Research on intelligent river water quality management system using blockchain-internet of things

Anitha Roy[1,2], Jubilant J Kizhakkethottam[3]
[1]Department of Information Technology, Lincoln University College, Petaling Jaya, Malaysia
[2]Marian College Kuttikkanam Autonoumous, Kerala, India
[3]Department of Computer Science and Engineering, Saintgits College of Engineering, Kottayam, India

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ABSTRACT

Each and every living thing needs fresh water to survive. Fresh water is becoming a precious resource as a result of the combined risks of rapid urbanization, pollution, and climatic changes. The quality of the water we drink every day has an impact on our lives, either directly or indirectly. Maintaining the sustainability and health of the environment requires constant attention to water quality. Modern technology makes it possible to gather and analyze data from water distribution networks in order to maximize resources and enhance decision-making for all parties. Despite the enormous global growth of the internet of things (IoT) and blockchain in recent years, their integration is still in its early stages. In this research contains a technological framework that combines blockchain and IoT called B-IoT and aims to reward and incentivize more sustainable water quality management with real-time monitoring and security. IoT is used to monitor water quality in water resources and find any violations. By using blockchain, it is possible to retain the accuracy, reliability, and transparency of the records of breaches. This system will be able to gauge the water's quality in real-time and allow for the quick identification of any infractions necessary to commit the crime.

Corresponding Author:

Anitha Roy
Department of Information Technology, Lincoln University College
Petaling Jaya, Selangor Darul Ehsan, Malaysia
Email: aroy@lincoln.edu.my

1. INTRODUCTION

Every year on March 22, World Water Day is celebrated to raise awareness of the value of fresh water and promote the ecological sustainability of freshwater resources. It entails taking action to address the worldwide water problem in support of sustainable development goal (SDG) 6: "water and sanitation for all by 2030" [1], [2]. Although a human may live for three weeks without food, most people can't last more than three to four days without water according to science. Even if the Sufferer keeps breathing after dehydration sets in, they will enter shock and wend into a vegetative state. The Primary need of mankind is therefore water. That is, a living thing cannot exist without it [3]. However, the sad reality is that there are billions of people without access to clean drinking water throughout the world. The majority of people believe that drinking well water, enjoying a swim at the beach, or frying up some freshly caught fish from the nearby river or a reservoir are all safe activities. The truth is that experts work hard behind the scenes to ensure the quality of water, the most precious resource on earth. Monitoring the quality of the water in lakes, streams, rivers, and coastal waterways is a significant procedure done in many different nations across the world. Numerous characteristics can be used to determine the quality of water, including the quantity of salt (or salinity), bacteria levels, dissolved oxygen concentrations, and the amount of foreign matter suspended in the water (turbidity) [4], [5].

The quantity of pesticides, herbicides, toxic substances, and other contaminants as well as the concentration of barely visible algae may be evaluated in some lakes and rivers to assess the quality of the water. It is not straightforward to claim “that water is clean” or “that water is unclean,” even though scientific measurements are used to describe water quality. So, the choice is usually made in light of the water’s intended use is it for drinking, washing cars or something else entirely?.

People’s health may be at risk from contaminated water. Ecosystems are also susceptible to health risks from poor water quality. Monitoring water quality is crucial to maintaining the sustainability and prosperity of the world [6]. Monitoring water quality becomes more crucial as humans continue to develop buildings, clear land for farming, and influence other aspects of nature. It’s important to recognize the effects of land-based activities on water systems and how they affect water bodies both above and below ground. Data from water quality monitoring is really helpful, but it’s not always simple to acquire. In order to collect data, experts employ a variety of procedures, including collecting samples of chemical conditions, analysing sediments, and extracting samples from fish tissue to investigate the presence of metals, oils, pesticides, dissolved oxygen, and nutrients [7].

a. Need of blockchain and internet of things (B-IoT) technology in water quality monitoring system

   There are some characteristics that a system for water quality management should ensure:

- The main goal of a water management system is water sustainability. Therefore, accurate water quality surveillance must be monitored.
- The data is entered into the records by IoT devices, and certain other end users should not modify the data.
- Any end user shouldn’t be able to commit violations against the network.
- According to the end user’s roles, the system should only allow them limited access.

The existing systems contain automatic systems including monitoring substations, monitoring using remote sensing, and monitoring based on laboratory-based water testing. It takes longer to manually sample water and analyze it in a lab. A remote sensing-based water monitoring system is less accurate and more expensive than an automatic system with control centers that include many monitoring substations [8]. Now is the time to start developing creative solutions that will allow us to inform others about how we are ruining the environment. Despite the internet of things (IoT) and blockchain having experienced rapid global expansion in recent years, their integration is still in its beginning stages. The purpose of this research is to reward and encourage more sustainable water quality management with real-time monitoring and security using a technological framework that combines B-IoT. The next layer of privacy would be added by using blockchain to record the information gathered by IoT environments, which makes it harder for attackers to gain access. The blockchain incorporates a stronger level of security, making it relatively difficult to replace current records. Therefore, the IoT is proposed in this research as a viable approach that can offer real-time monitoring and improve the effectiveness of data gathering. IoT makes it possible for internet-connected devices to transmit data to private blockchain networks in order to produce tamper-proof records of shared transactions. Blockchain technology will be utilized as a platform for all real-time data transactions in order to make the data reliable and safe. The proposed methodology will offer a better way for users to engage, access, and analyze actual and historical data as well as a better way to monitor the quality of the water resources [9], [10].

2. LITERATURE SURVEY

Governmental organisations and commercial organisations all over the world are now prepared in accordance with efficient ideas and develop long-lasting infrastructures for providing water management and security as a due to the recent dramatic increase in occurrences of droughts, floods, hurricanes, and tsunamis. Some developed IT economies, like Australia and Singapore, have successfully solved this technologically demanding issue of adopting practical solutions for protecting the quality and quantity of water in rural areas and urban areas [11], [12]. An embedded framework for monitoring and ensuring urban water supply was implemented in Australia as the South East Queensland (SEQ) water grid [13], [14]. This intelligent embedded system is made up of duplex pipelines for two-way water movement, water treatment facilities, hydro power, water pumping stations, systems for estimating water usage, water reservoirs and connected dams, and, most significantly, a number of different of water sources from recycling, precipitation, and rainwater [15]. The significant benefits of offering new water supply systems into the SEQ water infrastructure are to reduce scarcity, achieve climate resilience, and eliminate crises. The public utilities board (PUB) of Singapore established a water supply network (WSN) to develop a self-sufficient system for irrigation systems through a comprehensive method that involves water collection, reclamation, production, and distribution [16], [17]. To operate the water supply network effectively and sustainably, a comprehensive approach was used that involved the widespread use of intelligent sensors for real-time monitoring and analytical tools for decision-making systems [18].

The research was carried out in Ghana’s city of Accra at the Weija intake. The Weija treatment plant, which provides fresh water to residents of Greater Accra and sections of Central regions of Ghana, gets major water from the Weija dam inflow. At the intake, Libelium smart water sensors and smart water ion sensor devices were connected to measure physical and chemical data. The implementation offers a sustainable strategy that follows up on freshwater sources to assist local residents who rely on lakes, streams, rivers, and boreholes rather than having access to clean drinking water and who want to know the properties of the water they are consuming. A cloud storage facility receives the measured data value for analysis. A web portal was created by experts utilising a methodology to analyse the data that was collected. In comparison to other real-time deployed systems around the world, the suggested scheme is robust, makes use of an effective medium access control (MAC) layer protocol that improves transmission and reception times, and employs a network layer protocol that addresses the issue of transmission latency. If a parameter is monitored and a data link is not accessible, we build the setup at the network level to do retransmissions until the data link becomes available [19].

There are numerous diverse industries situated across the Saudi Arabia, many of which fall under the high category and frequently generate hazardous products. By discharging contaminated materials into water, the industry is alleged to be violating the guidelines established by the general authority for meteorology and environmental protection (GAMEP). It is advised to use a strategic strategy to combat the contamination of all living organisms and starting with industry, which is one of the main causes of water contamination, is the simplest way to accomplish this. Industrial water tanks are now gauged physically; it is difficult to identify businesses that are violating these rules. As a result, gathering a sample for measurement becomes more difficult. To solve the aforementioned issue, a system that not only recognises water contamination but also takes steps to prevent it has been developed. The system now combines two different technologies. This work combines IoT sensors and blockchain to detect water pollution in industrial effluent and assess whether it contains components that violate GAMPE rules in order to handle security of violations effectively. These components were all put together into a web - based application that the administrator may use to monitor the progress of water measurements for registered firms and analyse the data on water violations in precise graphs [20], [21].

A “smart city” is an area where modern technology and communication are combined and the IoT is used to connect a vast number of devices IoT. Monitoring water resources is necessary in response to issues caused by population growth, rapid industrialization, and urbanisation. So, a blockchain-based network is developed, which improves in monitoring usage of water effectively and supports in managing wastewater appropriately by offering an effective quality control mechanism. It is planned for the smart water tank and reservoir to function in either the running mode or the filling mode. With the use of IoT, the user in the smart city is constantly informed about their water consumption on a daily basis [22]. The method has made use of a sensor-based setup to determine how the residents of the smart city would use drinking water as this resource is frequently used for other purposes, such as washing cars, cleaning houses, and tending to plants, among others. In order to effectively use drinking water, a flow-sensor nozzle online system is also necessary. With the use of customized pipelines, this system provides drinking water in a predetermined quantity to each home. The flow sensor detects how much water is provided, and when the predetermined threshold for a given residence is reached, the valve automatically closes. Using sensors, this system also makes sure that no drinking water is lost owing to pipeline leaks, and it notifies the appropriate party if any such loss is noticed. As a result, problems with shortage can be addressed and drinking water usage can be controlled. The blockchain is used to drive real-time monitoring and abnormality detection throughout the entire system, which is connected to the cloud. The system provides an efficient approach for managing water resources that is controlled by the blockchain for security and dependability, ensuring proper drinking water use and reducing industrial water contamination [23].

3. EXISTING SYSTEM

Rivers provide food, water, and hydroelectricity for powering machinery in many industrial settlements constructed along their banks throughout the world. In fact, wastewater with suspended particles and sediments from urban, agricultural, and industrial sources is discharged into the river. It causes marine animals to die, which disrupts the natural food chain. River pollution has a significant impact on humans as well. It results in a decrease in the availability of clean water for consumption. To get an accurate and useful water quality model in complex water systems, however, is still challenging due to the heterogeneity, complexity, anomalies, and noise that are typically encountered in the actual world during data collection and Model structure. The main focus of quality control methodologies for water monitoring analysis is typically analytical laboratory tests involving hazardous chemicals, skilled personnel, and time-consuming procedures. Water’s quality is determined by the criteria for use and includes its chemical, physical, and biological characteristics [24]. It refers most frequently to a set of criteria that can be used to gauge compliance, which is commonly obtained by water treatment. There is no sufficient system in place to precisely monitor all these infractions in real time and make appropriate corrections. In order to support actions aimed at preventing and addressing negative anthropogenic impacts on the aquatic environment, water monitoring is the practice of repeatedly analyzing the water quality at fixed locations, processing data, and anticipating trends. Water samples are typically collected and given to laboratories for testing in order to manually evaluate the quality of the water. Due to the fact that these methods were unable to provide real-time data, an intelligent IoT-based water quality monitoring system based on a wireless network was developed in India, as shown in Figure 1. It offers convenient and ongoing analysis of water quality information. The monitoring scenario is divided into four broad categories, each of which builds a network of several wireless sensor nodes that are in control of sensing, gathering and processing data, and communicating. The pH, conductivity, and temperature are some of the most crucial factors that affect water quality and are monitored by the system's wireless sensor node. Since the quality of river water fluctuates depending on the pigment/dye that is mixed into the river, there is a constant monitoring of the pigment/dye that is added to the river's water.

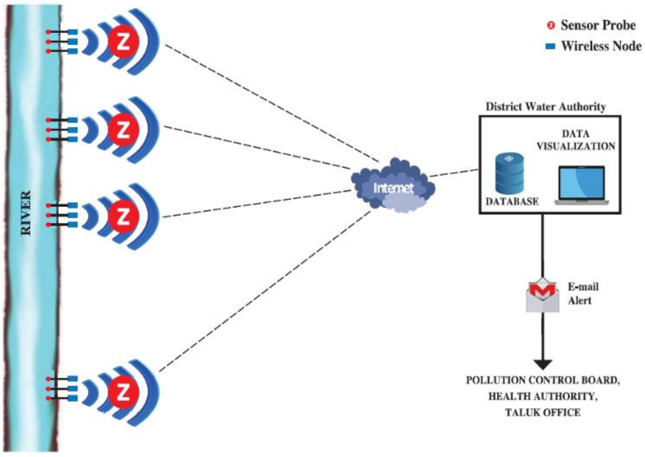

Figure 1. Existing system architecture

Consider about the possibility that a dye "X" mixed in with 20 liters of river water will reduce water purity by 25%, and a dye "Y" used in with 50 liters of river water will also reduce water purity by 25%. Monitoring the dye that is poured into the water is crucial. Periodically, the amount of dye mixing in water is recorded, and if the daily limit for purity reduction (i.e., a reduction of 25% in purity) is exceeded, a warning email is issued to the corporation. Here, wireless sensors are utilized to measure the water's cleanliness at different depths to check on the health of any aquatic life (i.e., how clean the water is up to 50 meters and how clean it is up to 100 meters). The exact same method is used by the proposed model which makes use of several IoT sensors to monitor water quality is shared by all the reviewed studies. In terms of data security and privacy, there aren't enough measures. This makes the proposed methodology stand out is because we integrate B-IoT sensors to address this vulnerability [25].

4. PROPOSED SYSTEM

The B-IoT system marks a groundbreaking shift in the way river water quality is monitored. Utilising a network of IoT sensors, it gathers immediate data on key water quality indicators like pH levels, temperature, clarity, and pollutants. These sensors are meticulously positioned throughout rivers to ensure accurate and comprehensive data collection. The innovative use of blockchain technology in this system guarantees the security and reliability of the data collected. It does so by forming a tamper-proof, decentralised record-keeping mechanism that enhances the data's credibility. Furthermore, the integration of cloud computing plays a crucial role, offering a platform for data storage, processing, and sophisticated analysis. This infrastructure not only streamlines data management but also facilitates accessibility for various stakeholders, including environmental bodies, scientific researchers, and the general populace. The B-IoT system, by blending IoT capabilities, blockchain security, and cloud technology, delivers a robust, real-time solution for effectively monitoring the health of river ecosystems.

4.1. System design

The framework is simply categorized into two parts: the first deals with the IoT water quality monitoring parameter system, and the second deals with Blockchain technology. The significant advantage of a water quality monitoring system should include high traceability, accurate data transmission, and efficient and reliable data storage for water resource data. The Figure 2 illustrates the overall architecture of proposed system. The IoT sensors placed at various points in the river are connected to the respective base station controller and the sensor leads are dipped in river water. The reason why sensors are placed in different parts of the river is that the quality of the river water is not the same everywhere. Data is collected from monitoring nodes using sensors like pH sensor, and temperature sensor. A pH sensor measures the hydrogen ion concentration in water to determine whether it is more acidic (acidity balancing test) or more alkaline (alkaline balancing test). Temperature of water is measured/monitor using temperature sensor. Turbidity Senor calculates clearness of water. pH, temperature, turbidity, and conductivity parameters are sent to wireless link to respective base stations controller.

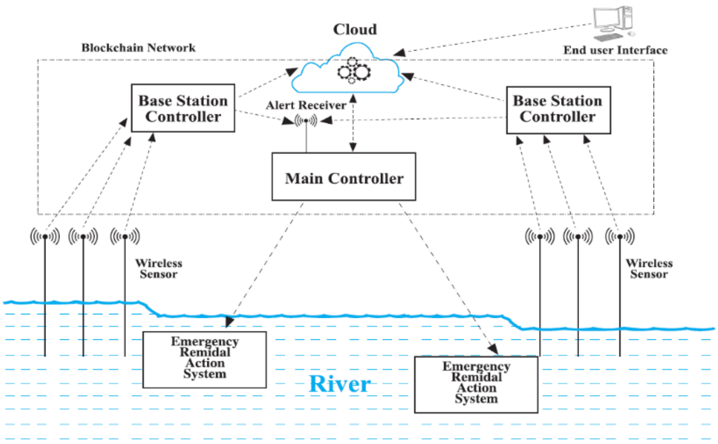

Figure 2. Proposed system architecture

The values from the IoT sensor will be continuously monitored by determining whether or not the sensor value exceeds the threshold. If there is any kind of variation in the threshold value, it reaches the alert receiver in the main controller. At that time, the main controller forwards that information to the emergency remedial action system. The system immediately initiates the steps for that i.e., if the pH value of the river water exceeds or falls below the set threshold value, the base controller will inform the main station controller and thus the emergency remedial action system will control the pH value. The base station controller and main controller store their respective values in the cloud. The end user gets all the records related to river water quality from the cloud. All these are connected to blockchain network. This innovative technology can ensure the quality of river water and security through blockchain network.

With the blockchain and IoT technologies, water contamination conceivably reduced. To detect contaminants, gauge their amount, and alert the appropriate water authorities by using automated sensors (IoT sensor). Water authorities can use blockchain to modify that the efficient in the way is managed. It will assist in offering a secure, open, and decentralized blockchain platform to record transactions between diverse parties. Blockchain can be used to develop a decentralized, open, and fairer approach to allocating water equally over enormous distances and setting water rates. Peer-to-peer communication will make it easier for the numerous stakeholders engaged in the distribution, preservation, and conservation of water to interact with each other. As blockchain data is decentralized, it cannot be altered, making it a secure platform to record different elements like fees, quantity, and distribution. By monitoring system user activity, a crucial indicator of water usage and management, blockchain can ensure sustainable development. The users get access to data on water use and thresholds. Water contamination will be reduced as a result. A comparison between the intended and actual consumption of the water allowance will be possible due to water monitoring systems that will provide real-time data on water quality. Water utility administration could be transformed by blockchain by ensuring transparency, security, and decentralized systems for its effective usage. Everyone has a duty to use water sensibly, and blockchain can help give people the breakthrough they require to fulfill that responsibility. It will assist in making the most of this precious commodity and in addressing the ongoing sustainability challenge.

4.2. Blockchain core component technologies

A database of information that has been shared and distributed over a computer network in various locations is known as distributed ledger technology (DLT). DLT is a subset of blockchain. In breaking down DLT [26], we build a peer-to-peer network of nodes, or computers; these nodes work together to create a distributed network. Each node executes client-submitted transactions. The ledger, or committed records, of a replicated database on each node becomes the result of these transactions. The groups of records in this immutable ledger are called blocks. I.e., data is stored using blocks and encryption, while distributed node's communications and data are verified using peer-to-peer networks, and consensus mechanisms. It creates a novel means of data recording, storage, and expression by using on-chain scripting to accomplish complicated business activities.

Cryptography, distributed storage, immutable ledger, consensus technology, and smart contracts are core aspects of the blockchain. The hash function, asymmetric encryption, digital signature, and digital certificate focus on ensuring that the transaction information is secure and reliable and that the source of information in water resource management may be verified throughout transmissions. The distributed system makes sure that transaction records are distributed throughout the decentralized system.

a. Cryptography: data security using cryptography prevents illegal access. Cryptography is incorporated into the blockchain to authenticate transactions between two nodes in a blockchain system. Cryptography and hashing are the two fundamental aspects of a blockchain. In a peer-to-peer network, data are encrypted using cryptography and a blockchain's block data and link blocks are authenticated using hashing. The SHA-256 hashing method is generally used as the hash function in blockchain.
b. Distributed storage: blockchain is a public ledger or distributed database that contains all committed transactions or other functions and is accessible by all parties involved. Blockchain storage is a method of storing data in a decentralized network that takes advantage of the free hard drive space of users all over the world. A decentralized architecture can address several issues present in a centrally managed system and is a solution to central cloud storage.
c. Immutable ledger: blockchain technology uses the term "immutable ledger" to describe any records with the ability to remain unmodified and as a result, the data cannot be easily changed, ensuring very tight security. Immutability makes it very challenging to make changes without consent.
d. Consensus technology: making sure that a decision is made regarding who has the authority to record data and synchronize the data is the aim of the consensus process Mechanism. The data copies can be made by nodes in the decentralized network. The data is organized into blocks and distributed to the blockchain network by the nodes determined by the consensus method. These data are recognized by all nodes, which then determine if they should be sent by authorized nodes that are valid. The data are synced and added to the blockchain ledger that is kept by each node if agreement is reached on the block data and other formatting specifications. This two-step process is repeated to update and synchronize the blockchain ledger reliably, preventing data instability and manipulation.
e. Smart contracts: a smart contract (or crypto contract) is a computer code that directly and automatically manages the exchange of digital assets between both parties under specified conditions, i.e., smart contracts are basically programs kept on a distributed ledger that execute when specified requirements are met. Without a mediator, smart contracts enable secure transactions between both parties. Before the blockchain, smart contracts could not be carried out in a secure environment. The blockchain makes sure that smart contract data is traceable and difficult to alter.
f. They can also manage a workflow such that when circumstances are met, the following action is executed. The detailed audit trail and all contract transactions are accessible and stored in the blockchain in a sequential manner. To provide complete privacy, the parties involved can be encrypted with a chain of blocks. The terms of the smart contract cannot be modified by one of the parties and are guaranteed to be available to everyone on the network.

4.3. System layer architecture

The interaction layer, application layer, blockchain network layer, and collection and transmission layer are the four layers that make up the system layer architecture for B-IoT-based water quality management, as shown in Figure 3. In order to prevent data tampering, distributed data storage and data sharing between nodes use blockchain technology at both the network and application layers. In order to evaluate whether the permission has been exceeded, smart contracts are utilized to compare the monitoring data of river flow with the authorized level. The outputs are sent to the blockchain for storage. The smart contract code is used to automatically identify issues and provide rewards or infractions.

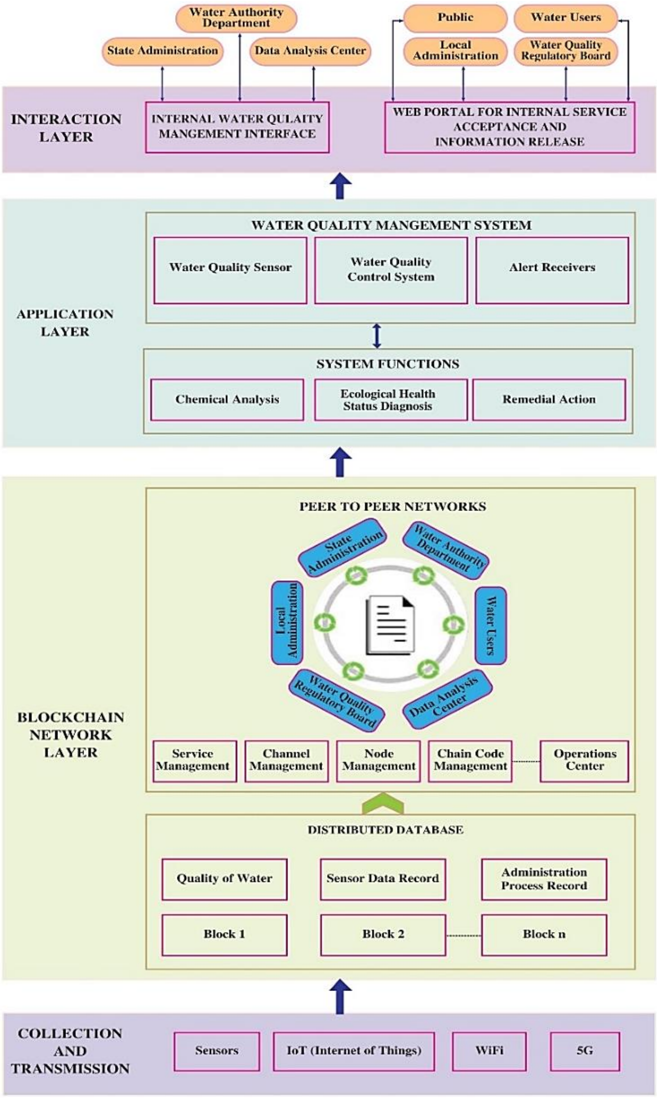

Figure 3. System layer architecture

a. Interaction layer: the interaction layer is the online interface of the water quality monitoring system. In the interaction layer, End-user related to the internal water quality management interface, the State Administration and the Water Authority Department are responsible for making sure there is a reliable supply of drinking water and the quality of the water pumped from rivers. A data analysis center or research institute plays a major role in measuring water quality and developing new technologies. Web portal for internal service acceptance and information release, it is typically the responsibility of public, water users, local administration, and the water quality regulatory board to ensure that everyone has access to fresh water and sanitary facilities, and this responsibility depends on efficient local government, resource management, and urban planning. Once the system has been implemented, this layer offers a common integration platform and information gateway.
b. Application layer: the application layer contains the water quality management system and system functions. A water quality management system consists of IoT sensors that measure the quality of river water, a control system that controls it, and alert receivers to notify when any kind of river water variation is detected. System function consists of chemical analysis of river water, ecological health status diagnosis, and remedial action. River water pH, dissolved oxygen, turbidity, chlorophyll (to monitor changes in algae growth), and nitrate and phosphate levels (to monitor nutrients) are recorded through chemical analysis. An ecological health status diagnosis tells us whether an ecosystem is in a good state. If any kind of variation is detected in the water, measures are taken by the remedy action system. It is the most effective method for separating blockchain's with cross-chain functionality in order to reach the goal of complete interoperability.

c. Blockchain network layer: the node (such as the State Administration, the department of the water authority, and the water users) stores data on water management-relevant data and examines the outcomes on the block. A peer-to-peer system is constructed between the nodes as a sequence of blockchain's is developed using time stamps. Planning frameworks and index criteria are kept in the block as fundamental information. Data uploads data transfers between nodes, data queries, and the creation of smart contract rules are all handled by the blockchain network layer. To implement the blockchain service functions and simplify the control of the water management, the operation and maintenance of the blockchain are carried out in cooperation with internet service providers.
d. Collection and transmission layer: records should be received in the similar order as it was transmitted, according to this layer's assurance. This layer provides a variety of services for gathering and transmitting real-time data about water resources and combining it with existing databases. It is dependent on the monitoring system.

4.4. Proposed system advantages

Combining B-IoT for monitoring river water quality brings a more efficient and reliable way to manage our water resources. With IoT devices collecting real-time data directly from the river, the need for manual checks is eliminated, speeding up the process and ensuring timely information. Blockchain then securely stores this data, making sure it stays accurate and can't be tampered with. This system not only saves time but also minimizes errors and mismanagement, making it easier to maintain water quality. Here are some key benefits of the proposed system:

a. Increased efficiency of information transmission: with IoT devices deployed along the river, data is collected in real-time and transmitted wirelessly to a central data management system. This eliminates the need for manual data collection, reducing the time and effort required to gather information. The automated data transmission ensures that the latest water quality data is available promptly for analysis and decision-making.
b. Reliable and secure storage of data: blockchain technology provides a secure and decentralized method of storing data. Each data point collected from IoT devices is encrypted, time-stamped, and added to a block within the blockchain network. This ensures data integrity and eliminates the risk of data tampering or manipulation. The distributed nature of blockchain also enhances data resilience, as there is no single point of failure.
c. Timesaving compared to existing systems: traditional methods of water quality monitoring often involve manual sampling, laboratory analysis, and data entry, which can be time-consuming and prone to human errors. By using IoT devices and real-time data collection, the proposed system eliminates the need for manual sampling and reduces the time required to obtain water quality information. This enables quicker response times to potential water quality issues or changes.
d. Immutable values: the data recorded on the blockchain is immutable, meaning once a data point is added to the blockchain; it cannot be altered or deleted. This provides a reliable and auditable record of water quality parameters over time. Immutable values enhance data transparency and credibility, as stakeholders can trust the accuracy and authenticity of the recorded data.
e. Reduction in mismanagement: by utilizing B-IoT technologies, the proposed system reduces the risk of mismanagement in river water quality monitoring. Real-time data collection and secure storage minimize the chances of data loss, manipulation, or human error. The transparent and decentralized nature of blockchain also reduces the possibility of data misrepresentation or bias, enhancing the overall reliability and accountability of the monitoring process.

The integration of B-IoT technology in the monitoring of river water quality introduces numerous benefits, such as enhanced efficiency in data transmission, dependable data storage solutions, the ability to save time, the assurance of unchangeable data values, and a decrease in the potential for mismanagement. These advantages significantly enhance the management of water resources, support more informed decision-making processes, and foster a forward-thinking strategy for preserving the quality of river water.

5. RESULTS AND OBSERVATIONS

Using this advanced water quality monitoring technology, water quality was measured and monitored in five areas (Chengannur Segment of Pamba river) of Alappuzha district where the Pamba river, the third largest river in Kerala, a state in India flows. Table 1 shows desirable limits of water quality monitoring parameters. The water quality parameters mentioned are indicative of a healthy and desirable condition for a river ecosystem. Let's explore each parameter and its implications in more detail:

a. pH: the pH range of 6.5-8 reflects a near-neutral to slightly alkaline condition, which is favorable for the overall health of the river ecosystem. This pH range supports the survival and reproduction of various aquatic organisms, including fish, plants, and invertebrates. It also facilitates essential biological processes and nutrient availability, contributing to the ecological balance of the river.

b. Turbidity (TUR): with a turbidity level of 1 NTU, the river exhibits clarity and low levels of suspended particles. Clear water is important for aquatic life as it allows sunlight to penetrate the water column, enabling photosynthesis in aquatic plants. Adequate light availability supports the growth of submerged vegetation, which provides habitat and food for many organisms. Additionally, low turbidity promotes improved water quality and ensures a healthier environment for aquatic organisms.
c. Total dissolved solids (TDS): the TDS concentration of 500 mg/L falls within an acceptable range for river water quality. TDS represents the dissolved substances in the water, including minerals, salts, and organic matter. This moderate TDS level supports the overall well-being of aquatic organisms and indicates the presence of essential minerals necessary for their growth and development.
d. Total hardness (TH): a TH level of 200 mg/L indicates moderately hard water. While high hardness can have implications for certain species, a moderate hardness level poses no significant harm to the river ecosystem. Aquatic organisms have adapted to varying water hardness levels, and the current value is within a range that supports their survival and reproduction.
e. Chloride: the chloride concentration of 250 mg/L is within the acceptable range for river water quality. Chloride is a naturally occurring compound, and at this level, it does not pose any immediate harm to aquatic life. However, continuous monitoring is essential as high chloride concentrations can negatively impact freshwater organisms and vegetation.
f. Coliform and E. coli: the absence of coliform and E. coli bacteria is a positive indication of good water quality. These bacteria are indicators of fecal contamination, and their absence suggests that the water is free from harmful pathogens that can cause waterborne diseases. This is crucial for maintaining the health of both the river ecosystem and any human activities reliant on the water.

Table 1. Desirable limits of water quality parameters

Parameters	Desirable limits
pH	6.5–8
TUR	1 NTU
TDS	500 mg/L
TH	500 mg/L
Chloride	250 mg/L
Coliform	Zero
E. coli	Zero

Overall, the combination of these water quality parameters suggests a healthy and desirable condition for a river ecosystem, supporting the diversity and abundance of aquatic life. Regular monitoring and ongoing assessment of water quality parameters are vital to ensure the continued well-being of the river and its inhabitants. Chengannur Section of the River Pamba served as the research region. With an elevation of 23 feet above mean sea level, it is situated at latitude 9.31830 N and longitude 76.1110 E specifically, five study locations were chosen. Puthencavu (S1), Mundankavu (S2), Pandanad (S3), Parumala (S4), Veeyapuram (S5) were their names. The water’s pH, TUR, TDS, TH, chloride, coliforms, and E. coli were all measured.

IoT water quality sensors can be used in river water quality monitoring to gather real-time data on various parameters such as temperature, pH levels, dissolved oxygen, and turbidity. The water quality sensors are strategically deployed at different locations in the river, ensuring good coverage across the monitoring area. The number of sensors and their placement depend on the size and characteristics of the Pamba River. The sensors continuously measure the water quality parameters at their respective locations. The sensors may also have built-in data logging capabilities to store the collected data in case of intermittent connectivity. The IoT sensors are connected to the internet, either through a cellular network or a wireless network such as Wi-Fi or LoRaWAN.

They periodically transmit the collected data to a base station controller. The transmission can be scheduled at regular intervals or triggered based on specific events or thresholds. Upon receiving the data, base station controller processes and analyzes the collected information. If there is any kind of variation occur the base station controller transfer only the variation occurred values to main controller. Table 2 shows the test findings for water samples taken during the summer season (30/03/2023) from different areas of Alappuzha district. Based on the desirable limits for water quality parameters, let’s analyze the data for each site:

Site S1:

a. The pH level of 6.6 is within the desirable range of 6.5-8.
b. The turbidity level of 5.9 NTU is below the desirable limit of 1 NTU.
c. The TDS concentration of 33 mg/L is well below the desirable limit of 500 mg/L.

d. The TH level of 26 mg/L is also below the desirable limit of 200 mg/L.
e. The chloride concentration of 12 mg/L is within the desirable limit of 250 mg/L.
f. However, the presence of coliform bacteria with a count of 1250 CFU/100 mL and E. coli bacteria with a count of 31 CFU/100 mL exceeds the desirable limit of zero.

Site S2:
a. The pH level of 6.5 falls within the desirable range.
b. The turbidity level of 5.7 NTU is below the desirable limit.
c. The TDS concentration of 34 mg/L is below the desirable limit.
d. The TH level of 25.8 mg/L is also below the desirable limit.
e. The chloride concentration of 9.1 mg/L is within the desirable range.
f. However, similar to Site S1, the presence of coliform bacteria and E. coli bacteria exceeds the desirable limit.

Site S3:
a. The pH level of 6.5 falls within the desirable range.
b. The turbidity level of 6 NTU slightly exceeds the desirable limit.
c. The TDS concentration of 33.7 mg/L is below the desirable limit.
d. The TH level of 26.1 mg/L is below the desirable limit.
e. The chloride concentration of 11.4 mg/L is within the desirable range.
f. The presence of coliform bacteria and E. coli bacteria exceeds the desirable limit.

Site S4:
a. The pH level of 6.4 is slightly below the desirable range.
b. The turbidity level of 5.9 NTU is below the desirable limit.
c. The TDS concentration of 33.9 mg/L is below the desirable limit.
d. The TH level of 26.4 mg/L is below the desirable limit.
e. The chloride concentration of 10.9 mg/L is within the desirable range.
f. The presence of coliform bacteria and E. coli bacteria exceeds the desirable limit.

Site S5:
a. The pH level of 6.5 falls within the desirable range.
b. The turbidity level of 5.7 NTU is below the desirable limit.
c. The TDS concentration of 33.6 mg/L is below the desirable limit.
d. The TH level of 25 mg/L is below the desirable limit.
e. The chloride concentration of 11 mg/L is within the desirable range.
f. The presence of coliform bacteria and E. coli bacteria exceeds the desirable limit.

Table 2. Test results (before)

	Ph	TUR	TDS	TH	Chloride	Coli form	E. coli
S1	6.6	5.9	33	26	12	1250	31
S2	6.5	5.7	34	25.8	9.1	1100	35
S3	6.5	6	33.7	26.1	11.4	900	29
S4	6.4	5.9	33.9	26.4	10.9	1010	38
S5	6.5	5.7	33.6	25	11	960	30

In observation, while some water quality parameters in the provided sites fall within the desirable limits, the presence of coliform bacteria and E. coli bacteria indicates the potential for contamination and poses a concern for water safety. Further actions should be taken to address the bacterial contamination and ensure the water meets the desired standards for safe use. The base station controller will only transfer the values that have fluctuated to the main controller in the case of any variation. Here the main controller immediately instructs the emergency remedial action system and takes corrective actions like Upon receiving alerts indicating high levels of E. coli and coliform bacteria, the controller initiates emergency response protocols. This involves activating pre-defined plans and procedures to address the contamination issue promptly. Table 3 shows the test findings after redmial action of water samples taken during the summer season (30/03/2023) from different areas of Alappuzha district.

Table 3. Test results (after)

	pH	TUR	TDS	TH	Chloride	Coli form	E. coli
S1	6.6	5.9	33	26	12	0	0
S2	6.5	5.7	34	25.8	9.1	0	0
S3	6.5	6	33.7	26.1	11.4	0	0
S4	6.4	5.9	33.9	26.4	10.9	0	0
S5	6.5	5.7	33.6	25	11	0	0

Figure 4 shows two bar charts representing the levels of various parameters in water samples collected from a site before and after remedial action. In the top chart, labelled "before remedial action," the y-axis represents the corresponding values of a certain parameter, which scales into the thousands. Each bar corresponds to a sample site, labelled S1 through S5 on the x-axis, and all the bars reach high values, suggesting significant contamination or high levels of a specific parameter at each site. The lower chart, titled "after remedial action," shows multiple parameters, including pH, turbidity (TUR), TDS, chloride, coliform, and E. coli, with much lower values, indicating a successful reduction in contamination. The bars are colour-coded for each parameter, demonstrating that the remedial actions have effectively improved the quality of the water by reducing the concentration of contaminants to much lower levels.

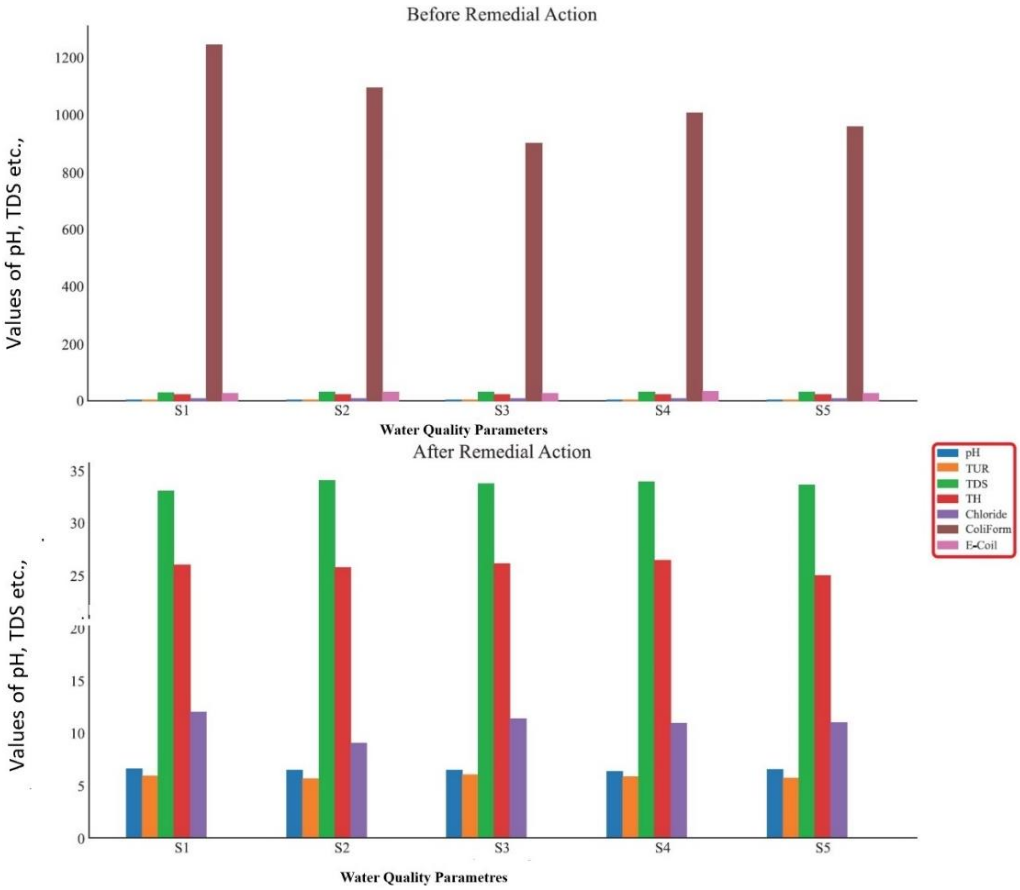

Figure 4. Comparative analysis of water quality parameters before and after remedial action

The processed data is presented in a user-friendly manner through web interfaces. Users, such as environmental agencies, researchers, or the general public, can access these visualizations to monitor the water quality parameters in real-time. Blockchain technology can be utilized to enhance data security, immutability, and trust in the monitoring process. Each data point collected by the sensors can be time stamped and recorded on a blockchain network, creating an immutable and transparent ledger. This ensures the integrity of the data and prevents tampering or unauthorized modifications.

6. CONCLUSION

A wireless river water quality monitoring technique is discussed in this research. As the universe enters the era of advanced technologies, an enormous number of ideas are being developed that improve our quality of life. The proposed B-IoT system for monitoring water quality in rivers brings a new technological breakthrough to the universe. The application of B-IoT technology in river water quality monitoring has emerged as a promising solution with significant benefits. The integration of these technologies has revolutionized the way water quality is monitored, providing real-time and accurate data, ensuring transparency, and enhancing overall water management strategies. Our proposed methodology uses an integrated network of IoT sensors and blockchain networks to monitor real-time status and provide a secure data storage solution for water quality monitoring. By deploying IoT devices such as sensors and crucial parameters of river water quality, including pH levels, turbidity, dissolved oxygen, and temperature, can be continuously monitored at multiple points along the river. These devices collect data and transmit it wirelessly to a centralized platform, where it is securely stored and processed. The data received from the sensors is secured with the help of a blockchain network. The utilization of blockchain technology further enhances the credibility and integrity of the collected data. By recording the data in a decentralized and immutable ledger, blockchain ensures transparency and prevents tampering or manipulation of the information. This feature is particularly crucial in ensuring the reliability of water quality data for regulatory compliance, scientific research, and public awareness. If there is any kind of variation in the water, it can be solved through an emergency remedy system placed in the river. Moreover, the combination of B-IoT technology allows for seamless data sharing among various stakeholders involved in river water management, including government agencies, water utilities, researchers, and the public. This enables collaborative decision-making, timely response to pollution incidents, and the implementation of effective remediation strategies. Overall, the integration of B-IoT technology in river water quality monitoring has revolutionized the field by providing accurate, real-time data, ensuring transparency, and facilitating informed decision-making. As we continue to face increasing challenges in water resource management, this innovative approach holds immense potential to enhance the health and sustainability of our rivers and ecosystems.

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BIOGRAPHIES OF AUTHORS

Anitha Roy received the Master of Computer Applications from Bangalore University in Bangalore in 2000. She is currently working as the Chief Operating Officer at a company in the Kingdom of Bahrain. She is currently a research scholar in Computer Science at Lincoln University College, Malaysia. Her research interests include the internet of things (IoT), blockchain, B-IoT, and water quality management. Published paper "real time water quality monitoring of River Pamba (India) using internet of things" in E3S Web Conf [Volume 477, https://doi.org/10.1051/e3sconf/202447700093]. She can be contacted at email: aroy@lincoln.edu.my.

Jubilant J Kizhakkethottam is a distinguished technologist, educator, and visionary leader with a diverse educational background spanning technology, management, psychology, and cyber law. His impressive career encompasses academia, where he has served as a principal and head of department, and cutting-edge research in computer networks, web security, software engineering, and blockchain. He is also committed to social responsibility, certified as an HR trainer, and actively engaged with organisations, including the United Nations Academic Impact. Currently he a Professor in the Department of Computer Science and Lead of Saintgits Blockchain Innovations, he continues to shape the future of technology and education. He can be contacted at email: jubilantjob@gmail.com.