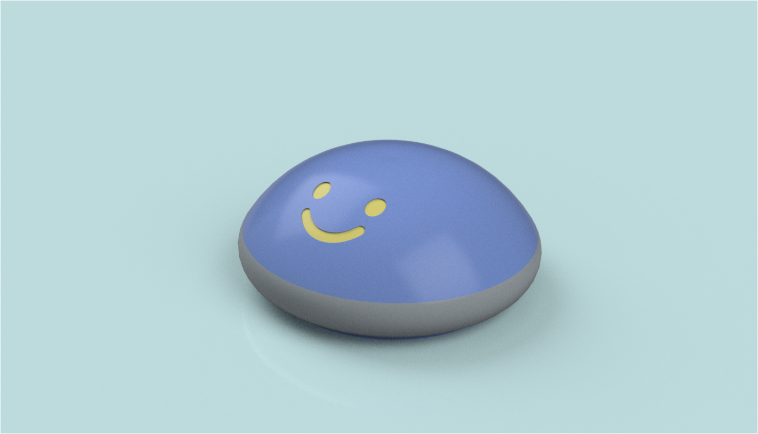


Figure 3.4: The 3D design of the head

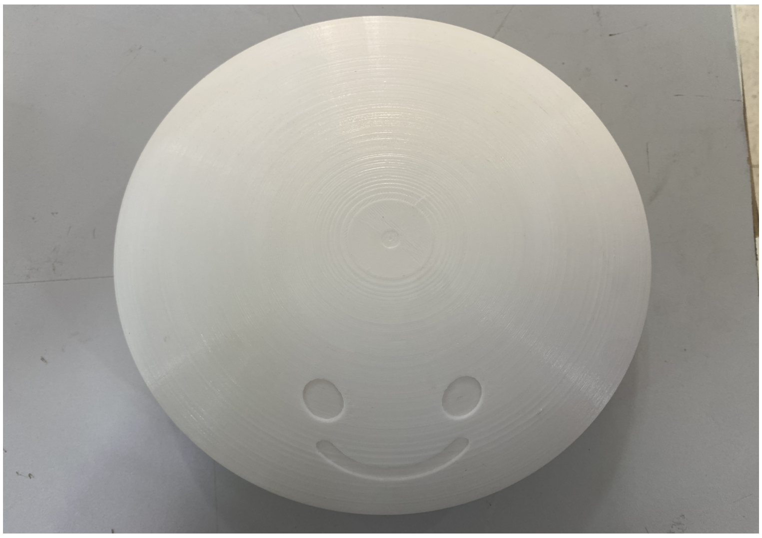


Figure 3.5: the head

sensors will emerge. This section houses all the components and the battery. providing stability and ensuring that the buoy remains upright in the water.

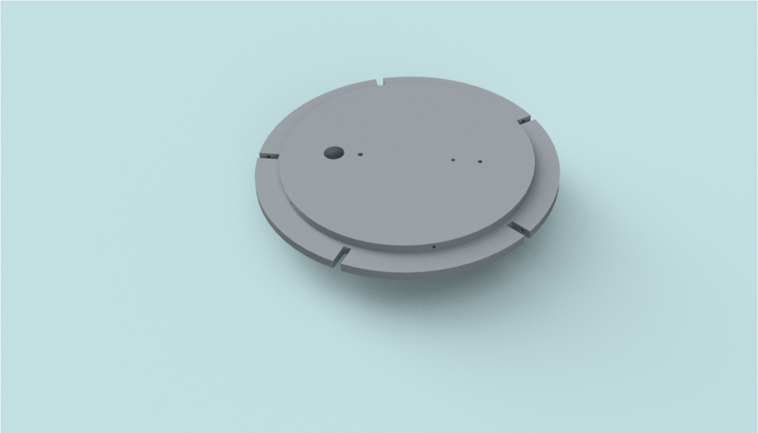


Figure 3.6: The 3D design of the base

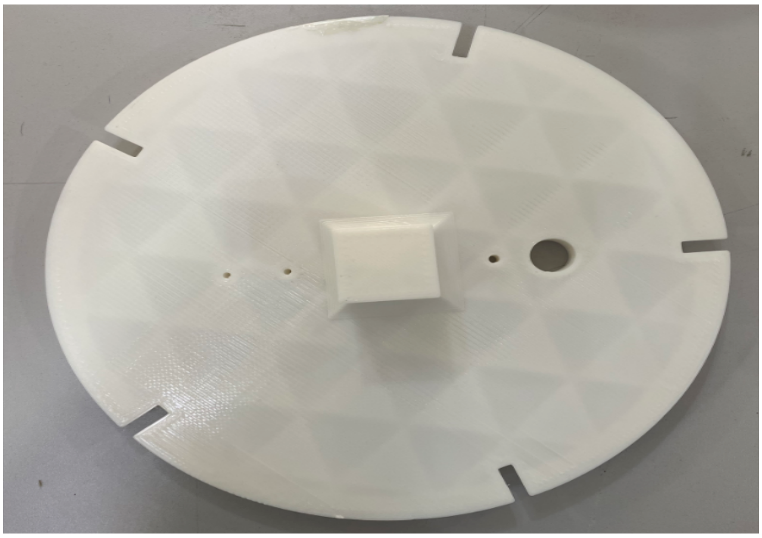


Figure 3.7: The base

- **Tentacles:** The tentacles extend from the base, but they do not mount any sensors. They are designed for stability and aesthetics, enhancing the jellyfish-like appearance of the buoy.

Figure 3.8: The Tentacles

3.6 Results of measurements

3.6.1 first experiment

At first, we present the results of the measurements for 15 minutes conducted in distilled water to ensure the purity and consistency of the experimental conditions.

Date	Time	PH	Water Temp	inside Temp	Turbidity	TDS	WQI
12/06/2024	12:05:18	7.04	25.16	21.69	0	2.00	1.01
12/06/2024	12:05:28	6.81	25.21	21.75	0	1.51	4.68
12/06/2024	12:05:39	7.01	25.31	21.75	0	1.51	0.34
12/06/2024	12:05:50	6.79	25.35	21.75	0	1.51	5.02
12/06/2024	12:06:01	6.77	25.40	21.75	0	1.51	5.68
12/06/2024	12:06:11	7.00	25.49	21.81	0	1.03	0.00
12/06/2024	12:06:22	7.00	25.49	21.81	0	1.03	0.00
12/06/2024	12:06:33	6.77	25.49	21.75	0	1.51	5.68
12/06/2024	12:18:56	7.03	25.92	21.87	0	-1.35	0.66
12/06/2024	12:19:07	6.77	25.92	21.87	0	-1.35	5.67
12/06/2024	12:19:18	6.95	25.96	21.87	0	-1.35	1.33
12/06/2024	12:19:28	6.82	25.96	21.87	0	-1.35	4.34
12/06/2024	12:19:39	6.82	25.92	21.87	0	-1.35	4.34
12/06/2024	12:19:50	7.03	26.01	21.87	1	-1.35	13.13
12/06/2024	12:20:01	7.07	26.01	21.94	0	-1.83	1.66
12/06/2024	12:20:12	6.81	25.96	21.87	1	-1.35	17.13
12/06/2024	12:20:22	7.03	26.06	21.87	1	-1.35	13.13
12/06/2024	12:20:33	6.82	25.96	21.94	1	-1.83	16.80

3.6.2 Discussion

The results of the measurements indicate some variations over the 15 minutes of the experiment:

PH values results

The pH of the distilled water varied between 6.77 and 7.07 throughout the 15 minutes of the experiment.

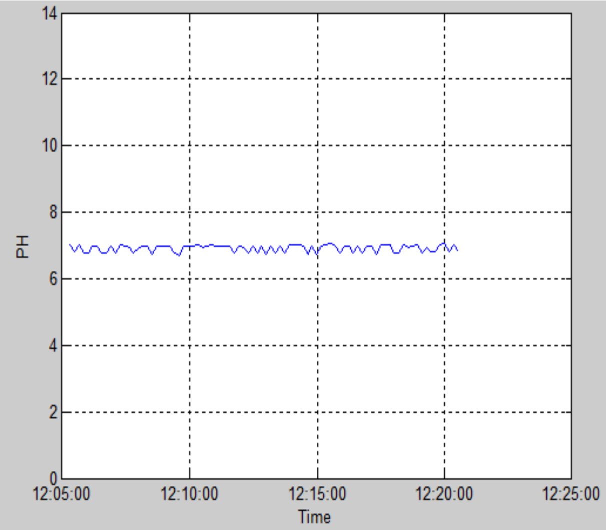


FIGURE 3.9: PH values sensors plots

Temperature values results

The temperature of the distilled water increased from 25°C in the first measurement to 26°C in the last measurement after 15 minutes.

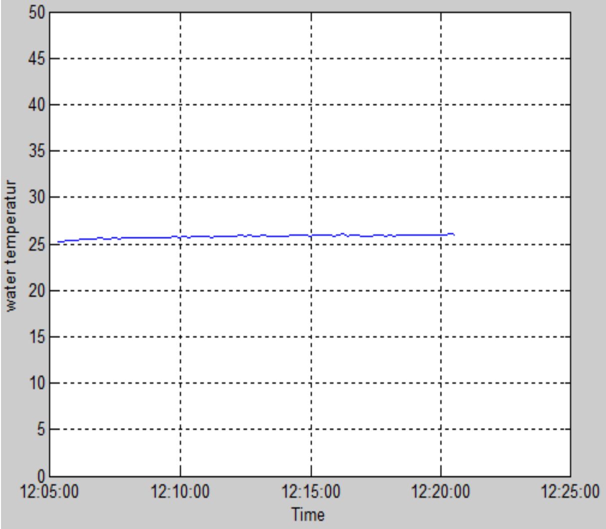


FIGURE 3.10: Temperature values sensors plots

Turbidity values results

The turbidity level increased from 0 NTU in the first measurement to 1 NTU in the last measurement after 15 minutes.

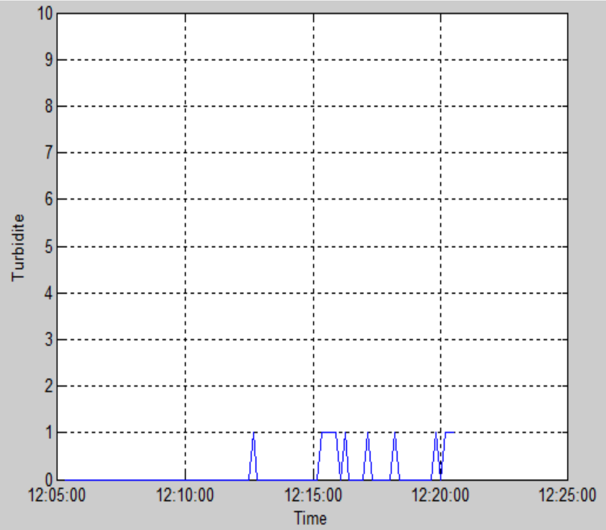


FIGURE 3.11: Turbidity values sensors plots

TDs values results

The TDS readings started at 2 ppm in the first measurement and decreased to -1.83 ppm in the last measurement after 15 minutes. This variation is likely due to the calibration adjustments performed on the TDS sensor.

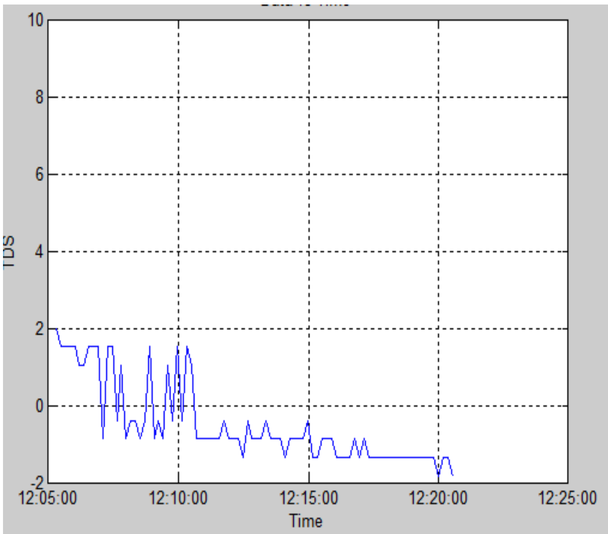


FIGURE 3.12: TDs values sensors plots

Conclusion

The use of distilled water provided a controlled environment for the calibration and testing of various sensors. The slight variations observed in temperature, turbidity, pH, and TDS readings indicate changes over time, which could be due to various factors such as sensor calibration drift or environmental influences. These baseline measurements will serve as a reference point for future experiments involving different water qualities or additional variables.

3.6.3 second experiment

In the second experiment, the setup was altered by adding salt and lemon zest to the distilled water at various times. This variation was introduced to observe the impact of these additives on the measurements and to simulate more complex environmental conditions.

Date	Time	PH	Water Temp	inside Temp	Turbidity	TDS	WQI
12/06/2024	14:26:30	7.03	24.36	22.19	0.15	1.56	2.49
12/06/2024	14:26:41	6.75	24.46	22.19	0.15	1.56	7.83
12/06/2024	14:26:52	7.00	24.46	22.12	0.02	0.16	0.29
12/06/2024	14:27:02	6.77	24.46	22.19	0.02	1.56	5.98
12/06/2024	14:28:50	6.70	24.84	22.19	0.39	281.99	13.18
12/06/2024	14:29:01	6.29	24.88	22.19	0.27	242.24	21.54
12/06/2024	14:29:33	6.71	24.93	22.25	0.27	251.21	11.22
12/06/2024	14:31:53	6.34	25.02	22.31	-0.10	207.69	15.53
12/06/2024	14:32:04	6.36	25.16	22.37	0.27	235.17	19.85
12/06/2024	14:32:15	6.26	25.12	22.31	0.27	233.52	22.18
12/06/2024	14:32:26	5.84	25.02	22.31	0.39	231.14	34.05
12/06/2024	14:32:37	5.81	25.02	22.31	0.15	233.52	31.69
12/06/2024	14:40:52	5.41	25.40	21.75	3.56	324.66	84.28
12/06/2024	14:41:03	5.35	25.45	21.75	3.32	324.66	82.91
12/06/2024	14:41:46	5.35	25.31	21.75	3.69	324.66	87.48

Discussion

The results of the measurements indicate some variations over the 15 minutes of the experiment:

PH values results

The pH value was around 7 at first. As we added a little zest of lemon, it started varying around 6 throughout the 15 minutes of the experiment.

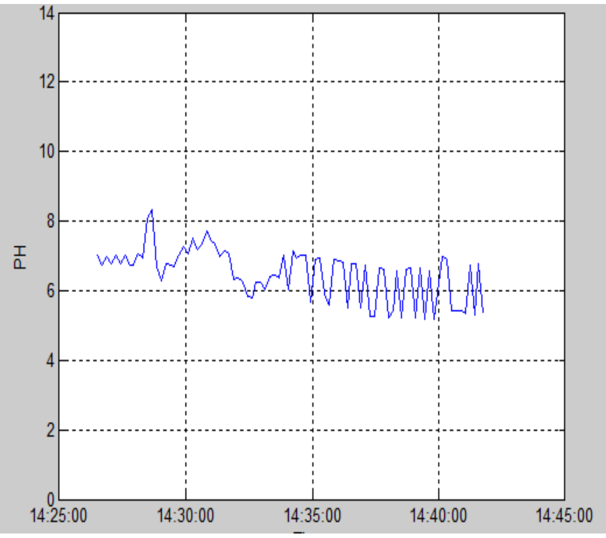


FIGURE 3.13: PH values sensors plots

Temperature values results

The temperature of the water increased from 25°C in the first measurement to 26°C in the last measurement after 15 minutes.

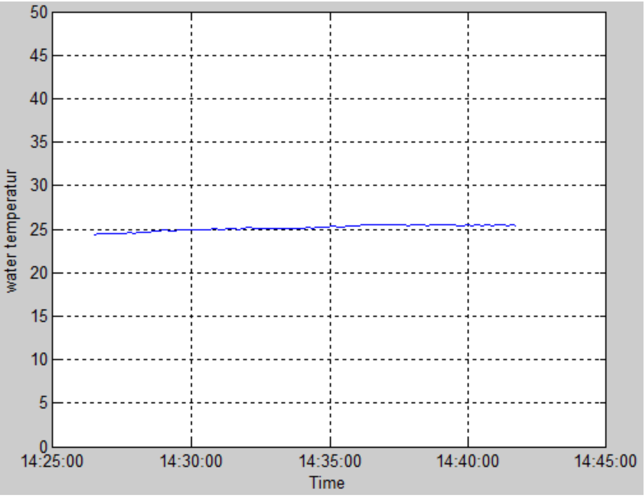


FIGURE 3.14: Temperature values sensors plots

Turbidity values results

The turbidity level increased from 0 NTU in the first measurements to 3.5 NTU in the last measurements after 15 minutes due to the addition of salt.

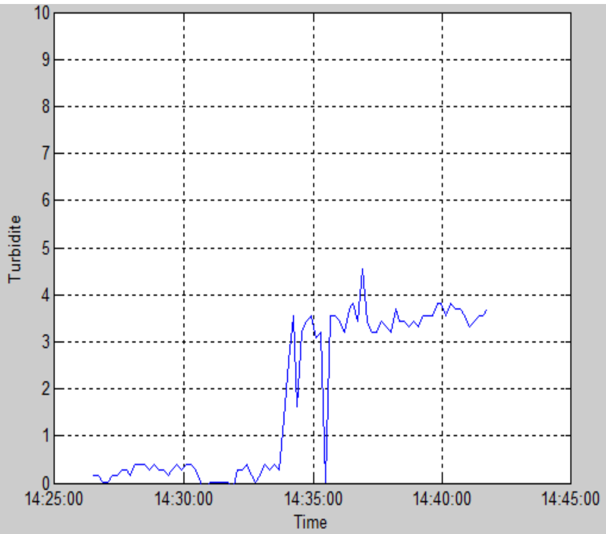


FIGURE 3.15: Turbidity values sensors plots

TDS values results

The TDS readings started at 0 ppm in the first measurement and increased to 300 ppm after adding salt.

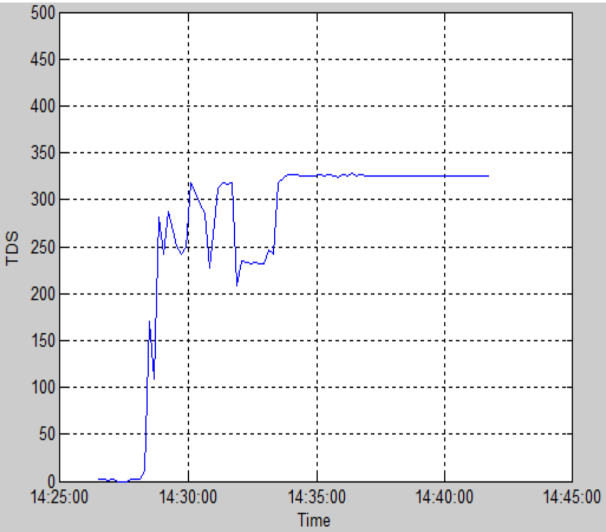


FIGURE 3.16: TDs values sensors plots

WQI results

In the first set of measurements, the WQI was under 10 because the distilled water had no additives. After adding salt, the TDS sensor values exceeded 200 ppm, causing the WQI to increase, though it did not exceed 25. This indicated that the water remained drinkable.

However, after introducing lemon zest and additional salt, the pH levels dropped to between 5.30 and 5.80, and the TDS reached 324 ppm. The water became slightly cloudy, and turbidity levels rose above 3 NTU. Consequently, the WQI ranged between 60 and 80, rendering the water undrinkable.

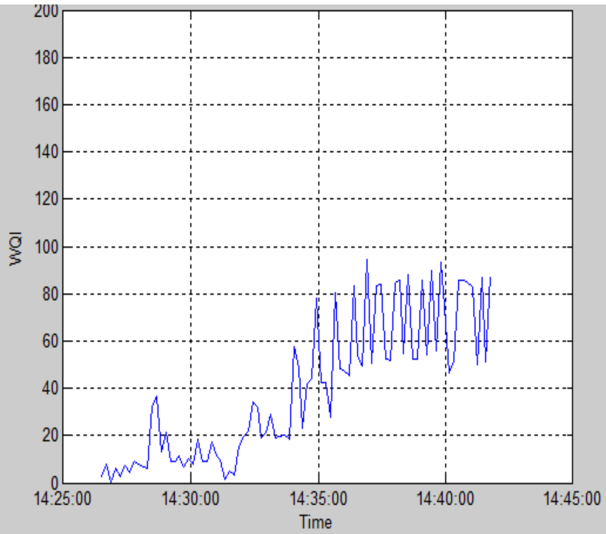


Figure 3.17: WQI value

3.6.4 Conclusion

In this chapter, we systematically examined the electrical architecture, power management, and communication protocols integral to our project. By evaluating the Serial Peripheral Interface (SPI) and I2C communication, we ensured robust and efficient data transmission between various components.

We also detailed the design and implementation phase, with particular attention to the 3D printing process. From the initial concept through STL file creation to the actual printing, we encountered and overcame several practical challenges, resulting in the successful construction of the buoy structure.

The measurement results from our experiments provided valuable insights into the performance of our system. The data showed the sensors' reliability and responsiveness under different test conditions, offering a solid basis for analyzing their effectiveness.

Overall, this chapter highlighted our methodical approach to designing and implementing the electrical and structural aspects of the project. The results obtained from our experiments validate our design choices and set the stage for further optimization and real-world application of the system.

GENERAL CONCLUSION

In this project, we developed and validated a robust water quality monitoring system . The system's architecture, based on the Arduino Mega platform, effectively integrated multiple sensors to measure pH, Total Dissolved Solids (TDS), turbidity, and temperature. The use of modern communication protocols, such as I2C and SPI, ensured reliable data transmission between components.

This project highlights the importance of continuous and accurate water quality monitoring. The system's design and implementation provide a scalable and efficient solution for real-time water quality assessment, which is essential for maintaining safe and clean water sources. Future work will focus on enhancing the system's capabilities, including the integration of wireless communication and data analytics for more comprehensive water quality management.

By addressing the challenges and solutions encountered during this project, we have laid the groundwork for further advancements in water quality monitoring technologies, contributing to better environmental and public health outcomes.

APPENDIX

A

CALIBRATION CODES OF SENSORS

PH sensor calibration Code

```
#include <Wire.h>
float voltph,calibph;
float phVol,ph_act;
void setup(){
   voltph=analogRead(A0)*5.0/1024;
  calibph=2.7*voltph ;
  }
void loop(){
 volt=analogRead(A0);
  float phVol=volt*5.0/1024;
  ph_act=-2.7*phVol+calibph+7;
   Serial.println(ph_act);
}
}
```

TDS sensor calibration Code

```
#include <Wire.h>
#include "GravityTDS.h"
float calibtds,tdsValue;
float dTempWater=25;
void setup(){
 gravityTds.setTemperature(dTempWater);
gravityTds.update();
calibtds = gravityTds.getTdsValue();
  }
void loop(){
 gravityTds.setTemperature(dTempWater);
 gravityTds.update();
 tdsValue = gravityTds.getTdsValue()-calibtds;
 Serial,println(tdsValue);
}
```

Turbidity sensor calibration code

```
#include <Wire.h>
float volturb,calibturb,volt,ntu;
void setup(){
  volturb =(float)analogRead(A7)*5/1024;
  calibturb=25*volturb;
}
void loop(){
 volt = (float)analogRead(A7)*5/1024;
  ntu=-25*volt+calibturb+1 ;
  }

```

GY-521 sensor calibration

```
#include <Wire.h>
#include <MPU6050.h>
void setup() {
 for (int i = 0; i < calibration_samples; i++) {
    int16_t ax, ay, az, gx, gy, gz;
    mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);
```

```

    ax_total += ax;
    ay_total += ay;
    az_total += az;
    gx_total += gx;
    gy_total += gy;
    gz_total += gz;

    delay(3); // Allow some time between readings
  }

  ax_offset = ax_total / calibration_samples;
  ay_offset = ay_total / calibration_samples;
  az_offset = az_total / calibration_samples;
  gx_offset = gx_total / calibration_samples;
  gy_offset = gy_total / calibration_samples;
  gz_offset = gz_total / calibration_samples;
  }
}
void loop() {
mpu.getMotion6(&ax, &ay, &az, &gx, &gy, &gz);

  float ax_g = (ax - ax_offset) / 16384.0;
  float ay_g = (ay - ay_offset) / 16384.0;
  float az_g = (az - az_offset) / 16384.0;
  float gx_dps = (gx - gx_offset) / 131.0;
  float gy_dps = (gy - gy_offset) / 131.0;
  float gz_dps = (gz - gz_offset) / 131.0;


}
```

BIBLIOGRAPHY

[1] FW Owa. “Water pollution: sources, effects, control and management”. In: *International Letters of Natural Sciences* 3 (2014).

[2] Li Lin, Haoran Yang, and Xiaocang Xu. “Effects of water pollution on human health and disease heterogeneity: a review”. In: *Frontiers in environmental science* 10 (2022), p. 880246.

[3] Robert C Ward, Jim C Loftis, and Graham B McBride. *Design of water quality monitoring systems*. John Wiley & Sons, 1991.

[4] Ashok Lumb, TC Sharma, and Jean-François Bibeault. “A review of genesis and evolution of water quality index (WQI) and some future directions”. In: *Water Quality, Exposure and Health* 3 (2011), pp. 11–24.

[5] Shweta Tyagi et al. “Water quality assessment in terms of water quality index”. In: *American Journal of water resources* 1.3 (2013), pp. 34–38.

[6] Bjarne Sivertsen. “Air quality monitoring systems and applications.” In: *NILU TR* (1997).

[7] Daudi S Simbeye and Shi Feng Yang. “Water quality monitoring and control for aquaculture based on wireless sensor networks”. In: *Journal of networks* 9.4 (2014), p. 840.

[8] Carter Borden and Dimple Roy. *Water quality monitoring system design*. International Institute for Sustainable Development Manitoba, 2015.

[9] Peter Kruse. “Review on water quality sensors”. In: *Journal of Physics D: Applied Physics* 51.20 (2018), p. 203002.

[10] Irina Yaroshenko et al. “Real-time water quality monitoring with chemical sensors”. In: *Sensors* 20.12 (2020), p. 3432.

[11] John B Copp et al. “Towards the automation of water quality monitoring networks”. In: *2010 IEEE International Conference on Automation Science and Engineering*. IEEE. 2010, pp. 491–496.

[12] Olga Korostynska, A Mason, and AI Al-Shamma’a. “Monitoring pollutants in wastewater: traditional lab based versus modern real-time approaches”. In: *Smart sensors for real-time water quality monitoring* (2013), pp. 1–24.

[13] Siti Nadhirah Zainurin et al. “Advancements in monitoring water quality based on various sensing methods: a systematic review”. In: *International Journal of Environmental Research and Public Health* 19.21 (2022), p. 14080.

[14] Jyotirmoy Bhardwaj, Karunesh K Gupta, and Rajiv Gupta. “Towards a cyber-physical era: soft computing framework based multi-sensor array for water quality monitoring”. In: *Drinking Water Engineering and Science* 11.1 (2018), pp. 9–17.

[15] Brinda Das and PC Jain. “Real-time water quality monitoring system using Internet of Things”. In: *2017 International conference on computer, communications and electronics (Comptelix)*. IEEE. 2017, pp. 78–82.

[16] Mohammad Salah Uddin Chowdury et al. “IoT based real-time river water quality monitoring system”. In: *Procedia computer science* 155 (2019), pp. 161–168.

[17] Michael V Storey, Bram Van der Gaag, and Brendan P Burns. “Advances in on-line drinking water quality monitoring and early warning systems”. In: *Water research* 45.2 (2011), pp. 741–747.

[18] Ramesh Saha et al. “A working prototype using DS18B20 temperature sensor and arduino for health monitoring”. In: *SN Computer Science* 2.1 (2021), p. 33.

[19] Fanharis Chuzaini and Dzulkiflih Dzulkiflih. “IoT Monitoring Kualitas Air dengan Menggunakan Sensor Suhu, pH, dan Total Dissolved Solids (TDS)”. In: *Jurnal Inovasi Fisika Indonesia (IFI)* 11.3 (2022), pp. 46–56.

[20] Soraya Bouslah, Lakhdar Djemili, and Larbi Houichi. “Water quality index assessment of Koudiat Medouar Reservoir, northeast Algeria using weighted arithmetic index method”. In: *Journal of water and land development* 35.1 (2017), p. 221.

Abstract

This study investigates the impact of environmental factors on the fish market in Algeria, with a specific focus on water quality analysis. Utilizing advanced AItechniques, we analyzed data from multiple sources, including local fish markets and water samples from various regions. Our findings indicate a direct correlation between water qualities and fish market prices, emphasizing the need for improved water management practices. The collaboration with the local fish and aquaculture administration of Tlemcen provided critical insights and data, significantly enhancing the scope and accuracy of our research.

Keywords: Water Quality Monitoring, Water Quality Index, Sensors, Total Dissolved Solids, pH, Turbidity

Résume

Cette étude examine l'impact des facteurs environnementaux sur le marché du poisson en Algérie, en mettant un accent particulier sur l'analyse de la qualité de l'eau. En utilisant des techniques avancées d'intelligence artificielle, nous avons analysé des données provenant de multiples sources, y compris les marchés locaux de poissons et des échantillons d'eau de diverses régions. Nos résultats indiquent une corrélation directe entre la qualité de l'eau et les prix du marché du poisson, soulignant la nécessité d'améliorer les pratiques de gestion de l'eau. La collaboration avec l'administration locale de la pêche et de l'aquaculture de Tlemcen a fourni des informations et des données cruciales, renforçant considérablement la portée et la précision de notre recherche.

Mots-clés : Surveillance de la qualité de l'eau, Indice de qualité de l'eau, Capteurs, Solides dissous totaux, pH, Turbidité

ملخص

تتناول هذه الدراسة تأثير العوامل البيئية على سوق السمك في الجزائر، مع التركيز بشكل خاص على تحليل نوعية المياه. وباستخدام تقنيات الذكاء الاصطناعي المتقدمة، قمنا بتحليل البيانات من مصادر متعددة، بما في ذلك أسواق الأسماك المحلية وعينات المياه من مناطق مختلفة. وتشير نتائجنا إلى وجود علاقة مباشرة بين نوعية المياه وأسعار سوق الأسماك، مما يسلط الضوء على الحاجة إلى تحسين ممارسات إدارة المياه. وقد وفر التعاون مع الإدارة المحلية لمصايد الأسماك وتربية الأحياء المائية في تلمسان معلومات وبيانات مهمة، مما عزز بشكل كبير نطاق ودقة بحثنا.

الكلمات المفتاحية: مراقبة جودة المياه، مؤشر جودة المياه، أجهزة الاستشعار، إجمالي المواد الصلبة الذائبة، الرقم الهيدروجيني، العكارة