Chapter 18
An Efficient Design and Development of IoT Based Real-Time Water Pollution Monitoring and Quality Management System

Hakam Singh and P. Sivaram

Abstract Water pollution is a significant cause of several diseases and requires intensive monitoring, procuring techniques to control contamination in water. Several techniques are implemented to stop water pollution, but somehow real-time monitoring achieves a significant impact among these. In this work, a real-time monitoring system based on Internet of Things (IoT) techniques is implanted to monitor, control, and take precautionary action through intimation to the authorities. The wireless sensor nodes are planted at different locations of water resources to check the water quality, significant impact among these. In this work, a real-time monitoring system based on Internet of Things (IoT) techniques is implanted to monitor, control, and take precautionary action through intimation to the authorities. The wireless sensor nodes are planted at different locations of water resources to check the water quality. The data obtained from sensor nodes are transmitted to a remote server, i.e., a cloud platform, and an analysis is carried out to check the water quality condition. The data samples collected from the different locations were analysed to identify the quality; the intimation is provided to the specific region controllers if water quality changes. The resultant information from the analysis can be used to take precautionary measures and identify the source of water pollution. The implementation of IoT makes it feasible to monitor and prevent water pollution in a real-time environment in a remote fashion.

Keyword Internet of Things · Wireless sensor nodes · Real-time environment · Cloud platform

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18.1 Introduction

Water is a vital element for living beings. However, numerous biological, physical, and chemical factors affect the water quality of rivers, ponds, streams, ground, and oceans. The contamination of aquatic resources causes many health problems and has become a problematic global issue. The man-made pollution of water resources globally is presently uncontrollable Fig. 18.1 (Veluda Water Filters 2021; Zaho et al. 2017; Sanjenbam Jugeshwor Singh 2019; Times of India 2019; Global Health 2020; Suraj Rajendran 2016; Jenn Savedge 2019) depicts the images of various water pollution sites. Several methods are implemented, and guidelines are set to solve the aquatic pollution problem. Traditional methods include a collection of samples from sites and testing in laboratories. These methods are ineffective and have issues like time and effort, barriers in data collection, and tough to monitor.

The emergence of the IoT in water management is a step toward real-time monitoring and flexibility, e.g., irrigation water management systems and automated water supply systems. IoT is an interconnection of intelligent communicable objects in a real-time environment. The objects are embedded within the electronic equipment and networked to sense and transmit data at the remote end for processing. Ideal IoT devices consist of Input/Output, storage, audio/video, and internet interfaces and comprise four layers named sensing, networking, data processing, and application layer. The sensor layer consists of sensing actuators that sense and transform the data over the network. The network layer regulates all networking functionalities like routing, network configuration. The data processing layer is

Fig. 18.1 Various water pollution sites

accountable for analytical analysis; many emerging techniques are functioning in this layer. The application layer is responsible for facilitating higher-level services to end-users, such as interface alerts. The emergence of the IoT in water management is a step toward real-time monitoring and flexibility, e.g., irrigation water management systems and automated water supply systems. IoT is an interconnection of intelligent communicable objects in a real-time environment. The objects are embedded within the electronic equipment and networked to sense and transmit data at the remote end for processing. Ideal IoT devices consist of Input/Output, storage, audio/video, and internet interfaces and comprise four layers named sensing, networking, data processing, and application layer. The sensor layer consists of sensing actuators that sense and transform the data over the network. The network layer regulates all networking functionalities like routing, network configuration. The data processing layer is accountable for analytical analysis; many emerging techniques are functioning in this layer. The application layer is responsible for facilitating higher-level services to end-users, such as interface alerts on suitable platform.

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Figure 18.2 depicts the key features of the water quality management system for controlling water pollution (Chapman 1996). Several techniques enable the IoT networks (Doni et al. 2018; Ullo and Sinha 2020; Čolaković and Hadžialić 2018; Navarro-Hellín 2016; Rao and Sridhar 2018):

(a) Wireless sensor network configured by sensor nodes to collect, exchange and transmit data over the internet.
(b) Cloud computing services like storage, software applications over the internet. It makes a virtual computer using the same personalized experience worldwide.
(c) Big data analytics services like cleaning, pattern extraction, transformation, and visualization of a large volume of data.
(d) A communication protocol that allows devices to transfer data over networks.
(e) Microprocessor-based computer hardware system to carry out computation for real-time operations.

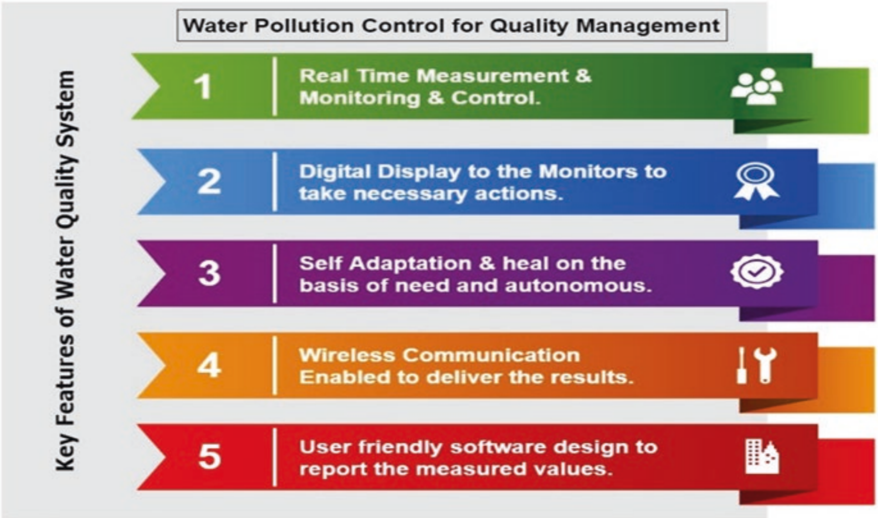

Fig. 18.2 Key features of water quality management system

18.1.1 Internet of Things in Water Pollution Monitoring

The robust operational environment of IoT encourages its enactment in water pollution monitoring. Sensor nodes are deployed in water sources (reservoirs) to collect and transmit real-time data to a remote server. The offered real-time data is processed and utilized to solve various water issues like quality, nonregularity, and contamination. The different sensors available to measure water quality such as, *pH Sensor:* The potential Hydrogen (pH) of a solution defines the acidic or basic nature, a significant indicator of water quality. Sensors used for determining pH are usually a single electrode, typically made of glass and quite delicate. The electrode is typically attached to an analyzer with an interface for data collection, calibration, and alerts. *Turbidity Sensors:* are used to measure turbidity, i.e., suspended solids in water. These are used for testing in rivers and streams and ponds. *Conductivity Sensors:* are used to obtain the total ionic concentration, i.e., the dissolved compounds in water. A standard conductivity sensor can be either an inline sensor directly inserted or a sensor in a housing, with a cable linked to a transmitter, which sends signals to a processing and/or recording device etc. IoTs remotely enable and reliably continuous water quality monitoring, consistent with precautionary activities. In available technologies, the IoT provides flexibility and ease of use components with strict integrity. Various research papers related to the proposed work were analyzed to identify the exact proposed systems and their operational capabilities. These have been detailed under the IoT-based Real-Time Water Pollution Monitoring and Quality Management System section. The paper also discusses the possibilities for extending the proposed work with various additional features.

18.2 Related Work

An automated water quality monitoring system was developed and implemented with active and passive sensors to collect data and Message Queue Telemetry Transport protocol to transmit between IoT devices (Budiarti et al. 2019). This is very much suitable for our proposed system. Another real-time system was proposed to measure river water quality; with this system, real-time data can be collected from the active site and analysed at a remote server (Chowdury et al. 2019). The system is highly flexible and helpful to stop the consumption and pollution of river water. Using IoT, a water parameter monitoring system has multiple sensor nodes integrated into a single platform to collect water parameters and communicate to remote servers (Krishna et al. 2020). An IoT system monitors the water level in storage tanks. The ultrasonic sensor checks the water level and transmits it on the cloud platform. This system helps the user to know the real-time status of stored water (Sivaiah et al. 2018). Another IoT-enabled water monitoring system uses an IoT device integrated with the water source to collect data and transmit it to the cloud. This system enables the user to monitor the water leakages and reduces water wastage (Mhaisen et al. 2018). A system using emerging techniques equipped with various water sensors and actuators to monitor and assist the fish farmer was proposed to address the effect of water pollution on fish farming (Nocheski and Naumoski 2018). Further, an IoT-based system was used to increase fish production and facilitate real-time monitoring (Tolentino et al. 2020). An underground water pipeline leakage-monitoring system was equipped with a pressure sensor to monitor the water pressure level and generate an alert message to the user on detecting any abnormality. Overall, this system reduced water wastage (Badawi 2019).

A systematic review was provided on applications of IoT on water monitoring systems, and various sensing devices were summarized and implemented in water quality monitoring systems (Radhakrishnan and Wu 2018). An IoT-based smart application was developed for gardening that automated the plants watering process and reduced the human efforts of checking the water level, switching water supply (Thamaraimanalan et al. 2018). A dispenser's water level monitoring system reduced the labor or supervision of the dispenser's monitoring. If the dispenser's water level becomes low, the system notifies to take necessary actions (Parashar et al. 2018). An IoT and machine learning was integrated to monitor the drinking water quality (Koditala and Pandey 2018). Niswar et al. have designed and implemented an IoT-based system to monitor water quality in soft-shell crab farming. This system provides awareness and suggests the acceptable water quality level for soft-shell crab farming (Niswar et al. 2018). Perelman and Ostfeld worked on the security aspect of water distribution sources. The stationary and non-stationary sensor nodes data is analyzed to implement security in water distribution sources (Perelman and Ostfeld 2013). Moparthi proposes a drinking water management system using the Arduino board and GSM techniques (Moparthi et al. 2018). Miry and Aramice worked on the water quality monitoring and analysis techniques. The system provides a quick turbidity analysis and informs the water quality to the user

(Miry and Aramice 2020). Doni et al. has done a systematic survey on air and water quality techniques and reveals that manual or laboratory methods are time-consuming and do not provide long-range results (Doni et al. 2018). Further, Ullo and Sinha have also done a review on smart environment monitoring systems and concluded that the involvement of emerging techniques strengthens the environment monitoring system (Ullo and Sinha 2020). Kodali et al. automated the greenhouse operation with the help of IoT, additionally, this system makes the market and buyer connection and reduced the efforts and times of farmers (Kodali et al. 2016). Kamienski et al. developed an IoT-based application in precision agriculture, that handles water resources as per their real-time environments (Kamienski et al. 2018). Zhao et al., have developed a Lora network-based system for smart irrigation (Zhao et al. 2017). This system allows the user to work from a remote location. An automatic water supplying system for plow-land is reported in the literature. This system is equipped with different actuators and sensing devices to make agriculture operations more flexible and easier (Imteaj et al. 2016). Devi et al. (2019) have designed an IoT, blockchain-based smart agriculture system. The blockchain architecture of this model involves several IoT sensors like smoke, PH control node, water moisture control, etc. The acquiesced data is processed on the cloud platform to control the agriculture field actions.

18.3 IoT Based Real-Time Water Pollution Monitoring and Quality Management System

The proposed system works in three phases: data acquisition, processing, and recommendation. In the data acquisition phase, the parametric values of water are obtained via sensor nodes and transmitted to a remote server. While in the processing phase, different optimization techniques are applied to bring out the result. The processing phase outputs are communicated to monitoring authorities in the recommendation phase, where the water quality management is done. A detailed description of the proposed system is depicted in Fig. 18.3.

1. **Data Acquisition Phase:** In this phase, basic parameters of the water are retrieved from the water sources and transmitted to a remote server or cloud platform. The initial task is the deployment of water sensors in the water source of interest. Due to predetermined operational sites and network coverage requirements, the deterministic sensor deployment method is suggested in this work. Afterwards, the sensor nodes get configured and start functioning, i.e., taking up water quality percept in real-time, the transformation of data, and transmission to a remote server. The transmitted data is a composite pack with fields such as Sensor Identity, Sample number, water quality parameters, location coordinates and time, e.g., W1pH, S1, ph-6, 31.5648 76.6409, 11:12 AM.
2. **Data Processing:** In this phase, an analytical process is carried out on a cloud platform. The acquiesced data, i.e., the data collected from the acquisition phase,

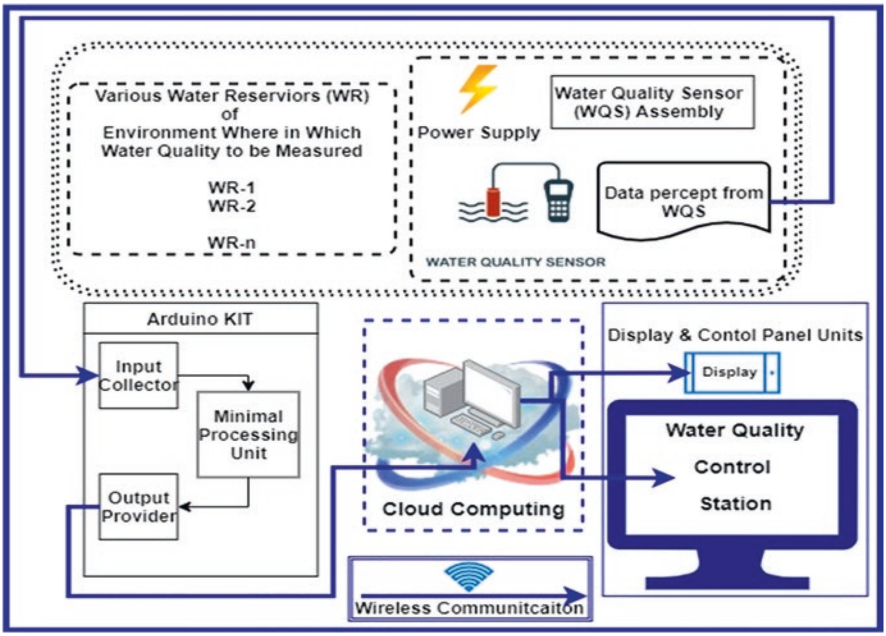

Fig. 18.3 The architecture of IoT-based real-time water pollution monitoring and quality management system

Table 18.1 Water quality standard value

Parameters	Acceptable limit	Permissible limit in the absence of alternate source
pH value	6.5–8.5	No-relaxation
Turbidity	1	5
Dissolved solids, mg/l	500	2000

is processed to identify abnormality and intensity of pollution. *Abnormality in water quality:* This can be identified using classification techniques. The values collected from sensors are compared with predefined or standard values in Table. 18.1. An approximation function is implemented to identify the upper and lower range of values. Suppose the resultant values are between the appropriation function. In that case, they are predicted as the quality of the water being at an acceptable level, else an alert message with the precautionary measure is sent to the monitoring authorities. This phase is named as recommendation phase for quality control.

Identify water pollution region: The location coordinates of the sensor nodes are used to identify the pollution region. The variation in water samples parameters is taken into consideration to identify the region, e.g., W1pH, S1, pH-6, 31.5648, 76.6409, 11:12 AM has a pH value of 9, while the W2pH, S1, pH-11, 32.5428, 79.6409, 11:20 AM has a pH value of 11. This means that the source is responsible for pH value variation between these two locations. The location coordinates are treated as vector entries to compute distance or to draw a location vector. The well-known Euclidean distance formula is used to draw a location vector among polluted sources. The vectored area is visualized as a polluted water region and considered for further water pollution prevention actions.

3. **Recommendation Phase:** This is the phase where the processed output data reaches the display/control unit for decision-making. The water quality management system is functioning so that human interaction is essential with the proposed system. Apart from the purpose of the corrective measures taken by the human to adjust the water quality, the generalized display panel-based reporting to the handheld devices is an additional feature added, where the user can have the details of the water quality values in the form of easy user interface like the water from so and so resources, is potable/usable or not.

Toy Example

1. **Data Acquisition Phase:** Water samples from different location (Tables 18.2, 18.3, 18.4, and 18.5).
2. **Data Processing:** Analysis is carried out on cloud platform or remote end (Table 18.6).

Table 18.2 Acquisition phase data location 1

Sensor identity	Sample number	Parameter-value	Location coordinates		Time
			Longitude	Latitude	
W1pH	S1	pH-6	31.5648	76.6409	11:12 AM
W1TD	S1	TD-1	31.5648	76.6409	11:12 AM
W1DS	S1	DS-1000	31.5648	76.6409	11:12 AM

Table 18.3 Acquisition phase data location 2

Sensor identity	Sample number	Parameter-value	Location coordinates		Time
			Longitude	Latitude	
W2pH	S2	pH-6.5	31.3444	76.3752	12:01 PM
W2TD	S2	TD-4.6	31.3444	76.3752	12:01 PM
W2DS	S2	DS-855	31.3444	76.3752	12:01 PM

Table 18.4 Acquisition phase data location 3

Sensor identity	Sample number	Parameter-value	Location coordinates		Time
			Longitude	Latitude	
W3pH	S3	pH -9	31.6138	76.2960	10:00 AM
W3TD	S3	TD-1	31.6138	76. 2960	10:00 AM
W3DS	S3	DS-1000	31.6138	76. 2960	10:00 AM

Table 18.5 Acquisition phase data location n

Sensor identity	Sample number	Parameter-value	Location coordinates		Time
			Longitude	Latitude	
WnpH	Sn	pH-8	31.1521	76.1023	11:12 AM
WnTD	Sn	TD-6	31. 1521	76. 1023	11:12 AM
WnDS	Sn	DS-800	31. 1521	76. 1023	11:12 AM

Table 18.6 Data processing

Locations	pH	TD	DS
L1 (31.5648, 76.6409)	6	1	1000
L2 (31.3444, 76.3752)	6.5	4.6	855
L3 (31.6138, 76. 2960)	9	1	1000
Ln (31.1521, 76.1023)	8	6	800

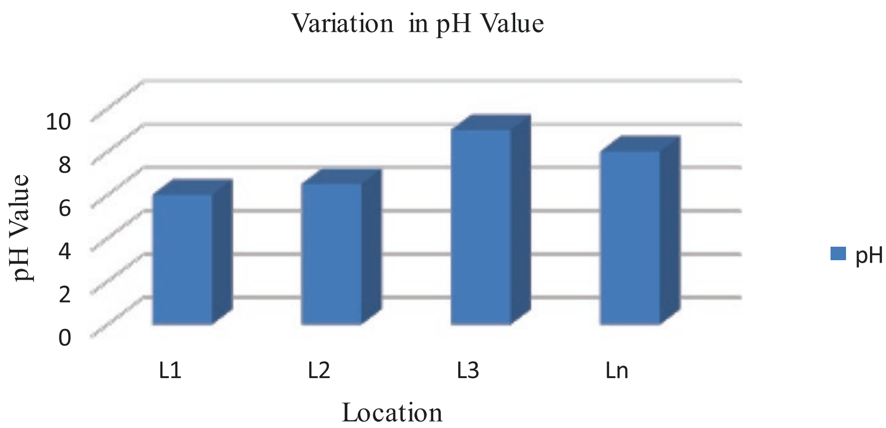

Fig. 18.4 Variation in pH value

3. **Recommendation Phase**
The processed output data reaches the display/control unit for the decision-making e.g., Ln has highest variation in turbidity (TD), and above the permissible level. In this case an alert message can be circulated/exhibited etc. Figures 18.4, 18.5, and 18.6.

18.4 Conclusion and Future Scope

An IoT-based water pollution monitoring system is proposed in this work that identifies the abnormalities and their source regions. The proposed system works in three phases, data acquisition, processing, and recommendation. In the data

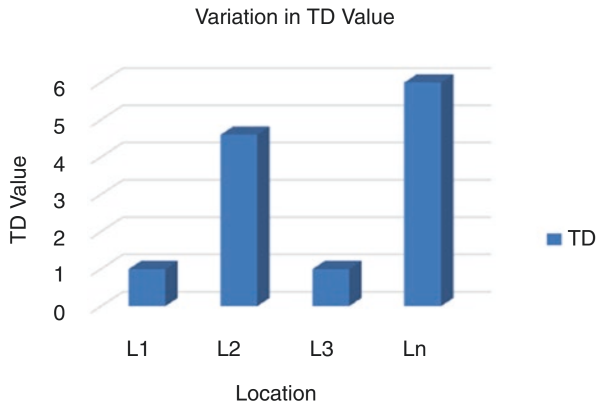

Fig. 18.5 Variation in TD value

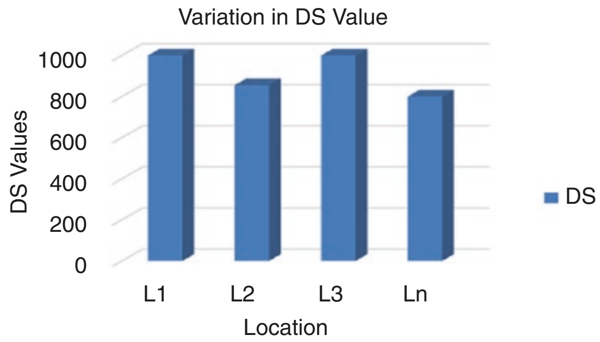

Fig. 18.6 Variation in DS value

acquisition phase, the fundamental parameter values are collected and transmitted to a cloud platform. On a cloud platform, analysis is carried out, and an appropriate response is made, such as an alert message in case of abnormality in water quality, region identification of pollution region. The adaptability of IoT, wireless sensors, data mining empowers the user to monitor and control resources from a remote location. IoT with accurate sensors and smart pieces of equipment are considered an essential component in smart farming. In future work, some other external parameters will be considered, and geographical analysis will be carried out to preserve the water quality.

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