Project: IoT-Based Water Quality Monitoring System for Urban/Rural Water Distribution

Introduction

Water is a fundamental necessity in daily human activities. The United Nations defines the human right to water as the entitlement of everyone, without discrimination, to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use [*insert reference*].” As part of the 6th Sustainable Development Goal (SDG), the UN aims to improve water availability, promote sustainable water management, and enhance sanitation for the entire population. To achieve this goal, most countries have established water supply network/system to manage resources from various sources—such as rivers, lakes, and underground wells—through treatment plants to the final point of consumption, whether for residential, industrial, commercial, or firefighting use.

The structure of a water supply system typically involves two key phases:

1. Water sources – Treatment Plant (Water supply): In this phase, water is sourced from rivers, lakes, bore wells, etc., and transported to a treatment plant, where it undergoes filtration, aeration, and disinfection to make it suitable for human consumption.
2. Water Distribution network (WDN): Once treated, the water is stored in a Clearwell for distribution. This phase involves the transportation of water from centralized storage to the end users through a network of pipes, valves, pumps, and storage tanks, which is influenced by city topography and demand.

A screenshot of a computer

Description automatically generated

This project focuses on the **second phase: the Water Distribution network (WDN)**

After treatment, water is stored and distributed through a complex system of infrastructure. During distribution, it is crucial to monitor water quality to ensure it meets regulatory standards, such as those outlined in the European Union Water Framework Directive, the U.S. Clean Water Act, and WHO drinking water quality guidelines.

However, water quality monitoring is not the only challenge in WDNs. Issues such as pipe cracks, bursts, and leaks can lead to water contamination or service disruptions. Traditional management techniques struggle to effectively handle these challenges due to the spatial complexity of WDNs. According to [1], WDN management consists of nine distinct components. While this project will not cover leak detection, pressure control, demand prediction, or other aspects of WDN management, it will address one critical component: **Water Quality Monitoring using IoT technology**.

**Project Description:**

The quality of water distributed for human consumption must meet specific standards defined by governing bodies. These standards typically classify water quality metrics into three categories: physical, chemical, and biological. Physical parameters include color, temperature, and odor, while chemical metrics focus on substances like pH, hardness, and the presence of metals (iron, aluminum, zinc) or ions (carbonate, sulfates, nitrates). Biological factors might include contaminants like pathogens or microorganisms. These measurements must be conducted at various stages throughout the water distribution network (WDN) to ensure that water quality is maintained.

Water Distribution Network (WDN)

The WDN comprises two key components involved in transporting treated water from storage to consumers:

1. **Regional Storage Tanks**: After treatment, water is moved from the Clearwell to large-capacity regional storage tanks positioned at elevated altitudes to supply water to different zones.
2. **Distribution Pipes**: These pipes transport water from the storage tanks to the consumers, following various network configurations depending on the city's topography and demand.

Project Scope:

This project focuses on real-time monitoring of water quality at two critical points in the WDN: regional storage tanks and distribution pipes. The goal is to develop a system that continuously monitors key water quality parameters, provides alerts when thresholds are breached, and activates actuators to mitigate potential issues based on the detected anomalies.

**Objective**:

* Develop and deploy an IoT-enabled system for real-time monitoring of water quality across the city's water distribution network, ensuring the safety and reliability of water supplied to households.

**Project Deliverables**:

* Installation of IoT sensors at key points in the city's water distribution network to monitor parameters such as pH, turbidity, temperature, conductivity, and contamination levels.
* Real-time data collection, storage, and analysis.
* Automated alerts for abnormal water quality readings or contamination risks.
* A user-friendly dashboard for water authorities and households to monitor water quality trends.

**Exclusions**:

* Maintenance of water distribution infrastructure (e.g., pipelines, tanks).
* Monitoring of non-potable water sources (e.g., industrial effluents or untreated water bodies).

Sensors:

1. ORP Sensor (Oxidation Reduction Potential): Measures the overall water quality based on the voltage between platinum electrodes, indicating the oxidative or reductive capacity of the water.
2. pH Sensor: Measures the hydrogen ion concentration in water, indicating its acidity or alkalinity (pH range: 0-14, ideal range: 6-8.5).
3. Salinity Sensor: Measures the level of salt in water by detecting its conductivity, which is influenced by the presence of dissolved salts.
4. Ultrasonic Level Sensor: Measures water levels in storage tanks or canals by emitting ultrasonic pulses and calculating the time it takes for the pulses to return.
5. Turbidity Sensor: Measures the cloudiness or haziness of water due to suspended solids, which can indicate contamination.
6. Temperature Sensor: Monitors the temperature of water, which affects chemical reactions and the solubility of contaminants.
7. Flow Sensor: Measures the flow rate of water in pipes or storage tanks by detecting pulses that correlate to the volume of water passing through.

Metrics description

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S/N | Sensor | Measurement Range | Acceptable value for the human body | Influence | Stage needed |
| 1 | Oxidation Reduction Potential | -100 -1000 | 650mV –700 | Temperature and PH | Storage Tanks |
| 2 | PH sensor | 0-14 | 6-8.5 |  | Storage tanks and distribution pipes |
| 3 | Salinity Sensor | 0 - 50000 mg/L | Acceptable level: 0- 600  Fair: 600 -900  Poor level: 900 – 1000  unacceptable: >1000 |  | Storage tanks and distribution pipes |
| 4 | Water level (ultrasonic sensors) | 8 meters | Depending on the storage capacity (0-max)  >0 |  | Storage Tanks distribution pipes |
| 5 | Turbidity | 0 -50 NTU | 0-5 (<1 best) |  | Storage Tanks |
| 6 | Temperature Sensor (digital thermometer) | -55 – 150 oC | 25 to 30 |  | Storage Tanks |
| 7 | Flow sensor |  | > 3-10 feet per second |  | distribution pipes |
| 8 | Water Age |  |  |  |  |

To Read

<https://evogov.s3.amazonaws.com/media/60/media/17107.pdf>

<https://mimoza.marmara.edu.tr/~orhan.gokyay/enve311/ch8.pdf>

Water Age

Actuators

* Solenoid Water Valve: Controls the water flow in the system, allowing the sytem to divert water to filters or stop the flow as needed to mitigate issues detected by sensors.(<https://www.sciencedirect.com/science/article/pii/S2212827120308532> )
* Chemical Dosing pumps
* Backflow Preventers
* Automatic flushing systems
* Cooling System

**System Description**

https://pmc.ncbi.nlm.nih.gov/articles/PMC10395319/

**Applicable Domain**

**Urban Utilities and Smart Cities**: The system is designed for water supply authorities, urban households, and municipal governance, particularly in cities looking to improve the efficiency and safety of their water distribution systems.

**Functional Requirements**

1. Data Collection: IoT sensors continuously monitor water quality parameters (e.g., pH, turbidity, temperature, etc.).
2. Data Transmission: Sensor data is wirelessly transmitted to the cloud using IoT communication protocols (e.g.MQTT).
3. Data Processing: Real-time analysis of the data using a middleware to detect anomalies such as contamination.
4. Notifications: Automated alerts sent to city authorities and affected households if water quality falls below acceptable standards.
5. Visualization: A dashboard that displays real-time and historical water quality data, including predictive insights.
6. Reporting: Automated reports for stakeholders to track water quality trends and compliance with regulations.
7. Configurable thresholds and targets: the system allows for the configuration of custom water quality thresholds and targets for different parameters (e.g., pH, turbidity, temperature).

**Non-Functional Requirements**

1. Performance: The system must provide real-time monitoring with minimal latency (<5 seconds) for critical alerts.
2. Scalability: It should support deployments in cities of various sizes, accommodating hundreds or thousands of sensors.
3. Reliability: Ensure 99.9% system uptime with redundancy for data storage and failover mechanisms.
4. Security: Implement strong encryption and access control to prevent unauthorized access or tampering.
5. Energy Efficiency: Use low-power IoT devices to ensure long-term operation without frequent battery replacements.
6. Compliance: Adhere to local and international water quality standards and regulations. Use of low-power IoT devices to ensure long-term deployment without frequent battery replacements.

References

1. N. K. Velayudhan, P. Pradeep, S. N. Rao, A. R. Devidas and M. V. Ramesh, "IoT-Enabled Water Distribution Systems—A Comparative Technological Review," in IEEE Access, vol. 10, pp. 101042-101070, 2022, doi: 10.1109/ACCESS.2022.3208142.

keywords: {Water resources;Monitoring;Distribution networks;Statistics;Sociology;Internet of Things;Ocean temperature;Internet of Things;IoT communication technologies;IoT services;water distribution network},

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