Entry to the UK Junior Water Prize 2023

Intelligent Water Management System for Smart Homes, Buildings, Communities, and Cities to monitor and notify in advance about Water Quality and Distribution issues

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Preliminary Matters

Summary

The availability of clean water has become a major concern due to various issues such as pollution, leakage, and obstruction in distribution pipelines. To address these challenges, this research project was undertaken to develop a technology-driven system for smart houses that can detect and predict water quality issues and clogging in distribution pipelines. The system leverages sensors, IoT, and AI technology to collect and analyse data, and generates alarms in case of any water-related issues. A real-time Water Security Index is calculated to assess the safety of the water supply. The system can be scaled up for larger areas using LoRa network technology. This proposed system provides a cutting-edge solution to the challenges of water contamination, leakages, and clogging, and ensures the safe and efficient use of this precious resource.

Keyword: Artificial Intelligence, IoT, LoRa network, Machine Learning, Water Security Index, wireless sensors.

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Abbreviations and Acronyms

AI	Artificial Intelligence
COM	Communication Port
CSV	Comma Separated Values
IDE	Integrated Development Environment
IoT	Internet of Things
iOS	iPhone Operating System
LoRA	Long Range

ML	Machine Learning
NTU	Nephelometric Turbidity Unit
TSS	Total Suspended Solids
UNICEF	United Nations International Children's Emergency Fund
WAN	Wide Area Network
WHO	World Health Organisation
WSN	Wireless Sensor Network

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1 INTRODUCTION

1.1 As is and current challenges

Access to clean drinking water is a fundamental human right, yet many people around the world continue to face challenges in accessing safe and reliable water. According to the World Health Organization (WHO), at least 2 billion people worldwide use contaminated water that poses the greatest risk to drinking-water safety [1]. Even in developed countries, the water supply infrastructure can be outdated, leaky, and poorly maintained, leading to water contamination, leakages, and clogging that can have severe health and structural consequences. In fact, the Environment Agency UK estimates that 3 billion litters of drinkable water a day are lost in the UK alone through leakages, equivalent to that used by over 20 million people [2].

Studies have shown that the occupants of damp or mouldy buildings, both houses and public buildings, are at an increased risk of respiratory symptoms, respiratory infections, and exacerbation of asthma, with some evidence suggesting increased risks of allergic rhinitis and asthma [3]. Primary reasons for dampness and mould are seepage in the building which in turn caused by water leakages and clogging in the pipelines. The health and structural damages caused by seepage and leakages can be very expensive to repair. Poor and underdeveloped countries are more susceptible to these issues due to a lack of infrastructure and economic challenges.

To address these challenges, researchers have been exploring various technology-based solutions to monitor water quality, detect leakages and clogging, and prevent health and structural consequences. Previous studies have investigated the use of IoT devices and machine learning algorithms to predict water quality and detect issues in real-time [4]. Others have explored the use of acoustic sensors to detect leaks in pipes and advanced imaging techniques to identify clogs [5]. These solutions offer promising results but require further research and development to be scaled and implemented effectively.

As the world faces the mounting challenges of water contamination, leakages, and clogging, it is crucial to continue exploring and advancing technology-based solutions to ensure safe and reliable access to clean drinking water for a safer world.

1.2 Proposed Solution

The proposed smart water quality and leakage detection system offers a comprehensive solution to address the growing concerns of water safety and security. By utilizing cutting-edge technologies such as the Internet of Things (IoT) and artificial intelligence (AI), this system provides a hybrid approach that tackles water quality, leakages, and clogging issues together in a residential setting.

The proposed system uses a combination of sensors and machine learning algorithms to detect and predict water leakages and clogs. The system continuously monitors water quality and alerts users in real-time if any issues are detected. The system can also predict future events and identify areas where the probability of leaks and clogs is high, allowing for proactive maintenance and repair.

The solution is scalable to deal with these issues at broader level – city, states and country levels. A mesh of wireless sensor by using industry standard LoRa WAN gateways can be built to allow real-time monitoring of the facilities and notify any related issue [9].

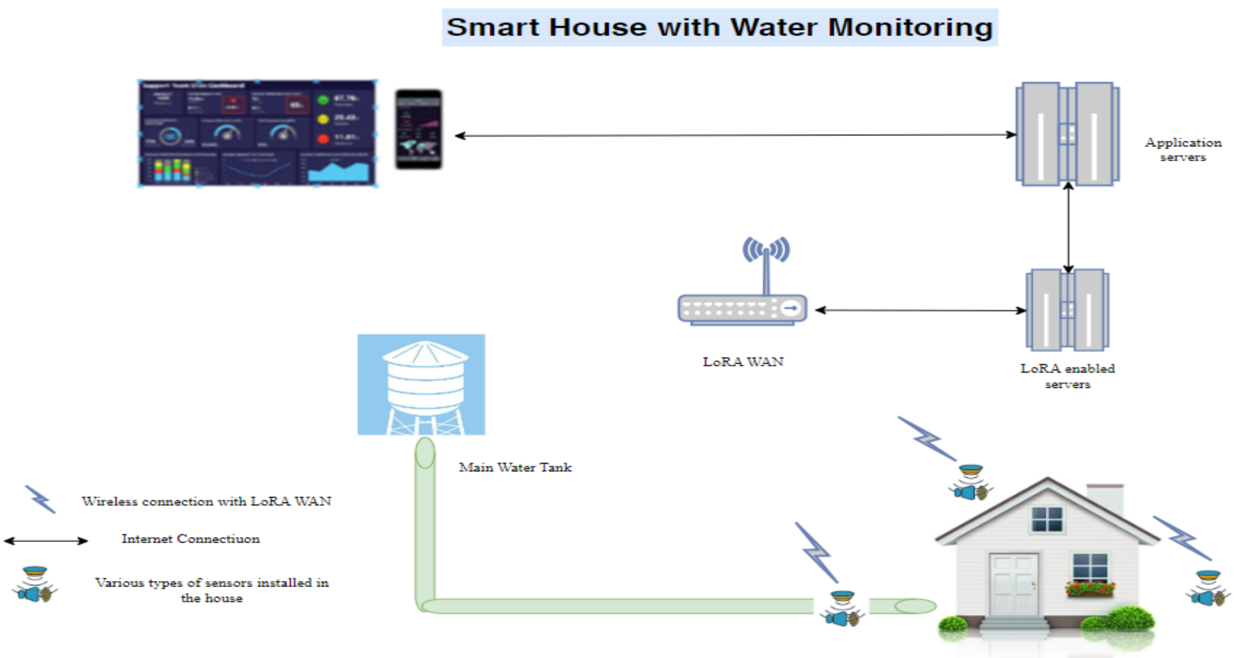


Figure -1-1 Water Smart Home

2 METHODOLOGY

IoT based wired sensors to monitor various environmental factors, such as sound, pH, water level, and turbidity, is being employed to carry out experimentation. To ensure accurate data collection, a microcontroller is used to calibrate the sensors and record readings for subsequent analysis, facilitating a comprehensive understanding of the environment being monitored.

2.1 Methods and Materials

We performed several experiments to simulate water clogging, leakage and water contamination scenario separately at house and collected the sensors' readings as mentioned below.

2.1.1 Water Clogging Detection

The concept that a moving object produces disturbance, particularly sound waves, in a medium of travel, is widely observed and applied in various fields. In particular, the intensity of sound varies depending on the degree of disturbance in the medium through which the object travels [6]. These disturbances create pressure in the medium which is directly proportional to the intensity of the sound produced as established by below Equation 1.

$$I = \frac{\Delta P^2}{2\rho V} \qquad \text{----- Equation 1}$$

I - Intensity of sound in dB; ΔP - Change in pressure; ρ - Density of the material the sound is traveling through**;** V - Speed of the observed sound

Higher the pressure when object is moving through more disturbed medium, so the sensor record higher values in the form of voltage. The pressure fluctuates more when pipe is clogged so as the sensors values changes.

Based on this simple yet powerful concept, we can design a solution of identifying clogging and predict the clogs well in time.

Material used

S.No.	***Name of the material***	***Specification***	***Purpose***
1.	Arduino Mega 2560 Board	Digital I/O PINs 54 Analog Input Pins: 16	Micro-controller to receive and store the data in CSV format
2.	Arduino IDE	MAC OS based Arduino based IDE	For compilation and pushing the code to microcontroller to collect readings
3.	Sound Sensor	Power: 3.3/5.00V Current :4-5 mAmp	To detect the sound and send the analogue values to micro-controller

		sensitivity: 52-48 impedance: 2.2K Ohm frequency: 16-20KHz	
4.	Connecting wires	Male-to-Female	Connecting sensor to Arduino board
5.	USB Cable	UNO R3	Connecting Arduino to laptop
6.	Plastic Drainpipe	1.5 inches diameter plastic pipe	Pipe on which mount the sensor to record the sound
7.	Laptop	MAC OS	For communicating with Arduino Mega 2560 Board

Table 2-1 Material required to collect data for Clogging Detection and Prediction

Experimental Procedure:

We use a small drainpipe connected to the hardware and Sound sensor is mounted on it. Shower hose is used as water source in the bathtub. We used some pieces of cloth to clog the pipe. The sensor is connected to microcontroller (Arduino) with the help of connecting wires and Arduino connected via COM port of the laptop. Arduino IDE used to develop code and push software image to microcontroller. Serial monitor kept at 9600 baud rates. Overall setup depicted in Figure 2-1 and 2-2 along with experimentations summarised in Table 2-2.

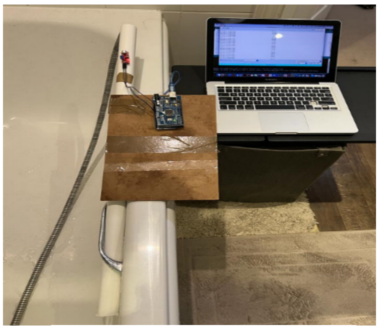


Figure 2-1 Clear Pipe

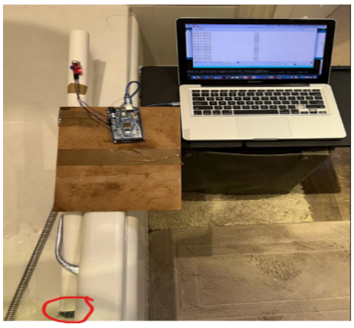


Figure 2-2 Clogged Pipe

Experiment ID	***Scenario***	***Outcome***
Experiment 1.1 (Figure 2-1)	Pipe is clear and water flowing freely from the pipe	Reading taken for 10min and stored in CSV format for predictive analysis
Experiment 1.2 (Figure 2-2)	Pipe is clogged with the help of a piece of cloth and water flow is impeded	Reading taken for 30min and stored in CSV format for predictive analysis
Experiment 1.3 (Figure 2-1)	Pipe is clear again and water flowing through it	Reading taken for 10min and stored in CSV format for predictive analysis

Table 2-2 Clogging Detection and Prediction sub-experiments details

2.1.2 Water Leakage Detection

To detect the water leakages, water level detection sensors are used. It works on the principle that resistance varies inversely with the depth of immersion of the sensor in water. The sensor contains power and sense traces that forms a variable resistor much like a potentiometer whose resistance varies based on how much they are exposed to water.

$$Resistance\ \alpha\ \frac{1}{Depth\ of\ immersion} \quad \text{---}\quad \text{Equation 2}$$

The more the sensor immersed in water, the better the conductivity and the lower the resistance and vice-versa as established in the Equation 2.

Material used

S.No.	***Name of the material***	***Specification***	***Purpose***
1.	Arduino Mega 2560 Board	Digital I/O PINs 54 Analog Input Pins: 16	Micro-controller to receive and store the data in CSV format
2.	Arduino IDE	MAC OS based Arduino based IDE	To develop code and pushing software image to microcontroller.
3.	Water Level Sensor (KY-038)	Voltage: DC 3-5V Current: <20mA Detection Area: 40 mm x 16 mm Temperature: 10 °C to 30 °C	To detect the sound and send the analogue value to micro-controller
4.	Connecting wires	Male-to-Female	Connecting sensor to Arduino board
5.	USB Cable	UNO R3	Connecting Arduino to laptop
6.	Glass Container		Container to keep water sensor

Table 2-3 Material required to collect data for Detecting Water presence

Experimental Procedure

Sensor is placed in the container, and container is empty for some time. Initially, a small amount of water was poured in the container and then increased gradually. Higher the amount of water, higher the voltage recording by the sensor. Microcontroller, sensor and laptop connection are remained same as in Experiment 1. The setup and experimentations depicted in Figure 2-3 and Table 2-4.

Figure 2-3 Experimental setup for water presence detection

Experiment ID	*Scenario*	*Outcome*
Experiment 2.1	Container is empty initially for 200 sec	Sensor values recorded and values stores in CSV format for analysis
Experiment 2.2	Added small amount of water for	Sensor values recorded and values stores in CSV format for analysis
Experiment 2.3	Poured in more water	Sensor values recorded and values stores in CSV format for analysis
Experiment 2.4	Container full of water	Sensor values recorded and values stores in CSV format for analysis

Table 2-4 Water Presence Detection sub-experiments details

2.1.3 Water Quality Detection

To assess the water quality, we used two different types of sensors – pH and turbidity sensor to measure quantity of free ions and Total Suspended Solids (TSS) in the water respectively.

pH Value

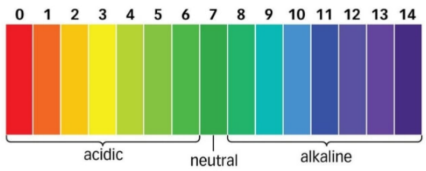


Figure 2-4 pH Value scale

pH sensor measures the amount of hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. The pH values vary from 0 to 14. WHO recommends pH value of safe drinking water lies between 6.5-8.5 [7].

Material used for pH value experimentation

S.No.	*Name of the material*	*Specification*	*Purpose*
1.	Arduino Mega 2560 Board	Digital I/O PINs 54 Analog Input Pins: 16	Micro-controller to receive and store the data in CSV format
2.	Arduino IDE	MAC OS based Arduino based IDE	To develop code and pushing software image to microcontroller.
3.	pH Value Sensor (SEN0161)	Power: 5.00V Range :0 - 14PH Accuracy: ± 0.1pH (25 □)	pH Value measurements
4.	Connecting wires	Male-to-Female	Connecting sensor to Arduino
5.	USB Cable	(UNO R3)	Connecting Arduino to laptop
6.	Glass Container		Container to keep pH sensor

Table 2-5 Material required to record pH values of different solutions

Experimental Procedure for pH Value

To prove that if water get contaminated by becoming more acidic or alkaline then its pH changes, different type of the liquids were used in the sensor tube as shown in Figure 2-5.

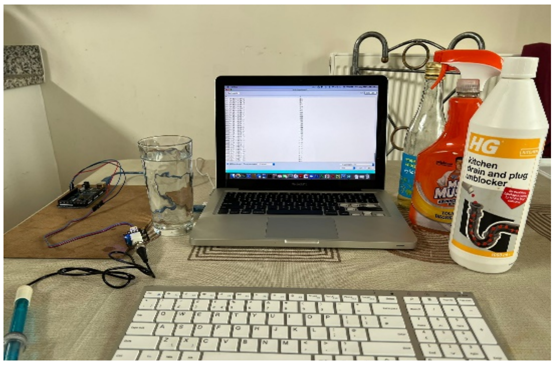


Figure 2-5 Experimental setup for pH Valu

We performed two experimentations to contaminate the drinking water by making it more acidic or alkaline. We started with clean water and gradually added different type of liquids such as vinegar, orange and lemon juice etc. to make it more acidic and later diluted the solutions to observe the changes in pH value when solution become more neutral. Similarly, for other experimentation, we added detergent, toilet cleaners and handwash to clean water to make it more alkaline. Experimental setup and details are able depicted in Figure 2-5, Table 2-6, and 2-7.

Experiment ID	***Scenario***	***Outcome***
Experiment 3.1	Clean drinkable water poured in the container	We took readings for 3min and stored in CSV format for analysis
Experiment 3.2	Added vinegar first and later lemon juice to the solution	We took readings for 20min and stored in CSV format for analysis
Experiment 3.3	Diluted the solution by adding more water	We took readings for 5min and stored in CSV format for analysis

Table 2-6 pH value (acidic solution) detection sub-experiments details

Experiment ID	***Scenario***	***Outcome***
Experiment 4.1	Clean drinkable water poured in the container	We took readings for 20sec and stored in CSV format for analysis
Experiment 4.2	Added baking soda powder first and later soap & detergent to the solution	We took readings for 140sec and stored in CSV format for analysis
Experiment 4.3	Diluted the solution by adding more water	We took readings for 20sec and stored in CSV format for analysis

Table 2-7 pH value (alkaline solution) detection sub-experiments detail

Turbidity

Turbidity is caused by suspended or dissolved particles and coloured material in water. Turbidity sensor measures amount of TSS in the water, which is the main cause of contamination. Turbidity is measured in Nephelometric Turbidity Unit (NTU).

Correlations between TSS or suspended sediment concentrations in mg/L and turbidity in NTU can be made with linear regression analysis, provided enough data is collected. In purely mineral-based samples, this relationship is expressed through the following equation [8].

$$\mathrm{NTU} = \mathrm{a} * TSS^{b} \qquad \text{--- Equation 3}$$

NTU = Turbidity Measurement; TSS = Suspended solids measurement in mg/L; a = regression-estimated coefficient; b = regression-estimated coefficient, approximately equal to 1

Turbidity sensor works on the principle that when light pass through the water, the amount of light transmitted through is dependent upon number of suspended particles (soil, bacteria etc.) in the water. Higher the suspended particles, less light transmitted. Hence, higher turbidity value. This relationship can be established via above linear regression Equation 3.

Sensor records turbidity values in voltage which needs to be converted into NTU. Below quadratic function provides NTU values for corresponding voltages

$$\mathbf{Y} = -1120.4X^{2} + 5742.3\mathrm{X} - 4352.9 \qquad \text{--- Equation 4}$$

NTU values can varies between 0 – 3000 as mentioned in the Table 2-8

Voltage	*NTU*	*Interpretation*
2.5 Volt	3000	Highest Turbidity
4.2 Volts	0	No Turbidity

Table 2-8 Voltage to NTU mapping

Material used for turbidity value experimentation

S.No.	*Name of the material*	*Specification*	*Purpose*
1.	Arduino Mega 2560 Board	Digital I/O PINs 54 Analog Input Pins: 16	Micro-controller to receive and store the data in CSV format
2.	Arduino IDE	MAC OS based Arduino based IDE	To develop code and pushing software image to microcontroller.
3.	Turbidity Sensor (SEN0189)	Power: 5V DC Response Time: < 500ms Output Method: Analog Analog output: 0-4.5V	Turbidity measurements
4.	Connecting wires	Male-to-Female	Connecting sensor to Arduino board
5.	USB Cable	(UNO R3)	Connecting Arduino to laptop

6.	Glass Container		Container to keep sensor

Table 2-9 Material required to collect data for Detecting turbidity

Experimental Procedure for Turbidity Value

Figure 2-6 Experimental setup for recording Turbidity Value

Turbidity values of the water is recorded with the help of Turbidity sensor to prove that polluted water and drinkable water have different turbidity values.

We took clean drinkable water and gradually added some contaminants such as home used spices, sand and soil to increase the concentration of suspended particles. We kept the test environment full of light to have accurate readings. Experimental setup and details are able depicted in Figure 2-6, Table 2-10.

Experiment ID	***Scenario***	***Outcome***
Experiment 5.1	Initially Clean water was taken in the container	We took readings for 200 sec and stored in CSV format for analysis
Experiment 5.2	Clean water was contaminated with dilute coffee, sand and pebbles	We took readings for 600 sec and stored in CSV format for analysis
Experiment 5.3	Diluted the water by adding water to it	We took readings for 600 sec and stored in CSV format for analysis

Table 2-10 Turbidity Detection sub-experiments details

3 RESULTS

3.1 Result and Analysis of Experiment 1– Clogging Detection

Result

The time period from 0 to roughly 550 seconds in Figure 3.1 shows the results from Experiment 1.1 when pipe is clean.

The time period from 550 seconds to roughly 1350 sec in Figure 3.1 shows the results from Experiment 1.2 when pipe is started clog. A clear variation observed in the readings when pipe is clogged.

The time period 1350 seconds onwards in Figure 3.1 shows the results from Experiment 1.3 when pipe is cleared again.

Analysis

The resulting graph shows a clear variation in sound intensity as the pipe became more and more clogged and negligible variation when pipe is open. This provides valuable insights into the relationship between sound intensity and clogging in the pipe. This variability in data is the key to train ML algorithm as mentioned below.

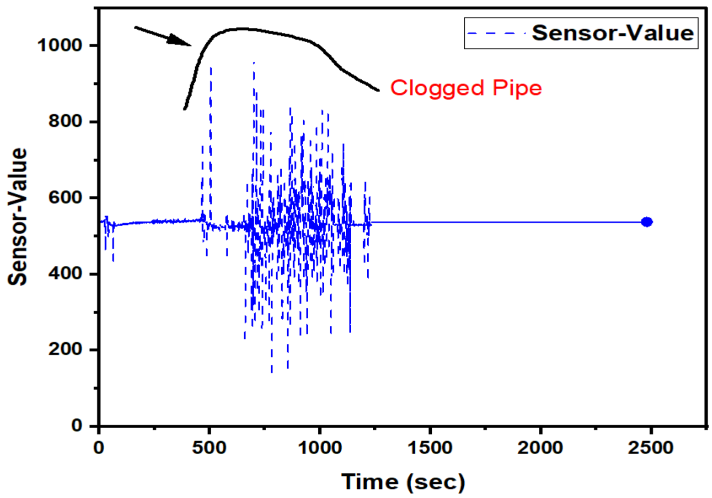


Figure 3-1 Graph representation of data from clogging setup

Machine Learning Algorithm

In this project, we aim to develop a ML model that can predict the values of a sensor based on its previous readings. The dataset we are using contains two columns: the sensor value and the time elapsed since the start of the recording.

Our first step is to load the data into a Pandas dataframe and visualize it using Matplotlib. We observe that the sensor value fluctuates over time, with some periodic patterns and occasional spikes. We also notice that there are some missing values, which we choose to interpolate using linear interpolation.

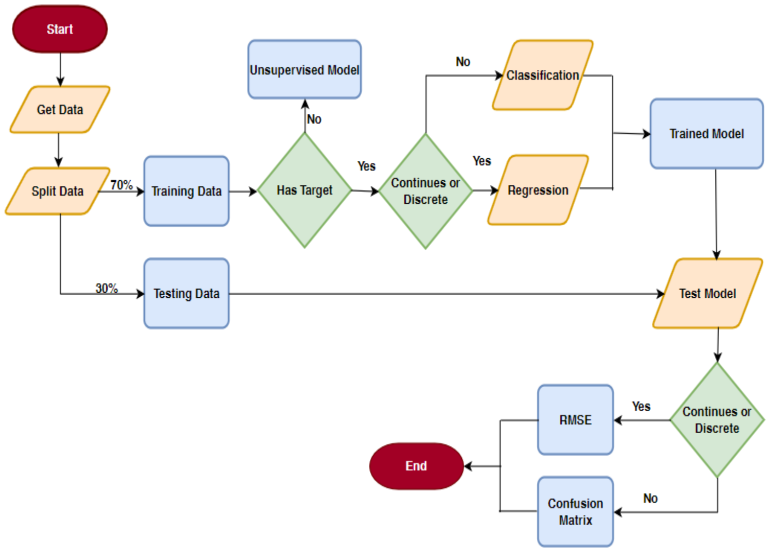


Figure 3-1-1 Machine Learning Algo. flowchart

Next, we split the data into training and testing sets, with a 70-30 ratio. We use the training set to train a linear regression model using scikit-learn. The model takes as input the sensor value at time t and tries to predict the sensor value at time t+1. We choose linear regression because it is a simple and interpretable model that works well for many datasets.

We evaluate the performance of the model on the testing set by computing the mean squared error (MSE) and the coefficient of determination (R^2). The MSE measures how close the predicted values are to the actual values, while the R^2 measures how much of the variance in the data is explained by the model. We obtain a MSE of 5.28 and an R^2 of 0.98, which indicates that the model can accurately predict the sensor values. Basic flowchart of the algorithm shown in Figure 3-1-1.

To visualize the results, we plot the actual sensor values and the predicted sensor values over time using Matplotlib as depicted in Figure 3-2. We observe that the predicted values closely follow the actual values, with some minor deviations due to the noise in the data. We also plot the residual errors, which show the difference between the actual values and the predicted values. We observe that the errors are mostly small and random, which indicates that the model can capture the main patterns in the data.

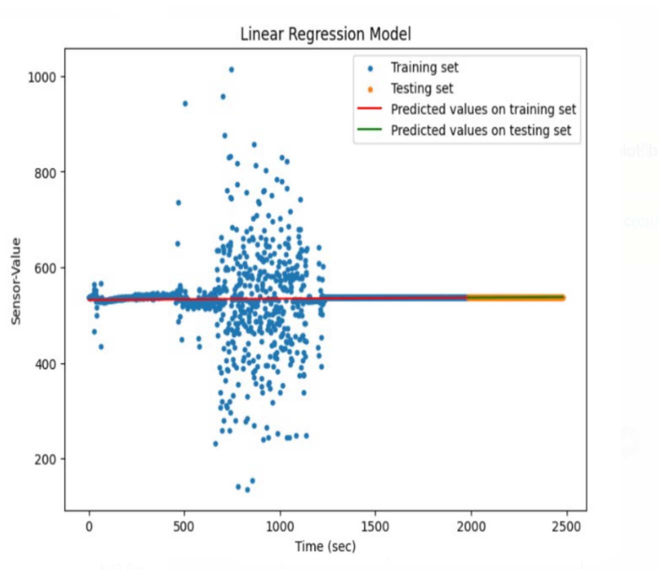


Figure 3-2 Actual Vs Predicted values over time using machine learning algorithm

In conclusion, we have developed a ML model that can accurately predict the values of a sensor based on its previous readings. The model uses linear regression and achieves a high accuracy on the testing set. We have also visualized the results using Matplotlib and saved the plots as JPG files. This project demonstrates the use of machine learning and data visualization techniques for solving real-world problems.

3.2 Result and Analysis of Experiment 2 – Water Leakage Detection

Result

Initially, roughly, 200 seconds in Figure 3.3 shows the results from experiment 2.1 when these was no water in the container.

After initial 200 seconds till roughly 550 seconds in Figure 9 shows the results from experiment 2.2 when we started pouring in the water gradually.

Around 600 seconds in the Figure 3.3 shows the results from experiment 2.3 when we simulated the overflow scenario by adding more water to container.

After 650 seconds onwards in Figure 3.3 shows the results from experiment 2.4 when we started removing the water from the container and made it empty eventually.

Analysis

The resulting graph in the Figure 3.3 depicts sensor value varies based on amount of water present, allowing us to monitor the water level in real-time. The sensor can detect even a single drop of water. The fluctuation on graph clearly illustrates the linear relationship between the water level and the sensor's output value. Sensor successfully registers the trend in water presence right from no water during initial 200 seconds to overflow conditions around 600 seconds and gradually decreases when water was removed slowly.

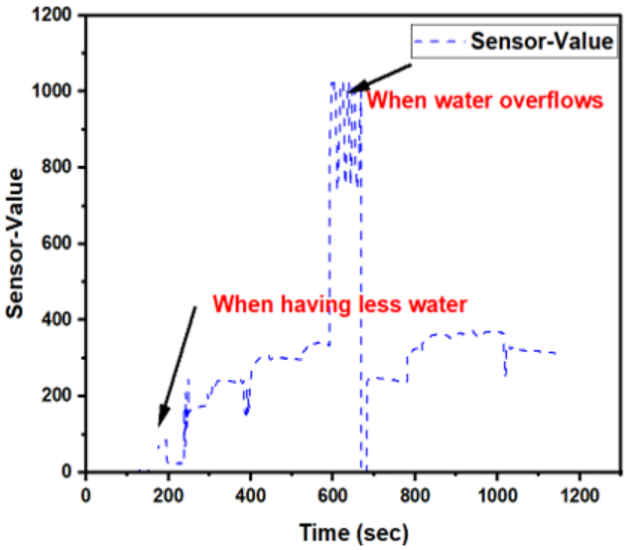


Figure 3-3 Graph representation of data from leakage

3.3 Result and Analysis of Experiment 3, 4 and 5 – Water Quality Detection

Result of pH experiments 4 and 5

Initial 200 seconds, we measure the pH of clean drinkable water that shows the result of experiment 3.1 and the value remained around 7.0 as shown in Figure 3.4.

After 200 seconds, pH decreased on addition acidic solution to water that shows the result of experiment 3.2 and the value falls down to roughly 4.2 as shown in Figure 3.4.

From 2200 seconds onwards, we added water to acidic solution that shows the result of experiment 3.3 and the values start rising as shown in Figure 3.4.

Similarly, results are obtained by gradually making the water more alkaline under experiment 4.1, 4.2 and 4.3 by adding soap, detergent, baking soda etc. as depicted in the Figure 3.5.

Analysis of pH experiments 3 and 4

Result says that if water, get contaminated due to pollutants then its pH values changes. The graph clearly illustrates the impact of adding different acidic solutions to drinkable water. As expected, the pH value of the water decreases as we add more acidic solutions. For instance, when orange juice is added to water, the pH drops from nearly 7 to 5.5. As more orange juice is added, the concentration of H+ ions in the solution increases, resulting in a further decrease in pH value around 4.7. Similarly, the addition of lemon juice, which is even more acidic, causes the pH value to fall to around 4.5. Although the sensor used in the experiment may not be highly sensitive, it was able to sufficiently demonstrate the concept.

It is worth noting that pH is a logarithmic scale, where a change of one unit in pH represents a ten-fold change in acidity or alkalinity. Hence, a decrease in pH from 7 to 6 indicates a ten-fold increase in acidity [7].

$$pH = -\log[H+] \qquad \text{---- Equation 5}$$

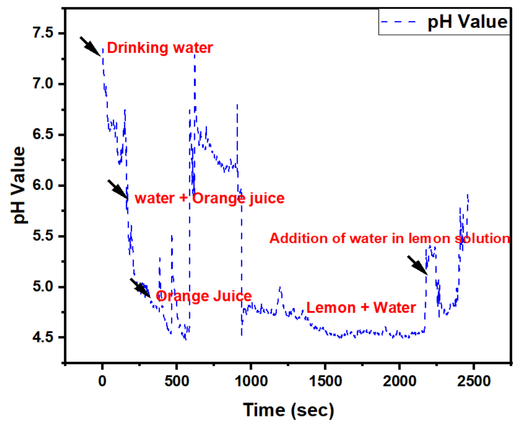


Figure 3-4 Water made acidic

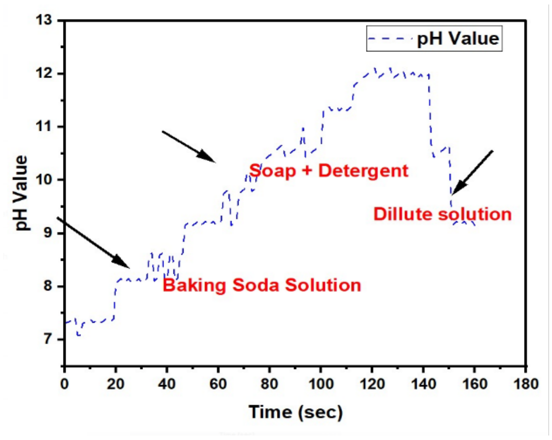


Figure 3-5 Water made alkaline

<u>Result of turbidity experiment 5.1, 5.2 and 5.3</u>

For first 100 seconds, we kept the water clean to capture the reading for experiment 5.1 as shown in the graph Figure 3.6.

After 100 seconds, we added contaminants to monitor the reaction of turbidity sensor. We kept adding the contaminants till roughly 650 seconds to record the data for experiment 5.2. Here we see significant rise in NTU values as expected.

After 650 seconds, we added more water to the contaminated solution to dilute it and observed the fall in NTU value as TSS decrease. This simulates scenario under experiment 5.3.

<u>Analysis of turbidity experiment 5</u>

The resulting graph depicted in Figure 3.6 showed variations in the turbidity of the water, which attributed to fluctuations in the number of suspended particles in the water. More the pollutants in the water more will be the turbidity. This is in accordance with the relations between NTU and TSS established by equation 3. Hence, turbidity sensor is a reliable tool to assess the water quality.

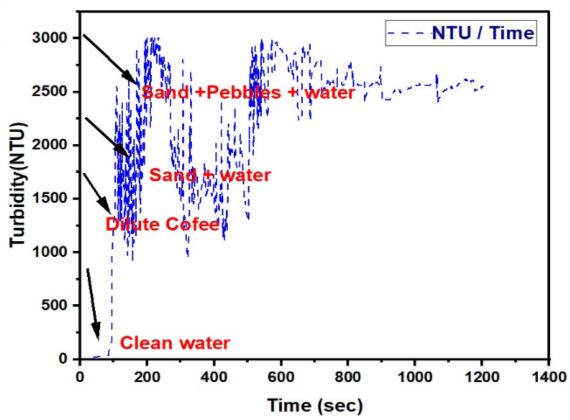


Figure 3-6 Graph showing variations in turbidity values

Summary of Results

Experiment	*Expected Results*	*Actual Results*	*Conclusion*
Experiment 1	Clear variation in data when pipe is clear and clogged	Data showed variations as expected	The concept of using sound intensity to detect & predict clogs in pipes has been proven. However, better quality sensors can be used for a practical system to detect minute details of the sound of water to avoid inaccuracy in machine learning algorithm.
Experiment 2	Sensor detects water presence and vary intensity of analogue signal as per amount of water present	Analogue signal voltage fluctuated as expected at different levels of water.	Water presence – even a single drop – was detected by the sensor. Relationship between Resistance and depth of immersion in water was correctly established. However, better sensitivity sensors can be used for practical purposes.
Experiment 3 and 4	pH changes when water made more acidic [0-7] or alkaline [7-14] by adding acidic and alkaline pollutants to water.	pH values are as expected	pH value is a good parameter to use to assess the quality of water.
Experiment 5	Turbidity changes when solution made contaminated by adding acidic and alkaline pollutants to water.	Turbidity values are as expected	Turbidity value is a good parameter to use to assess the quality of water.

4 DISCUSSION

We have carried out sufficient experimentation to prove the concept how technology can be exploited to devise a hybrid solution to tackle issues related to water quality, leakage and distribution management system in a house or residential building. However, it is worth researching and exploring further from implementation and scalability perspective.

4.1 Design and implementation aspects to consider

Due to economic reasons, this research has been carried out by using the wired sensors, however, real solution will make use of wireless sensor network (WSN) using LoRA gateway as depicted in Figure 4-1.

The wireless sensors nodes exchange data with LoRA gateway. The gateway, which acts as a link between the LoRA network and the internet, is in charge of data aggregation and real-time updates. We have many iOS and android based smart phone applications that allows easy visual monitoring of the status of water condition in the area [10].

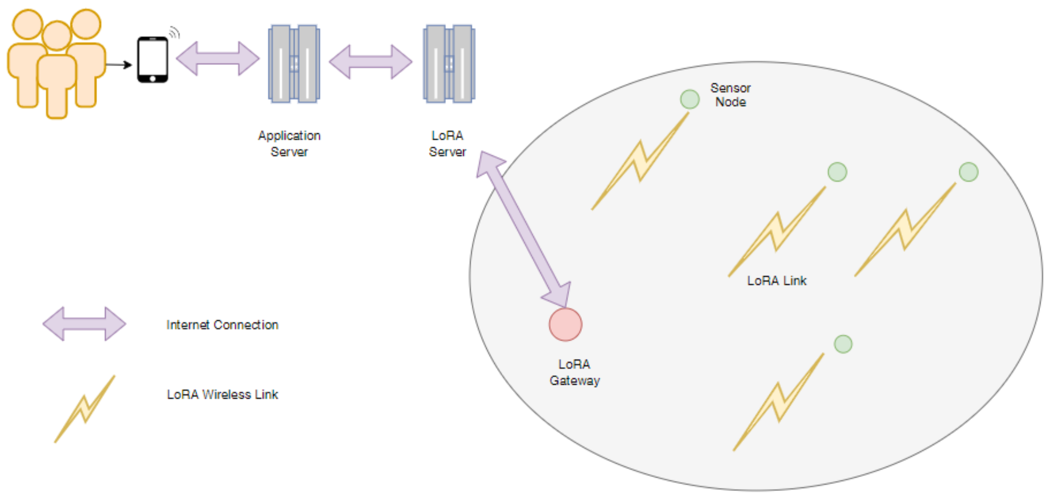
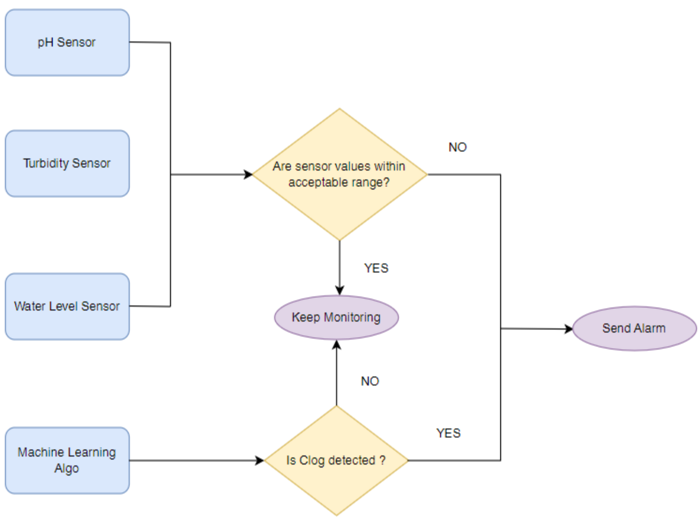


Figure 4-1 Overview of the system

On the basis of parameters derived from analyses of data received from water quality, leakage and clogging, system can generate the alarms as shown in the below flowchart in Figure 4.2 and calculate water security index to depict real-time status of water parameters in the house.



Water security Index can be calculated on the basis of various conditions of quality, leakages and clogging status returned by the system, and shown as low, medium and high values on the real-time dashboard.

Establishing a WSN comes with the multiples challenges, but below are critical one to design the system

Figure 4-2 Flowchart of alarm generation

- *Power Consumption*: Generally, WSNs are battery operated with limited lifetimes. This means sensors are designed to consume less power.
- *Security*: Sensor nodes are vulnerable to various types of attacks, including physical attacks, eavesdropping, and data tampering. Securing the network against these attacks is a significant challenge.
- *Reliability*: Usually, sensors are deployed in harsh environment so they must be designed to withstand these conditions.
- *Data Processing*: sensors produce high volume of data which can require significant storage and processing resources to analyse and extract the insights.
- Deployment: Careful planning is needed to decide the location of sensors that provide the desired coverage and that they are properly configured to communicate with each other.

4.2 Comparison with other state of arts

"A Distributed Sensor Network for Wastewater Management Plant Protection" by S. De Vito and team research paper suggests using a hybrid sensor network to monitor wastewater management plants and prevent illicit discharges. Data collected is processed using a model and machine learning to predict water quality and detect anomalies. An advanced interface conveys information to the management entity to take prompt action and reduce the impacts of illicit discharges [11].

"IoT Device Deployment for Optimal Wastewater Network Coverage" by Arkadiusz Sikorski by team research addresses the issue of coverage and cost minimization in a sewer network using wireless sensor networks (WSNs). A mixed-integer programming problem is formulated to solve the problem of sensor coverage in the sewer network. The use of a CPLEX solver ensures the optimal solution to the problem. Realistic data sets are used to perform the study for a relevant network within selected scenarios. This research is significant for the development of the Internet of Things (IoT) technology and its applications in sewer network management [12].

" Cost-Efficient Coverage of Wastewater Networks by IoT Monitoring Devices" by Fernando Solano Donado and team focuses on minimizing the cost of covering a sewer network using wireless sensor networks. It proposes a mixed-integer programming model to optimize the cost of acquiring and installing electronic components for sensor coverage. The proposed model can handle partial or complete coverage of the sewer network. The CPLEX solver is used to obtain an optimal solution. The study presents results for a practical network under different scenarios, demonstrating the potential of the proposed approach in reducing the cost of sensor coverage in sewer networks [13].

The proposed solution appears to be more effective as it takes a multifaceted approach to water management. By combining sensors, AI, and other technologies, our solution can provide real-time monitoring of water levels and quickly detect and respond to potential issues such as contaminants and clogging. Additionally, the use of sound sensors and AI for overflow and clogging detection demonstrates a commitment to using advanced technologies to improve the water management process.

Furthermore, the inclusion of a future plan to extend to IoT and AI shows a forward-thinking approach to water management that can lead to even more advanced and effective solutions. By utilizing cutting-edge technologies and continuously improving upon existing solutions, the proposed approach can help ensure the protection of critical infrastructure and safeguard the environment, public health, and economy.

Overall, the proposed solution appears to be more comprehensive and holistic compared to other solutions that only address a single aspect of water management. By incorporating multiple technologies and approaches, the solution can help ensure a more effective and efficient water management process that protects the environment, public health, and the economy.

4.3 Wider social, scientific, technological context

The use of sensors for water quality monitoring presents many opportunities for future advancements in this field. The data collected by these sensors can be processed using machine learning algorithms to provide more accurate and reliable predictions of water quality. This can help in detecting contamination at an earlier stage and prevent potential health hazards.

Moreover, the data collected by these sensors can be shared with local authorities and communities to raise awareness about water quality issues and promote responsible water usage. This can contribute to social welfare by ensuring access to safe drinking water and reducing the risk of waterborne diseases.

In addition, the low-cost and energy-efficient design of these sensors make them suitable for use in remote or underdeveloped areas, where access to clean water may be limited. This can help in improving the quality of life of people living in these areas and promote sustainable development.

Overall, the integration of sensors and machine learning algorithms for water quality monitoring can have a significant impact on social welfare and contribute to achieving the United Nations Sustainable Development Goals, particularly to ensure access to clean water and sanitation for all.

4.4 Applications of the proposed system

Every house needs a system which can monitor in real-time the quality, leakage and clogging presence in the house, and this system provide a hybrid solution to all. Other then, housing the system has wide range of application as mentioned below

- *Municipal Water Supply Networks:* can help to reduce water loss and prevent contamination of the water supply.
- *Industrial Applications*: can help to ensure that the water is free from contaminants and is of the required quality for the manufacturing process.
- *Aquaculture:* can help to ensure that the water is free from contaminants and is of the required quality for the fish to thrive.
- *Swimming Pools:* can help to maintain safe and clean swimming conditions.

Overall, such Intelligent Water Management System for Enhancing Water Quality and Distribution can be used in various applications where water usage and quality are critical factors to consider.

5 CONCLUSION

The experiments conducted in this study have demonstrated the effectiveness of using various sensors to detect and monitor different water quality parameters such as pH and turbidity. The data collected from these sensors can be used to identify potential water quality issues and help in taking necessary actions to mitigate them.

Furthermore, the integration of Internet of Things (IoT) and Artificial Intelligence (AI) can further enhance the monitoring and management of water quality. By connecting the sensors to a network and using AI algorithms to analyse the data in real-time, it would be possible to detect and respond to water quality issues even faster. This can help to prevent the spread of waterborne diseases, protect the environment, and ensure the availability of clean and safe drinking water for all.

In summary, the application of sensor technology and the use of IoT and AI can greatly improve our ability to monitor and manage water quality. By continuing to explore these innovative technologies, we can work towards a sustainable and resilient future for our water resources.

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