

# IOT BASED SMART WATER LEAKAGE DETECTION AND MONITORING SYSTEM

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**Abstract:** Clean water is a scarce resource for the human life and is subject to wastage due to leakage of the distribution pipes in large cities. Water pipe leakage is a big problem around the world of which most of the water distribution authorities faces difficulties to detect the location of the fault. This problem of leakage can be caused by several factors such as breakage of the pipelines due to aging or ongoing constructions in urban cities like Dar es salaam, consequently due to that case, the distribution authorities face hardship to identify the cause and enable them to take action. Therefore, the aim of this project was to develop an IoT- based system for water leakage detection and monitoring . The prototype was developed comprising two sensors embedded at the source and destination points to measure the flow rate of water. The result indicated that the volume of water generated at the start point can be compared with the other end to determine if there is any leakage . A greater focus on distance calculation could produce interesting findings that account for more research on IoT monitoring.

## I. INTRODUCTION

Many countries are known to face issues of scarce water resources, and corrective measures area unit taken to develop higher water management system. Water leakage and loss from the most distribution system has been one of the most problems faced not solely by the developing country and conjointly by the developed country round the world. Pipeline networks area unit are the main components for transporting water from one destination to a different place, especially to rural areas. Somehow, leaks could incur due pipeline ageing, corrosion and intensive pressure ensuing from operational error and also due to the fast closing or opening of valves. To forestall future water losses, several techniques are planned with completely different applications to sight leaks within the pipeline system or network.

The manual meter reading could be a tedious, overpriced and extremely labour-intensive job. The innovation in technology has given ways to measure water leak with a rising accuracy. The amount of water flow is unceasingly monitored. Leak within the pipeline is detected using the resistance detector. The solenoid valve mechanically turns off once water leaks. The location, resistance, distance, rate of water flow is monitored and viewed via mobile application.

Campaigns are being carried out in many countries around the world to sensitize people about the importance of water and actions are being taken to preserve it. Apart from drinking, almost all our daily chores require the use of water. Water obviously run when opening taps and this is being taken up for granted. Not until that there is draught and there is enforcement of restriction to the water supply that people realise the importance of savings up water. It is a commodity that not every individual unfortunately has access to. Pipeline system runs into home that facilitates the distribution of water to the entire house and leakage is certainly a risk. It is important to keep the home water pipeline system monitored to prevent water loss where possible. Detection of leakage has always been a challenging issue for plumbers who managed to get through by using their experience. Nowadays, technologies can be used to bring improvement to water pipeline systems. IoT can be a means to achieve the desired system.

The amount of freshwater in the world is limited. Water is a recirculating resource and must be appropriately managed to ensure its continued availability. According to the United States geological survey, 2.5% of the total water in the world is freshwater, 0.75% of the total water is stored in groundwater, and only 0.0072% of water is contained in lakes, rivers, and swamps [1]. So, great care must be taken in how we use and manage this resource. According to UNICEF, one in four children will live in an area of extreme water scarcity [2].

According to United Nations data, it is estimated that the world population expected to be 9.7 billion in 2050, and projected to grow to 10.9 billion in 2100 [3]. We need to supply considerable fresh water to support this vast population. At present, around half of the world's population, or around 3.6 billion people, suffer water scarcity for at least one month every year, and by the year 2050, this number is expected to be around 4.8 to 5.7 billion people [4]. Clean potable water is a basic human right, but according to Burek et al., water poverty will increase rapidly in the coming decades [5]. Even now, some parts of the world are already facing a water crisis.

The water crisis affects countries including Mexico, China, Western South America, South Africa, and South Europe [5]. On the other hand, Australia is blessed with having a diverse source of water production capacity. In 2018- 19, the Water Supply, Sewerage, and Drainage Services (WSSDS) industry extracted 9,936 GL of water from the environment [6]. Wastewater recycling and seawater are the biggest contributors to the supply water. Groundwater, industrial wastewater reuse, river, lakes and dam and treated effluent are the secondary sources [7]. Due to the loss in the supply network, all the supplied water does not reach the end consumer, and it is called non-revenue water. According to the World Bank global cost of non-revenue water is 14 billion USD per year [8]. This is also a substantial component of energy use with the water supply. In 2016, World Energy Outlook estimated that 4% of global electricity consumption was

by water in 2014. There are other detrimental effects of water pipe leakage as well. Water can cause soil expansion under property and causes structural damages [9]. It lets the disinfectant gas (i.e., chlorine) leak out of the system and contaminates the water [10]. The primary reason for water poverty is the lack of water resource management and water loss in the transmission lines.

## II. LITERATURE REVIEW

PLC-Assisted Smart Water Distribution with Rapid Leakage Detection and Isolation by Vaibhav Vilas Godase, Altaf Mulani, Rahul G Ghodake, Swapnil R Takale (2024) concluded that Traditional manual inspection methods and cloud-dependent monitoring systems often suffer from delays, making them unsuitable for real-time isolation and control. This study presents a PLC assisted smart water distribution system designed for rapid leakage detection and automated isolation, utilizing real-time sensor data processing and industrial-grade automation logic.

Using digitalisation for a real-word implementation of an early warning system for water leakages by Martin Oberascher, Claudia Maussner, Petra Hinteregger, Jürgen Knapp, Andreas Halm, Mario Kaiser, Wolfgang Gruber, Dietmar Truppe, Eva Eggeling, Robert Sitzenfrei (2024) concluded that The data are subject to the European General Data Protection Regulation, which requires the active customers consent (and therefore some refusals), and are also subject to data loss during transmission due to the use of wireless data communication. The incomplete data (costumer refusals and transmission failures) were then used for the early warning system, including data-based detection and model-based localisation, and tested on 10 engineered leakage events. Thereby, small leakages up to a size of 0.4 l/s could be detected reliably even under high demand fluctuation

A IOT driven leak detection in real water network using hydrophones published in (2023) paper concluded that IoT-driven leak detection in real water networks using hydrophones concluded that hydrophones are highly effective in detecting leaks with minimal false alarms. The study, published in Water Resources Management, developed AI-based models using hydrophone data and found that ensemble-based classifiers like Adaboost and Random Forest demonstrated promising performance.

Review and analysis of pipeline leak detection methods by Naga Venkata Saidileep Korlapati, Faisal Khan, Quddus Noor, Saadat Mirza, Sreeram Vaddiraju journal (2021) concluded that the main highlight of this paper is to provide a self-powered, sustainable and long-life solution for sensor systems for water monitoring in real-time.

## III. SYSTEM OVERVIEW

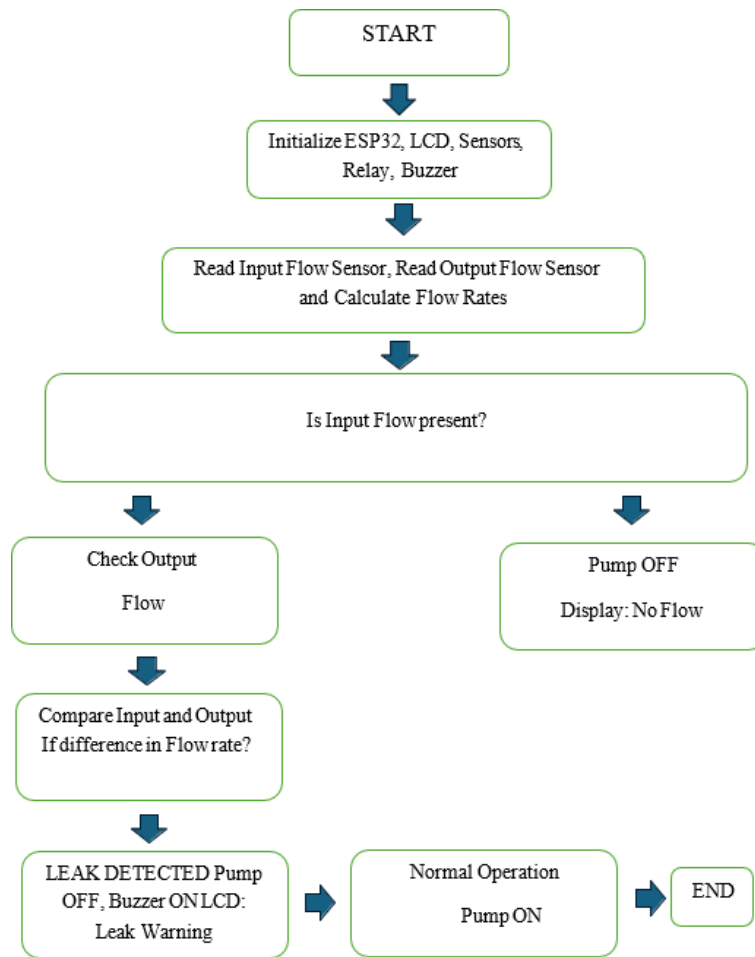


Fig : Block diagram of the water leakage detection system

The water leakage system using the IOT was done by which the system can detect and control the water flow with the help of the water flow sensor. Also, detect the leakage of the pipeline by the alert system through the notification in app. Smart Pipeline

Water Leakage Detection System by in which the leakage of the water can detected by the water flow sensor rate. The Hall effect is Utilized in the water flow sensor to determine the flow rate of water. The water flow sensor determines the water flow rate per sec.

We use the LCD for the Monitoring water flow rate during the normal and leakage condition are continuously monitored if the leakage occurred then the ESP 32 send the alert to the buzzer and also send the message alert to the user with the help of blynk app. Then with the help of blynk app we can have control over the water pump during the water leakage by turning off the motor using smart phone will minimize the water wastage.

The flowchart begins with the system powering on and entering the initialization stage. During this phase, the ESP32 sets up all required peripherals, including the LCD display, the two water flow sensors, the relay module, and the buzzer. Once initialization is complete, the ESP32 starts reading pulses from the input flow sensor, which represent the amount of water entering the pipeline. Immediately after this, it also reads pulses from the output flow sensor, which indicate the amount of water leaving the system.

Next, the microcontroller calculates the flow rate for both sensors by converting the pulses per second into liters per second using a predefined calibration factor. After computing the flow values, the ESP32 checks whether there is any incoming water flow. If no input flow is detected, the system switches the pump OFF and displays a “No Flow” message on the LCD, indicating that water is not entering the system.

If input flow is present, the system proceeds to compare the input flow with the output flow. It checks whether the output flow is too low or whether the difference between the two flows exceeds a preset threshold.

If this difference is greater than the safe limit, the system determines that a leak has occurred. In this case, it executes a safety response by turning the pump OFF, activating the buzzer alarm, and displaying a leak warning message on the LCD to alert the user.

If the flow rates of both sensors are within acceptable limits, the system identifies the situation as normal. The pump remains ON, and the LCD continuously displays the live flow readings and pump status. The entire process runs repeatedly in a loop, ensuring constant and real-time monitoring of the water flow to provide immediate detection of leakage or abnormal conditions.

#### IV. EXPERIMENTAL SETUP

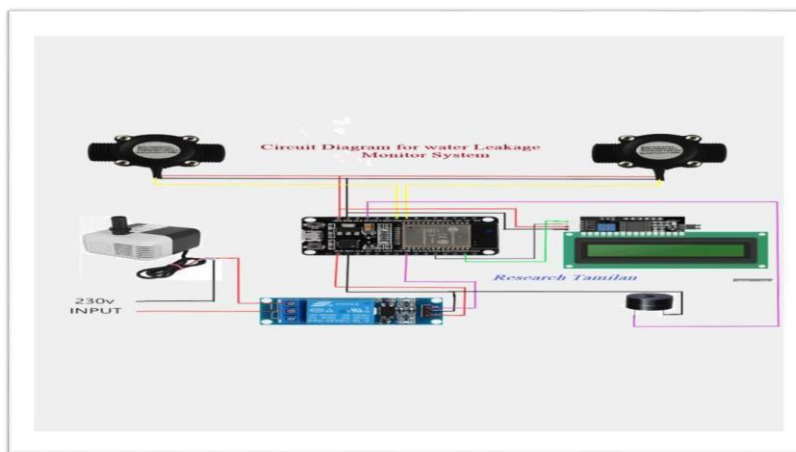


Fig : circuit diagram of the water leakage detection system

Hardware implementation involves translating a conceptual design into physical components and systems. It encompasses selecting and integrating electronic, mechanical and electrical parts to construct a functional product or system. This process typically includes fabrication, assembly, testing and optimizations to ensure the hardware meets specified requirements and functions reliably in its intended environment.

ESP32 is a chip that provides Wi-Fi and (in some models) Bluetooth connectivity for embedded devices – in other words, for IoT devices. While ESP32 is technically just the chip, the modules and development boards that contain this chip are often also referred to as “ESP32” by the manufacturer. The original ESP32 chip had a single core Tensilica Xtensa LX6 microprocessor. The processor had a clock rate of over 240 MHz, which made for a relatively high data processing speed.

More recently, new models were added, including the ESP32-C and -S series, which include both single and dual core variations. These two series also rely on a Risc-V CPU model instead of Xtensa. Risc-V is similar to the ARM architecture, which is well-supported and well-known, but Risc-V is open source and easy to use. from GNU compilers, while the Xtensa needed extra support and development to work with the compilers.

**Processors** – The ESP32 uses a Tensilica Xtensa 32-bit LX6 microprocessor. This typically relies on a dual core architecture, with the exception of one module, the ESP32-S0WD, which uses a single-core system. The clock frequency reaches up to 240MHz and it performs up to 600 DMIPS (Dhrystone millions of instructions per second). Moreover, its low power consumption allows for analog to digital conversions as well as computation and level thresholds, even while the chip is in deep sleep mode.

**Wireless connectivity** – The ESP32 enables connectivity to integrated Wi-Fi through the, Bluetooth connectivity is made possible with the v4.2 BR/EDR, and the series also features Bluetooth low energy .

**Memory** – Internal memory for the ESP32 is as follows. ROM: 448 KB (for booting/core functions), SRAM: 520 KB (for data/instructions), RTC fast SRAM: 8 KB and Moreover, some of the ESP32 chips, including the ESP32-D2WD and ESP32-PICO-D4, have internally connected flash. See the respective internal flash memory for each chip in the section.

**External flash and SRAM** – ESP32 support up to four 16 MB external QSPI flashes and SRAMs with hardware encryption based on AES to protect developers' programs and data. It accesses the external QSPI flash and SRAM through high-speed caches.

A 230 V water pump is an electric pump designed to run on an AC supply of about 230 volts, which is the standard mains voltage in many countries including India and most of Europe. These pumps convert electrical energy into mechanical energy to move water for a variety of applications — from small domestic uses like tank supply and garden irrigation.

We use the Motor pumps are single-phase 230V ac supply, meaning they're suitable for standard household power connections (though large models may require special wiring). The performance of a pump is described in terms of power (HP), current draw (amps), flow rate (volume of water moved per minute/hour), and head (how high the pump can lift water). Typical domestic centrifugal pumps for homes and small farms range from around 0.33 HP up to ~2 HP and deliver moderate flow and head; submersible models are used when the pump needs to be placed inside water, such as in sumps or wells.

A power supply IC that produces a constant output voltage in response to the input voltage, output current, and load resistance is called a voltage regulator. Many names are used for voltage regulators, such as linear regulator, series regulator, voltage r egulator, and low dropout .

Using a voltage regulator makes it possible to produce a constant output voltage from various input sources with differing input voltages (Ex: 12V power supply, dry cell batteries, and lithium secondary batteries).

A Transistor is one of the types of semiconductor devices that is used to conduct and insulate electric current or voltages. A transistor acts as a switch and as an amplifier. Transistors are considered one of the key components in most of the electronic components that we use today. It is also considered one of the best inventions in the history of science and engineering. It is used to conduct electric current and voltage and also to insulate it. A transistor is a semiconductor that controls voltage or current flow in electronic signals and it amplifies and acts as a switch for them. Transistor consists of three layers each of which can carry a current. If the transistor is working as an amplifier, then it transforms a small input current into a big output current.

When a small signal is applied between one pair of terminals in a transistor, a signal can be operated to control a much larger signal at another pair of terminals. In this part, the property of the transistor is gained due to signal strength in the process of switching and the output generated can be either voltage or current or electronic signal. If the input increases then the output also increases. In other words, it is simple to say that output is proportional to input. Due to this particular activity transistor can act as an amplifier. The main use of a transistor is that it makes the circuit more controllable and the current flow is determined by other circuit elements. Depending on the biasing conditions like forward or reverse, transistors have three major modes of operations cutoff, active, and saturation regions.

**Active Mode:** In this mode, the transistor is generally used as current amplifier. In active mode, two junctions are differently biased which means emitter-base junction is forward biased whereas collector-base junction is reverse biased. In this mode, current flows between emitter and collector and the amount of current flow in proportional to the base current.

**Cutoff Mode:** Here both collector base junction and emitter junction are reverse biased. As both the PN junction are reverse biased, there is almost no current flow except very small leakage of currents. In BJT mode it is switched OFF and is essentially an open circuit. This region is mainly used in switching and digital logic circuits

**Saturation Mode:** In this particular mode of operation, both the emitter-base and collector-base junctions are forward biased. Here current flows freely from collector to emitter with almost 0 resistance. In this mode, the transistor is fully switched ON and it is a closed circuit. It is mainly used in switching and digital logic circuits.

When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact(s) either makes or breaks (depending upon construction) a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa .

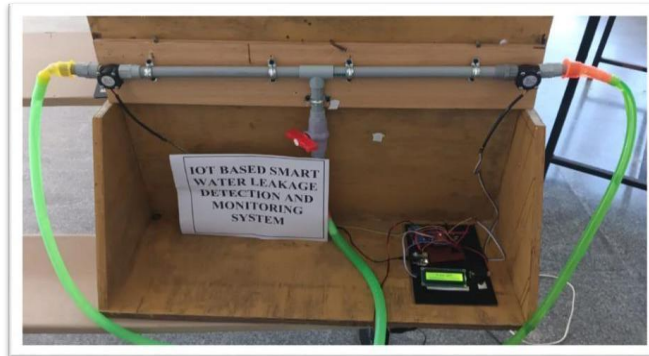
When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually, this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing.

When the coil is energized with direct current, a flyback diode or snubber resistor is often placed across the coil to dissipate the energy from the collapsing magnetic field (back EMF) at deactivation.

Such diodes were not widely used before the application of transistors as relay drivers, but soon became ubiquitous as early germanium transistors were easily destroyed by this surge. Some automotive relays include a diode inside the relay case. Resistors, while more durable than diodes, are less efficient at eliminating voltage spikes generated by relays and therefore not as commonly used.

## V. RESULTS AND DISCUSSION

The IoT-based water leakage detection and monitoring system was successfully designed, implemented, and tested. The system effectively monitored real-time water flow and accurately detected leakage conditions by comparing inlet and outlet flow sensor readings.



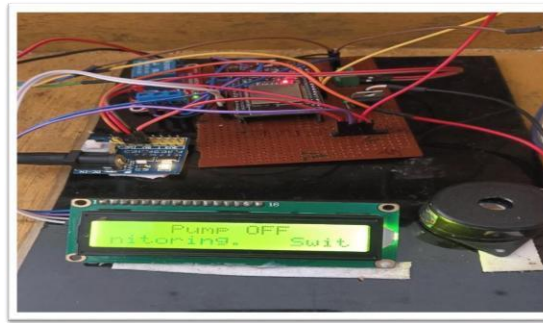
The implemented IoT-based water leakage detection and monitoring system was tested under both normal and leakage conditions to evaluate its effectiveness and reliability. During normal operation, the water flow sensors measured the expected flow rate and transmitted the data continuously to the ESP32 microcontroller. The ESP32 successfully processed the incoming sensor data without any delay or data loss. The LCD display showed a stable status message indicating normal water flow. At this stage, no alert was triggered in the Blynk mobile application. The relay module remained in the ON state, allowing the water pump to operate normally. This confirmed that the system does not generate false alerts during standard water usage. The buzzer also remained inactive, ensuring silent operation. The observed results demonstrate that the system maintains stable monitoring under non-leakage conditions. The integration of hardware and software components functioned as expected. Overall, the system performed efficiently during normal conditions without interruptions.

When a water leakage was artificially introduced into the pipeline, the system responded immediately to the abnormal flow rate. The water flow sensor detected an unexpected increase or imbalance in flow, which was then transmitted to the ESP32 controller. The microcontroller analyzed the data and compared it with predefined threshold values. Once the leakage condition was confirmed, the system triggered the leakage detection logic. The LCD instantly displayed a leakage warning message, providing local visual feedback. Simultaneously, the buzzer was activated to alert nearby users.



This immediate response demonstrates the system's ability to detect leakage events in real time. The detection accuracy was consistent across multiple test cases. No significant delay was observed between leakage occurrence and system response. The results confirm that the sensors are sensitive and reliable. This real-time detection capability is essential for preventing water wastage and damage.

One of the key results of this system is the automatic control of the water pump during leakage conditions. Upon detection of leakage, the ESP32 sent a control signal to the relay module. The relay immediately switched OFF the pump, stopping the water supply. This automatic shutdown mechanism prevents further water loss and minimizes damage to infrastructure. The relay operation was stable and showed no malfunction during repeated tests. The transition from ON to OFF state occurred smoothly without electrical noise issue.



This demonstrates effective coordination between the sensing unit and the control unit. The pump shutdown occurred within seconds of leakage detection. Such fast response significantly reduces the impact of water leakage. The system eliminates the need for manual intervention. This result highlights the importance of automation in water management systems. Overall, the relay-based pump control proved to be efficient and reliable.

Simultaneously, a real-time notification was sent to the user via the Blynk platform, and the relay-controlled pump was automatically shut down to prevent further water loss. All alert and control actions were synchronized and executed without delay, demonstrating the system's reliability and effectiveness for real-world water leakage monitoring applications.

## VI. CONCLUSION

The IoT-based smart water leakage detection and monitoring system provides an effective solution for managing water resources efficiently. Using a water flow sensor, the system continuously monitors flow rates in pipelines, allowing real-time detection of leaks. The ESP32 microcontroller processes sensor data and sends alerts through Wi-Fi, making the system highly responsive. The LCD display provides immediate on-site monitoring, while the buzzer delivers audible warnings in case of anomalies.

By detecting leaks early, the system minimizes water wastage and prevents potential damage to infrastructure. Automated alerts ensure that minor issues are addressed before they escalate. The system significantly reduces human intervention in routine monitoring. It is suitable for residential, industrial, and municipal applications. This combination of hardware and software forms a reliable and efficient water management solution. Overall, the system contributes to both economic savings and environmental conservation.

Integration with the Blynk mobile app allows users to remotely monitor water flow and receive instant notifications on their smartphones. This feature ensures that users can respond to leaks even when they are away from the site. The app also displays historical data, helping users track trends and detect recurring problems. Combining remote monitoring with local alerts, like the buzzer, improves the system's reliability. The use of transistors and thyristors enables automatic switching of high-power devices such as valves or pumps. This ensures a quick automated response to detected leaks.

The integration of IoT technology with mobile applications transforms conventional water systems into smart and interactive networks. Users benefit from enhanced control, convenience, and timely decision-making. The Blynk interface also facilitates long-term data logging for predictive maintenance. This combination of local and remote monitoring provides a comprehensive solution for water management. Automation is a major advantage of the proposed system. Once a leak is detected, the ESP32 can trigger actuators, buzzers, or solenoid valves to respond immediately. This reduces dependency on manual intervention and prevents further water loss.

The system can differentiate between minor and major leaks using real-time sensor data. Historical and current data help in determining appropriate responses for each situation.

Energy efficiency is another important aspect of this project. The system's components, including ESP32, sensors, transistors, and thyristors, are designed to operate at low power. High-power devices, like buzzers or valves, are activated only when necessary, reducing unnecessary energy consumption. This makes the system suitable for off-grid installations using small solar panels or batteries. Low power operation also allows deployment in large-scale monitoring networks without excessive energy costs. Efficient energy management contributes to the sustainability and longevity of the system. It reduces operational expenses while maintaining continuous monitoring. Users can rely on the system to operate reliably over extended periods.

The system contributes significantly to water conservation and resource management. Early leak detection prevents large-scale water wastage and associated financial losses. Residential users benefit from lower water bills, while industrial and municipal systems gain operational efficiency. Historical and real-time data allow users to plan maintenance, predict potential failures, and optimize water distribution. Environmental sustainability is supported through reduced water consumption. The system raises awareness about water conservation among users. Its predictive and real-time monitoring capabilities prevent minor leaks from escalating. By combining IoT, automation, and data analytics, the system ensures responsible water management.

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