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Water Quality Indicator in Storage Tanks of Industries by Design Thinking Framework

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A B S T R A C T

This project focuses on the development of a water quality indicator system tailored for monitoring water tanks in industrial settings. The objective is to enhance water management practices by providing real-time data on crucial parameters such as Pollutants, pH, turbidity, and microbial content. Leveraging sensor technologies and microcontrollers, the system aims to offer continuous monitoring capabilities. The initial stages involve comprehensive research and planning, considering factors such as sensor calibration, maintenance, and connectivity. Despite encountering challenges related to calibration precision, sensor maintenance, and connectivity issues, the project contributes valuable insights into the complexities of implementing such systems in industrial environments. The lessons learned emphasize the importance of thorough testing, continuous iteration, industrial surveys and adequate resource planning for the successful development of water quality indicators in industrial water tanks.

Keywords: Water Quality, Turbidity, Parameters

I. INTRODUCTION

Water, essential for life, undergoes constant changes due to natural and human factors, impacting its suitability for various purposes. Water quality indicators are crucial for assessing its health and detecting pollutants and contaminants.

Causes of Water Contamination

Temperature: Affects dissolved oxygen levels critical for aquatic life. Fluctuations influence biological processes, species composition, and nutrient availability.

pH: Measures acidity or alkalinity. Extremes are lethal to aquatic organisms and affect chemical interactions.

Total Dissolved Solids (TDS): Measures dissolved materials, influencing water quality for drinking and irrigation. Sources include natural weathering and industrial waste.

Electrical Conductivity: Reflects dissolved ion concentration, affected by geological factors and pollution.

Suspended Sediment: Impacts aquatic ecosystems by reducing light penetration and affecting temperature.

Eutrophication: Natural or human-induced process causing algae overgrowth, reducing oxygen levels and harming aquatic life.

E. coli: Indicator of fecal contamination, affecting water safety for recreational use.

Sources of Contamination

Mining: Pollutants like heavy metals and acid mine drainage compromise water quality and ecosystem health.

Industrial Waste: PCBs, dioxins, and furans pose risks to aquatic ecosystems and human health, accumulating in the food chain.

Metals: Copper, zinc, and mercury, when present in high concentrations, pose toxicity risks, impacting aquatic and human life.

Water quality indicators help assess and monitor water health amidst escalating environmental challenges. Addressing contamination sources is crucial for sustainable water management and human well-being.

II. LITERATURE SURVEY

T.C. Lobato, R.A. Hauser-Davis (2015) studied that the Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. However, WQI depicts the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers. In spite of absence of a globally accepted composite index of water quality, some countries have used and are using aggregated water quality data in the development of water quality indices. Attempts have been made to review the WQI criteria for the appropriateness of drinking water sources. Besides, the present article also highlights and draws attention towards the development of a new and globally accepted “Water Quality Index” in a simplified format, which may be used at large and could represent the reliable picture of water quality.

Curtis G. Cude (2007) studied The Oregon Water Quality Index (OWQI) is a single number that expresses water quality by integrating measurements of eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids, and fecal coliform). Its purpose is to provide a simple and concise method for expressing the ambient water quality of Oregon's streams for general recreational use, including fishing and swimming. This report describes the historical basis of the OWQI and defines the improved design of the present OWQI. The index allows users to easily interpret data and relate overall water quality variation to variations in specific categories of impairment. This report demonstrates the value of the OWQI in presenting spatial and temporal water quality information. The OWQI improves comprehension of general water quality issues, communicates water quality status, and illustrates the need for and effectiveness of protective practices.

H Boyacioglu (2007) studied the development of a new index called the ‘universal water quality index (UWQI)’. This index has advantages over pre-existing indices by reflecting the appropriateness of water for specific use, e.g.drinking water supply rather than general supply, and has been developed by studying the supranational standard. Water quality determinants of the new index are cadmium, cyanide, mercury, selenium, arsenic, fluoride, nitrate-nitrogen, dissolved oxygen, biochemical oxygen demand, total phosphorus, pH and total coliform. The mathematical equations to transform the actual concentration values into quality indices have been formulated. This technique is believed to assist decision makers in reporting the state of the water quality, as well as investigating spatial and temporal changes. It is also useful to determine the level of acceptability for the individual parameter by referring to the concentration ranges defined in the proposed classification scheme.

Hefni Effendi studied A rapid interpretation of river water quality is a compulsory since river is a dynamic ecosystem, influenced by various activities in the river bank. Hence a preliminary rapid river water quality status determination using pollution index on locations near IPB Dramaga Campus was simulated. Based on grab sampling on 5 sites in River Cihideung, River Ciapus, and Lake of PPLH, all water quality parameter met water quality standard class III for fisheries and animal husbandry as stipulated in Government Regulation No 82/2001. Application of water pollution index towards 5 sampling sites (selected by location map consideration) denotes good water quality status with water pollution index ranging from 0.728 to 0.892

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Common Failure Modes–

Water quality indicators (WQIs) are used to describe the quality of water based on physical, chemical, and biological factors that are combined into a single value that ranges from 0 to 100 1. However, the development of WQIs is a complex process that involves several stages such as parameter selection, transformation of raw data into a common scale, providing weights, and aggregation of sub-index values 1. Here are some common failure modes in water quality indicators projects:

1. Inadequate data collection: Incomplete or insufficient data can lead to inaccurate results and affect the overall quality of the WQI 1.

2. Inappropriate parameter selection: The selection of parameters should be based on the specific characteristics of the water body being studied. Failure to do so can lead to inaccurate results and affect the overall quality of the WQI

3. Inaccurate data transformation: The transformation of raw data into a common scale is a critical step in the development of WQIs. Failure to do so can lead to inaccurate results and affect the overall quality of the WQI 1.

4. Inappropriate weighting: The weighting of parameters should be based on their relative importance in determining water quality. Failure to do so can lead to inaccurate results and affect the overall quality of the WQI 1.

5. Inaccurate aggregation: The aggregation of sub-index values is a critical step in the development of WQIs. Failure to do so can lead to inaccurate results and affect the overall quality of the WQI 1.

It is important to note that the development of WQIs is a complex process that requires careful consideration of several factors. Therefore, it is essential to have a clear understanding of the specific characteristics of the water body being studied and to follow established protocols for the development of WQIs.

III. PROBLEM STATEMENT

Water contamination in industrial water tanks disrupts production operations in several ways. Firstly, due to the presence of contaminants, the water may no longer meet the required quality standards for specific manufacturing processes. This necessitates additional treatment steps or the need to source water from outside suppliers, resulting in increased costs and potentially causing delays in production schedules.

Moreover, contaminants in water tanks can damage equipment and machinery. Chemical pollutants or physical impurities may lead to corrosion, blockages, or fouling of production equipment, reducing their efficiency and reliability. The necessity for frequent maintenance, repairs, or even replacement of affected equipment adds to the financial burden on industries, hindering their ability to operate at full capacity.

Additionally, water contamination can have detrimental effects on the quality of the final products. Water used in the production process, if contaminated, can introduce impurities or alter chemical reactions, leading to product defects, increased waste, and decreased customer satisfaction. Subpar product quality can damage a company's reputation and competitiveness in the market, resulting in decreased sales and customer loyalty.

Furthermore, the potential health risks associated with using contaminated water in industrial processes pose a significant concern. If employees come into contact with the contaminated water, either through direct exposure or inhalation of harmful substances, their health and well-being may be compromised. This can result in increased absenteeism, decreased productivity, and potential legal liabilities for the industry due to occupational health and safety concerns. The problem of water contamination in industrial water tanks requires attention and immediate action. Effective strategies to address this issue include implementing regular monitoring and maintenance programs to ensure the cleanliness and integrity of water tanks. Continuous monitoring of water quality should be conducted to identify contamination sources promptly and take corrective actions. It is essential for industries to establish and follow standard operating procedures for the maintenance, cleaning, and disinfection of water tanks.

Investing in advanced water treatment technologies, such as filtration, disinfection, and reverse osmosis systems, can significantly reduce the risk of water contamination. Additionally, providing proper training and education to employees on the importance of water quality, handling procedures, and potential risks can help minimize the incidence of contamination due to human error.

By addressing water contamination in industrial water tanks, industries can enhance production efficiency, reduce costs, ensure the quality of their products, and protect the health and safety of their workforce. Ultimately, mitigating water contamination issues will contribute to the overall sustainability and success of industrial operations.

IV. PROPOSED SYSTEM

Maintaining water quality in industrial water tanks is crucial for various processes and product quality. To address this need, we propose the implementation of a Real-Time Water Quality Monitoring System for Industrial Water Tanks (RWQMS). This system will continuously monitor key water quality indicators, enabling prompt actions to ensure water integrity. The objective of this project is to develop a comprehensive water quality monitoring system for industrial water tanks and also to implement real-time data acquisition and analysis for key water quality parameters. Integrating water quality indicator in water tanks will notify relevant personnel of and deviations from specified water quality standards. This project will also provide a user-friendly interface for monitoring and analysis.

Benefits

Implementing a water quality indicator system in industrial water tanks offers numerous benefits, contributing to the overall efficiency, sustainability, and safety of industrial operations. Here are some key advantages:

1. Early Detection of Contamination:

Enables the early identification of contaminants, preventing potential damage to equipment and ensuring the integrity of products.

2. Preventive Maintenance:

Facilitates proactive maintenance by identifying and addressing water quality issues before they escalate, reducing downtime and minimizing repair costs.

3. Product Quality Assurance:

Ensures that water used in industrial processes meets specified quality standards, leading to consistent product quality and reducing the likelihood of defects.

4. Compliance with Regulations:

Helps industries comply with environmental and regulatory standards by ensuring that water quality parameters remain within permissible limits.

5. Operational Efficiency:

Contributes to operational efficiency by providing real-time data on water quality, allowing for immediate adjustments to maintain optimal conditions for industrial processes.

6. Cost Savings:

Reduces costs associated with equipment corrosion, fouling, and damage caused by poor water quality, leading to longer equipment lifespan and lower maintenance expenses.

7. Environmental Impact Reduction:

Minimizes the environmental impact of industrial processes by preventing the release of contaminated water, which can harm ecosystems and local water sources.

8. Risk Mitigation:

Mitigates risks associated with waterborne diseases and contaminants, ensuring a safer working environment for personnel and reducing the likelihood of health-related issues.

9. Real-Time Monitoring:

Enables continuous, real-time monitoring of water quality parameters, allowing for immediate response to deviations and ensuring timely corrective actions.

10. Remote Accessibility:

Allows remote access to the monitoring system, providing flexibility for personnel to monitor water quality status and take necessary actions from any location.

V. System Specifications

S.NO	COMPONENTS	SPECIFICATION
1	Arduino	UNO
2	Jumper wires	-
3	Bluetooth Module	HC-05
4	RGB Diffused Common Cathode	-
5	Resistor	330 ohm
6	Rotary potentiometer	-
7	Alphanumeric LCD	16 x 2
8	Resistor	1k ohm

WORKING OF THE PROPOSED SYSTEM

CONNECTIVITY MEASURES

Arduino Connections:

- Connect the 5V and ground pins of the Arduino to the power rails of the breadboard.
- Connect a 1k-ohm resistor from the ground to the analog pin A0 on the Arduino. This forms a voltage divider circuit.
- Connect wires from the resistor to 5V and ground. The free ends of these wires are connected to crocodile clips, which will be immersed in the water to measure its conductivity.

LCD Display Connections:

- Connect the VSS pin of the LCD to the ground rail, and the VDD pin to the 5V rail.
- Connect the V0 pin to the center pin of the potentiometer, which is used to adjust the contrast of the LCD.
- Connect the ends of the potentiometer to 5V and ground.
- Connect the RS, R/W, and E pins of the LCD to specific digital pins on the Arduino.
- Connect D4 to D7 pins of the LCD to other digital pins on the Arduino.

HC-05 Bluetooth Module Connections:

- Connect the VCC pin to the 5V rail, and the GND pin to the ground rail.
- Connect the TX pin of the Bluetooth module to the RX pin (pin 3) on the Arduino.
- Connect the RX pin of the Bluetooth module to the TX pin (pin 2) on the Arduino.

RGB LED Connections:

- Connect the common cathode (longest pin) of the RGB LED to the ground.
- Connect the red, green, and blue pins of the LED to PWM pins on the Arduino through respective resistors.

Derivation for Calculating Resistance:

The project involves using a resistor immersed in water to measure its conductivity. The resistance of the water is calculated using the formula $R = \rho * (L/A)$, where ρ is the resistivity, L is the length, and A is the cross-sectional area. The resistivity is then used to calculate the conductivity ($c = 1/\rho$), and finally, the Total Dissolved Solids (TDS) is determined using the formula TDS = c * 7000.

Derivation for calculating resistance between free wires:

We will be using Ohm's law, which states that the voltage [V] through a resistor of resistance R is directly proportional to the current [I] flowing through the resistor. In other words, V = IR. Although there is a wire connected between the 2 resistors [R_1 - 1000-ohm, and R_2 - between the free wires] to the Analog pin A0 on the Arduino, the resistance of that wire can be neglected, and hence, we can say that minimal current flows through the wire. So, R_1 and R_2 are connected in series.

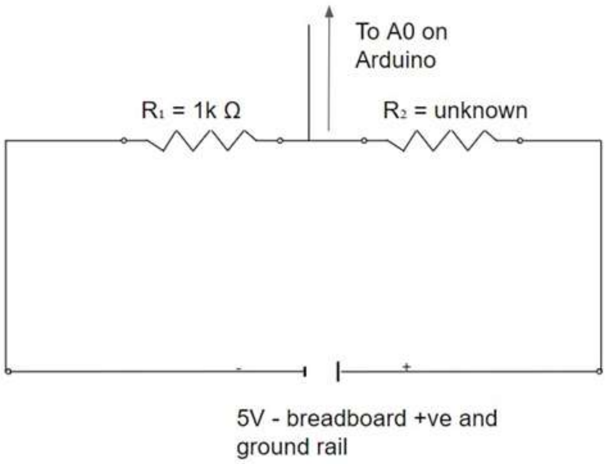


Figure : Schematic resistance system

So, we can say that $V_1 = IR_1$ and $V_2 = IR_2$.

Therefore, we can say $V_2/V_1= IR_2/IR_1 =R_2/R_1$

However, we do not know V_2.

We know that in a series combination of resistors, $V_1+V_2 = V$, where V = 5 Volts. From this, we can get $V_2 = 5-V_1$

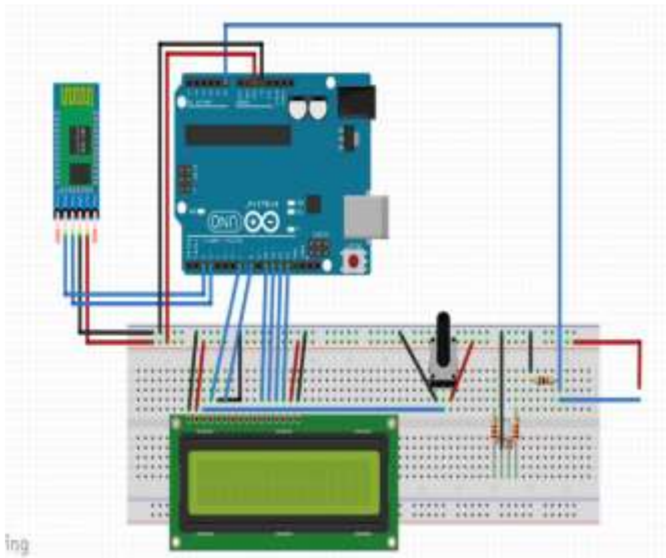
Finally, substituting the value we got for V_2 in $V_2/V_1 = R_2/R_1$, we can define a variable buffer to be $5-V_1/V_1$, instead of V_2/V_1.

Finally, we can say that R_2 = buffer * R_1.

WORKING OF THE PROJECT

- The crocodile clips immersed in the water create a circuit through the water and the resistor, forming a voltage divider.
- The Arduino reads the analog voltage from the voltage divider circuit, which is proportional to the resistance of the water.
- The Arduino calculates the TDS using the derived formulas.
- The TDS value is displayed on the LCD.
- The RGB LED may change color based on the TDS level, acting as a visual indicator of water quality.
- The HC-05 Bluetooth module allows for wireless communication and data logging or remote monitoring using a Bluetooth-enabled device.

BLOCK DIAGRAM:



VI. CONCLUSION & FUTURE SCOPE

In conclusion, the implementation of a water quality indicator system in industrial water tanks is a critical step towards ensuring the sustainability, efficiency, and safety of industrial operations. The real-time monitoring of key water quality parameters offers numerous benefits, including early contamination detection, preventive maintenance, product quality assurance, compliance with regulations, and cost savings. By leveraging technology to continuously assess and analyze water quality, industries can make informed decisions, mitigate risks, and optimize processes, contributing to both operational excellence and environmental responsibility.

The proactive approach enabled by water quality indicator systems not only safeguards equipment and products but also enhances the overall reputation of industries in the eyes of stakeholders, customers, and regulatory bodies. As industries face increasing scrutiny regarding environmental impact and sustainability, investing in advanced water quality monitoring becomes a strategic imperative.

FUTURE SCOPE:

The future scope for water quality indicators in industrial water tanks involves continuous advancements in technology and expanding the capabilities of monitoring systems. Some potential areas for future development include:

Integration with Smart Technologies:

Explore integration with smart technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to enhance predictive analytics and optimize system performance.

Real-Time Data Analytics:

Develop more sophisticated algorithms for real-time data analytics to identify subtle changes in water quality parameters and provide even earlier warnings of potential issues.

Automation and Control Systems Integration:

Further integrate water quality indicator systems with automation and control systems, allowing for automated adjustments based on real-time monitoring data.

Advanced Sensor Technologies:

Explore and implement advanced sensor technologies for improved accuracy, reliability, and expanded capabilities to monitor additional water quality parameters.

Cloud-Based Solutions:

Consider migrating towards cloud-based solutions for data storage, analysis, and remote accessibility, enabling scalability, flexibility, and enhanced security.

Machine Learning for Pattern Recognition:

Implement machine learning algorithms for pattern recognition to identify complex correlations and trends in water quality data that may not be apparent through traditional analysis.

Mobile Applications for Monitoring:

Develop mobile applications that allow personnel to monitor water quality on the go, receive alerts, and take immediate actions from their mobile devices.

Enhanced User Interfaces:

Focus on enhancing user interfaces with intuitive dashboards, augmented reality, and virtual reality for a more immersive and user-friendly experience.

Global Water Quality Monitoring Networks:

Explore the development of global or regional water quality monitoring networks to share data, best practices, and early warning systems, fostering collaboration and knowledge exchange.

Enhanced Cybersecurity Measures:

Prioritize the development and implementation of robust cybersecurity measures to protect sensitive water quality data from unauthorized access and potential cyber threats.

As technology continues to evolve, the future of water quality monitoring in industrial settings holds great promise, with ongoing innovations aimed at making monitoring systems more intelligent, adaptive, and integrated into the broader landscape of industrial processes and sustainability efforts.

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