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Page: 01-10

REAL-TIME WATER QUALITY MONITORING SYSTEM USING IOT

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ABSTRACT

Water contamination has become a serious en-vironmental challenge due to rising industrial waste, sewage discharge, and hazardous chemical pollutants entering natural water sources. Traditional methods of water quality assessment mainlyrelyonmanualsample collectionandlaboratory analysis, which are often costly, time-consuming, and unsuitable for continuous real-time monitoring.

This project presents an intelligent real-time water quality monitoring system that integrates Internet of Things (IoT) tech-nologywithmachinelearningtechniquesforeffectivewastewater management. The proposed system continuously monitors essen-tial water quality parameters such as pH, Turbidity, Temperature, dissolved oxygen, total dissolved solids (TDS), conductivity, and water level using interconnected sensors with Arduino, ESP32,or Raspberry Pi.

Water quality is continuously monitored through sensors that transmit data to cloud platforms, where it can be viewed in real time through a web-based dashboard. The collected readings are regularly compared with predefined safety limits to determine whether the water quality is safe. If the parameters remain within acceptablelevels,normalwaterflowismaintained.However, if contamination exceeds safe limits, the system automatically diverts polluted water for treatment or recycling using pumps, relays, andsolenoidvalves. This process helps ensuresaferwater management while allowing rapid detection and correction of potential issues.

Additionally, GSM-based alert systems immediately notify responsible authorities whenever unsafe conditions are detected. Byreducing manualintervention,improvingresponsespeed,and supporting predictive analysis, this system provides a reliable, cost-effective, and automated

solution for modern water quality management.

INDEX TERMS: Water Quality Monitoring, Internet of Things (IoT),Arduino, Raspberry Pi, Ultrasonic Sensor, Turbidity Sensor, TDS Sensor, Temperature Sensor, Dissolved Oxygen Sensor, Water Level Sensor, GSM Module, LCD Display, Motor Driver, ESP8266, Real-Time Monitoring, Sensor Networks, Environmental Monitoring

I. INTRODUCTION

Waterisoneofthemostessentialnaturalresourcesrequiredforhumansurvival,agriculture,industrial processes,andmain-taining ecological balance. However, rapid industrialization and urbanization have significantly contributed to water pol-lution. Industrial wastewater often contains toxic chemicals, and harmful substances that negatively affect both human health and aquatic ecosystems. The contamination of water bodies not only disrupts biodiversity but also leads to severe healthproblemssuchascholera,typhoid,andotherwaterborne diseases.

The old ways of checking water quality are not good enough.Theyinvolvetakingsamplesbyhandandtestingthem inalab,whichtakesalotoftimeandmoney.Theproblem is, bythe time we get the results, the polluted water may have alreadyspread and caused harm. We need a better systemthat can check the water quality automatically and quickly, so we can take action right away. This would help us keep the water clean and safe for everyone.

With advancements in (IoT) technology, real-time mon-itoring has become feasible. IoT enables continuous data collectionusingsensorsandallowsremotemonitoringthrough cloud platforms. Additionally, we can use techniques which cananalyzehistoricaldata,identifypatterns,andpredictfuture trends in water quality.

II. MOTIVATION AND PURPOSE

Water pollution is a big problem that affects everyone and the environment. Many factories and industries release dirty water into our rivers, lakes, and underground water sources without properly cleaning it first. This makes the water very contaminated. The systems we have in place to check for pollution are often old-fashioned, don’t work well, and can’t giveusupdatesrightaway.Thismeanswedon’tfindoutabout the pollution until it’s too late, and it hurts the environment even more. We need better ways to monitor the water so we can catch pollution early and prevent damage.

Theideabehindthisprojectistocreateasystemthat can keep an eye on water quality all the time and send out alerts right away if something goes wrong. This way, we can cut down on how

much people need to get involved, reduce mistakes, and make the monitoring systems more accurate. With the help of IoT technology, people can check the water conditions from anywhere, at any time, using real-time data. This makes it easier to stay on top of things and respond quicklytoanyproblemsthatcomeup.Thegoalistohave a smart and efficient system that can help us keep the water safe and healthy. By automating the process, we can free up people to focus on more important things and make sure that the water quality is always up to par.

The purpose of this system is not only to monitor water qualitybutalso to take necessaryactionsautomatically. When contamination is detected, the system diverts polluted water into a treatment tank, preventing it from entering naturalwaterbodies.Additionally,machinelearningtechniquesare
incorporated to analyze historical data and predict futurewater quality trends. This makes the system proactive rather than reactive, improving decision-making and environmental protection.

III. LITERATURE SURVEY

1) Yurav Singh et al. (2024) – Smart Water Quality Monitoring with IoT Wireless Sensor Networks They propose an Internet of Things (IoT)-based, wireless sensor networks for data acquisition in a water quality monitoring system. Parameters such as pH, turbidity, conductivityandchlorophyllaremeasuredwithdifferent sensors. The collected data is transmitted using low-power communication methods for continuous monitor-ing. Machine learning techniques like AdaBoost, SVM, and RandomForest areapplied topredict contamination levels, including biological indicators such as E.coli. While well-suited for large-scale monitoring, it does have its share of limitations stemming from sensor availability and accuracy.

2) Shanvendra Rai et al. (2024) – An Effective Smart Water QualityMonitoringand ManagementSystemUs-ingIoTandMLThisprojectaimstodevelopareal-time system using IoT technologyand machine learning algorithms.Toachievethis,sensorsareusedtotrackkey parameterssuchaspH,turbidity,andtemperature,which
arethentransmittedtothecloudforfurtheranalysis. A range of algorithms, including XGBoost, Random Forest, AdaBoost, and Decision Tree, are employed to predict water quality. One of the key features of this system is its ability to send alerts to users when itdetects any abnormal conditions. The results have been impressive, with XGBoost achieving accuracy levels of up to 99.9

3) Md. Ashraful Islam et al. (2025) – IoT-Enabled Intelli-gentWaterQualityMonitoringSystemforTouristSafety Using Machine Learning When it comes to providing safedrinkingwaterintouristareas,areliablesystem is crucial. This is where an IoT-based system comes in, utilizingsensorstocontinuouslymonitorkeyparameters such as pH, turbidity, total dissolved solids (TDS), and temperature. The collected data is then analyzed using various machine learning models, including Artificial Neural Networks (ANN), Random Forest, and Decision Tree.Interestingly,theANNmodelstandsoutforitsex-ceptional performance, boasting an impressive accuracy of approximately 92.66

4) Aravindan D et al. (2025) – Smart Aquaculture: Real-Time Water Quality Monitoring using IoT and Wireless Sensor Networks This study develops an IoT-based system for monitoring water quality in aquaculture en-vironments. Sensors are used to track parameters suchas pH and temperature continuously. When values cross the safe limit, alerts are sent through a GSM module. The system also includes automatic control actions like activatingpumpstomaintainwaterquality.Thisreduces manual work and improves efficiency in fish farming.

5) DanielQuintanaetal.(2025)–OnSmartWaterSystem Developments:ASystematicReviewThisstudytakes a close look at smart water systems and how they've changed over time. It talks about how new technologies like IoT, artificial intelligence, cloud computing, and digital twins are being used to monitor and manage water. Thereportalsolooksat what'shappeningaround the world with smart water systems, the challenges they face, and what might happeninthe future. Itshowshow these technologies can help make water systems more efficient and sustainable. By using these new tools, we canmakeabigdifferenceinhowweusewaterandmake sure wehaveenoughfor thefuture. Thegoalistocreate systems that are not only good for the environment but also help people and communities thrive.

6) Ritam Mitra et al. (2026) – High-Accuracy Water Quality Detection Using IoT-Integrated Ensemble Ma-chine Learning This work proposes a water quality monitoring system that combines IoT with ensemble machine learning techniques. The used various sensor andtheywillcollectthedataissenttothecloudfor processing. Multiple machine learning models are combined to improve prediction accuracy, achieving up to 99.9%. The systemprovides real-time results and can be used in both domestic and industrial applications.

7) Saurabh Sharma et al. (2026) – Intelligent Low-Cost Water Quality Monitoring System with On-Device Ma-chine Learning This study introduces a low-cost system that uses a small computer called an ESP32, along witha type of machine learning called TinyML, to keep an

eye on water quality in real-time. The system checks thingslikehowacidicthewateris,howcloudyitis,
itstemperature,andhowmanytinyparticlesareinit. It uses a special kind of computer program called a neural network that is trained to spot when the water is contaminated, and it can do this all on its own without needingtosendinformationtothecloud.Thismeans it can react quickly and still work even if there's no internet around. The system is very good at its job, getting it right about 99.28

8) N.R.Gayathrietal.(2024)–SmartWaterQualityMon-itoring and Management System This paper introduces an IoT-based system that monitors both water quality and water levels. It uses sensors such as pH, ultrasonic, RFID, GSM, and GPS. The system provides real-time alerts for impurities and tracks the location using GPS.It also controls water flow using solenoid valves. This improves water management and reduces the need for manual monitoring.

9) Xuyang Pu (2025) – Design and Implementation of an IoT-Based Smart Water Treatment Monitoring System This study presents a smart monitoring system that combinessensordatawithimageprocessingtechniques.
ItusestheYOLOv8deeplearningmodelalongwith
sensors to detect contamination in water. The system continuously collects data and sends it to a central plat-form for real-time monitoring. This approach improves accuracy and reduces the need for manual inspection.

10) Jiajia Guo et al.(2025)– Real-Time Online Monitoring System for River Water Quality Based on NB-IoT This paperproposesariverwatermonitoringsystembasedon NB-IoT communicationtechnology. Sensorsareusedto measure parameters such as pH, temperature, turbidity, and TDS. The collected data is sent to a cloud platform where it is stored and analyzed. The system provides alerts when values exceed the set threshold and allows users to view data through a mobile application.

11) PurnenduMandaletal. (2024) – IntelligentIoT System for Continuous Water Quality Monitoring This work develops an IoT-based system using Raspberry Pi asthe main controller. Multiple sensors are used to collect waterqualitydata, whichisthentransmittedusingGSM and Wi-Fi modules. Machine learning techniques are applied to detect anomalies and predict future condi-tions. The system provides continuous monitoring and supports remote access.

12) N. Sreekanth et al. (2025) – IoT-Based Smart Water Quality Monitoring System This paper presents a sim-ple and cost-effective IoT system for monitoring water quality. It uses

sensors to measure parameters such as pH, turbidity, temperature, and humidity. The data is sent to cloud platforms like ThingSpeak for storage and visualization. The system also provides basic analysis and recommendations to improve water quality.

13) Ganesha B P et al. (2025) – IoT Enabled Real-Time Water Quality Monitoring System This research is all about keeping an eye on water qualityin real time using theInternetofThings.Itusessensorstotrackthingslike how acidic or basic the water is, its temperature, and how cloudy it is.All this information is then shown onascreen,soyoucanseewhat'sgoingonrightaway.But that's not all - the data also gets sent to a special online platform, so people can check on the water quality from anywhere. This systemis reallyhelpful for catchingany problems with the water early on, before they become bigissues.Bydoingthis,wecanmakesurethewater is safe and healthy for everyone.

14) Vimala Ebenezer et al. (2024) – IoT-Based SmartWater Quality Monitoring System for Environmental Protection and Sustainability This paper proposes an IoT-based system that uses wireless sensor networks to monitor water quality parameters such as pH, turbidity, dissolved oxygen, and biological oxygen demand. The system provides real-time data, which can be used for environmentalmonitoringandimprovingwatermanage-ment practices.

15) Kumaran K et al. (2024) – River Water Quality Moni-toring System Using IoT and WQI Analysis This work presentsasystemthatcombines IoT withWater Quality Index(WQI)analysis.Sensorsareusedtomeasure

parameters such as pH, temperature, conductivity, and TDS. The collected data is processed to calculate a single WQI value, making it easier to understand water quality. Machine learning techniques are also used to improve prediction accuracy.

IV. TECHNOLOGY USED

1. Internet of Things

TheInternetofThings(IoT)playsanimportantrole in modern water quality monitoring by connecting sensors, microcontrollers, and communication devices. This network collectsandsendswaterquality datainrealtime.Itallows for remote monitoring without needing manual checks, which improvesefficiencyandspeedsupresponses.Sensordata is stored in cloud platforms or databases for analysis, visu-alization, and future prediction. IoT-based monitoring helps identify contamination early, supports quick decision-making, and enhances overall water management. By offering contin-uous monitoring, predictive abilities, and remote access, IoT technology provides an effective, reliable, and affordable way to maintain safe water quality and protect public health.

2. SensorsforWaterQualityMeasurement

Water is full of secrets, and to uncover them, we use a variety of sensors. Take pH sensors, for instance- they helpus figure out if the water is acidic or alkaline. But that's not all, we also have turbidity sensors that measure the clarity of thewater,temperaturesensorsthatcheckhowhotorcold itis,TDSsensorsthatlookatthetotaldissolvedsolids, and dissolved oxygen sensors that make sure there's enough oxygen in the water. All these sensors work together, sendinga constant stream of information to the processing unit, which thenhelpsusmakesenseofitall.Thisway,wecankeep acloseeyeonthewater'scondition,makingsureit'ssafe and healthy for us to use. By monitoring the water's quality, we can catch any potential problems early on and take action to fix them, whether it's adjusting the pH levels or removing impurities. It's a big job, but with the help of these sensors,we can do it.

3. Microcontroller/ProcessingUnit

The heart of our system is a tiny computer called a microcontroller. We have three options for this: Arduino UNO, ESP32, or Raspberry PI. These tiny computers collect informationfromsensors,dosomecalculations,andthensend theinformationtothecloudforsafekeepingandlateranalysis.

TheESP32isusuallythefavoritebecauseithasWi-Fibuilt-in, doesn't cost too much, and is really good at talking to other devices. This makes it perfect for projects that need to send information through the air.

4. CommunicationTechnologies

We have a range of communication technologies available, including Wi-Fi and GSM, which can be used for sending SMS alerts. Then there's NB-IoT, a great option for low-powercommunication,and Zigbeeand LoRaWAN, whichare ideal for long-distance communication. These technologies play a crucial role in delivering measured parameters to the server,makingiteasiertoaccessandanalyzethedata.By leveraging these communication technologies, we can ensure seamlessdata transmissionand make the mostofthecollected information.

5. CloudcomputingandIoTplatforms

We use cloud computing tools like Blynk, ThingSpeak, or custom dashboards to keep an eye on the information coming from IoT systems. These tools are really helpful because they let us store the data and then look at it in a way that makes sense, using things like graphs and charts to visualize what's happening.Thismakesiteasiertounderstand what'sgoingon with our

IoT systems.

6. AlertandNotificationSystems

Various Alert and Notification system like GSM SMS system, mobile notification or web alerts are used to alert the user if any parameters go beyond the predefined limit.

V. CHALLENGES AND APPLICATIONS

A. Challenges

Though smart water quality monitoring systems offer clear benefits,severalpracticalchallengesremainduringimplemen-tation. Sensor accuracy and long-term reliability are critical issues.Environmentalfactorsliketemperaturechanges,chemi-calbuildup,andcontaminationcanimpactsensorperformance over time. Regular calibration and maintenance are necessary to ensure precise measurements.

Power management is another major concern, especially in remote or rural areas where a steady electricity supply might belimited.Renewableenergysourcessuchassolarpanelscan help support system operations, but maintaining stable power for continuous monitoring is still a challenge.

Communicationreliabilityisalsoimportant.Inisolated regions, poor network connectivity can disrupt real-time data transmission,whichreducessystemeffectiveness.Further-more, managing large amounts of sensor data requires secure storagesystems,cloudinfrastructure,andeffectivecybersecu-rity measures to protect sensitive environmental information. The initial costs of deployment can be high due to expenses related to sensor installation, communication modules, cloud integration,andmaintenance.Additionally,integratingIoT devices,machinelearningmodels,andcloudplatformsinto onesystemrequirestechnicalexpertise.

Despite these challenges, ongoing improvements in sensor technology, energy-efficient systems, and data management solutions continue to make smart water monitoring systems more feasible and effective.itoring system that helps us keep our water safe and clean.

B. Advantages

Thesystemhasanumberofapplicationsindifferentsectors:

- Continuousmonitoringofthewaterphysical,chemical and biological quality
- Monitoringdrinkingwatertoensureitissafe
- **DrinkingWaterManagement**Providingsafeandclean drinking water supply
- **EnvironmentalMonitoring**River,lakeandgroundwa-ter quality monitoring

- **Agriculture Application** For managing irrigation water quality
- **Industrial Application**Monitoringindustrialwastewa-ter to obey regulation
- **SmartCity**Controlandmonitorwatersupply systems for leak detection and contamination
- **Aquaculture**Water qualitymaintenance

VI. CONCLUSION

This project introduces a smart and practical approach to water quality monitoring by combining IoT technology for continuous observation and analysis.The system regularly checks important water parameters such as pH, turbidity, temperature, and dissolved oxygen, helping detect contamination at an early stage and allowing faster action when problems occur.

Byusingcloudconnectivity,automatedcontrolsystems,and instant alert mechanisms, the system reduces manual effort whileimprovingmonitoringefficiencyanddecision-making.It not only helps manage industrial wastewater more effectively but also supports environmental safety and public health.

Overall, this system provides a reliable, affordable, and modernsolutionforimproving water quality managementand promoting sustainable use of water resources.

VII. FUTURE SCOPE

Additional sensors can be integrated to measure advanced water quality parameters such as BOD, COD, and microbial contamination for more detailed analysis.

Advancedmachinelearninganddeeplearningmodels can further improve prediction accuracy, anomaly detection, and early warning capabilities. Integration with government monitoring systems, smart city infrastructure, and industrial platforms can expand large-scale adoption.

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